



فصلنامه علمی نشریه فناوری آموزش



دوره ۲۰، شماره ۱، زمستان ۱۴۰۴

نشریه فناوری آموزش

دوره ۲۰، شماره ۱، زمستان ۱۴۰۴

QUARTERLY PUBLICATION

Technology of Education Journal (TEJ)



Volume 20, Issue 1,- Serial Number 77 Winter 2026



Publisher: Shahid Rajaei Teacher Training University (SRTTU)

Director-in-Charge

Prof. M. Mazloom

Editor-in-Chief

Prof. H. R. Azemati, Dr. M. Rahimi

Executive Chief

Assis. Prof. Dr. R. Ahmadi

English/Persian Text Editor

Assis. Prof. Dr. M. Rahimi

Manager

E. Baghbani

Editorial Board:

Prof. A. Kaveh

IUST, Tehran, Iran

Prof. A. Afshar

IUST, Tehran, Iran

Prof. A. Shokuhfar

K. N. University of Technology

Prof. A. Khaki Sedigh

K. N. University of Technology

Prof. G.R. Ghodrati Amiri

IUST, Tehran, Iran

Prof. R. Ebrahimpour

Sharif University of Technology, Tehran, Iran

Prof. M. Ghazavi

K. N. University of Technology

Prof. B. Hassani

Shahrood University of Technology

Assoc. Prof. Dr. M. Rahimi

SRTTU, Tehran, Iran

Prof. M. Shams Esfand Abadi

SRTTU, Tehran, Iran

Prof. H.R. Arasteh

Kharazmi University, Tehran Iran

Prof. H. R. Azemati

SRTTU, Tehran, Iran

Prof. Mahnaz Moallem

Towson University, Maryland, US

Publisher: Shahid Rajaei Teacher Training University

Graphic Designer: Eng. M. Motamedinezhad

Page Designer: N. Firouzi

Contact info: Shahid Rajaei Teacher Training University, Lavizan, 1678815811

PO Box: 16785-163

Tel: (+9821) 22970060-9 (Ext. 2598)

Fax: 22970070

Indexing and Abstracting: <https://jte.sru.ac.ir/journal/indexing?lang=en>

صاحب امتیاز:

دانشگاه تربیت دبیر شهید رجائی

مدیر مسئول:

پروفسور موسی مظلوم

سر دبیر:

پروفسور حمیدرضا عظمتی، دکتر مهرک رحیمی

دبیر اجرایی:

دکتر روشن احمدی

ویراستار فارسی/انگلیسی:

دکتر مهرک رحیمی

مدیر داخلی و مدیر پایگاه:

انسیمه باغبانی

هیأت تحریریه:

پروفسور علی کاوه

دانشکده مهندسی عمران، دانشگاه علم و صنعت ایران

پروفسور عباس افشار

دانشکده مهندسی عمران، دانشگاه علم و صنعت ایران

پروفسور علی شکوفه‌فر

دانشکده مهندسی مکانیک، دانشگاه صنعتی خواجه نصیرالدین طوسی

پروفسور علی خاکی‌صدیق

دانشکده مهندسی برق، دانشگاه صنعتی خواجه نصیرالدین طوسی

پروفسور غلامرضا قدرتی امیری

دانشکده مهندسی عمران، دانشگاه علم و صنعت ایران

پروفسور رضا ابراهیم‌پور

دانشکده مهندسی کامپیوتر، دانشگاه تربیت دبیر شهید رجائی

پروفسور محمود قضاوی

دانشکده مهندسی عمران، دانشگاه صنعتی خواجه نصیرالدین طوسی

پروفسور بهروز حسینی

دانشکده مهندسی عمران، دانشگاه صنعتی شاهرود

دکتر مهرک رحیمی

دانشکده علوم انسانی، دانشگاه تربیت دبیر شهید رجائی

پروفسور محمد شمس اسفندآبادی

دانشکده مهندسی برق، دانشگاه تربیت دبیر شهید رجائی

پروفسور حمیدرضا آراسته

دانشکده علوم تربیتی و روان‌شناسی، دانشگاه خوارزمی

پروفسور حمیدرضا عظمتی

دانشکده مهندسی معماری و شهرسازی، دانشگاه تربیت دبیر شهید رجائی

پروفسور علیرضا آزموه اردلان

دانشکده فنی مهندسی، دانشگاه تهران

دکتر حمید مسگرانی

دانشکده علوم پایه، دانشگاه تربیت دبیر شهید رجائی

دکتر حامد ارزانی

دانشکده مهندسی عمران، دانشگاه تربیت دبیر شهید رجائی

پروفسور علی غفاری

دانشکده مهندسی معماری و شهرسازی، دانشگاه شهید بهشتی

لیتوگرافی و چاپ: دانشگاه تربیت دبیر شهید رجائی

ناشر: انتشارات دانشگاه تربیت دبیر شهید رجائی

طرح جلد: محمد معتمدی‌نژاد

صفحه آرا: نیره فیروزی

نشانی: تهران لویزان خیابان شهید شعبانلو دانشگاه تربیت دبیر شهید رجائی

صندوق پستی: ۱۶۳-۱۶۷۸۵ کد پستی: ۱۵۸۱۱-۱۶۷۸۸

تلفن: ۲۲۹۷۰۰۶۰ داخلی ۲۵۹۸ فکس: ۲۲۹۷۰۰۷۰

وب سایت: www.sru.ac.irوب سایت اختصاصی: <http://jte.sru.ac.ir>پست الکترونیکی: jte@sru.ac.ir

این نشریه توسط مراکز زیر نمایه‌سازی می‌شود:

- پایگاه استنادی علوم جهان اسلام (ISC) (www.ricest.ac.ir)
- پایگاه اطلاعات علمی جهاد دانشگاهی (www.sid.ir)
- بانک اطلاعات نشریات کشور (www.magiran.com)
- مرکز اطلاعات و مدارک علمی ایران (www.irandoc.ac.ir)
- پایگاه مقالات علمی همایش و ژورنال (www.civilica.com)

نشریه فناوری آموزش طی مجوز شماره ۳/۱۱/۱۴۶۱ مورخ ۱۳۸۸/۹/۴ از وزارت علوم، تحقیقات و فناوری حائز رتبه علمی- پژوهشی شده است و دارای ضریب تأثیر ۰/۲۱۹ و جز نشریات هسته و Q2 در پایگاه (ISC) است. همچنین این نشریه بر اساس آئین نامه نشریات علمی مصوب ۱۳۹۸/۲/۹ در ارزیابی سال ۱۴۰۴، موفق به کسب رتبه (ب) شده است.

Technology of Education Journal

CONTENTS

Volume 20, Issue 1, - Serial Number 77, Winter 2026

Teacher-made 360-degree VR tours for foreign language learning: Insights into learned helplessness in a low socioeconomic status context	1-22
<i>M. Eftekhari, M. Rahimi</i>	
Meta-analysis of research related to gamification with emphasis on its long-term effects on the academic performance of elementary students	23-42
<i>J. Keyhan, Go. Sheikhlou</i>	
The power of time: how spacing techniques revolutionize ESP vocabulary learning online	43-64
<i>Z. Cheraghi, H. Omranpour, A. Motaharinejad</i>	
Technological beliefs, knowledge structures, and individual characteristics: determinants of technology integration in the classroom	65-78
<i>S. Bibak, S. Asadian</i>	
The mediating role of academic engagement in the relationship between social support and student satisfaction in online learning environments	79-96
<i>A. Taghizade, A. Akbari Balootbangan</i>	
ICT self-efficacy, ICT engagement and teaching enjoyment among Iranian EFL teachers: an age-moderated model	97-114
<i>R. Nejati</i>	
Are self-directed learners the author of their learning? The role of AI in transforming students' cognitive agency	115-132
<i>A. Ramezani</i>	
Future opportunities for teaching "career and technology" textbooks in lower secondary school education in Iran based on technological trends: a futures studies approach	133-156
<i>M. Keshavarz Turk</i>	
Evaluating pre-service teachers' mathematical modelling task performance: a comparison with ai responses	157-178
<i>N. Azadi, E. Reyhani, M. Ghorbani, R. Ebrahimpour, S. Haghjoo</i>	
Parental involvement in digital learning environments: examining school-parent communication, parental self-efficacy, and students' positive digital agency	179-197
<i>M. Namdari-Pejman, M. Zandian</i>	



ORIGINAL RESEARCH PAPER

Teacher-made 360-degree VR tours for foreign language learning: insights into learned helplessness in a low socioeconomic status context

M. Eftekhari, M. Rahimi*

English Department, Shahid Rajaee Teacher Training University, Tehran, Iran

ABSTRACT

Received: 17 July 2025
Reviewed: 10 September 2025
Revised: 09 October 2025
Accepted: 12 December 2025

KEYWORDS:

VR
360-Degree Videos
EFL Learning
Learned-Helplessness
Low SES

* Corresponding author

✉ rahimi@sru.ac.ir

☎ (+9821) 22970035

Background and Objectives: Educational technology has long been recognized as a powerful tool for enhancing foreign language learning opportunities, with particular relevance for students in under-resourced environments where instructional quality and materials are often limited. Among emerging tools, virtual reality (VR) videos have gained increasing attention for their capacity to create immersive, authentic learning experiences in recent years. Despite the promise of these emerging technologies, little is known about how their pedagogical effectiveness varies among learners with different psychological profiles. One such psychological factor-learned helplessness (LH)- plays a critical role in students' academic behaviours, motivation, and resilience. Learners with high LH often experience persistent negative expectations about their abilities, reduced perseverance, and diminished engagement, potentially limiting the benefits they receive from technology-enhanced learning environments. Although previous research has explored LH in EFL settings and the equity implications of educational technology, no study to date has examined how teacher-made 360° VR videos influence language learning outcomes across LH levels in a low socioeconomic status (SES). Therefore, the present study was designed to fill this gap by examining the effects of teacher-made 360° VR tours on English achievement among students with different levels of LH in an underprivileged setting.

Materials and Methods: The study employed a mixed-methods experimental design. Fifty-eight female 10th-grade students (aged 15-16) from an underprivileged school were randomly assigned to an experimental (n=29) and a control group (n=29). The experimental group used tailored 360° VR tours, made by a Samsung Gear 360 camera, and the control group used ready-made 360 VR videos from YouTube for one academic year. The learning gains were assessed by the English final exam, and the level of LH was evaluated by the EFL-LH scale. Quantitative data were analyzed using a two-way analysis of variance (ANOVA) to compare post-test performance between research groups and participants with different levels of LH. To explore learner perceptions, an open-ended questionnaire was used with a purposive subsample representing both high- and low-LH groups. Qualitative data were analyzed thematically to identify patterns in learners' perceptions of the VR learning experience.

Findings: Quantitative results showed no statistically significant difference in English achievement between the teacher-made 360° VR tour group and the ready-made VR video group, although the experimental group demonstrated slightly higher mean gains. However, LH emerged as a strong differentiating factor [$F(2, 52)=5.311, p=0.008<0.05$]. Learners with low LH significantly outperformed high-LH learners both within and across the two instructional conditions. Low-LH learners in the experimental group demonstrated the greatest improvement, suggesting that immersive, teacher-designed experiences may be particularly effective for motivated and self-efficacious learners. Qualitative findings illustrated that low-LH learners expressed positive attitudes, describing the tours as engaging, relevant, and helpful in improving vocabulary and comprehension. In contrast, high-LH learners reported difficulties in maintaining interest, scepticism about the educational value of the VR tours, and occasional feelings of being overwhelmed by the immersive environment.

Conclusions: The study highlights the nuanced role of LH in shaping learners' responses to immersive educational technologies. While teacher-made 360° VR tours have the potential to enhance engagement and learning, their benefits are not equally distributed among all

learners. In low-SES contexts, where LH may be more prevalent due to environmental and systemic constraints, simply introducing advanced technologies is not sufficient for ensuring equitable learning outcomes. Effective integration of VR tools requires pedagogical scaffolding, emotional support, and targeted interventions to address LH-related barriers. These findings underscore the need for context-sensitive technology integration frameworks that consider both technological affordances and learners' psychological differences.



COPYRIGHTS

© 2026 The Author(s). This is an open-access article distributed under the terms and conditions of the Creative Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) (<https://creativecommons.org/licenses/by-nc/4.0/>)



NUMBER OF REFERENCES

56



NUMBER OF FIGURES

1



NUMBER OF TABLES

5

مقاله پژوهشی

بکارگیری تورهای واقعیت مجازی ۳۶۰ درجه معلم ساخت در یادگیری زبان خارجی: وا کاوی درماندگی آموخته شده در یک بافت اقتصادی-اجتماعی پایین

ملیکا افتخاری، مهرک رحیمی*

گروه زبان انگلیسی، دانشکده علوم انسانی، دانشگاه تربیت دبیر شهید رجایی، تهران، ایران

چکیده

پیشینه و اهداف: تکنولوژی آموزشی همواره به عنوان ابزاری قدرتمند در جهت ارتقای فرصت های یادگیری زبان دوم شناخته شده است. استفاده از فناوری در آموزش به ویژه در مناطق کم برخوردار، که عموماً در آن کیفیت آموزشی پایین و منابع آموزشی محدود است، اهمیت بیشتری می یابد. در میان ابزارهای نوظهور، محیط های مبتنی بر واقعیت مجازی توجه بسیاری را به دلیل توانایی ایجاد تجربه های اصیل و احاطه گر جلب کرده است. با وجود قابلیت های آموزشی این فناوری ها، اثربخشی آنان در میان فراگیرانی که ویژگی های روانشناختی متفاوتی دارند چندان مشخص نیست. یکی از این ویژگی های مهم، درماندگی آموخته شده است که نقش تعیین کننده ای در عملکرد تحصیلی، انگیزش و تاب آوری دانش آموزان دارد. فراگیران با درماندگی بالا معمولاً انتظارات منفی مداومی نسبت به توانایی های خود دارند، از خود پشتکار کمتری نشان می دهند و کمتر در فعالیتهای کلاسی درگیر می شوند؛ عواملی که ممکن است مزایای محیط های یادگیری فناورانه را برای آنان محدود سازد. اگرچه پژوهش های گذشته به بررسی درماندگی در بافت آموزش زبان انگلیسی به عنوان زبان خارجی و کاربردهای فناوری در جهت ارتقا برابری آموزشی پرداخته است، اما هیچ پژوهشی تا کنون تأثیر فیلم های واقعیت مجازی طراحی شده توسط معلم را بر یادگیری زبان انگلیسی در میان سطوح مختلف درماندگی آموخته شده در مناطق کمتر برخوردار بررسی نکرده است. از این رو، مطالعه حاضر تأثیر تورهای واقعیت مجازی ۳۶۰ درجه معلم-ساخت را بر پیشرفت تحصیلی درس زبان انگلیسی با در نظر گرفتن سطوح درماندگی آموخته شده در یک بافت اجتماعی-اقتصادی پایین بررسی کرده است.

روش ها: این پژوهش با استفاده از یک طرح آزمایشی با رویکرد آمیخته انجام شد. ۵۸ دانش آموز دختر پایه دهم (دامنه سنی ۱۶-۱۵) مدرسه ای واقع در یکی از مناطق کم برخوردار شهر تهران به صورت تصادفی به دو گروه آزمایشی (۲۹ نفر) و گواه (۲۹ نفر) تقسیم شدند. آموزش گروه آزمایشی با تورهای واقعیت مجازی ۳۶۰ درجه که همسو با محتوای کتاب درسی توسط معلم و با استفاده از دوربین گیر ۳۶۰ درجه سانسونگ تهیه شده بود به مدت یک سال تحصیلی انجام شد؛ در حالیکه برای آموزش گروه کنترل طی این زمان از ویدئوهای آماده واقعیت مجازی ۳۶۰ درجه برگرفته از یوتیوب با موضوعات مشابه استفاده شد. عملکرد زبان آموزان با نمره ی نهایی درس زبان انگلیسی ارزیابی شد و سطح درماندگی آموخته شده به وسیله مقیاس درماندگی آموخته شده زبان اندازه گیری شد. داده های کمی با استفاده از تحلیل واریانس دو سویه برای مقایسه عملکرد پس از آزمون گروه ها بررسی شد. نگرش شرکت کنندگان از طریق

تاریخ دریافت: ۲۶ تیر ۱۴۰۴

تاریخ داوری: ۱۹ شهریور ۱۴۰۴

تاریخ اصلاح: ۱۷ مهر ۱۴۰۴

تاریخ پذیرش: ۲۱ آذر ۱۴۰۴

واژگان کلیدی:

واقعیت مجازی

ویدئوهای ۳۶۰ درجه

زبان انگلیسی به عنوان زبان خارجی

درماندگی آموخته شده

بافت اقتصادی-اجتماعی پایین

* نویسنده مسئول

rahimi@sru.ac.ir

۰۲۱-۲۲۹۷۰۰۳۵ ①

پرسشنامه باز-پاسخ که در بین نمونه ای هدفمند از فراگیران دارای درماندگی بالا و پایین توزیع شده بود جمع آوری و سپس با روش تحلیل محتوا بررسی شد.

یافته‌ها: نتایج تحلیل کمی نشان داد تفاوت معناداری بین عملکرد گروه تورهای واقعیت مجازی ۳۶۰ درجه معلم ساخت و گروه ویدئوهای آماده وجود ندارد، هرچند که میانگین پیشرفت تحصیلی گروه آزمایش از گروه گواه بالاتر بود. در مقابل، درماندگی آموخته شده نقش بسیار تعیین کننده ای در یافته ها داشت، بطوریکه عملکرد دانش آموزان با درماندگی پایین در آزمون نهایی، چه در مقایسه درون گروهی و چه در مقایسه بین گروه ها، بطور معناداری بهتر از دانش آموزان دارای درماندگی بالا بود $[F(2,52) = 5/311, p = 0/008 < 0/05]$. بالاترین میزان پیشرفت تحصیلی در میان دانش آموزان کم درمانده ی گروه آزمایشی مشاهده شد که نشان می دهد تجربه با فناوری های احاطه گر و طراحی شده توسط معلم، برای فراگیران با انگیزش و خودکارآمدی بالا سودمندتر است. یافته های کیفی نیز نشان داد که فراگیران با درماندگی پایین، تورهای مجازی را جذاب، مرتبط و موثر بر بهبود واژگان و درک مطلب توصیف کردند. در مقابل، فراگیران با درماندگی بالا از نبود علاقه، تردید نسبت به ارزش آموزشی ویدئوهای واقعیت مجازی و گاهی احساس تردید و سردرگمی سخن گفتند.

نتیجه‌گیری: این مطالعه نقش نهفته و پیچیده ی درماندگی آموخته شده را در واکنش فراگیران به فناوری های احاطه گر نشان می دهد. در حالیکه تورهای واقعیت مجازی ۳۶۰ درجه معلم ساخت می تواند یادگیری و میزان درگیر شدن دانش آموز با محتوای آموزشی را افزایش دهند، مزایا و ارزش آموزشی این فناوری ها برای همه فراگیران یکسان نیست. در مناطق محروم و کم برخوردار که میزان درماندگی آموخته شده در میان دانش آموزان بیشتر است، بکارگیری صرف فناوری های نوظهور و پیشرفته تضمین کننده عدالت آموزشی نیست. ادغام این فناوری ها نیازمند حمایت های آموزشی، عاطفی و مداخلات هدفمند برای کاهش موانع ناشی از درماندگی و بی انگیزگی دانش آموزان است. یافته های این پژوهش بر ضرورت کاربست فناوری با در نظر گرفتن متغیرهای بافت زندگی و تحصیلی دانش آموزان با در نظر گرفتن ویژگی های فناوری آموزشی و تفاوت های روانشناختی دانش آموزان تأکید می کند.

Introduction

The diffusion of information and communication technologies (ICTs) has significantly contributed to educational equality by providing the resources disadvantaged learners need and helping them reach their full potential in academic and professional arenas. However, providing technological services to narrow the digital divide does not automatically lead to academic success or community empowerment in low-socioeconomic-status (SES) environments. The reason lies in the fact that using technology for pedagogical purposes depends on many factors, including "economic conditions, teachers, social dynamics, and institutional culture differences" [1, p. 1070] in this milieu. While previous research on this issue has mainly focused on technological variables [2], the role of disadvantaged students' psychological characteristics in benefiting from technology to support their academic success remains under-researched.

One particular motivational variable in this survey scheme is learned helplessness (LH), defined as a psychological condition in which people come to believe that they have no control over their situation and stop their effort to change [3]. People who experience persistent failure, abuse, and poverty are more prone to suffer from LH and often stop trying to improve their situations, even when opportunities to change are provided. LH is reported to be connected to living status in underprivileged areas [4], where individuals and communities often face chronic poverty, economic hardship, limited access to social services, undeveloped technological infrastructure, and educational disadvantages.

In underprivileged environments, the experiences of being overlooked or excluded from society may lead to the passivity of the elder members of the family and their withdrawal from fighting for their rights or better living conditions. Unfortunately, this may deeply affect young people because children

often learn from their parents' behaviors, attitudes, and beliefs. Doubting the ability to overcome difficulties leads to low confidence and self-esteem that immensely impacts learning, motivation, and academic success at school. In this context, the students may not show any willingness to pursue their academic tasks, not because of resource disparity or digital divide, but because of their LH, which may be the underlying reason for the modest effect of technology on disadvantaged students' learning [5]. As no study has examined the role of emerging technologies in learning outcomes and LH among disadvantaged students, the current study aimed to probe into the effect of teacher-made 360° VR virtual tours on learning English as a foreign language (EFL) in an underprivileged area when students' LH is taken into account. The study utilized an exploratory sequential mixed-methods design where the quantitative and qualitative data collection and analyses were integrated sequentially. The purpose of this study is threefold:

- (a) Identifying the effects of teacher-made 360° VR tours on learning English as a school subject in a low SES environment;
- (b) Assessing the role of students' level of LH in learning English when teacher-made 360° VR tours are integrated into instruction in a low SES environment; and
- (c) Understanding the participants' perceptions of the experience of teacher-made 360° VR tours in their English classes with a focus on their level of LH.

Review of the Related Literature

Educational Technology and Digital Divide (DD)

The advent of different types of technologies and their presence in almost all spheres of human professional and personal endeavor

have raised awareness of DD, where a sector of society is deprived of access and use [6]. As for pedagogical purposes, the use of educational technologies at schools is reported to be immensely correlated with the SES of where the school is located and where the students live [7]. Three levels of DD, including deprivation of devices and infrastructure at schools, a lack of teachers' readiness to integrate technology in instruction, and technology use to empower each student [8], cause digital inequality between advantaged and disadvantaged areas.

The first level of DD that has been frequently surveyed is concerned with the equitable access to technology, including hardware, software, and internet connection within school environments. Insufficient IT infrastructure development (environmental determinants) as a first-order barrier to technology use at schools [9] plays a key role in technology acceptance and integration by both teachers and students. Previous literature shows that satisfactory access to technology at schools increases the quantity and quality of educational activities [10], causes more collaboration among teachers and school staff [11], and lowers technostress while enhancing IT literacy [12].

It is notable to mention that satisfactory access to technology at schools is associated with the diffusion of technology and its normalization in a social system [13]. This includes a range of technologies that have been in the process of being normalized in different learning contexts (advantaged vs. disadvantaged) for the past two decades, such as computer simulations and interactive white boards (IWB), learning platforms, mobile devices, digital games, electronic books, immersive technologies (AR, VR), robotics, and AI [10]. Therefore, schools' digital capacity is dependent on school leadership, management, and strategic planning [14] and how the school culture inspires teachers and students to adopt

a positive mindset towards technology and its educational benefits [15].

Central to this argument is the fact that DD is never eradicated, considering the reluctance of the educational stakeholders to accept constant change that takes place in the realm of educational technology and the limited resources the governments have for the development of technological infrastructure [16]. Hence, in this context, there is a need to understand why a satisfactory IT infrastructure does not necessarily guarantee widespread use of technology for pedagogical purposes [17]. This concern widens the avenue of research on second-order barriers, that is, personal determinants [9], including teachers and students, and their role in technology disparity.

Teachers' ICT integration is often studied within the 'Will Skill Tool' framework [18] that deals with teachers' attitudes to technology, their competence to work with technological systems and devices, the time they spend working with technology, and whether they own any technological devices. Type of school leadership, as well as availability of technological tools and devices, are found to be the determinants of these three attributes. Teachers' attitudes and motivation to use technology are reported to be related to school culture, where the school administration supports and encourages technology integration [19]. Also, teachers' knowledge base to use technology operationalized in the TPACK framework [20] is influenced by how schools provide them with innovative technologies and ways of using them in their instruction. Teachers' willingness to own modern digital devices is hugely impacted by their job satisfaction, job demand, and the financial resources and professional support they receive from administrators and policymakers [12].

As for students' use of educational technologies, past research indicates a variance in the way students used technologies for academic purposes, with task type and social context of learning playing a mediating role [21]. In addition to academic gains, other student variables, including pedagogical (e.g., skill development), psychological (e.g., attitudes), sociological (e.g., gender), and technological (e.g., technology type), have been studied [22]. The results of the studies show mixed findings with respect to the effect of educational technology on students' academic performance and an insignificant correlation between ICT use and learning gains, suggesting more research is required on the issue when school culture, philosophy of education, and learning environments are taken into account.

Learned Helplessness and EFL Learning

Learned Helplessness is a psychological phenomenon through which an individual stops trying to change their situation after experiencing repeated negative events beyond their control, even if opportunities for improvement arise [23]. LH shows its effects in almost any human activity that needs concerted effort to set goals and reach them with persistence and endeavor, such as education, professionalism, and social/individual relationships. The negative impact of LH often shows itself in lowering motivation or depression, where people feel powerless to progress and thus quit trying to overcome problems or improve their conditions. LH can be a major barrier to success and productivity because when people repeatedly encounter failure, setbacks, or uncontrollable obstacles, they may develop negative perceptions and beliefs that their actions do not matter in altering the circumstances. This mindset leads to inaction, reduced effort, and a lack of motivation, even if a positive and healthy

environment provides the conditions for thriving and improvement. Research shows that LH can reduce initiative, creativity, and problem-solving skills [24] and lead to procrastination, avoidance, and stress [25].

Learned Helplessness plays a pivotal role in education as it can affect students' learning motivation, engagement, and overall academic success [26]. When students experience failure on different occasions during learning different subject matters, they may develop an attitude that their efforts will not aid them in acquiring knowledge or improving their skills. Previous research shows that a high level of LH results in disengagement from schoolwork [27] and poor performance in tasks or tests [28] and thus creates a sense of reluctance for trying harder to achieve academic goals. LH leads students to avoid challenging assignments because the fear of failure causes avoidance of difficult subjects, assignments, or projects. The constant fear of failure and low self-esteem may create learning anxiety [29] and lead students to lose their worth and capability for participating in class activities. This feeling gradually turns them into passive learners and destroys their risk-taking potential to take the initiative to answer questions or take the responsibility of completing group or individual tasks. The interplay among these negative feelings causes students to lose their interest in studying and reinforces lower academic performance as a result of poor grades [30].

Learned Helplessness in students may develop due to various factors rooted in repeated experience of failure or a lack of control over academic progress. Schools, teachers, teaching content, assessment techniques, and the type of syllabus, as well as parents and students themselves, are among the sources of school LH. Consistently struggling with school subjects, tests, and assignments without receiving appropriate feedback and/or

guidance to help them thrive makes students believe that their effort for success is pointless and doomed to failure. A system of education that puts lots of pressure on students for unrealistic objectives through overemphasizing product-oriented syllabuses creates a strong fear of committing mistakes and self-worthlessness among students, which heavily affects their willingness to try hard. Overwhelming expectations from the students by their parents hinder students from improving their problem-solving skills, and thus, their self-confidence is destroyed, leading to the feeling of incapability to do anything [24]. Teachers' authoritative approach limits students' freedom and engagement in school work and lowers their autonomy and self-directedness, which ultimately results in passive learning behaviors. Students' negative feelings towards themselves and their capabilities may increase their fear of making mistakes or being judged by other students. These emotional struggles may drain learning motivation and contribute to the development of depression and stress over time, and lead to avoiding taking risks or learning new skills [31]. When LH is examined within an EFL setting, it leads to a condition called EFL LH or a language learner's perception of their intrinsic incapability to master English, typically formed through a pattern of repeated failures in their language acquisition journey. Unlike other school subjects, foreign language learning distinctly demands regular public risk-taking (e.g., speaking in front of peers). Several factors, such as fear of speaking, repeated negative feedback, and overemphasis on accuracy over communication, which often expose learners to anxiety, embarrassment, and judgment, are ideal conditions for helplessness to take root [32].

EFL LH is a critically important issue, as students with this mindset start to believe that

being successful in language learning is gained only due to their innate skills rather than their efforts. This fixed mindset can affect language learners' lives in different ways. The first one is the motivational aspect, which is viewed as the heart of LH. Lack of motivation in this context may manifest as unwillingness to participate in language tasks or undermining goal-setting and persistence in language learning [3]. Another aspect of EFL LH is the emotional dimension of language learning that often triggers intense emotions such as anxiety, shame, frustration, and hopelessness in language learners [32]. Moreover, there is the cognitive aspect of EFL LH, which involves maladaptive beliefs about one's capabilities, like overgeneralization of past failures and low self-efficacy [33]. Finally, the behavioral deficit of EFL LH is the most visible factor observed by teachers. It includes disruptive behaviors, passivity, and task avoidance [34]. Since the negative interaction of these four dimensions can hinder language acquisition, understanding EFL LH as a complex, intertwined system of different psychological aspects is of utmost importance.

Into the bargain, several studies have been done investigating the relationship between LH and English language learning since the conception of LH. It is known that an individual's outlook has a great influence on their sensitivity to LH, and the neuroticism trait, which refers to people with emotional instability and vulnerability to failure, increases the risk of experiencing LH in learning English [35]. Students' self-concept and beliefs toward themselves have a crucial role in developing a sense of helplessness during language learning [31]. To put it another way, students with an internal locus of control and a low level of LH tend to show a more positive attitude toward English [36]. Evidently, LH and language learning anxiety are two affective variables that adversely affect the educational process [29].

A few studies underscore the fact that LH has a domain-specific component, and there is a negative relationship between helplessness and academic achievement in language [36, 37]. Sucu and Bulut [38] found a significant relationship between students' level of LH in English language learning and their objectives in terms of perceived English achievement levels. Interestingly, people who had good career expectations as their objective in learning English experienced a higher degree of LH than those who learned English because they enjoyed it. Similarly, Kolber [39] claimed that the degree of LH in English lessons is nearly the same as in other high school subjects, such as Polish and math, and motivational deficit strongly influences the growth of LH.

It should not be neglected that teachers' positive attitudes toward students' capabilities improve students' English language performance [40]. The significant role of teachers' care in alleviating LH is undeniable, as it increases students' motivation and educational success in EFL classrooms [26]. Motivational intervention, along with supportive feedback provided by the teacher, exhibited successful results in reducing learners' LH and enhancing English language learners' academic achievements [41]. Investigation into the influence of the L2 Motivational Self System program on secondary students' LH in English language learning shows that the intervention program improved learners' future self-guides, visualization capacity, and scholastic achievements, as well as minimizing the negative effects of LH [42].

Method

Participants

A total of 58 female 10th-grade students, aged 15-16, participated in the study as the control (n=29) and the experimental groups (n=29). The

study was conducted in a public high school located in District 18 of Tehran. This area is classified as one of the less developed neighborhoods of the capital, considering the indices of life quality, including population density, economy, culture and identity, safety and urban management, sports/recreation centers, and quality of transportation/passages [43]. Due to financial issues the families faced, the majority of the students had to work to enhance their living conditions. No student owned a digital device, and this was their first experience of using portable digital devices for educational purposes.

Instruments

The English Test

An English achievement test was used to assess participants' knowledge of the content covered in the Grade 10 English textbook (Vision 1). The test was developed by the English Department of the Ministry of Education (MOE) and had 53 multiple-choice items and 4 parts, including vocabulary (14 items), pronunciation (4 items), grammar (25 items), and reading (10 items). Before the intervention, the test was administered as a pretest to assess students' baseline knowledge of the course content and to ensure the homogeneity of the control and experimental groups. The same test was administered again at the end of the study as a posttest to measure students' learning gains following the instructional intervention.

Test validity and reliability were calculated before the experiment through a pilot study based on test development guidelines [44]. To this aim, first, a detailed table of specifications was outlined to encompass a well-balanced representation of the content of the book. Then, the test items were studied in detail, and a thorough assessment was conducted to ensure the effectiveness of the distractors. Following that, the test was piloted with 104

students, and a thorough item analysis (item distribution, item facility, and item discrimination) was done in order to evaluate test validity. The indices were checked by two experienced English teachers, and the final version of the test was approved after undergoing revisions on specific items. Internal consistency reliability was estimated using the Kuder-Richardson formula 21 (KR-21), yielding a coefficient of 0.92.

EFL-LH Scale

To assess students' LH in English classes, the EFL-LH scale [25] was used. The scale has 25 items rated on a five-point Likert-type scale, ranging from '1=strongly disagree' to '5=strongly agree'. The EFL-LH scale measures four dimensions of LH in learning English as a foreign language, including motivational (M), emotional (E), cognitive (C), and behavioral (B) deficits. The reliability coefficients of the EFL-LH scale and its factors were estimated by Cronbach's alpha and found to be 0.93, 0.82, 0.85, 0.87, and 0.85, respectively.

The Open-Ended Perception Questionnaire

The participants were asked to express their perceptions of their experience of watching teacher-made 360° VR tours by completing a researcher-made open-ended perception questionnaire. The questionnaire consisted of seven open-ended questions designed to elicit students' reflections on engagement, perceived learning benefits, teacher role, and challenges encountered during the intervention.

Before the main study, the questionnaire was piloted with 30 students from a school with similar socioeconomic and educational characteristics. Based on the pilot results, minor revisions were made to the wording of some questions to improve comprehensibility. The final version was reviewed by two experienced EFL teachers for content clarity and relevance.

Example questions are: *“How did watching the 360° VR tours affect your understanding of the lesson content?”* and *“How would you describe your teacher’s role in encouraging you to use this technology?”*

Materials

The Textbook

The textbook was Vision 1, developed by Iran’s MOE for grade 10 of high school [45]. The book has four lessons focusing on teaching all four language macro skills, as the Vision Series is developed based on the Nation’s four strands proposition [46]. Vision Series utilizes “an adapted version of communicative approach labeled ‘the self-esteemed and active approach’ [16, p. 486] and follows the Content and Language Integrated Learning (CLIL) framework to present the content [46].

360° VR Tours

Teacher-Made 360° VR Tours

Eight 360° VR videos were prepared by the teacher to be incorporated into teaching the content of Vision 1 (Fig. 1). To design the videos, certain stages were taken as described below:

- Identifying the subthemes and topics of each lesson of Vision 1;
- Identifying the parts of the book where 360° VR videos were to be incorporated (coursebook reading, workbook reading, and the passages of the fluency section);
- Selecting the venues for making the 360° VR tours in Tehran in association with the themes of the lessons;
- Writing the scenarios of the tours, considering the general and linguistic (vocabulary and grammar) contents of each lesson;
- Reviewing the scenarios by two colleagues;
- Finalizing the scenarios;
- Recording the 360° VR tours by Samsung Gear 360 camera; and

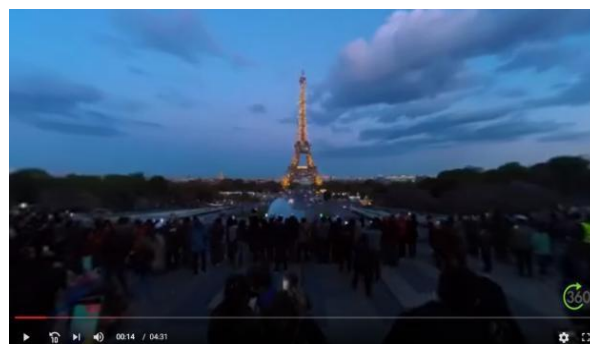
- Editing and finalizing the VR videos with Movavi 360 Video Editor

Ready-Made 360° Virtual Tours

Unlike the experimental group, the control group was provided with authentic 360° tours. The videos were selected based on their compatibility and relevance with the topics and content of the lessons of Vision 1 (Fig 1).



(a)



(b)

Fig 1: 360° VR Tours: (a) Teacher-made 360° VR tour (Darabad Wild Life Museum in Tehran), and (b) Ready-made 360° VR tour (Paris Tour)

Digital Devices

The Samsung Gear 360 camera was utilized by the teacher (the first author of the study) to capture 360° videos. The 360 Dual lens video recording resolution of the camera is up to 2048 x 4096 (24 fps), and the Single lens video recording resolution is up to 1920 x 1080 (60 fps). The camera comes with a special application called Samsung Gear 360 Manager that lets users manage the recorded content (Fig. 2).

GTab S8X tablets were used in the classes so that the students could watch 360° videos during instruction. The tablets had an 8-inch screen with a resolution of 800 x 1280 pixels of the IPS type that provided a completely acceptable image resolution and readability to watch 360° videos.

The Software

The Samsung Gear 360 Manager was used to control the process of filming teacher-made 360° videos with the Samsung Gear 360. The application allows users to create, view, and share 360° content on their smartphones.

Movavi 360 Video Editor was used to edit teacher-made 360° VR videos after filming. Special effects, background music, graphics, animations, and texts were added to the recorded tours to make the content more pedagogical. VR Media Player was installed on the tablets to enable students to watch the videos easily. The application not only supports 360° or spherical videos and photos but also allows users to have 180° equirectangular, regular lens, and fisheye lens views (Fig 2).

Research Design

The study adopted an exploratory sequential mixed methods design, combining quantitative and qualitative data [46]. The quantitative phase employed a pretest-posttest quasi-experimental design with an experimental and a control group. The qualitative phase was subsequently conducted to provide deeper insights into learners' experiences and perceptions of 360° videos and to support the quantitative findings.

Procedure

Research Procedure

Fifty-eight female grade 10 students were selected randomly and were assigned to be the control and experimental groups by the

fishbowl draw. The students were informed about the research study and the upcoming events. Participants were assured that all findings and data gathered from tests and the open-ended questionnaire would remain confidential and exclusively utilized for research objectives, without being shared with external parties. To ensure participant anonymity, pseudonyms were used when reporting excerpts from participants' written responses to the open-ended questionnaire.

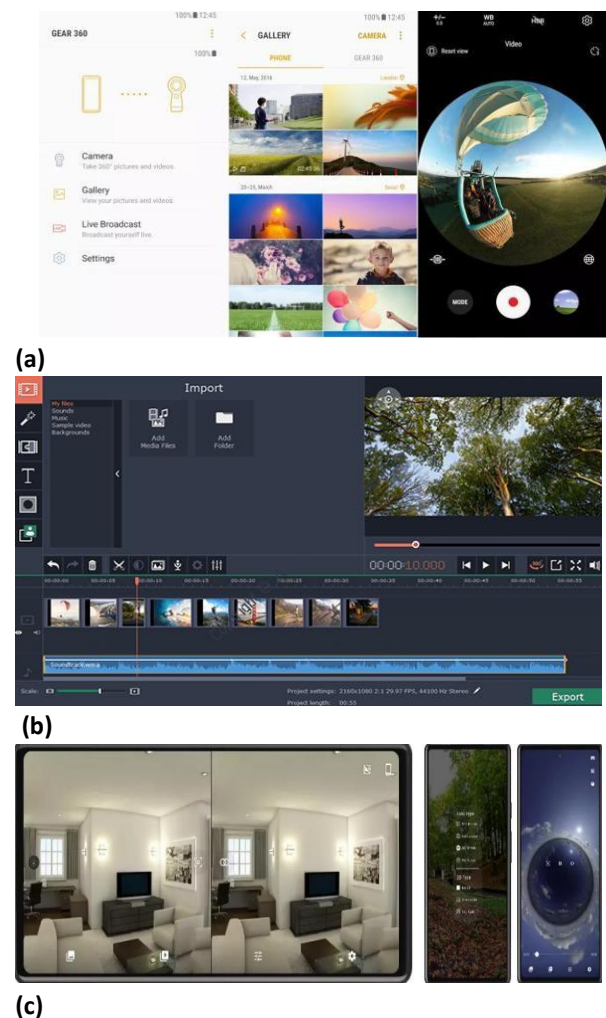


Fig 2: Software used for creating, editing, and viewing 360° virtual tours: (a) Samsung Gear 360° Manager, (b) Movavi 360° Video Editor, and (c) VR Media Player

Since this study was the students' first encounter with VR videos at school, an introduction along with certain instructions was

given to make them familiar with the technology. Before the study, all participants took part in pretests in two consecutive sessions, including English test administration and questionnaire completion. The study lasted for one academic year from October 2023 to June 2024. At the end of the study, both groups participated in posttests, and the experimental group members completed the open-ended questionnaire.

Instructional Practice

The 360° VR videos were integrated into teaching reading sections of Vision 1 since reading texts function as the context of introducing new words and grammar, and a basis for developing the other three language skills (listening, speaking, and writing) in this book. Reading passages were taught based on the pre-during-post reading cycle. This approach involves the initial step of stimulating students' prior knowledge of the subject before instructing them to engage in reading and understanding the text. After reading the passage, the teacher assesses the student's comprehension through post-reading exercises like reading comprehension questions [46]. 360° videos were used in the pre-reading stage to make students familiar with the topics and contents of the text they were going to read. The goals of each phase of reading instruction are depicted in Table 1 [47].

Table 1: Major goals of each phase of the pre-during-post reading framework [47, p. 249]

Pre-Reading Phase	During-Reading Phase	Post-Reading Phase
-Establish reading purpose	-Guide reading to facilitate comprehension	-Check comprehension
-Tap prior knowledge	-Help students construct meaning and monitor comprehension	-Explore how text organization supports comprehension
-Provide information needed for		-Consolidate learning

Pre-Reading Phase	During-Reading Phase	Post-Reading Phase
comprehension (e.g., vocabulary, background)	-Give students opportunities to connect what is read with what is known; to evaluate what is being read	-Provide opportunities for students to summarize, synthesize, evaluate, elaborate, integrate, extend, and apply text information
-Set up expectations	-Provide opportunities for fluency development	-Give students the chance to critique the author and aspects of the text (e.g., writing, content)
-Stimulate interest	-Support ongoing summarization	-Establish and recognize comprehension successes
-Build confidence and motivation		
-Explain or support text organization		

Results and Findings

Pretests

To examine the entry-level performance of the participants on the English test and EFL-LH scale, two independent samples t-tests were run. The results showed that both groups were homogeneous in their English knowledge [$t(56)=0.54$, $p=0.591>0.05$] and LH level [$t(56)=0.54$, $p=0.360>0.05$] before the experiment.

Effects of Teacher-Made 360° VR Tours on Achievement

Two-way Analysis of Variance (ANOVA) was used to explore the effect of teacher-made 360° virtual tours on the achievement of students across groups, considering their level of LH. Before running ANOVA, the preliminary assumptions (normality, linearity, multicollinearity, and homogeneity of variances) were checked [48]. As the result of ANOVA shows (Table 2), the interaction effect

between research group (type of intervention) and level of LH was not statistically significant [$F(2, 52) = 0.068, p = 0.934 > 0.05$]; however, there was a statistically significant main effect for LH level [$F(2, 52) = 5.311, p = 0.008 < 0.05$], with a big effect size ($\eta^2 = 0.17 > 0.14$) [49].

Post-hoc comparisons using the Tukey HSD test indicated that the mean score of achievement for the low LH group ($M = 42.85, SD = 7.672$) was significantly different from the mid LH ($M = 33.556, SD = 13.249$) and the high

LH ($M = 33.950, SD = 9.610$) groups. The main effect for group did not reach statistical significance [$F(2, 52) = 0.957, p = 0.333 > 0.05$].

The estimated marginal means of both groups' performance in the posttest across levels of LH show that students with a lower level of LH outperformed those with mid and high levels of LH in both control and experimental groups. Moreover, students of all three sub-sets in the experimental group outperformed their counterparts in the control group (Fig. 3).

Table 2: The result of a two-way ANOVA on post-test across research groups, considering the levels of LH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1206.671	5	241.334	2.188	.070	.174
Intercept	76925.225	1	76925.225	697.527	.000	.931
Group	105.505	1	105.505	.957	.333	.018
LH level	1171.406	2	585.703	5.311	.008	.170
Group* LH level	15.010	2	7.505	.068	.934	.003
Error	5734.709	52	110.283			
Total	85900.000	58				
Corrected Total	6941.379	57				

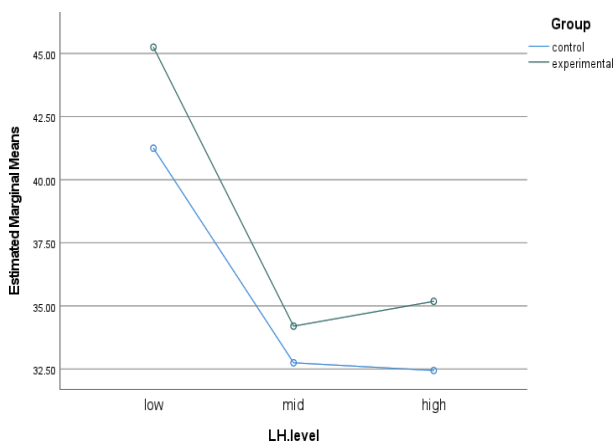


Fig 3: Estimated marginal means of post-test

Perceptions of Teacher-Made 360° VR Tours

The qualitative data were obtained from the participants' written responses to the open-ended questionnaire administered at the end of

the intervention. The responses were analyzed using qualitative content analysis. The texts were coded first manually and then by utilizing QSR NVivo Enterprise 20. To do the content analysis, first, both researchers read the texts carefully and independently and coded the responses manually. In three elaboration sessions, the codes were compared, and disagreements were resolved (Kappa index=0.92). The coded responses were then grouped into themes and subthemes. The codes, themes, and subthemes were inserted into the software for further analysis. The frequency and percentage of codes are presented in Table 3 to support the interpretation of the themes.

As can be seen in Table 3, five main themes emerged from the students' perceptions of

their experience with 360° VR tours, including: attitudes/evaluative perceptions, perceived disadvantages, language learning, perceived challenges, and teacher role.

Table 3: Participants' perceptions of 360° VR tours for learning English

Themes	Rank	Word	Count	Percentage	Subthemes
Attitude and evaluative perceptions	1	Effective	21	4.30	Likes
	2	enjoyable	18	3.72	Dislikes
	3	think	15	3.33	
	4	interesting	14	3.26	
	5	good	16	2.97	
Perceived Advantages	1	watching	19	3.98	-Motivation
	2	self-confidence	16	3.90	-Cognition
	3	better	12	2.93	-Self-confidence
	4	work	14	2.36	
	5	involve	10	2.32	
Language learning	1	words	57	8.86	-Macro skills
	2	reading	54	7.28	-Micro skills
	3	improved	26	4.11	
	4	grammar	22	3.48	
	5	comprehension	26	2.85	
Perceived Challenges	1	questions	17	12.9	-Technology
	2	tasks	7	5.22	-Language tasks
	3	difficult	6	3.98	
	4	discussion	5	3.73	
	5	details	4	2.99	
Teacher role	1	motivated	9	5.00	-Caring behavior
	2	explained	6	3.33	
	3	tried	6	3.33	-TPACK
	4	energetic	5	2.78	
	5	encouraging	6	2.22	

Attitudes and Evaluative Perceptions towards 360° VR Videos

Students generally expressed positive feelings and perceptions toward the 360° VR tour experience, often highlighting the enjoyment and novelty of exploring new places virtually. Many described the tours as engaging and immersive, as Mina (a low-LH student) explained that the experience allowed her “to

get familiar with famous places and people in Tehran and learn many words about them.” Mid-LH students echoed this appreciation, emphasizing the realism and accessibility of the virtual visits. Sara noted that “the 360° videos allowed us to experience the locations as if we were actually there”, and Zahra said that the experience motivated them “to study more about these places and ... plan to visit these great tourist attractions.”

Students also expressed enthusiasm for working with mobile devices as Shamim found the technology “user-friendly”, noting that “interacting with the videos multiple times supported accessibility, especially for students with low eyesight”. Low-LH learners like Atena described the experience as “very interesting”, explaining how surprising and exciting it was “to work with tablets in our school” for the first time. The sense of enjoyment was frequently mentioned, as Hadis (one low-LH student) stated, “It was an interesting experience ... I get eager to listen and watch more English content” and highlighted the immersive quality of the videos by referring to their “high resolution and high-quality sound”.

Despite the overall positivity, some high-LH students expressed negative perceptions, primarily due to the difficulty they had with the content. Maryam stated that, “It made me confused because I couldn’t understand the contents of it,” while Yara noted that they “would rather have more practice and teaching on grammar” instead of using the tours.

Perceived Advantages of 360° VR Videos

Across LH levels, many students emphasized the motivational impact of the 360° videos. Several described how the tours activated prior knowledge and made subsequent readings more comprehensible. Sima (a low-LH student) noted, “The videos introduce you to new information, and then when you read passages

with the same topic, it is much more comprehensible". Mid- and high-LH learners also reported increased interest in English, as Sanam (one mid-LH student) stated, *"I am more interested in learning English now,"* and Yekta (a high-LH learner) explained that the videos encouraged them *"to try my best to learn new things"*.

Students also described clear cognitive benefits, particularly in comprehension, memory retention, and working memory. Low-LH learners reported that the videos *"boosted our comprehension skills"*, while mid-LH students emphasized the advantage of visual support, noting that *"pictures will be remembered more than sounds"*, giving 360° videos superiority over audio files or ordinary videos. Many highlighted the value of multimodal input; for example, Nasim (one low-LH student) appreciated receiving information *"from different sources, such as pictures, voices, some transcriptions, and words"*; and Hasti (a mid-LH student) added that watching and listening simultaneously helped them understand context that would be missing from audio-only files.

Despite overall benefits, a few high-LH students reported that the videos were *"too difficult"* and *"not interesting"*, noting that they sometimes struggled with comprehension and found this technology less useful for learning some parts of their books, like grammar and writing.

Language Learning by 360° VR Videos

Students widely agreed that 360° tours supported their language learning, particularly in receptive skills and vocabulary development. Many described improved reading comprehension. Mobina (a mid-LH student), for instance, stated that *"I could understand the reading of my textbook and workbook better*

after watching these videos," and Rojan (a high-LH student) similarly reported that her reading had *"grown much better,"* despite still struggling with some comprehension questions.

Vocabulary development emerged as a strong outcome as well. Low-LH students described recalling words by *"referring to their pictures in the video,"* while high-LH students acknowledged vocabulary growth even when other areas felt less supported, stating that the experience enabled them to *"write new sentences and express... opinions"* with newly learned words. However, consistent with earlier themes, some high-LH suggested that the benefits were more pronounced for receptive language skills than for form-focused aspects of language learning.

Perceived Challenges in Using 360° VR Videos

Students reported a few technical challenges or minor technical problems while using the devices. More commonly, students highlighted challenges with the follow-up language tasks. Some low-LH learners initially found the tasks difficult but engaging, explaining that looking for unfamiliar words in the videos using their fingers *"was some kind of a game and drove our curiosity,"* and encouraged them to persist despite the difficulty. A few high-LH learners, however, were more likely to describe the activities as difficult or overwhelming. Kiana, for instance, noted that *"I found them too difficult for me"*, while Roshanak stated that fill-in-the-blank and writing tasks were challenging *"since my English language skills are low"*.

Teacher role

Students across all LH levels consistently highlighted the teacher's crucial role in shaping their experience with VR videos. Many described the teacher as caring, supportive, and motivating, emphasizing her efforts to guide them and encourage participation. Students

also appreciated the teachers' technological and pedagogical skills. Low-LH learners were impressed by the creation of the 360° content, as Roya stated, *"I have never imagined that someone could make such educational content by recording 360° videos."* Mid-LH students praised her creativity, noting that she *"always came up with new tasks and ideas"* to stimulate their interest, while high-LH students valued her patience and clarity, describing her role as *"a facilitator who helped us in need and explained everything clearly."*

Despite this overwhelmingly positive view, a few high-LH students felt that the teacher's effort could not fully compensate for the difficulty they experienced with the videos. Pardiss explained that although the teacher *"explained everything multiple times, the videos were more beneficial for more proficient students,"* suggesting a mismatch between the technology's demand and their own proficiency level.

Discussion

Over the past decade, researchers have explored how LH manifests in EFL learners, its underlying causes, and its impact on language acquisition and motivation. Since this condition significantly impacts language learning and teaching, this study was done to find a remedy for enhancing EFL achievement and helplessness in a low SES setting by integrating teacher-made 360° VR tours into English classes.

Based on the findings of the study, the implementation of 360° VR videos, either ready-made or teacher-made, was found to have a statistically positive effect on EFL learning gains at the end of the experiment, supporting what is already reported in the literature that using VR technology leads to better language learning outcomes as it offers

an active learning experience [50]. As a form of multimedia, VR can cognitively engage learners with the content by helping them select relevant information, organize it into visual or verbal formats, and connect it with what they already know. Using VR multimedia can reduce the cognitive load on WM and help students manage their intrinsic cognitive load, freeing their capacity to process information more confidently [51]. Also, optimization of the germane cognitive load minimizes the extraneous cognitive load that ultimately leads to better retention and learning outcomes [52].

Virtual videos increase learners' engagement and motivation and lower their language learning anxiety as they offer an opportunity for learners to practice, understand, and build their confidence in real-life interactions through simulated environments [53]. Further, virtual learning environments are perceived positively by students as they facilitate interactional behavior through developing cross-cultural competence [54]. It is obvious that physical travel for the purpose of language learning is not always feasible. Thus, the simulated environment that the 360° VR videos offer can reinforce language learning as the learners have the opportunity to practice the target language in a virtual world [55]. In addition, former studies show that integrating VR into the CLIL framework can increase comprehension and language learning as students are engaged both physically and cognitively in the learning environment [51].

Noteworthy to mention, however, that although the experimental group outperformed their counterparts in the achievement posttest, the difference between both groups was not significant when the group members' level of LH was not considered. In other words, what could make a change in benefiting from the integration of teacher-made 360° VR videos was

students' level of LH, as students with a lower level of LH in the experimental group outperformed their peers in the control group in all three subsets. In other words, students with high LH did not benefit from the intervention as low LH groups did, and LH is an underlying key factor in making students exploit the advantages of technology-enhanced learning environments. One reason for this outcome can be the study context, that is, a low SES setting, where the classes are not homogeneous, and many students lack the prerequisite knowledge base when they enter the upper grades. Schools in this area are overcrowded with many low achievers who show no motivation for learning English as a school subject. Their weakness in English accumulates grade after grade, and a challenging situation arises as learners with low English levels struggle to fit in the class and keep up with other students. Many of these students lack enough knowledge of grammar and vocabulary, and their language proficiency in the four skills is lower than expected grade [25].

In this process, repeated failure and consistently disappointing results lead to withdrawal from any classroom participation and, at higher levels, self-abandonment. This sense of constant failure is reinforced by what they experience out of school, where they live, as well. Families with low socio-economic status may experience repeated job rejections, low wages, and limited economic status, and over time develop the belief that no matter how hard they try, their situation will not change, and thus they may stop seeking better jobs or education. When parents feel powerless in the face of challenges and consistently express defeat, hopelessness, or the belief that they cannot change anything, children may develop the same fixed mindset [3]. As a result, the students lose their passion, motivation, and hunger for progressing in their studies and

develop the belief that studying does not help them have better lives.

Furthermore, the analysis of the qualitative data showed noteworthy results in all five main themes. Regarding feelings and evaluative perceptions, students with a lower LH level had more positive feelings toward virtual tours and their overall experience compared to those in the mid and high LH groups. Generally, using teacher-made VR videos made the students able to not only travel to different places in their city but also listen to the familiar voice of their teacher and learn new vocabulary and grammatical items better because of its context-based approach. Therefore, teacher-made 360° VR videos could lower students' foreign language anxiety and improve students' interaction with the content that was more familiar to them. Meanwhile, one of the reasons for some negative perceptions toward virtual tours could be the educational and financial status of the students' families. This study was conducted in a school where the majority of the students came from families with low educational levels and financial problems. As a matter of fact, most of the students were not willing to study, let alone learning a foreign language. Since their priority is to financially support their families, learning English tends to be neglected over time, and sometimes it leads to school drop-out, corroborating the fact that ill-suited academic courses and financial and personal issues are the main reasons that make a student not willing to continue an educational program [56].

Considering the benefits, all students in the low and mid LH group found the experience useful and effective in motivation, cognition, and self-confidence. However, a few students in the high LH group doubted the efficiency of virtual tours in their language learning experience. Evidently, utilizing teacher-made

360° videos along with related activities in the process of language learning brought about positive perceptions among the students of the experimental group, as the instructional content was attractive and impressive. The teacher-made materials have been reported to be encouraging for students because of the sense of relativity that the learners feel while doing them, since the contents are created with the students' culture in mind [57]. As the pupils can relate to the content and activate the related schemata, they have a sense of accomplishment. In terms of language learning, all students claimed significant improvements in developing their receptive skills, vocabulary, and pronunciation. Yet, a few members of the high LH group were not sure about the effectiveness of 360° VR videos in learning language structures and grammar. One possible reason for this finding is that the experimental group was provided with teacher-made 360° videos in which the instructor narrated the scenes with her own voice. Obviously, teacher-generated materials are more appropriate in terms of language and vocabulary for students, as they are simplified or developed in accordance with lexical and linguistic norms [58]. This provided an environment for exchanging ideas and negotiation, which boosted participants' interactions in the classroom that ultimately improved their pronunciation [59]. Notably, the effective use of voice is pivotal for students' academic achievements and overall well-being in school, as it significantly affects their information processing and comprehension abilities [60]. The native accent of the speakers and the speed of speaking may sometimes cause problems in the comprehension and understanding of the students as non-native speakers, but intelligible English pronunciation is reported to be more understandable for EFL learners [61].

It is worth mentioning that some students had challenges with tasks that followed the

360° VR videos. Despite facing some difficulties, the low-LH learners were able to deal with the situation by applying language learning strategies. However, the high-LH ones struggled with the tasks due to their low English levels and questioned the benefits. This could be because of the fact that students have different capacities to handle difficult situations and adjust to the challenges. The more helpless a participant thinks they are, the more likely they are to withdraw from tasks [25].

Finally, the role of the teacher was claimed to be facilitating, motivating, and supporting by all the students with either low LH or high LH. The caring behavior and knowledge of teaching were two factors that highlighted the positive role of the teacher in the process of using 360° videos for language learning. Regardless of the constructive role of the teacher, few high-LH learners assumed that language learning via virtual tours was a better option for students with a high proficiency level in English. The interactions between learners and educators play an undeniably significant role in different domains of a learner's progress. The consistent and active support that the students receive from their teacher leads to their development and, as a result, builds self-esteem [62]. Also, healthy relationships between students and educators hinder the level of LH and reduce the possibility of experiencing higher levels of this phenomenon [63]. Former studies have highlighted the crucial role of teachers in learners' academic success, as they were suggested to pay more attention to students' emotional state and build positive rapport with them [12] [41], which can be achieved more effectively by teacher empathy in VR learning environments [64] [65]. Teachers' care is not only concerned with learners' emotional well-being but also with the guidance they can provide to help the students reach their highest

level of capacity [26] through integrating presence and agency as two key affordances of VR lessons [66].

Conclusions

The present study explored the effects of teacher-made 360° VR tours on EFL achievement and helplessness in an underprivileged setting. Through a mixed-methods research design, quantitative and qualitative data were collected from 58 Iranian female high-school students. Insignificant differences between experimental and control groups in terms of learning gains at the end of the experiment were revealed, with the experimental group members outperforming their counterparts. In terms of different levels of LH, students in the low LH group surpassed their peers in the high LH group within and between study groups. Further, learners in the low LH group demonstrated positive perceptions toward virtual tours and the effectiveness of this technology in their foreign language learning journey, while some high LH group members expressed their unwillingness to learning by this technology and questioned the educational benefits of the 360° videos. The outcome indicated that 360° VR tours not only acted as an entertaining agent and adventure guide but also as an educational medium, which facilitated the language learning process by exposing students to the use of different language items in specific contexts.

Certain limitations were identified in this study, which highlight the need for cautious interpretation of the results and pave the way for future research to address these constraints. One key limitation was the prohibition of smartphones or personal devices in the school, forcing the study to rely on a limited number of tablets supplied by the researchers. Another constraint stemmed from

Iran's single-gender education system, as the study included only female participants. While this allowed a focused examination of factors affecting female students, it overlooked potential gender-based differences that might emerge in co-educational settings, restricting the applicability of the results to mixed-gender populations. Furthermore, selecting culturally and educationally appropriate 360° VR videos posed a challenge for the researchers. The videos needed to align with the national coursebook and reflect Iranian cultural values, leading to the use of authentic content with caution after being evaluated by two colleagues.

Despite the limitations, further investigation by other researchers on this topic is recommended. In future studies, it would be advantageous to conduct a similar study that includes both male and female participants, allowing for a comparison of their performances, since this study highlighted only female participants. Moreover, it is advised to conduct further studies with a larger sample size to improve the generalizability of the findings. Also, a comparable study between students of different fields of study or learners from different high schools would be beneficial for the future of this research scope.

The results of this study provide valuable insights into the field of EFL and immersive technologies, thanks to its novel focus on VR-based language instruction. With ongoing technological advancements, the future of VR-based language learning looks very promising; thus, it is not impossible to think that VR can revolutionize language learning and teaching. Considering the EFL helplessness, the findings of the present study showed that learners with lower levels of LH demonstrated higher engagement and reported improved comprehension and vocabulary learning when using teacher-made 360° VR tours, while some high-LH learners expressed difficulty

maintaining interest and confidence. This suggests that the technology works in favor of EFL students when appropriate pedagogical support is improved, as it creates an enjoyable learning experience. EFL learners may become more engaged in the lesson, and the positive learning experience reported by participants may help reduce negative feelings associated with helplessness during the process of learning a foreign language. Thus, immersive technologies could be considered as a potential supportive approach for addressing EFL LH.

The study's implications extend beyond the classroom, potentially benefiting educational authorities, including the MOE, by addressing learned helplessness, which could lead to better academic outcomes and fewer dropouts. Introducing VR into teacher training programs could also equip new educators with knowledge of its potential. Additionally, material developers could capitalize on this approach by creating tailored 360° VR videos for various lessons, supporting teachers, and addressing the lack of culturally relevant content online. Local material developers, in particular, could produce educationally and culturally appropriate videos for language learners that boost their learning motivation and outcomes.

Authors' Contribution

Author 1 carried out the study and gathered the data. Author 2 conceptualized, designed, and supervised the research and drafted the manuscript. Both authors cooperated in writing the final edit of the manuscript. The authors have read the article and approved the submitted version.

Acknowledgments

Not applicable

Conflicts of Interest

The authors have no conflicts of interest.

References

- [1] Warschauer M, Xu Y. Technology and equity in education. In: Voogt J, Knezek G, Christensen R, Lai KW (Eds). *Second Handbook of Information Technology in primary and secondary education*. Springer; 2018. pp. 1063-79. doi:10.1007/978-3-319-71054-9_76
- [2] Cappola R. Using technology with low-income students: How schools can help students' success? [master's thesis]. Bethel University; 2020.
- [3] Seligman MEP. *Helplessness: On depression, development, and death*. Henry Holt & Co; 1975.
- [4] Camacho EM, Verstappen MM, Symmons PM. Association between socioeconomic status, learned helplessness, and disease outcome in inflammatory polyarthritis. *Arthritis Care Res*. 2012;64(8):1225-33. doi:10.1002/acr.21677
- [5] Di Pietro G, Muñoz JC. A meta-analysis on the effect of technology on the achievement of less advantaged students. *Comput Educ*. 2025;226:105197. doi: 10.1016/j.compedu.2024.105197
- [6] Mubarak F, Suomi R, Kantola S-P. Confirming the links between socio-economic variables and digitalization worldwide: the unsettled debate on digital divide. *J Inf Commun Ethics Soc*. 2020;18(3):415-30. doi:10.1108/JICES-02-2019-0021
- [7] Kim HJ, Yi P, Hong JI. Are schools digitally inclusive for all? Profiles of school digital inclusion using PISA 2018. *Comput Educ*. 2021;170:104226. doi:10.1016/j.compedu.2021.104226
- [8] Wang P. Examining the digital divide between rural and urban schools: Technology availability, teachers' integration level, and students' perception. *J Curriculum Teach*. 2013;2(2):127-39. doi:10.5430/jct.v2n2p127
- [9] Bowman MA, Vongkulluksn VW, Jiang Z, Xie K. Teachers' exposure to professional development and the quality of their instructional technology use: the mediating role of teachers' value and ability beliefs. *J Res Technol Educ*. 2020;1-17. doi:10.1080/15391523.2020.1830895
- [10] Timotheou S, Miliou O, Dimitriadis Y, Sobrino SV, Giannoutsou N, Cachia R, et al. Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review. *Educ Inf Technol*. 2023;28(6):6695-726. doi:10.1007/s10639-022-11431-8
- [11] Balanskat A, Blamire R, Kefala S. The ICT impact report. European Schoolnet; 2006.
- [12] Rastegar N, Rahimi M. Teachers' post-pandemic outlook on the role of Technological and Pedagogical Content Knowledge in coping with burnout under adverse conditions: How a job

- demand transformed into a job resource. *Front Psychol.* 2023;14:1129910. doi:10.3389/fpsyg.2023.1129910
- [13] Rogers M, Scott KL. The Diffusion of Innovations Model and outreach from the National Network of Libraries of Medicine to Native American communities. 1997.
- [14] Ređep NB. Comparative overview of the digital preparedness of education systems in selected CEE countries. Center for Policy Studies, CEU Democracy Institute; 2021.
- [15] Condie R, Munro RK. The impact of ICT in schools: a landscape review; 2007.
- [16] Rahimi M, Alavi J. The role of teaching experience in language teachers' perceptions of a top-down curriculum change. *Curric J.* 2017; 28(4) :479-503. doi:10.1080/09585176.2017.1344134
- [17] Sun JC, Yu C, Metros SE. The Digital Divide and its impact on academic performance. *US-China Educ Rev.* 2011;A2:153-61.
- [18] Knezek G, Christensen R, Hancock R, Shoho A. Toward a structural model of technology integration. Paper presented at: Hawaii Educational Research Association Annual Conference; 2000; Honolulu, HI.
- [19] Kim C, Keller J. Towards technology integration: The impact of motivational and volitional email messages. *Educ Technol Res Dev.* 2011;59(1):91-111. doi:10.1007/s11423-010-9174-1
- [20] Mishra P, Koehler MJ. Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers Coll Rec.* 2006;108(6):1017-54. doi:10.1111/j.1467-9620.2006.00684.x
- [21] Sweeney DM. Students' experiences of educational technology use to facilitate university learning: factors influencing their mediation of learning. *Res Learn Technol.* 2024;32:1-16. doi:10.25304/rlt.v32.3193
- [22] Valverde-Berrocoso J, Acevedo-Borrega J, Cerezo-Pizarro M. Educational Technology and student performance: a systematic review. *Front Educ.* 2022; 7: 916502. doi:10.3389/educ.2022.916502
- [23] Maier SF, Seligman MEP. Learned helplessness: Theory and evidence. *J Exp Psychol Gen.* 1976; 105:3-46. doi:10.1037/0096-3445.105.1.3
- [24] Khan A. Psychological influences on problem-solving following lab-induced learned helplessness. [master's thesis]. Western Michigan University; 2023.
- [25] Eftekhari M. Effects of adapted 360-degree videos on EFL learners' grammar achievement, reading comprehension, and learned helplessness. [master's thesis]. Shahid Rajaee University; 2024.
- [26] He H. Students' learned helplessness and teachers' care in EFL classrooms. *Front Psychol.* 2021; 12: 806587. doi:10.3389/fpsyg.2021.806587
- [27] Seifert TL. Understanding student motivation. *Educ Res.* 2004;46(2):137-49. doi: 10.1080/0013188042000222421
- [28] Akca F. The relationship between test anxiety and learned helplessness. *Soc Behav Person.* 2011. 39(1): 101–111. doi:10.2224/sbp.2011.39.1.101
- [29] Fer S, Akpur U. Learned helplessness, foreign language anxiety and their impacts on language learning. *MSGSÜ Sosyal Bilimler.* 2021;1(23):283-95.
- [30] Schleider JL, Vélez CE, Krause EL, Gillham JE. Perceived psychological control and anxiety in early adolescents: The mediating role of attributional style. *Cogn Ther Res.* 2014;38:71-81. doi:10.1007/s10608-013-9573-9
- [31] Daggol GD. An examination of Turkish college-level students' learned helplessness states in EFL context. *J Higher Educ Sci.* 2018;8(1):145-61. doi:10.5961/jhes.2018.257
- [32] Horwitz EK, Horwitz MB, Cope J. Foreign language classroom anxiety. *Mod Lang J.* 1986;70:125-32. doi:10.1111/j.1540-4781.1986.tb05256.x
- [33] Weiner B. An attributional theory of achievement motivation and emotion. *Psych Rev.* 1985;92(4): 548-573. doi:10.1037/0033-295X.92.4.548
- [34] Abramson LY, Seligman MEP, Teasdale JD. Learned helplessness in humans: Critique and reformulation. *J Abnorm Psychol.* 1978;87:49-74. doi:10.1037/0021-843X.87.1.49
- [35] Hsu L. A qualitative analysis on the occurrence of learned helplessness among EFL students. *J Educ Dev Psychol.* 2011;1(1):162-75. doi:10.5539/jedp.v1n1p162
- [36] Aydoğan H. The relations of learned helplessness, locus of control, and attitudes toward English with academic success. *Inonu Univ J Educ.* 2016; 17:177-83. doi:10.17679/inuefd.17391488
- [37] Krejtz I, Nezelek JB. It's Greek to me: Domain specific relationships between intellectual helplessness and academic performance. *J Soc Psychol.* 2016;156:664-73. doi:10.1080/00224545.2016.1152219
- [38] Sucu HÖ, Bulut M. Investigating University Preparatory Students' Level of Learned Helplessness in Learning English in Terms of Different Variables. In: Erçetin, Ş., Potas, N. (Eds),

- Chaos, Complexity & Leadership (Eds) 2017. Springer; 2019. doi:10.1007/978-3-319-89875-9_49
- [39] Kolber M. Learned Helplessness during a high school English lesson. *Forum Oświatowe*. 2020;32:87-97. doi:10.34862/fo.2020.2.4
- [40] Moghari HE, Lavasani M, Bagherian V, Afshari J. Relationship between perceived teacher's academic optimism and English achievement: Role of self-efficacy. *Procedia - Soc Behav Sci*. 2011. 15: 2329-2333. doi:10.1016/j.sbspro.2011.04.102
- [41] Ghasemi F. A motivational response to the inefficiency of teachers' practices towards students with learned helplessness. *Learn Motiv*. 2021;73:101705. doi:10.1016/j.lmot.2020.101705
- [42] Ghasemi F. L2 motivational self-system in practice: Alleviating students' learned helplessness through a vision-based program. *School Ment Health*. 2022;14:179-88. doi:10.1007/s12310-021-09464-4
- [43] Ahmadi A, Jahangard E. Ranking of the neighborhoods of Tehran metropolis in terms of development and quality of life: A fuzzy TOPSIS approach. *Urban Econ*. 2020; 5(1): 127-148. <https://doi.org/10.22108/ue.2021.124422.1151>
- [44] Farhady H, Jafarpur A, Birjandi P. Testing language skills: From theory to practice. SAMT Publications; 1994.
- [45] Alavi Moghaddam B, Kheirabadi R, Rahimi M, Davari H. Vision 1, English for schools (English for K-10)-student book. Ministry of Education of Iran, Organization for Educational Research and Planning; 2018.
- [46] Sabeghi Z, Rahimi M. Integrating STEAM activities into teaching reading: Examination of comprehension and cognitive load. *Anadolu J Educ Sci Int*. 2024;14:218-39. doi:10.18039/ajesi.1278816
- [47] Grabe W, Stoller FL. Teaching and researching reading. Routledge; 2011.
- [48] Pallant J. SPSS survival manual: A step-by-step guide to data analysis using the SPSS program (4th ed). McGraw Hill; 2010.
- [49] Cohen J. Statistical power analysis for the behavioral sciences (2nd ed). Hillsdale; 1998.
- [50] Dolgunsöz E, Yıldırım G, Yildirim S. The effect of virtual reality on EFL writing performance. *Journal of Language and Linguistic Studies*. 2018; 14(1): 278-292.
- [51] Chen CJ, Liu PL. Combining immersive virtual reality with CLIL and TPR to enhance English as foreign language learners' language acquisition. *Educ Tech Soc*. 2025; 28:78-108. doi:10.30191/ETS.202501_28(1).SP05
- [52] Mayer R. Multimedia enhanced learning. Cambridge University Press; 2001.
- [53] Chen MR, Hwang GJ. Effects of experiencing authentic contexts on English speaking performances, anxiety and motivation of EFL students with different cognitive styles. *Interact Learn Environ*. 2020;30:1619-39. doi:10.1080/10494820.2020.1734626
- [54] Shadiev R, Chen X, Sintawati W, Altinay F, Li Y, Kerimbayev N, Tlili A. Facilitating cross-cultural competence of students in an interactive VR learning environment. *Educ Tech Soc*. 2025;28:78-108. doi:10.30191/ETS.202501_28(1).RP05
- [55] Tai TY. Impact of mobile virtual reality on EFL learners' listening comprehension. *Lang Learn Tech*. 2022;26:1-23.
- [56] Davies R, Elias P. Dropping Out: A Study of Early Leavers from Higher Education. DfES Publications; 2023.
- [57] Richards JC, Renandya WA. Methodology in Language Teaching: An anthology of current practice. Cambridge University Press; 2002.
- [58] Fitria TN. Using authentic material and created material (Teacher-made) for English Language Teaching (ELT): Benefits and limitations. *JADEs J Academ Eng Educ*. 2022; 3(2): 117-140. doi:10.32505/jades.v3i2.4674
- [59] Intang A, Latief H, Prabawati Rum E. Improving students' speaking skills through social interaction in the classroom. *J Lang Test Assess*. 2023; 3(1): 1-10. doi:10.56983/jlta.v3i1.194
- [60] Rogerson J, Dodd B. Is there an effect of dysphonic teachers' voices on children's processing of spoken language? *J Voice*. 2005; 19(1): 47-60. doi:10.1016/j.jvoice.2004.02.007
- [61] Rahimi M, Ruzrokh S. The impact of teaching Lingua Franca Core on English as a foreign language learners' intelligibility and attitudes towards English pronunciation. *Asian Englishes*. 2016;18:141-56. doi:10.1080/13488678.2016.1173466
- [62] Xie F, Derakhshan A. A conceptual review of positive teacher interpersonal communication behaviors in the instructional context. *Front Psychol*. 2021;12:2623. doi:10.3389/fpsyg.2021.708490
- [63] Wang MT, Eccles JS. Social support matters: longitudinal effects of social support on three dimensions of school engagement from middle to high school. *Child Dev*. 2012;83:877-95. doi:10.1111/j.1467-8624.2012.01745.x
- [64] Hu Y, Chen Y, Wu B. Impact of 360° VR on empathy of pre-service teachers: An experimental study. *Educ Tec Soc*. 2025; 28(1): 371-382. doi:10.30191/ETS.202501_28(1).SP04

[65] Rahimi M, Aghabarari M. The impact of virtual reality-assisted listening instruction on English as a foreign language learners' comprehension and perceptions. *Intl J Tech Educ.* 2024; 7(2); 239-258. <https://doi.org/10.46328/ijte.741>

[66] Wu YJA, Chun DM. An exploration of preservice teachers' use of immersive VR to design English lessons. *Educ Tech Soc.* 2025; 28:412-28. doi:10.30191/ETS.202501_28(1). SP07

AUTHOR(S) BIOSKETCHES

Mehrak Rahimi is an associate professor of Applied and Computational Linguistics. Her main area of interest is Computer-Assisted Language Learning (CALL) with a focus on multimedia learning. Dr. Rahimi has authored several books and book chapters and published extensively in international journals on topics related to technology integration in language teaching and learning.

Rahimi, M., Associate Professor, Applied and Computational Linguistics, Shahid Rajaee Teacher Training University, Tehran, Iran

✉ rahimi@sru.ac.ir

Melika Eftekhari is an MA student of Teaching English as a Foreign Language (TEFL) at the English Department of Shahid Rajaee Teacher Training University. Ms. Eftekhari is a TEFL teacher. Her primary area of interest is the integration of technology in language teaching and learning, with a focus on utilizing Extended Reality tools for content creation and delivery.

Eftekhari, M., MA student, Teaching English as a Foreign Language, Shahid Rajaee Teacher Training University, Tehran, Iran

✉ meli.eftekhari@gmail.com

Citation (Vancouver): Eftekhari M, Rahimi M. [Teacher-made 360-degree VR Tours for Foreign Language Learning: Insights into Learned Helplessness in a Low Socioeconomic Status Context] *Tech. Edu. J.* 2026; 20(1): 1-22

 <https://doi.org/10.22061/tej.2026.12814.3342>





ORIGINAL RESEARCH PAPER

Meta-analysis of research related to gamification with emphasis on its long-term effects on the academic performance of elementary students

J. Keyhan^{*}, Go. Sheikhlloo

Department of Educational Studies and Curriculum Planning, Ur.C., Islamic Azad University, Urmia, Iran

ABSTRACT

Received: 01 July 2025
Reviewed: 08 September 2025
Revised: 21 October 2025
Accepted: 15 December 2025

KEYWORDS:

Semantic Web
Distance Education
E-Learning

* Corresponding author

✉ Javad.keyhan@iau.ac.ir

☎ (+98914) 1400199

Background and Objectives: In recent years, gamification has emerged as a prominent strategy for redesigning learning experiences and enhancing students' motivation and engagement, gaining a significant position in the literature on school-based education. Despite the growth of empirical studies, a considerable portion of the existing evidence has focused on short-term outcomes, and a conclusive synthesis of the long-term effects of gamification on academic performance, particularly in elementary education, is still lacking. Given that the early school years are critical for the development of learning habits and stable motivational patterns, evaluating the long-term impacts of gamification from the perspective of curriculum planning and educational policy is of particular importance. Accordingly, the present study aimed to conduct a meta-analysis of quantitative studies on gamification, with an emphasis on its long-term effects on the academic performance of elementary school students, to determine the combined effect size and the consistency of longitudinal study results in this domain.

Materials and Methods: This study was conducted using a meta-analytic approach. The research population included all published domestic and international quantitative studies over the past 24 years that reported the long-term effects of gamification on the academic performance of elementary school students. Literature search and retrieval were conducted using keywords related to gamification, academic performance, longitudinal studies, and elementary education, and the retrieved studies were screened based on inclusion and exclusion criteria. Key inclusion criteria comprised a focus on elementary school students, use of quasi-experimental longitudinal designs, provision of quantitative data convertible to effect sizes, and reporting of outcomes over a long-term period. Following evaluation and coding of data using the data extraction forms, a total of 21 quasi-experimental and longitudinal studies were included in the analysis. Data analyses were performed using Comprehensive Meta-Analysis (CMA) software, focusing on effect sizes and heterogeneity indices across studies.

Findings: The fixed-effect model indicated that gamification exerts a positive and statistically significant long-term impact on students' academic performance, yielding a pooled effect size of 0.472, which falls within the moderate range. The heterogeneity indices suggested no statistically meaningful between-study variability ($Q = 19.14$, $\chi^2 = 36.415$, $I^2 = 0\%$), indicating overall consistency across the included studies. Nevertheless, interpretation of the long-term effect should remain sensitive to contextual conditions and implementation quality, as substantive variations in real-world impact may not be fully captured by heterogeneity statistics. Within this framework, students' developmental and individual characteristics, classroom and school contexts, and the intensity and quality of gamified technology design and use may moderate the magnitude and durability of academic outcomes. Moreover, intervention duration and the timing of follow-up assessments are key factors that likely shape whether gamification effects are sustained or attenuate over time in longitudinal research.

Conclusions: Based on the synthesized evidence, gamification can positively and significantly improve the long-term academic performance of elementary school students. This finding extends gamification beyond a short-term motivational intervention, positioning it as a reliable strategy for designing sustainable learning experiences, provided that game elements align with educational objectives and curriculum logic. Practically, it is recommended that the development and implementation of gamified approaches in elementary schools be supported, with emphasis on design quality, developmental appropriateness, and continuity of implementation. Furthermore, future research that reports detailed intervention components, follow-up duration, and implementation quality can enable more nuanced analyses and clarify the mechanisms underlying the long-term effectiveness of gamification.



COPYRIGHTS

© 2026 The Author(s). This is an open-access article distributed under the terms and conditions of the Creative Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) (<https://creativecommons.org/licenses/by-nc/4.0/>)



NUMBER OF REFERENCES

45



NUMBER OF FIGURES

2



NUMBER OF TABLES

6

مقاله پژوهشی

فرا تحلیل پژوهش‌های مرتبط با بازی گونه سازی با تاکید بر اثرات دراز مدت آنها بر عملکرد تحصیلی دانش آموزان ابتدایی

جواد کیهان^{*}، گلستان شیخ لو

گروه مطالعات تربیتی و برنامه ریزی درسی، واحد ارومیه، دانشگاه آزاد اسلامی، ارومیه، ایران

چکیده

پیشینه و اهداف: بازی‌وارسازی در سال‌های اخیر به‌عنوان راهبردی برای بازطراحی تجربه یادگیری و تقویت انگیزش و مشارکت دانش‌آموزان، جایگاه برجسته‌ای در ادبیات آموزش مدرسه‌ای یافته است. با وجود گسترش مطالعات تجربی، بخش قابل توجهی از شواهد موجود به پیامدهای کوتاه‌مدت معطوف بوده و درباره پایداری اثرات بازی‌وارسازی بر عملکرد تحصیلی، به‌ویژه در دوره ابتدایی، هنوز جمع‌بندی قاطع و مبتنی بر شواهد تلفیقی در دسترس نیست. از آنجا که سال‌های ابتدایی مدرسه زمان شکل‌گیری عادات یادگیری و الگوهای انگیزشی پایدار است، ارزیابی اثرات بلندمدت بازی‌وارسازی از منظر برنامه‌درسی و سیاست‌گذاری آموزشی اهمیت ویژه دارد. بر این اساس، پژوهش حاضر با هدف فرا تحلیل مطالعات کمی مرتبط با بازی‌وارسازی و با تأکید بر اثرات بلندمدت آن بر عملکرد تحصیلی دانش‌آموزان دوره ابتدایی انجام شد تا اندازه اثر ترکیبی و میزان همسویی نتایج مطالعات طولی در این حوزه تعیین شود.

روش‌ها: این پژوهش با رویکرد فرا تحلیل انجام شد. جامعه پژوهش شامل کلیه مطالعات کمی داخلی و خارجی منتشر شده طی ۲۴ سال گذشته بود که اثرات بلندمدت بازی‌وارسازی بر عملکرد تحصیلی دانش‌آموزان دوره ابتدایی را گزارش کرده بودند. جست‌وجو و بازیابی منابع بر اساس کلیدواژه‌های مرتبط با بازی‌وارسازی، عملکرد تحصیلی، مطالعه طولی و دوره ابتدایی انجام گرفت و مطالعات بازیابی‌شده بر پایه معیارهای ورود و خروج غربالگری شدند. معیارهای اصلی ورود شامل تمرکز بر دانش‌آموزان ابتدایی، استفاده از طرح‌های شبه‌آزمایشی با رویکرد طولی، ارائه داده‌های کمی قابل تبدیل به اندازه اثر و گزارش سنجش پیامدها در افق زمانی بلندمدت بود. پس از ارزیابی و کدگذاری داده‌ها با فرم‌های استخراج داده، در نهایت ۲۱ مطالعه شبه‌آزمایشی و بلندمدت وارد تحلیل شد. تحلیل‌ها با نرم‌افزار CMA و با تمرکز بر اندازه اثر و شاخص‌های ناهمگنی بین مطالعات انجام گرفت.

یافته‌ها: مدل اثر ثابت نشان داد بازی‌وارسازی در بلندمدت اثر مثبت و معناداری بر عملکرد تحصیلی دانش‌آموزان دارد و اندازه اثر ترکیبی برابر با ۰.۴۷۲ به‌دست آمد که در دامنه متوسط تفسیر می‌شود. شاخص‌های ناهمگنی نیز بیانگر عدم ناهمگونی معنادار بین مطالعات بود ($Q = 19.14$ ، $k = 21$ ، $p < 0.001$ ، $I^2 = 92\%$) و از همسویی کلی نتایج در مجموعه مطالعات منتخب حکایت داشت. با وجود همسویی شاخص‌های ناهمگنی، تفسیر اثر بلندمدت بازی‌وارسازی باید با توجه به شرایط زمینه‌ای و کیفیت اجرا انجام شود؛ زیرا تفاوت‌های واقعی اثر ممکن است در آمار ناهمگنی به‌طور کامل منعکس نشده باشد. در این چارچوب، ویژگی‌های رشدی و فردی دانش‌آموزان، بافت کلاس و مدرسه، و نیز شدت و کیفیت طراحی و استفاده از فناوری‌های بازی‌واره می‌توانند دامنه و پایداری اثرات تحصیلی را تعدیل کنند. همچنین مدت مداخله و زمان‌بندی سنجش پیگیری از عوامل کلیدی‌اند که احتمالاً بر استمرار یا فرسایش اثرات در مطالعات طولی اثر می‌گذارند.

نتیجه‌گیری: بر مبنای شواهد تلفیقی، بازی‌وارسازی می‌تواند در بلندمدت نیز عملکرد تحصیلی دانش‌آموزان دوره ابتدایی را به‌طور مثبت و معنادار بهبود دهد. این نتیجه بازی‌وارسازی را از سطح یک مداخله انگیزشی کوتاه‌اثر فراتر می‌برد و آن را به‌عنوان راهبردی قابل اتکا در طراحی تجربه‌های یادگیری پایدار مطرح می‌کند؛ مشروط بر آنکه عناصر بازی در خدمت اهداف آموزشی و منطق برنامه‌درسی قرار گیرند. از منظر کاربردی، توصیه می‌شود توسعه و استقرار رویکردهای بازی‌واره در مدارس ابتدایی با تأکید بر کیفیت طراحی، تناسب رشدی، و استمرار اجرای مداخله حمایت

تاریخ دریافت: ۱۰ تیر ۱۴۰۴
تاریخ داوری: ۱۷ شهریور ۱۴۰۴
تاریخ اصلاح: ۲۹ مهر ۱۴۰۴
تاریخ پذیرش: ۲۴ آذر ۱۴۰۴

واژگان کلیدی:

وب معنایی
آموزش از راه دور
یادگیری الکترونیکی

* نویسنده مسئول

Javad.keyhan@iau.ac.ir

۰۹۱۴-۱۴۰۰۱۹۹ (۱)

شود. همچنین پژوهش‌های آینده با گزارش دقیق‌تر اجزای مداخله، مدت پیگیری، و کیفیت اجرا می‌توانند امکان تحلیل‌های تفکیکی و شفاف‌سازی سازوکارهای اثرگذاری بلندمدت بازی‌وارسازی را فراهم کنند.

Introduction

In recent decades, educational systems across the globe have been confronted with a growing set of complex and interrelated challenges. Among the most prominent of these are the declining levels of students' active participation in the learning process, the erosion of intrinsic motivation to engage with academic tasks, and the persistent weaknesses observed in learners' basic academic performance [1]. These issues have become especially pressing in a world that is rapidly changing due to technological advancements, shifting societal demands, and increasingly diverse learning populations. As a result, traditional pedagogical approaches, which often emphasize rote memorization and passive knowledge transfer, have been criticized for their inability to address the evolving needs of contemporary learners [2].

In response to these concerns, educational researchers and practitioners have begun to explore modern, student-centered, and more engaging approaches to teaching and learning. One of the most promising of these approaches is gamification, which has attracted significant scholarly attention over the past decade. Gamification (rooted in principles of game design) refers to the deliberate incorporation of motivational and interactive elements into non-game environments such as the classroom, to enhance students' engagement and persistence [3]. In the field of education, this means constructing learning environments in which students perceive themselves to be on a path marked by progress, meaningful challenges, and rewarding achievements [3,4].

When applied to educational practice, gamification often involves the integration of specific components such as scoring systems,

badges, immediate feedback mechanisms, and structured opportunities for collaboration or competition among learners. Together, these elements attempt to shift the learning experience away from a passive reception of information toward a more active, immersive, and meaningful process of knowledge construction [5]. Put differently, gamification seeks to enrich educational environments by drawing inspiration from the inherently attractive and motivating features of games. By doing so, it not only injects excitement and novelty into learning activities but also strengthens learners' intrinsic desire to engage, persist, and ultimately succeed in their academic endeavors. It is important to note that gamification is different from game-based learning; in game-based learning, complete games are used as educational tools, whereas gamification merely adds some elements of games (such as scoring or competition) to the real educational environment [6]. This approach has been applied across a wide range of subjects—from mathematics and science to language education—and in both digital (e.g., online classes with game-like platforms) and non-digital forms (e.g., paper-based scoring systems in the classroom) [7]. The main goal of using game elements in education is to increase students' motivation and participation in learning activities by creating incentives and rewards for their efforts. In fact, gamification is a structured process aimed at reinforcing learning behaviors and improving academic outcomes by creating game-like experiences in educational settings [8]. For instance, Kirikova et al showed that adding rewards and recognition of achievements in class can stimulate students' active participation and make learning more attractive [9]. Thus,

gamification is an attempt to utilize the intrinsic appeal of games to create meaning in learning and enhance students' interaction with educational content [10].

A meta-analysis of studies related to gamification indicates that this approach can play a significant role in enhancing students' academic performance, particularly at the elementary level [11]. The reviewed findings reveal that gamification has been associated with increased active participation, improved intrinsic motivation, and the enhancement of learning processes [12,13,14]. Furthermore, the meta-analyses conducted by Seiler and Homner [13] and Zhao et al. [15] demonstrated that gamification exerts a positive (though moderate) effect on both cognitive and motivational outcomes, thereby contributing to the consolidation and reinforcement of learning [15]. In this regard, Huang et al [16] emphasized the importance of tools such as leaderboards, which were found to significantly improve learning performance. In addition, Harris and Park reported that gamification can foster improvements in memory, concentration, and attention, thereby laying the foundation for more sustainable academic achievement among students. Longitudinal investigations have further supported these findings: Barta et al. [17], in a three-year study, and Nehring et al. [18], during an 11-week intervention, both documented continuous improvements in student performance within gamified learning contexts [9,10,2,11,12,13,14,19]. Overall, the available evidence suggests that gamification not only produces short-term positive effects on learning but also contributes, in the long run, to knowledge retention, the cultivation of sustained motivation, and the continuous improvement of elementary students' academic performance [16, 20].

However, this issue is particularly important in elementary education because children may

initially respond enthusiastically to game elements but may become accustomed to or bored with them after a while. A recent systematic review conducted by Rodriguez et al. [21], specifically in the context of elementary schools, also emphasizes this point [22]. They, by reviewing 31 recent studies at the elementary level, found that although most gamification experiences at this level led to improved participation, motivation, and self-efficacy among students, there was no conclusive evidence of improvement in learning outcomes and academic performance in these studies [23]. In other words, in elementary schools, the effects of gamification on student collaboration have sometimes been negative, and the learning outcomes resulting from it have been reported as contradictory or inconclusive. These findings are a warning that although gamification may boost the excitement and enthusiasm for learning in the short term, to assess its true value, one must examine whether this approach also leads to sustainable improvement in academic performance. Overall, the lack of certainty about the continuation of the positive effects of gamification in the long term (especially for young students) indicates a necessity that the present research aims to address [24,25,26].

Therefore, the main research question of the present study is: Does augmented reality and gamification have a long-term effect on the academic performance of elementary school students? What are the effect sizes of this technology on students' academic performance in the long term? What variables have contributed to the heterogeneity of the observed effect sizes on students' academic performance over the long term

Review of the Related Literature

As mentioned, numerous studies have examined the effects of gamification on

students' motivation, engagement, and academic performance, reporting positive outcomes [9,10,2,11,28,28,29,30,31,32,33]. Some of these studies are discussed in detail below. Lin et al. [34] conducted a long-term study comparing computer-based and game-based formative assessments. The results showed that game-based assessments increased students' average scores, improved academic performance, and enhanced learning motivation over time. Nabizadeh et al [35] carried out a ten-year study on students' behavior in a gamified course. Findings indicated that students with higher interaction with game content demonstrated more stable academic performance and maintained motivation consistently throughout the period. Recabarren et al [36] examined the effects of gamification on gamer and non-gamer students. Results showed that gamer students exhibited higher motivation and academic performance, and gamified learning increased their engagement and participation in the learning process. Pesek et al [37] investigated the "Troubadour" gamified e-learning platform for music education. The study found that students using the platform achieved higher test performance and experienced better user engagement compared to traditional methods.

Keyhan [38] studied the effects of a computer-based jigsaw puzzle game on accuracy, speed, learning, and retention in mathematics among lower secondary students. Findings indicated significant improvements in academic performance, problem-solving speed, and learning retention. Van Roy and Zaman [39] assessed the motivational effects of gamification over a semester. Results demonstrated that students' controlled motivation persisted over time, suggesting that well-designed gamified elements can foster sustained engagement and active participation in learning. Nehring et al [40] examined

gamification's impact on student performance in a quasi-experimental study. Results showed that gamification improved both motivation and academic performance, with students in the experimental group outperforming those in the control group. Barata et al [41] investigated individual differences in student responses to gamified education. Findings indicated that students with higher engagement in gamified activities showed greater motivation and learning outcomes, emphasizing that long-term effects depend on individual student characteristics.

Hakulinen et al [42] explored gamification effects on students with different achievement goal orientations. The study found that badges and game elements enhanced mastery-oriented motivation and reduced avoidance behaviors, though effects varied depending on students' goal orientations. Dodero et al [43] applied tangible co-design gamification in primary schools. Results showed students enjoyed gamified activities, increasing participation and motivation in voluntary tasks, highlighting the positive influence of gamified learning on active engagement. Barata et al [44] examined gamification's impact on participation and learning. Findings revealed that online gamified activities increased student engagement, reduced score gaps, and enhanced learning outcomes, confirming gamification as an effective instructional strategy.

Method

Design

This study was conducted as a quantitative meta-analysis to synthesize empirical evidence on the long-term effects of gamification on elementary students' academic performance. Meta-analysis was selected because it enables the systematic integration of findings from

independent controlled studies, producing a pooled estimate of sustained impact and clarifying whether observed benefits persist beyond short-term engagement gains. The scope of the review covered studies published between 2001 and 2025, reflecting both early foundational research and more recent technology-supported gamification interventions in primary education. A systematic search strategy was implemented across national and international sources. Iranian databases and repositories included Irandoc, Noormags, MagIran, SID, and Elmnet. International coverage was sought through major bibliographic and publisher platforms, with emphasis on Scopus and relevant full-text environments such as ScienceDirect/Elsevier and Wiley Online Library, where applicable. To minimize retrieval bias, the reference lists of eligible papers were also examined. Search terms were structured around three concept domains and combined using Boolean operators: gamification; long-term/follow-up/retention/sustained effects; and academic performance/achievement/grades/learning outcomes.

Materials

Eligibility criteria were defined a priori to ensure conceptual relevance and methodological comparability. Studies were included if they (1) examined gamification as a clearly identifiable educational intervention (e.g., structured use of points, levels, badges, leaderboards, feedback loops, or digital gamified environments integrated into instruction); (2) targeted elementary school students (typically ≤ 12 years); (3) used experimental or quasi-experimental designs with a control or comparison condition; (4) reported long-term or follow-up assessments of academic performance beyond the immediate post-intervention measurement; (5) implemented

interventions lasting at least four weeks to support more credible inferences about sustained learning effects; (6) were published in English or Persian; and (7) provided sufficient quantitative information to compute standardized effect sizes (group sample sizes, means, and standard deviations). Studies were excluded if they were theoretical papers, commentaries, or reviews; focused on non-elementary populations; lacked explicit gamification components; did not include follow-up outcomes; had interventions shorter than four weeks; or failed to report adequate statistical data for effect size estimation. Study selection proceeded through sequential screening of titles/abstracts and full texts according to the predefined criteria. After eligibility assessment and methodological verification, 21 longitudinal experimental or quasi-experimental studies were retained for final synthesis. Data were extracted using a structured form adapted from Mesrabadi and Yadollahi [45], capturing bibliographic details, sample characteristics, features of the gamification intervention, duration and timing of follow-up, and outcome statistics. When studies reported multiple relevant outcomes, academic performance indicators most directly aligned with achievement at the follow-up point were prioritized to maintain conceptual coherence across the dataset.

Procedure

Effect sizes were calculated using the *d* family of standardized mean differences. For each eligible study, group-level sample size, mean, and standard deviation of academic performance at the follow-up assessment were extracted for intervention and comparison conditions. Meta-analytic computations were conducted using Comprehensive Meta-Analysis (CMA) software. Pooled effect size estimates with confidence intervals were generated, and

between-study heterogeneity was assessed using the Q statistic and the I^2 index. Given the study's explicit focus on long-term impact in a developmentally sensitive educational stage, this analytical framework was intended to provide a rigorous and policy-relevant estimate of the sustained academic value of gamification in elementary education.

Results and Findings

First, the present study examines the key characteristics of the 21 studies related to gamification, as summarized in Table 1. This analysis focuses on several critical dimensions, including the educational level of participants, the subject or discipline under investigation, the type and duration of gamified interventions, and the specific gamification elements implemented (e.g., scoring systems, badges, leaderboards, or collaborative tasks). By

systematically reviewing these characteristics, the study aims to provide a comprehensive overview of the current research landscape, identify common patterns and trends, and highlight potential gaps in the existing literature. In particular, understanding these study features is essential for interpreting the effectiveness and generalizability of gamification interventions across different educational contexts. Moreover, examining the diversity in study designs, sample sizes, and methodological approaches enables researchers to assess the robustness of reported outcomes and to make informed recommendations for future research and practical implementation of gamification in education. Table 1 thus serves as a foundational reference, offering a structured summary of the 21 selected studies and facilitating a deeper understanding of how gamification has been applied, evaluated, and reported across various settings.

Table 1: Longitudinal Studies on Gamification and Academic Performance

No.	Researcher	Year	Article Title	Findings	Key Effect Info	Approach	Duration	Country
1	Hanus & Fox	2015	Assessing Gamification Effects in Classrooms	Gamified students showed lower intrinsic motivation and exam scores.	Motivation , Performance Exp: N=71, M=4.78 Ctrl: N=71, M=4.95 ...	Quasi-Experimental	4 months	USA
2	Barta et al.	2017	Differentiation in Gamified Learning	Students reacted differently but showed higher motivation.	Motivation Exp: N=46, M=77.80 Ctrl: N=46, M=75.67	Quasi-Experimental	36 months	Germany
3	Nehring et al.	2018	Improving Student Performance via Gamification	Gamification improved student motivation and performance	Motivation Exp: N=64, M=78.58 Ctrl: N=55, M=77.80	Quasi-Experimental	3 months	Germany

No.	Researcher	Year	Article Title	Findings	Key Effect Info	Approach	Duration	Country
4	Putz et al.	2020	Gamification & Learning Enhancement	Gamification improved retention and learning outcomes.	Performance Exp: N=39, M=3.33 Ctrl: N=44, M=1.68	Quasi-Experimental	24 months	Austria
5	Lin et al.	2023	Game-Based vs Formative Assessment	Game-based testing showed higher average scores.	Performance Exp: N=51, M=59.90 Ctrl: N=59, M=71.49	Quasi-Experimental	4 months	China
6	Nabizadeh et al.	2021	Gamified Learning Over a Decade	High interaction predicted stable long-term scores. Improved participation and voluntary task engagement.	Motivation Exp: N=99, M=3.22 Ctrl: N=35, M=2.20	Quasi-Experimental	120 months	Iran
7	Lusap & Opma	2014	Gamification in Technical Higher Ed		Motivation Exp: N=36, M=3.24 Ctrl: N=36, M=3.00	Quasi-Experimental	36 months	Netherlands
8	Recabarren et al.	2023	Gamers vs Non-Gamers in Classrooms	Gamified learning improved academic outcomes.	Motivation , Performance Exp: N=49 Ctrl: N=47	Quasi-Experimental	12 months	Chile
9	Dudero et al.	2014	Tangible Gamified Design in School	Students enjoyed using the designed gamified objects.	Motivation Exp: N=42, M=12.32 Ctrl: N=42, M=10.74	Quasi-Experimental	12 months	Italy
10	Pesk et al.	2020	TROUBADOR: Gamified E-Learning Platform	Higher test performance ; UX encouraged participation.	Performance Exp: N=19, M=68.9 Ctrl: N=19, M=60.60	Quasi-Experimental	12 months	USA
11	Van Roy & Zaman	2018	Gamification Needs in Education	Controlled motivation persisted across the semester.	Motivation Exp: N=40 Ctrl: N=40	Quasi-Experimental	4 months	Belgium
12	Barata et al.	2013	Boosting Participation with Gamification	Improved online activity and reduced score gaps.	Participation Exp: N=52, M=79.99 Ctrl: N=52, M=81.06	Quasi-Experimental	60 months	Portugal

No.	Researcher	Year	Article Title	Findings	Key Effect Info	Approach	Duration	Country
13	Hong & Masoud	2014	Gamification & Secondary Student Motivation	Gamified students had higher intrinsic motivation.	Motivation Exp: N=29, M=5.35 Ctrl: N=31, M=4.94	Quasi-Experimental	5 months	Taiwan
14	Hakolin en & Auvinen	2014	Gamification Effects by Goal Orientation	Badges linked with mastery and reduced avoidance.	Achievement Exp: N=26, M=1.77 Ctrl: N=26, M=0.98	Quasi-Experimental	5 months	Finland
15	Zhou et al.	2019	Long-Term Literacy Growth via Gamification	Improved reading habits, emotions, and skills.	Performance Exp: N=29, M=4.83 Ctrl: N=29, M=3.95	Quasi-Experimental	6 months	China
16	Khan et al.	2017	GBL & Gender Differences in Science	Girls outperformed boys in engagement and scores.	Performance Exp: N=31, M=7.16 Ctrl: N=41, M=4.79	Quasi-Experimental	6 months	Pakistan
17	Yildirim	2017	Gamified Practices & Student Progress	Gamified methods boosted progress and attitude.	Achievement Exp: N=49, M=24.23 Ctrl: N=48, M=21.04	Quasi-Experimental	6 months	Turkey
18	Ortiz Rojas et al.	2017	Gamification in Programming Education	Higher participation, but no significant gain in performance.	Performance Exp: N=50, M=9.64 Ctrl: N=50, M=4.74	Quasi-Experimental	5 months	Colombia
19	Wang et al.	2017	Gamification for Chinese Language Learning	Improved speaking belief, but no effect on other skills.	Performance Exp: N=30, M=3.65 Ctrl: N=30, M=3.46	Quasi-Experimental	6 months	China
20	Andrade et al.	2020	Gamified STEM App in Secondary Schools	Motivation unchanged; other factors improved.	Performance Exp: N=22, M=9.59 Ctrl: N=26, M=8.88	Quasi-Experimental	6 months	Brazil
21	Hamzeh et al.	2015	Gamification & Motivation in E-Learning	Gamified students were more motivated to use platforms.	Motivation	21	Hamzeh et al.	2015

From the information in Table 1, it can be seen that among the reviewed studies, no Iranian research with a long-term approach was retrieved, and 21 foreign studies (100%) were identified, all of which were quantitative and conducted with a quasi-experimental approach. Furthermore, according to Table 2, the status of these studies in terms of the long-term duration used in the reviewed research is presented in Table 1.

Table 2: Frequency of Long-Term Duration in Gamification Studies

Research Duration	Absolute Frequency	Relative Frequency
Less than 12 months	13	62%
12 to 36 months	6	29%
More than 36 months	2	9%
Total	21	100%

Table 2 shows that the majority of research durations fall within the period of less than 12 months, accounting for 62% of the studies; the 12 to 36 months period includes 6 studies, equal to 29%; and the least frequent duration is more than 36 months, with 2 studies, comprising 9% of all the studies reviewed. In addition, the frequency distribution of the studies based on their publication years is presented in Table 3.

Table 3: Frequency Distribution of Gamification Studies by Publication Year

Publication Year	Absolute Frequency	Relative Frequency
2000 to 2010	0	0%
2011 to 2020	18	67%
2021 to 2024	3	23%
Total	21	100%

According to Table 3, most of the reviewed studies were conducted between the years 2011 and 2020, with a frequency of 18 studies

(86%), and 3 studies, equal to 14%, were conducted between 2021 and 2024. However, in the period from 2000 to 2010, no long-term study with a longitudinal gamification approach was retrieved.

Assessment of Publication Bias

At the beginning of the meta-analysis, the researcher examined the publication bias of gamification studies. In meta-analysis, evaluating publication bias is important because there is a possibility that certain studies or data have not been assessed due to non-publication or being overlooked, which might be disregarded by researchers. This issue may lead to errors and bias in the final results of the meta-analysis.

Therefore, identifying and correcting publication bias in the early stages of meta-analysis is essential to improve the accuracy and validity of the results. The funnel plot is a simple and standard method for detecting publication bias in meta-analyses. In this plot, the effect of the intervention on individual study estimates is displayed in relation to the sample size of each study. This chart can assist in making decisions related to publication bias and the credibility of meta-analysis results.

Fig. 1 displays the funnel plot of the gamification studies. In the presented funnel plot, the standard error is plotted on the vertical axis, and the standardized mean difference is plotted on the horizontal axis. The central line, which passes through the middle of the plot, represents the mean standardized effect size across all studies. The dashed lines indicate the 95% confidence intervals for the mean effect size. As can be observed, the data points are symmetrically distributed around the central line, with no significant deviation from it. This suggests that the likelihood of publication bias in this meta-analysis is low.

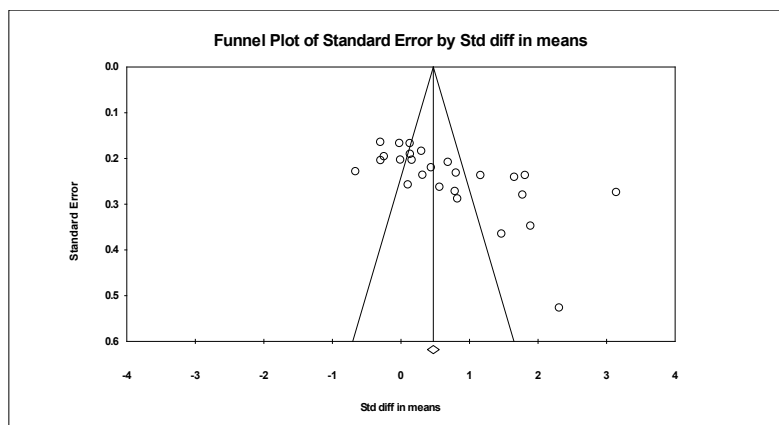


Fig. 1: Funnel Plot of Gamification Studies

Effect Size Calculation

Effect size is a statistical index that indicates the strength or importance of the relationship between two variables or the difference between two groups [27]. As a standardized metric, effect size allows us to compare the results of different studies with each other.

One of the most well-known and widely used effect sizes is Cohen's *d*, introduced by Jacob Cohen in 1988. This index is calculated based on the difference between the means of two groups and their pooled standard deviation, and it is commonly used to compare group differences in experimental and clinical studies. To calculate the effect sizes of the gamification studies, the CMA (Comprehensive Meta-Analysis) software was used, and the results are presented in Table 4.

According to Table 4, studies in which the mean differences were statistically significant and had a considerable effect size—such as Barata et al. [41], Putz et al. [22], and Lin et al. [34]—demonstrated large or medium effect sizes. In contrast, studies where the mean differences were not statistically significant—such as Hanus and Fox [21], and others—showed small or very small effect sizes.

According to Table 5, the fixed effect size of the studies is 0.472, which indicates a medium and statistically significant effect size. This effect size shows that the mean difference favors the first group and is statistically

significant, as the *p*-value is less than 0.05. Additionally, the upper and lower bounds of the 95% confidence interval are 0.199 and 0.397, respectively, indicating a reliable and precise estimate of the effect size. The *Z*-value also indicates a substantial standard deviation, confirming that the observed difference is statistically significant.

Fig. 2 presents the effect size (standardized mean difference) and the 95% confidence interval for each of the studies. The horizontal axis represents the effect size, while each horizontal line shows the 95% confidence interval for a study. The vertical lines on both sides of the graph represent points A and B. The dots and squares represent the estimated effect sizes of each study, and the size of the squares reflects the weight of each study in the overall meta-analysis.

According to this plot, the studies with negative effect sizes (located to the left of the zero axis) include Hanus and Fox [21]. These studies indicate a preference for Group A over Group B (i.e., the control group over the experimental group), but this preference is not statistically significant, as the confidence intervals include zero. On the other hand, the studies with positive effect sizes (located to the right of the zero axis) include Barata et al. [41], Putz et al. [22], Lin et al. [34], Nabizadeh et al. [35], Recabarren et al. [36], Dudero et al. [15],

Table 4: Effect Sizes of Research Variables at the 95% Confidence Level

Model	Study name	Statistics for each study						
		Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
	Hanus & Fox (2015)_1	-0.291	0.165	0.027	-0.615	0.033	-1.758	0.079
	Hanus & Fox (2015)_2	0.138	0.168	0.028	-0.191	0.468	0.823	0.410
	Hanus & Fox (2015)_3	-0.013	0.168	0.028	-0.342	0.316	-0.079	0.937
	Barata et. al (2017)	1.662	0.242	0.058	1.188	2.136	6.873	0.000
	Nehring et. al (2018)	0.307	0.185	0.034	-0.056	0.669	1.658	0.097
	Putz et. al (2020)	1.170	0.238	0.057	0.704	1.636	4.917	0.000
	Lin et. al (2023)	0.142	0.191	0.037	-0.234	0.517	0.739	0.460
	Nabizadeh et. al (2021)	3.150	0.275	0.076	2.610	3.689	11.448	0.000
	Iosup & Epema (2014)	0.324	0.237	0.056	-0.141	0.789	1.367	0.171
	Recabarren et. al (2023)_1	0.168	0.205	0.042	-0.233	0.568	0.819	0.413
	Recabarren et. al (2023)_2	-0.289	0.205	0.042	-0.691	0.113	-1.409	0.159
	Recabarren et. al (2023)_3	0.000	0.204	0.042	-0.400	0.400	0.000	1.000
	Dodero et. al (2014)	0.448	0.221	0.049	0.015	0.881	2.028	0.043
	Pesek et. al (2020)	1.475	0.366	0.134	0.758	2.193	4.032	0.000
	VanRoy & Zaman (2018)_1	0.812	0.233	0.054	0.356	1.268	3.489	0.000
	VanRoy & Zaman (2018)_2	-0.655	0.230	0.053	-1.105	-0.205	-2.853	0.004
	Barata et. al (2013)	-0.238	0.197	0.039	-0.624	0.148	-1.210	0.226
	Hong & Masood (2014)	0.573	0.264	0.069	0.056	1.089	2.173	0.030
	Hakulinen & Auvinen (2014)	0.833	0.289	0.084	0.266	1.399	2.879	0.004
	Zhu et al. (2019)	0.796	0.273	0.074	0.261	1.331	2.918	0.004
	Khan et al. (2017)	1.783	0.281	0.079	1.233	2.333	6.354	0.000
	Yildirim (2017)	0.695	0.209	0.044	0.285	1.105	3.323	0.001
	OrtizRojas et al (2017)	1.819	0.238	0.057	1.353	2.285	7.650	0.000
	Wang et al. (2017)	0.110	0.258	0.067	-0.396	0.617	0.427	0.669
	Andrade (2020)	1.899	0.349	0.121	1.216	2.582	5.449	0.000
	Hamzah et al. (2015)	2.317	0.528	0.278	1.283	3.351	4.390	0.000
Fixed		0.472	0.044	0.002	0.386	0.559	10.693	0.000

Meta Analysis

Table 5: Combined Effect Size of Gamification Studies

Model	Studyname	Statistics for each study						
		Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Fixed		0.472	0.044	0.002	0.386	0.559	10.693	0.000

Meta Analysis

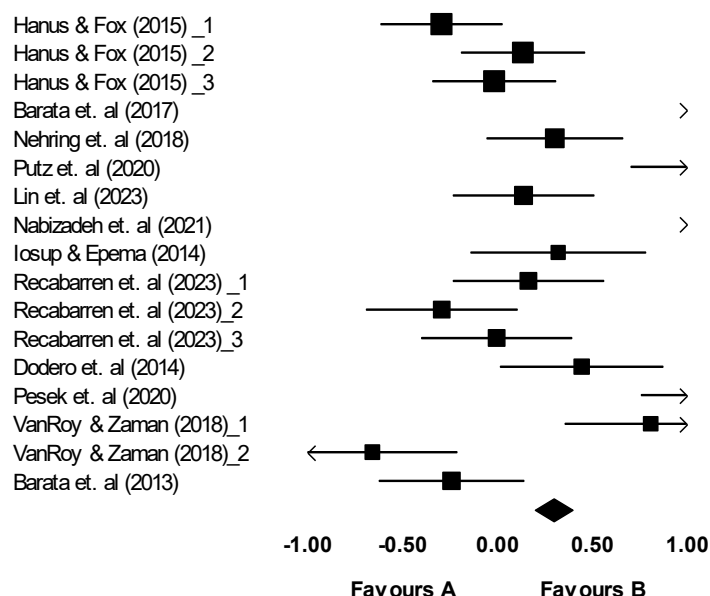


Fig. 2: Forest Plot of Confidence Intervals (Accumulation Chart) for Gamification Studies

Pesk et al. [17], Van Roy and Zaman [39], and Barata et al. [44]. These studies show a preference for Group B over Group A, and this preference is statistically significant, since the confidence intervals do not include zero.

In addition, the studies whose confidence intervals include zero (located around the zero axis) include Nehring et al. [40], Lusap and Opma, and Van Roy and Zaman [39]. These studies indicate that there is no clear preference between Group A and Group B, and the differences are not statistically significant. Overall, based on the forest plot, many studies show significant differences in favor of Group B, while a few studies show insignificant differences or differences in favor of Group A.

Assessment of Study Heterogeneity

In the final section of the meta-analysis, study heterogeneity was assessed using the Q-test for between-study variability [28]. The Q-test indicates whether there is a statistically significant heterogeneity among the studies. The results of the analysis of all the reviewed studies, which included 17 variables across 12 studies, are presented in Table 6.

Table 6: Q-Test Results at 95% Confidence Level

Q Statistic	Number of Variables	d f	Chi-square (X ²)	Result
278.918	17	16	26.629	Heterogeneity Exists

The results in Table 6 show that the total Q-value is 278.918, which is much higher than the critical value of 26.296 for 16 degrees of freedom at the 0.05 significance level. This result indicates the existence of considerable heterogeneity among the studies under review.

Alongside the Q-test in assessing the heterogeneity of gamification studies, the I^2 index was also calculated and found to be 94.29%. This value indicates that about 94.29% of the observed variation in study results is due to heterogeneity among the studies and not due to random differences; this demonstrates substantial heterogeneity among the studies.

Accordingly, various variables may play a key role in this heterogeneity in the effect of gamification on the academic performance of students in longitudinal studies. To this end, the variables influencing the heterogeneity in the effect of gamification on students' academic

performance in longitudinal studies can be outlined as follows:

- Changes in student characteristics: Over time, students develop and evolve in terms of cognitive skills, learning abilities, interests, and motivations. These changes can affect the effectiveness of educational games throughout the study period and over time. Students' learning needs and goals change during their educational course and as time progresses. Educational games should adapt to these changes and address the new needs and goals to maintain their effectiveness.
- Changes in the educational environment: Curricula evolve based on new educational needs and approaches. Educational games must align with these curriculum changes and be designed and implemented accordingly to remain effective.
- Changes in intervening variables: Shifts in the socio-economic status of students and their families can occur over time. These changes can influence access to educational resources, family and school support, and ultimately the effectiveness of educational games throughout the study period. Additionally, changes in the attitudes and beliefs of teachers, parents, and the community regarding educational games can vary over time. These changes may impact the acceptance and implementation of this educational method in schools and ultimately affect its effectiveness during the study period.
- Emergence of long-term effects: Longitudinal and extended studies provide an opportunity to observe the long-term effects of gamification on students' academic performance. These long-term effects may not be visible in short-term studies and may emerge over time as the study progresses.

- Variation in individual responses: Different students respond differently to educational games, and the effects of this method can vary among them. Longitudinal and extended studies, by examining the effects of gamification on a wide range of students over time, can contribute to a better understanding of the diversity in individual responses and the factors influencing them.

In fact, the factor of time and the duration of the study play a complex and multifaceted role in the heterogeneity observed in the effects of gamification on students' academic performance in longitudinal studies. A deeper understanding of these effects requires a more detailed examination of changes in student characteristics, the educational environment, intervening variables, and the emergence of long-term effects of gamification over time.

Discussion

The present study aimed to conduct a meta-analysis of research related to gamification, with an emphasis on its long-term effects on the academic performance of elementary school students. Based on the findings, several of the reviewed studies showed notable effect sizes, including those by Barata et al. [41], Putz et al. [22], Lin et al. [34], Nabizadeh et al. [35], Recabarren et al. [36], Dudero et al. [15], Pesk et al. [17], Van Roy & Zaman [39], and Barata et al. [44], where the effect sizes were large or medium.

Alongside this, the overall fixed effect size across all studies was found to be 0.298, which indicates a small to medium effect size. This means that variables such as learning performance, achievement motivation, learning motivation, academic performance, and achievement drive have been most impacted by gamification in the long term.

This result aligns with the studies of Lopez and Tucker [8], which have shown that the success of digital games in long-term education contributes to improved motivation, engagement, and social impact, allowing students to enhance their learning and experience joy and depth in the process. It also aligns with the longitudinal study by Harris and Park [20], which showed that gamification leads to improvements in memory, focus, and attention over the long run. Furthermore, the results are consistent with the longitudinal studies by Buckley and Doyle and Barata et al. on the improvement of student performance.

To explain this finding, it should be said that large and significant effect sizes can indicate meaningful impacts that may reflect the sustainability of results in experimental and longitudinal research. In particular, the enjoyment of digital games in education helps enhance students' motivation, engagement, and deep learning; such that game elements in instructional design can create engaging experiences for players and associate learning with positive emotions and enjoyment.

In contrast, studies where the difference in means was not statistically significant, such as Hanus and Fox [21] had small or very small effect sizes. This means that achievement and learning motivation may decline in the long term. This result also aligns with the longitudinal studies of Hanus and Fox, who found that students in the gamified condition demonstrated lower motivation and lower final exam scores compared to the non-gamified class.

Additionally, the study by Hanus and Fox [21]. showed that gamification did not affect performance, dropout rates, or pass rates compared to the control group.

This suggests that the effects of gamification may vary in the short term and long term. Longitudinal studies that cover different time

frames may produce different outcomes. Differences in the duration of intervention can result in variations in the magnitude and sustainability of gamification effects. Longitudinal studies should aim to measure effects across different time intervals to accurately assess changes over time.

Multiple variables may play a key role in this heterogeneity in the long-term impact of gamification on students' academic performance. The effectiveness of educational games over time may be influenced by changes in student characteristics, the educational environment, and intervening factors. Students grow over time in terms of cognitive skills, interests, and motivation, and their learning needs and goals evolve. The educational environment also transforms through changes in the curriculum and new instructional approaches. Additionally, socioeconomic status and the attitudes of teachers and parents can influence access to and acceptance of educational games. Longitudinal studies reveal the long-term effects of gamification on student academic performance and help in better understanding the diversity in individual responses.

This finding is in line with the studies of Hanus and Fox [21]. All these studies highlight the challenges and limitations of long-term gamification in educational environments. Hanus and Fox showed that gamification could lead to reduced motivation and lower scores, emphasizing the need to adapt educational games to changing student characteristics and environments. Hanus and Fox [21]. showed that gamification had no impact on performance, dropout rate, or success rate in distance learning, possibly due to changes in intervening variables and the educational context.

Several reasons may explain why gamification may have reduced effects over time. First, the initial motivation driven by the

novelty and appeal of these technologies may wane as students become accustomed to them, reducing their effectiveness. Second, the repetitive and monotonous nature of content may lower student interest and engagement. Third, shifts in the educational environment and evolving student needs and learning goals may render such technologies less effective over time.

Additionally, intervening factors such as students' socio-economic status and the attitudes and beliefs of teachers and parents can affect access to and acceptance of these technologies. Lastly, individual differences among students and their varying responses to these methods may contribute to a general decline in the long-term effectiveness of gamification and augmented reality.

Based on the findings and analyses, it appears that gamification can significantly influence students' academic performance. However, these effects vary over time and depend on various contextual factors. In general, the effect size of gamification has been positive and notable, especially when these technologies are implemented over extended periods. Research has shown that gamification can effectively enhance students' motivation, engagement, and deep learning, which aligns with the findings of longitudinal studies that emphasize the sustainability and positive impacts of such approaches.

Conversely, some studies have shown that the positive effects of gamification may diminish over time, possibly due to factors such as repetitive content, reduced novelty and appeal, and habituation. Ultimately, multiple variables can affect the heterogeneity of gamification's effect sizes and its influence on students' academic outcomes. These variables include students' individual characteristics, the educational environment, duration of the intervention, frequency and intensity of

technology use, and environmental and psychological changes.

Therefore, the use of these technologies in education should be approached with care and tailored to the evolving needs of students and the learning context to achieve long-term and sustainable positive effects.

Conclusions

The findings of this meta-analysis indicate that gamification has a generally positive, small-to-medium long-term effect on the academic performance of elementary school students, with an overall fixed effect size of 0.298. Several studies demonstrated medium to large effects, particularly in areas such as learning performance, achievement motivation, learning motivation, and deep engagement. These results align with longitudinal evidence showing that digital games and game elements can sustain learners' motivation, improve cognitive processes such as memory and attention, and enhance academic performance over extended periods. However, the analysis also revealed that not all studies report favorable long-term outcomes. Some investigations, particularly those by Hanus and Fox [21], indicate that the effectiveness of gamification may diminish over time, potentially due to declining novelty, repetitive instructional content, and changes in learner characteristics or contextual conditions.

Despite these insights, the present meta-analysis faces several limitations. First, the studies reviewed vary considerably in terms of duration, intervention design, educational settings, and participant characteristics, which contributes to heterogeneity in the findings. Second, differences in measurement tools and outcome variables across studies may limit comparability. Third, relatively few longitudinal studies with extended follow-up periods exist in

the field, which restricts the depth of conclusions regarding long-term sustainability. Additionally, contextual moderators such as socio-economic status, teacher attitudes, and instructional design quality were not consistently reported, limiting the ability to conduct moderator analyses. The results of this research have important practical implications for instructional designers, teachers, and policymakers. Gamification can be an effective approach for enhancing learner motivation and performance when implemented strategically and aligned with students' developmental and contextual needs. Sustaining its effectiveness requires integrating diverse game elements, avoiding monotonous content, and continuously adapting activities to maintain novelty and relevance. Educators should also consider environmental and psychological variables—such as learner readiness, classroom climate, and support from teachers and parents—that shape the success of long-term gamified learning.

Future research should address the existing gaps by conducting longitudinal studies with standardized measures, consistent time intervals, and robust experimental designs. Scholars should examine the role of moderating factors such as intervention duration, intensity of game use, learner characteristics, and changes in educational environments. Moreover, comparative studies between gamification and emerging technologies—such as augmented reality or adaptive learning systems—may provide deeper insights into how different digital tools support sustained student engagement and performance. Finally, future research should explore qualitative dimensions of learner experiences to better understand the psychological mechanisms underlying long-term changes in motivation and achievement.

Acknowledgments

We would like to express our sincere gratitude to all the professors and students who supported the research team throughout the process of compiling and writing the present article.

Conflicts of Interest

The authors have no conflicts of interest.

Authors' Contribution

Javad Kayhan contributed to the conceptualization and design of the study, supervision of the research process, data analysis, drafting the initial manuscript, and critical revision of the manuscript. Golestan Sheikhlou was responsible for data collection. Both authors contributed to the interpretation of findings, reviewed and approved the final version of the manuscript, and agreed to be accountable for all aspects of the work.

References

- [1] Deterding S, Dixon D, Khaled R, Nacke L. From game design elements to gamefulness: Defining "gamification". In: *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*. ACM; 2011. p. 9–15. doi.org/10.1145/2181037.2181040
- [2] Li M, Ma S, Shi Y. Examining the effectiveness of gamification as a tool promoting teaching and learning in educational settings: a meta-analysis. *Front Psychol*. 2023;14:1253549. doi.org/10.3389/fpsyg.2023.1253549
- [3] Wijaya TT, Cao Y, Bernard M, Rahmadi IF, Lavicza Z, Surjono HD. Factors influencing microgame adoption among secondary school mathematics teachers supported by structural equation modelling-based research. *Front Psychol*. 2022;13:952549. doi.org/10.3389/fpsyg.2022.952549
- [4] Kapp KM. *The gamification of learning and instruction: game-based methods and strategies for training and education*. Pfeiffer; 2012. doi.org/10.1145/2207270.2211316
- [5] Sailer M, Homner L. The gamification of learning: a meta-analysis. *Educational Psychology Review*. 2020;32(1):77–112. doi.org/10.1007/s10648-019-09498-w

- [6] Bai S, Hew KF, Huang B. Does gamification improve student learning outcome? Evidence from a meta-analysis and synthesis of qualitative data in educational contexts. *Educational Research Review*. 2020;30:100322.
- [7] Romero-Rodríguez JM, Martínez-Menéndez A, Alonso-García S, Victoria-Maldonado JJ. The reality of the gamification methodology in Primary Education: A systematic review. *Int J Educ Res*. 2024;128:102481.
- [8] Lopez CE, Tucker CS. The effects of player type on performance: a gamification case study. *Computers in Human Behavior*. 2019;91:333–45.
- [9] Diaz AF, Estoque-Loñez H. A meta-analysis on the effectiveness of gamification on student learning achievement. *International Journal of Education in Mathematics, Science and Technology*. 2024;12(5):1236–53.
- [10] Martínez-Hita M, Miralles-Martínez P, Gómez CJ. Gamificar la enseñanza de la historia: Percepciones del alumnado. *REDIE: Revista Electrónica de Investigación Educativa*. 2024;26:e03.
- [11] Price A, Beckey A, Collins D. Developing a love for playing games: A clarification of why digital video games approach is not gamification. *Physical Education and Sport Pedagogy*. 2022;1–15. doi:10.1080/17408989.2022.2125946
- [12] García E, Fernández G. Intervención educativa mediante una propuesta de gamificación para mejorar la adhesión a la dieta mediterránea en estudiantes gallegos de Primaria. *Retos*. 2022;44:128–35. doi:10.47197/RETOS.V44I0.90142
- [13] Anim NAHM, Suffarruddin SH, Najib NM, Sabarudin NA. Ensuring the sustainability of sadaqah-based crowdfunding platforms: the role of gamification and user experience. *J Muamalat Islam Finan Res*. 2023;20:35–48. doi:10.33102/jmifr.475
- [14] Noshini Sh, Abdollahi M, Shirazi MR. Investigating the effect of virtual reality-based educational games on English language learning among students. *Journal of Research in Foreign Language Teaching and Learning*. 2019;7(15):13–28. [In Persian]
- [15] Mazaheri S, Shahrokhi Z. Augmented reality-based educational games in learning educational concepts among primary school students. *Journal of Research in Educational Systems*. 2019;13(4):1–14. [In Persian]
- [16] Buckley P, Noonan S, Geary C, Mackessy T, Nagle E. An empirical study of gamification frameworks. *J Organ End User Comput*. 2019;31(1):1–17. doi:10.4018/JOEUC.2019010102
- [17] Chen CH, Huang CY, Chou YY. Integrating augmented reality into blended learning for elementary science course. In: *Proceedings of the 5th International Conference on Information and Education Technology*. 2017. p. 68–72. doi.org/10.1145/3029387.302941
- [18] Dichev C, Dicheva D. Gamifying education: what is known, what is believed, and what remains uncertain. *International Journal of Educational Technology in Higher Education*. 2017;14(1):9. doi.org/10.1186/s41239-017-0042-5
- [19] Kim J, Castelli DM. Effects of gamification on behavioral change in education: a meta-analysis. *Int J Environ Res Public Health*. 2021;18(7):3550. doi.org/10.3390/ijerph18073550
- [20] Harris A, Park Y. The effect of augmented reality on student engagement: An analysis of the experiential aspects of augmented reality. *J Educ Technol Dev Exch*. 2017;10(1):1–14. doi.org/10.3390/info11040209
- [21] Hanus MD, Fox J. Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance. *Computers & Education*. 2015;80:152–61. doi.org/10.1016/j.compedu.2014.08.019
- [22] Hamari J, Koivisto J, Sarsa H. Does gamification work? – A literature review of empirical studies on gamification. In: *Proceedings of the 47th Hawaii International Conference on System Sciences (HICSS)*. IEEE; 2014. p. 3025–34. doi.org/10.1109/HICSS.2014.377
- [22] Putz LM, Hofbauer F, Treiblmaier H. Can gamification help to improve education? Findings from a longitudinal study. *Computers in Human Behavior*. 2020;110:106392. doi.org/10.1016/j.chb.2020.106392
- [23] Jamiat N, Othman NFN. Effects of Augmented Reality Mobile Apps on Early Childhood Education Students' Achievement. In: *Proceedings of the 3rd International Conference on Digital Technology in Education*. 2019. p. 30–3. https://doi.org/10.1145/3369199.3369203
- [24] Enzai NIM, Ahmad N, Ghani MAHA, Rais SS, Mohamed S. Development of augmented reality (AR) for innovative teaching and learning in engineering education. *Asian Journal of University Education*. 2021;16(4):99–108. doi:10.24191/ajue.v16i4.11954
- [25] Chapell MS, Blanding ZB, Silverstein ME, Takahoshi M, Newman B, Gubi A, McCann N. Test anxiety and academic performance in undergraduate and graduate students. *J Educ Psychol*. 2005;97(2):268–74. doi:10.1037/0022-0663.97.2.268
- [26] Bornstein M, Hedges LV, Higgins JP, Rothstein HR. *Introduction to meta-analysis*. Wiley; 2021. doi:10.1002/9780470743386
- [27] Safari Y, Marzoughi R. An experimental study on the effect of metacognitive teaching method on academic performance and metacognitive awareness in middle school science

curriculum. *Daneshvar Raftar Journal*. 2009;16(39):45–54. [In Persian]

[29] Yaftian N, Abdi H. The effectiveness of gamification-based teaching on math anxiety and motivation among ninth-grade students. *Scientific Journal of Research in School and Virtual Learning*. 2021;9(1):27–36. [In Persian]

[30] Buttler D, Winne P. Feedback and Self-Regulated Learning: A Theoretical Synthesis. *Review of Educational Research*. 1995; 65:245–81. doi: 10.2307/1170684

[31] Chen CM, Tsai YN. Interactive augmented reality system for enhancing library instruction in elementary schools. *Computers & Education*. 2012;59(2):638–52. doi: 10.1016/j.compedu.2012.03.001

[32] Cechanowicz J, Gutwin C, Brownell B, Goodfellow L. Effects of gamification on participation and data quality in a real-world market research domain. In: Nacke LE, Harrigan K, Randall N, editors. *Proceedings of the First International Conference on Gameful Design, Research, and Applications*. New York: ACM; 2013. p. 58–65. doi:10.1145/2583008.2583016

[33] Elliot AJ, McGregor H. A 2 × 2 Achievement Goal Framework. *J Pers Soc Psychol*. 2001;80(3):501–19. doi:10.1037/0022-3514.80.3.501.

[34] Lin J-W, Tsai C-W, Hsu C-C. A comparison of computer-based and game-based formative assessments: a long-term experiment. *Interact Learn Environ*. 2023;31(2):938-954. doi:10.1080/10494820.2020.1815219.

[35] Nabizadeh AH, Jorge J, Gama S, Gonçalves D. How do students behave in a gamified course? A ten-year study. *IEEE Access*. 2021;9:81008-81031. doi:10.1109/ACCESS.2021.3083238.

[36] Recabarren M, Corvalán B, Villegas M. Exploring differences between gamer and non-gamer students in the effects of gamification on their motivation and learning. *Interact Learn Environ*. 2021;31(6):3529-3542. doi:10.1080/10494820.2021.1933543.

[37] Pesek M, Vučko Ž, Šavli P, Kavčič A, Marolt M. Troubadour: a gamified e-learning platform for ear training. *IEEE Access*. 2020;8:97090-97102. doi:10.1109/ACCESS.2020.2994389.

[38] Keyhan J. The effectiveness of a computer-based jigsaw puzzle game on accuracy, speed, learning, and learning retention in mathematics among lower secondary school students in Salmas County. *New Educational Ideas*. 2020;16(3):167-189. doi:10.22051/jontoe.2020.17731.1991.

[39] Van Roy R, Zaman B. Need-supporting gamification in education: an assessment of motivational effects over time. *Comput Educ*. 2018;127:283-297. doi:10.1016/j.compedu.2018.08.018.

[40] Nehring N, Baghaei N, Dacey S. Improving students' performance through gamification: a user study. In: *Proceedings of the 10th International Conference on Computer Supported Education (CSEDU)*. Vol 2. 2018:213-218. doi:10.5220/0006687402130218.

[41] Barata G, Gama S, Jorge J, Gonçalves D. Studying student differentiation in gamified education: a long-term study. *Comput Hum Behav*. 2017;71:550-585. doi:10.1016/j.chb.2016.08.049.

[42] Hakulinen L, Auvinen T, Korhonen A. The effect of gamification on students with different achievement goal orientations. In: *Proceedings of LaTiCE 2014*.

[43] Dodero G, Gennari R, Melonio A, Torello A. Towards tangible gamified co-design at school: two studies in primary schools. In: *Proceedings of the 2014 ACM Conference*. 2014.

[44] Barata G, Gama S, Jorge J, Gonçalves D. Improving participation and learning with gamification. In: *Proceedings of the 1st International Conference on Gameful Design, Research, and Applications (Gamification '13)*. 2013.

[45] Mesrabadi J, Nasrollahi Y. *Meta-analysis: Concepts, Software, and Reporting*. Tabriz: Shahid Madani University of Azerbaijan Press; 2016.

AUTHOR(S) BIOSKETCHES

Javad Kayhan is an associate professor in the Department of Educational Sciences, Islamic Azad University, Urmia Branch. He received his Bachelor of Education degree in 2005 from Urmia University and his Master of Education degree in Curriculum Planning from Tabriz University in 2009. In 2010, he was admitted to the PhD program in Curriculum Planning at Islamic Azad University, Tehran Science and Research Branch, with the third rank in the country, and graduated in 2014. He has presented more than 100 scientific and research articles in domestic and foreign journals and conferences, and has also served as a referee and member of the scientific committee in most domestic and some foreign journals. His areas of expertise and study include: Curriculum Studies, Multicultural Education, and Educational Technology.

Keyhan, J. Associate Professor, Department of Educational Science, Ur., C., Islamic Azad University, Urmia, Iran

✉ Javad.keyhan@iau.ac.ir

Ms. Golestan Sheykhloou an elementary education teacher in Urmia, holds a Bachelor's degree in

Educational Sciences from Islamic Azad University, Khoy Branch (2003), and a Master's degree in Educational Sciences with a specialization in Primary Education from Islamic Azad University, Urmia Branch (2025). She has received various provincial awards for outstanding teaching methods and has published four books in the field of educational

sciences. Her main areas of interest include lesson study and educational technology. She was responsible for conducting the study, analyzing the data, and writing the manuscript.

Department of Educational Science, Ur. C., Islamic Azad University, Urmia, Iran

 gh.shikhloo@gmail.com

Citation (Vancouver): Keyhan J, Sheikhlloo Go. [Meta-Analysis of Research Related to Gamification with Emphasis on Its Long-Term Effects on the Academic Performance of Elementary Students] *Tech. Edu. J.* 2026; 20(1): 23-42

 <https://doi.org/10.22061/tej.2026.12202.3251>





ORIGINAL RESEARCH PAPER

The power of time: how spacing techniques revolutionize ESP vocabulary learning online

Z. Cheraghi*, H. Omranpour, A. Motaharnejad

Department of English Language, Faculty of Humanities, Shahid Rajaei Teacher Training University, Tehran, Iran

ABSTRACT

Received: 28 August 2025
Reviewed: 20 October 2025
Revised: 22 November 2025
Accepted: 28 December 2025

KEYWORDS:

Digital Flashcards
ICT
Technical Vocabulary
Quizlet

* Corresponding author

✉ z.cheraghi@sru.ac

☎ (+98912)5383046

Background and Objectives: The growing influence of Information and Communication Technology (ICT) has considerably altered educational practices, particularly in language learning contexts. In English for Specific Purposes (ESP) courses, mastering technical vocabulary is a fundamental yet challenging requirement due to the specialized nature of the content and learners' limited exposure beyond academic settings. Traditional vocabulary instruction methods often provide insufficient repetition and lack flexibility, which can negatively affect retention and long-term learning. In response to these challenges, technology-enhanced learning tools have emerged as effective alternatives for supporting vocabulary development. Digital flashcards, especially when used through online platforms, offer structured repetition, learner autonomy, and increased engagement. However, despite their widespread use, there is limited empirical research examining the effectiveness of digital flashcards implemented at predetermined time intervals in ESP contexts. Therefore, this mixed-methods study aimed to investigate the effects of using ICT-based digital flashcards with spaced repetition on undergraduate ESP learners' acquisition of technical vocabulary. Additionally, the study explored learners' perceptions of using Quizlet as a technology-supported instructional tool.

Materials and Methods: The study employed a mixed-methods research design integrating quantitative and qualitative data to provide a comprehensive understanding of the research objectives. The participants were 60 undergraduate students enrolled in ESP courses, who were randomly assigned to an experimental group and a control group. Before the instructional intervention, both groups completed a background questionnaire and a technical vocabulary pre-test to ensure comparability in terms of prior knowledge. During the treatment phase, the experimental group learned technical vocabulary through digital flashcards delivered via an online platform at planned and systematic time intervals based on spaced learning principles. In contrast, the control group received conventional vocabulary instruction without the use of digital flashcards or ICT-based tools. Data collection instruments included technical vocabulary pre- and post-tests, post-treatment questionnaires, and semi-structured interviews. Quantitative data were analyzed using paired-samples t-tests to examine within-group changes and an independent-samples t-test on gain scores to compare the magnitude of vocabulary improvement between the two groups. Qualitative interview data were analyzed through content analysis using NVivo software.

Findings: The results of the quantitative analysis showed that the experimental group achieved significantly greater vocabulary gains than the control group, as confirmed by an independent-samples t-test on gain scores. These findings indicate that the use of digital flashcards with spaced intervals had a positive and statistically significant effect on ESP learners' vocabulary acquisition. Learners who experienced repeated and structured exposure to technical terms demonstrated higher levels of retention and recall. Moreover, the results suggested that Quizlet functioned as an effective and reliable ICT-based platform for facilitating vocabulary learning. The qualitative findings further supported the quantitative results, revealing that learners held positive attitudes toward the use of digital flashcards. Participants reported increased motivation, improved engagement, and greater control over their learning process. They also noted that spaced repetition helped reduce cognitive load and made learning complex technical vocabulary more manageable.

Conclusions: The findings of this study demonstrate that integrating ICT-based tools, particularly digital flashcards with spaced repetition, can effectively enhance technical vocabulary learning in

ESP contexts. From a technology of education perspective, the results highlight the pedagogical value of online learning platforms in promoting learner autonomy and improving vocabulary retention. This study contributes to the field of educational technology by providing empirical evidence for the effectiveness of interval-based digital flashcards in ESP instruction. It is recommended that ESP instructors and curriculum designers incorporate technology-enhanced vocabulary learning strategies into their courses to achieve more effective and sustainable learning outcomes.



COPYRIGHTS

© 2026 The Author(s). This is an open-access article distributed under the terms and conditions of the Creative Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) (<https://creativecommons.org/licenses/by-nc/4.0/>)



NUMBER OF REFERENCES

32



NUMBER OF FIGURES

0



NUMBER OF TABLES

13

مقاله پژوهشی

قدرت زمان: چگونه فنون فاصله‌گذاری یادگیری واژگان ESP را در محیط آنلاین متحول می‌کند

زهرا چراغی^{*}، هنگامه عمرانپور، عطیه مطهری‌نژاد

گروه زبان انگلیسی، دانشکده علوم انسانی، دانشگاه تربیت دبیر شهید رجایی، تهران، ایران

چکیده

پیشینه و اهداف: گسترش روزافزون فناوری اطلاعات و ارتباطات (فاوا) تأثیر قابل توجهی بر شیوه‌های آموزشی، به‌ویژه در بافت‌های آموزش زبان، گذاشته است. در دوره‌های زبان انگلیسی برای اهداف ویژه (ESP)، تسلط بر واژگان تخصصی یک ضرورت اساسی اما چالش‌برانگیز محسوب می‌شود؛ زیرا ماهیت تخصصی محتوا و محدود بودن مواجهه زبان‌آموزان با آن خارج از محیط‌های دانشگاهی، فرایند یادگیری را دشوار می‌سازد. روش‌های سنتی آموزش واژگان غالباً تکرار کافی را فراهم نمی‌کنند و از انعطاف‌پذیری لازم برخوردار نیستند؛ امری که می‌تواند بر ماندگاری و یادگیری بلندمدت تأثیر منفی بگذارد. در پاسخ به این چالش‌ها، ابزارهای یادگیری تقویت‌شده با فناوری به‌عنوان گزینه‌هایی مؤثر برای حمایت از رشد واژگانی مطرح شده‌اند. فلش‌کارت‌های دیجیتال، به‌ویژه هنگام استفاده از سکوها آنلاین، امکان تکرار ساختاریافته، خودمختاری یادگیرنده و افزایش درگیری شناختی را فراهم می‌کنند. با وجود کاربرد گسترده این ابزارها، پژوهش‌های تجربی محدودی درباره اثربخشی فلش‌کارت‌های دیجیتال اجراشده در فواصل زمانی از پیش تعیین‌شده در بافت‌های انگلیسی برای اهداف ویژه وجود دارد. از این‌رو، پژوهش حاضر با رویکرد روش ترکیبی، با هدف بررسی تأثیر استفاده از فلش‌کارت‌های دیجیتال مبتنی بر فناوری اطلاعات و ارتباطات همراه با تکرار فاصله‌دار بر یادگیری واژگان تخصصی دانشجویان کارشناسی انگلیسی برای اهداف ویژه انجام شد. همچنین، این مطالعه به بررسی ادراک زبان‌آموزان از کاربرد Quizlet به‌عنوان یک ابزار آموزشی پشتیبانی‌شده با فناوری پرداخت.

روش‌ها: این پژوهش از طرح پژوهش ترکیبی بهره گرفت و داده‌های کمی و کیفی را به‌منظور دستیابی به درکی جامع از اهداف پژوهش تلفیق کرد. شرکت‌کنندگان شامل شصت دانشجوی کارشناسی مشغول به تحصیل در دوره‌های انگلیسی برای اهداف ویژه بودند که به‌صورت تصادفی در دو گروه آزمایشی و کنترل جای‌گذاری شدند. پیش از مداخله آموزشی، هر دو گروه پرسشنامه پیشینه و آزمون پیش‌آزمون واژگان تخصصی را تکمیل کردند تا از همگنی آن‌ها از نظر دانش پیشین اطمینان حاصل شود. در مرحله اجرا، گروه آزمایشی واژگان تخصصی را از طریق فلش‌کارت‌های دیجیتال ارائه‌شده در یک پلتفرم آنلاین و در فواصل زمانی برنامه‌ریزی‌شده و منظم مبتنی بر اصول یادگیری فاصله‌دار فراگرفت. در مقابل، گروه کنترل آموزش متعارف واژگان را بدون استفاده از فلش‌کارت‌های دیجیتال یا ابزارهای مبتنی بر فاوا دریافت کرد. ابزارهای گردآوری داده شامل پیش‌آزمون و پس‌آزمون واژگان تخصصی، پرسشنامه پس از مداخله و مصاحبه‌های نیمه‌ساختاریافته بود. داده‌های کمی با استفاده از آزمون‌های t برای مقایسه نتایج یادگیری واژگان دو گروه تحلیل شد و داده‌های کیفی حاصل از مصاحبه‌ها از طریق تحلیل محتوا با استفاده از نرم‌افزار NVivo مورد بررسی قرار گرفت.

تاریخ دریافت: ۰۶ شهریور ۱۴۰۴
تاریخ داوری: ۲۸ مهر ۱۴۰۴
تاریخ اصلاح: ۰۱ آذر ۱۴۰۴
تاریخ پذیرش: ۰۷ دی ۱۴۰۴

واژگان کلیدی:

فلش‌کارت‌های دیجیتالی
کویزلت
فناوری اطلاعات
واژگان تخصصی

^{*} نویسنده مسئول

z.cheraghi@sru.ac.ir

۰۹۱۲-۵۳۸۳۰۴۶ (۱)

یافته‌ها: نتایج تحلیل کمی نشان داد که گروه آزمایشی پیشرفت واژگانی معنادارتری نسبت به گروه کنترل کسب کرد، همانطور که آزمون مستقل t بر روی نمرات تفاضل تایید کرد. این یافته‌ها بیانگر آن است که استفاده از فلش کارت‌های دیجیتال با فواصل زمانی برنامه‌ریزی‌شده، تأثیر مثبت و معناداری بر یادگیری واژگان زبان‌آموزان انگلیسی برای اهداف ویژه داشته است. زبان‌آموزانی که در معرض مواجهه تکراری و ساختاریافته با اصطلاحات تخصصی قرار گرفتند، سطوح بالاتری از ملنگاری و یادآوری را نشان دادند. افزون بر این، نتایج حاکی از آن بود که Quizlet به‌عنوان یک پلتفرم مبتنی بر فاوا، ابزار مؤثر و قابل اعتمادی برای تسهیل یادگیری واژگان عمل کرده است. یافته‌های کیفی نیز نتایج کمی را تأیید کرد و نشان داد که زبان‌آموزان نگرش‌های مثبتی نسبت به استفاده از فلش کارت‌های دیجیتال داشتند. شرکت‌کنندگان افزایش انگیزش، بهبود درگیری یادگیری و کنترل بیشتر بر فرایند یادگیری خود را گزارش کردند. آن‌ها همچنین اشاره کردند که تکرار فاصله‌دار به کاهش بار شناختی کمک کرده و یادگیری واژگان تخصصی پیچیده را قابل مدیریت‌تر ساخته است.

نتیجه‌گیری: یافته‌های این پژوهش نشان می‌دهد که ادغام ابزارهای مبتنی بر فاوا، به‌ویژه فلش کارت‌های دیجیتال همراه با تکرار فاصله‌دار، می‌تواند به‌طور مؤثری یادگیری واژگان تخصصی را در بافت‌های انگلیسی برای اهداف ویژه تقویت کند. از منظر فناوری آموزشی، نتایج بر ارزش تربیتی پلتفرم‌های یادگیری آنلاین در ارتقای خودمختاری یادگیرنده و بهبود ملنگاری واژگان تأکید دارد. این مطالعه با ارائه شواهد تجربی درباره اثربخشی فلش کارت‌های دیجیتال مبتنی بر فواصل زمانی در آموزش انگلیسی برای اهداف ویژه، به حوزه فناوری آموزشی کمک می‌کند. پیشنهاد می‌شود مدرسان انگلیسی برای اهداف ویژه و طراحان برنامه درسی، راهبردهای یادگیری واژگان تقویت‌شده با فناوری را در دوره‌های خود ادغام کنند تا به نتایج یادگیری مؤثرتر و پایدارتر دست یابند.

Introduction

The integration of Information and Communication Technology (ICT) into language education has reshaped instructional practices and redefined how learners engage with linguistic input. Recent advancements in digital learning environments have shifted the focus from teacher-centered transmission models toward learner-centered, technology-mediated pedagogies that promote autonomy, sustained engagement, and data-driven feedback [1-2]. In addition, recent syntheses of research suggest that technology integration in language classrooms can significantly enhance learner interaction and self-regulated learning when pedagogically grounded [3-4]. Within applied linguistics, the growing emphasis on evidence-based instructional design has highlighted the importance of aligning technological tools with established cognitive learning principles. As a result, vocabulary instruction—long recognized as a cornerstone of second and foreign language proficiency—has increasingly been supported through digital platforms that enable

repeated exposure, retrieval practice, and adaptive review mechanisms [5-6].

Vocabulary knowledge constitutes a foundational dimension of communicative competence, directly influencing learners' reading comprehension, listening ability, speaking fluency, and academic achievement. In English for Specific Purposes (ESP) contexts, lexical competence becomes even more critical because learners must acquire discipline-specific terminology that occurs with limited frequency outside specialized domains [7-8]. Research on vocabulary acquisition further emphasizes that systematic and technology-supported lexical instruction can strengthen depth of processing and long-term retention, particularly when digital tools are integrated into structured learning environments [9]. The technical and often abstract nature of ESP vocabulary presents substantial learning challenges, particularly in contexts where learners have restricted exposure to authentic input. Consequently, relying solely on incidental vocabulary acquisition is insufficient; intentional, systematically structured lexical

instruction is necessary to facilitate durable retention and productive use [10].

From a cognitive perspective, vocabulary acquisition is incremental and requires multiple encounters distributed across time. One of the most robust findings in memory research—the spacing effect—demonstrates that learning episodes spaced over intervals yield stronger long-term retention than massed practice conducted within a single session [11-12-13]. Spaced retrieval enhances memory consolidation by strengthening neural encoding pathways and reducing cognitive overload, thereby increasing both accuracy and durability of recall [14]. In second language acquisition research, retrieval practice combined with distributed scheduling has been shown to significantly improve vocabulary retention compared to repeated exposure without temporal spacing [15].

Digital flashcard applications provide an ideal environment for operationalizing spacing principles within language classrooms. Platforms such as Quizlet incorporate automated review cycles, time-controlled repetition, gamified testing modes, and mobile accessibility, all of which may enhance both cognitive processing and learner motivation [16-2]. Unlike traditional paper-based flashcards, digital systems can algorithmically schedule review sessions, monitor performance, and adjust repetition intervals to optimize learning efficiency. However, despite the well-documented benefits of spaced practice in cognitive psychology, empirical investigations examining how digitally scheduled spacing influences ESP learners' technical vocabulary development remain limited.

Addressing this gap is important for both theoretical understanding and practical application. Examining spaced digital vocabulary learning in ESP contexts connects

research on cognitive memory with effective technology-enhanced language learning. Understanding learning outcomes and learner perceptions allows for informed curriculum design, enabling educators to purposefully integrate digital tools to support vocabulary instruction. In higher education, where time constraints and demanding subject matter often limit opportunities for repeated vocabulary practice, identifying efficient, research-backed instructional strategies is very essential. Recent empirical evidence suggests that retrieval-based instructional approaches, especially those employing systematic spacing improve long-term vocabulary retention in second language contexts [17].

Although the effectiveness of spaced learning was approved in recent years [18-19-20], the present mixed-methods research is aimed at examining the impact of spaced learning on the enhancement of ESP vocabulary using Quizlet digital flashcards. Additionally, the study sought to explore the following research inquiries:

- Is spacing technical vocabulary learning through digital flashcards more effective than massed learning?
- What are the perceptions of learners in the experimental group regarding the implementation of spaced retrieval?
- What are the ESP learners' attitudes toward using Quizlet digital flashcards with specific intervals for learning technical vocabulary?

Review of Related Literature

Theoretical Background

The present study is grounded in two complementary theoretical perspectives that explain learners' acceptance of digital learning tools and their engagement in structured vocabulary learning environments: the Technology Acceptance Model (TAM) and the

Theory of Planned Behavior (TPB). Rather than adopting these frameworks as isolated models, the study integrates them to explain how perceived usefulness, perceived ease of use, behavioral intentions, and perceived control may influence learners' engagement with spaced digital flashcards.

Recent extensions of TAM emphasize that learners' adoption of educational technologies is largely determined by their perceptions of usefulness, usability, and motivational affordances [3-21]. Empirical investigations in higher education settings further indicate that students' sustained engagement with digital learning platforms is strongly predicted by perceived usefulness and self-efficacy beliefs [22]. In language learning contexts, perceived usefulness often relates to improved performance, efficiency, and long-term retention, while perceived ease of use relates to reduced cognitive load and accessibility of the platform [2]. When learners perceive digital tools as beneficial and manageable, their intention to use such technologies increases significantly.

Similarly, the Theory of Planned Behavior posits that behavior is driven by behavioral intentions shaped by attitudes, subjective norms, and perceived behavioral control [23]. In digitally mediated vocabulary learning environments, perceived behavioral control may manifest as learners' belief in their ability to regulate their study schedules, manage repetition intervals, and successfully retrieve vocabulary items. Recent research has shown that students' intention to continue using educational technologies is strongly associated with motivational beliefs and perceived autonomy [2-4].

By integrating TAM and TPB, the present study provides a theoretical basis for examining not only the effectiveness of spaced digital vocabulary learning but also learners'

perceptions and attitudes toward scheduled repetition in Quizlet. These frameworks justify the inclusion of qualitative data exploring motivation, engagement, and perceived learning enhancement.

Spaced Retrieval and Vocabulary Learning

The spacing effect, one of the most robust findings in cognitive psychology, suggests that distributed learning episodes result in stronger long-term retention than massed practice [11-12]. Spaced retrieval enhances memory consolidation by allowing forgetting to occur between sessions, thereby strengthening retrieval pathways when information is reactivated [24].

In second language acquisition, retrieval-based practice combined with temporal distribution has demonstrated significant gains in vocabulary retention compared to repeated exposure without spacing [15]. Experimental research has also demonstrated that expanding retrieval schedules produces more durable vocabulary retention than fixed or massed repetition patterns, particularly when practice sessions are distributed across days rather than within a single session [17]. Meta-analytic evidence indicates that distributed practice yields medium to large effect sizes for long-term vocabulary retention, particularly when retrieval is effortful and feedback is immediate [14].

Although the cognitive advantages of spaced learning are well established, fewer studies have examined how spacing principles operate within digital vocabulary platforms that algorithmically schedule review sessions. As digital environments allow precise control over interval timing and frequency, they may optimize spacing more effectively than traditional classroom-based repetition. However, empirical research specifically targeting ESP learners and technical vocabulary

within digitally scheduled spacing remains limited. This gap highlights the need for research that combines cognitive principles with technology-enhanced language learning.

Vocabulary Learning in ESP Contexts

Vocabulary knowledge is widely recognized as a core component of language proficiency, particularly in academic and professional domains [25]. In ESP contexts, learners must acquire discipline-specific lexical items that are often abstract, low-frequency outside the field, and conceptually dense [7]. Technical vocabulary plays a decisive role in enabling learners to comprehend specialized texts and participate in professional discourse communities [8].

Contemporary perspectives emphasize that vocabulary acquisition is incremental and requires repeated, meaningful encounters across time [10-9]. Incidental exposure alone is insufficient for mastering technical terminology; instead, intentional and structured instructional approaches are necessary.

Moreover, digital learning environments offer expanded affordances for repeated exposure, multimodal presentation, and learner-controlled pacing. Research has shown that technology-mediated vocabulary learning can enhance engagement, autonomy, and retention when grounded in cognitive principles such as retrieval practice and spacing [5-2]. Despite these advances, the intersection of ESP vocabulary, digital flashcards, and algorithmically scheduled spacing remains underexplored.

Digital Flashcards and Quizlet

Digital flashcard applications operationalize key principles of vocabulary learning, including form–meaning mapping, retrieval practice, and distributed exposure. Recent empirical

investigations suggest that digital flashcards are effective tools for improving vocabulary retention, particularly when they incorporate adaptive scheduling and gamified features [6-16].

Unlike traditional paper-based flashcards, digital platforms such as Quizlet provide automated review cycles, performance tracking, and mobile accessibility. These features may enhance learner engagement and encourage sustained practice. A recent meta-analysis on technology-enhanced vocabulary learning confirmed that digital tools produce significant positive effects compared to traditional methods, especially when repetition is structured and interactive [2].

However, while previous studies have examined digital flashcards in general EFL settings [4-6-16], relatively limited research has investigated their effectiveness for technical vocabulary acquisition in ESP contexts, particularly through experimentally manipulated spacing intervals. Furthermore, the role of learners' perceptions, motivation, and competitive engagement in such environments requires further qualitative exploration.

ICT in ESP and Research Gap

ICT integration in ESP classrooms has been associated with increased learner autonomy, improved access to authentic materials, and enhanced professional relevance [26]. Nevertheless, much of the research on ICT in ESP focuses on general digital integration rather than cognitively principled instructional design.

Although separate bodies of research exist on (a) spacing effect in vocabulary learning, (b) digital flashcards in language education, and (c) ICT use in ESP contexts, there is a notable lack of mixed-method studies examining the combined impact of digitally scheduled spacing on technical vocabulary development within

ESP settings.

The present study addresses this gap by experimentally comparing spaced and massed vocabulary learning through Quizlet digital flashcards while simultaneously exploring learners' perceptions and attitudes. By integrating cognitive theory, technology acceptance models, and ESP pedagogy, this study contributes to both theoretical understanding and pedagogical practice in technology-enhanced language learning.

Method

Participants

The participants initially consisted of 90 Iranian undergraduate students majoring in Architecture, all enrolled in an ESP course. The cohort included both male and female students, aged between 19 and 24, who were in their second or third academic year. To ensure homogeneity in general English proficiency, an Oxford Placement Test was administered. Based on the test results, 60 learners who met the intermediate level criterion (B1 according to the Common European Framework of Reference [CEFR]) were selected as the final sample. The selected participants were then assigned to two intact groups: an experimental group ($n = 30$) and a control group ($n = 30$). Participation was voluntary and informed consent was obtained from all individuals involved.

Instruments

Placement Test

An Oxford Placement Test consisting of 50 multiple-choice items assessing grammar and vocabulary knowledge was administered to determine participants' general language proficiency. The test duration was 40 minutes (averaging 48 seconds per item). According to the test guidelines, scores above 31 correspond

to the intermediate (B1) level. Only those meeting this criterion were included in the study.

Technical Vocabulary Tests

To measure vocabulary development, a researcher-developed technical vocabulary test was administered as both a pre-test and a post-test. The tests included 30 multiple-choice items derived from Technical English for Architects.

To establish content and construct validity, the instrument was piloted with 120 EFL learners at another university who shared similar characteristics with the target population. Internal consistency was calculated separately for each administration, yielding a Cronbach's alpha of 0.82 for the pre-test and 0.86 for the post-test, indicating high reliability across both measurements. Both pre- and post-tests were scored independently by two raters to reduce scoring bias, and the average of the two scores was used as the final score.

Post-treatment Questionnaire

The post-treatment questionnaire, adopted from Lotfolahi and Salehi [19], was administered immediately after the post-test to explore the perceptions of the experimental group about using spaced digital flashcards. It addressed experiences and attitudes formed during the intervention, aiming to examine the effects of the spacing technique on learning target vocabulary. The questionnaire consisted of 14 Likert-scale items rated on a five-point scale (1 = Strongly Agree to 5 = Strongly Disagree). It was completed by all 30 participants in the experimental group. To prevent misunderstanding, the questionnaire was translated into Persian. The translated version underwent expert validation by bilingual specialists to ensure linguistic

accuracy, conceptual equivalence, and cultural appropriateness.

Semi-structured Interview

To obtain in-depth qualitative data, semi-structured interviews were conducted with 10 participants purposively selected from the experimental group to represent a range of final vocabulary test scores (high, medium, low), ensuring diverse perspectives on the learning experience. The interviews aimed to explore participants' attitudes, motivation, and perceptions regarding the use of Quizlet digital flashcards with scheduled intervals. All interviews were audio-recorded and later transcribed for analysis.

The interview protocol consisted of four open-ended questions (see Appendix) designed to collectively deepen and complement the quantitative findings across all three research questions. Rather than mapping each question to a single research question in isolation, the questions were constructed to allow participants to reflect on interconnected aspects of their learning experience—including motivation, engagement, perceived challenge, and vocabulary retention—which together inform all three research questions. This design ensured that the qualitative data captured the complexity and interrelatedness of learners' experiences with spaced digital flashcard practice, while allowing participants the freedom to elaborate on their unique perspectives. The integration of responses across all four questions enabled the researchers to identify recurrent themes that cut across the study's research objectives, thereby strengthening the triangulation of quantitative and qualitative findings.

Data Collection Procedure

Ethical approval for the study was obtained from the English Department of Pars Higher

Education Institute, Tehran, Iran. Participation was voluntary, and informed consent was obtained from all students. Following the administration of the placement test, 60 intermediate learners were selected and assigned to experimental and control groups. The intervention lasted six weeks, with classes held twice a week for two hours. Both groups were taught by the same instructor to control for teacher-related variables. At the beginning of the study, both groups took the technical vocabulary pre-test under standardized conditions. During the intervention period, both groups used Quizlet digital flashcards to learn technical vocabulary. However, the experimental group was required to follow a structured spaced schedule, reviewing vocabulary at two-day intervals. In contrast, the control group used Quizlet without predetermined intervals. At the end of the treatment, both groups completed the post-test under identical conditions. Afterward, a post-treatment questionnaire was administered only to the experimental group to gather data on their perceptions of the spaced digital flashcard use. This questionnaire was not given to the control group because their instruction did not involve a spaced schedule, making the questions irrelevant to their experience. Finally, semi-structured interviews were conducted with 10 participants from the experimental group to gain deeper insights into their learning experiences. A standardized protocol was followed to ensure consistency and depth across all sessions. Each interview was conducted individually in a quiet, private setting to minimize distractions. Before the interview, participants were briefed on the purpose of the study, assured of confidentiality, and provided informed consent. The interviews began with a brief, neutral opening question to establish rapport. The interviewer then followed the guiding questions (see Appendix),

allowing participants to speak freely while using prepared prompts (e.g., “Can you elaborate on that?” or “Could you give an example?”) to explore responses in greater depth when necessary. Each interview lasted approximately 20–30 minutes.

Data Analysis

A mixed-method approach was employed for data analysis. Quantitative data were entered into SPSS. Before conducting inferential statistics, assumption testing was performed. The normality of score distributions for both groups was examined using the Shapiro–Wilk test, and the homogeneity of variances was assessed through Levene’s Test of Equality of Variances. Descriptive statistics, including means and standard deviations, were calculated to summarize participants’ performance on the pre- and post-tests. To examine within-group changes from pre-test to post-test, paired-samples t-tests were conducted separately for the experimental and control groups. In addition, to compare the effectiveness of spaced versus non-spaced digital flashcard practice between the two groups, gain scores (post-test minus pre-test) were calculated for each participant. An independent-samples t-test was then performed on these gain scores to determine whether the magnitude of improvement differed significantly between the experimental and control groups. This approach was adopted because comparing raw post-test scores alone does not account for potential pre-existing differences in baseline vocabulary knowledge, whereas gain score analysis directly measures the amount of change attributable to the intervention. Statistical significance was set at $p < .05$. For qualitative analysis, interview transcripts were imported into NVivo software and analyzed using thematic content analysis. An inductive coding procedure was applied to

identify recurring themes related to motivation, engagement, competition, and perceived vocabulary improvement.

For qualitative analysis, interview transcripts were imported into NVivo software to facilitate systematic data management and coding. The analysis followed the six-phase thematic analysis protocol proposed by Braun and Clarke [27] to ensure rigor and transparency. First, the researchers familiarized themselves with the data by reading and re-reading the transcripts. Second, an inductive coding procedure was applied to generate initial codes for meaningful segments of text. Third, these codes were collated into potential themes related to motivation, engagement, competition, and perceived vocabulary improvement. Fourth, the themes were reviewed against the coded extracts and the entire dataset to ensure they accurately reflected the participants’ experiences. Fifth, the specific nature of each theme was defined and named. Finally, the analysis was written up, linking the identified themes back to the study’s research questions. This structured approach ensured that the findings were grounded in the data rather than researcher bias.

Design of the Study

The present study adopted a quasi-experimental mixed-methods design to examine the effect of digitally delivered flashcards via Quizlet on the acquisition of technical vocabulary under scheduled spaced intervals. Due to the use of intact classroom groups, random assignment was not feasible; therefore, control and experimental groups were compared within a quasi-experimental framework. Quantitative data were collected through pre- and post-tests measuring learners’ vocabulary knowledge, along with a structured questionnaire assessing their perceptions of spaced digital practice.

To gain deeper insights into the intervention’s impact, qualitative data were gathered through semi-structured interviews with participants in the experimental group. The integration of quantitative and qualitative findings allowed for triangulation and provided a more comprehensive understanding of how digitally scheduled spacing influenced vocabulary development and learner perceptions.

Results and Findings

Descriptive Statistics

To provide an initial overview of participants’ performance, descriptive statistics were calculated for both the control and experimental groups in the pre-test and post-test phases. The results are presented in Table 1.

As presented in Table 1, the pre-test mean scores of the control group ($M = 17.88$, $SD = 4.87$) and the experimental group ($M = 18.52$, $SD = 5.35$) were closely aligned, indicating a comparable level of technical vocabulary knowledge before the intervention. This

similarity suggests baseline equivalence between the two groups.

In the post-test phase, however, a clear divergence emerged. While the control group showed only a marginal increase in mean score ($M = 18.04$, $SD = 4.03$), the experimental group demonstrated a substantial improvement ($M = 24.00$, $SD = 2.70$). Additionally, the reduction in standard deviation in the experimental group suggests more homogeneous performance following the intervention. These descriptive findings indicate a notable gain in vocabulary achievement among learners exposed to scheduled spaced practice through Quizlet, warranting further inferential analysis to determine statistical significance.

Assumption Testing

Normality Tests

Before conducting parametric analyses, the assumption of normality was examined using the Kolmogorov–Smirnov and Shapiro–Wilk tests. These tests were applied separately to the pre-test and post-test scores of both groups to determine whether the data were normally distributed. The results are presented in Table 2.

Table 1: Descriptive Statistics for Pre-test and Post- test Scores

Group		N	Mean	Std. Deviation	Std. Error Mean
Pre-T	Control	30	17.88	4.87	0.975
	Experimental	30	18.52	5.35	1.068
Post-T	Control	30	18.04	4.03	0.805
	Experimental	30	24.00	2.70	0.539

Table 2: Kolmogorov–Smirnov and Shapiro–Wilk Tests of Normality

Group		Kolmogorov-Smirnova			Shapiro-Wilk		
		Statistic	Df	Sig.	Statistic	Df	Sig.
Pre-test	Control	0.175	30	0.092	0.950	30	0.364
	Experimental	0.144	30	0.240	0.958	30	0.461
Post-test	Control	0.165	30	0.132	0.946	30	0.346
	Experimental	0.173	30	0.109	0.925	30	0.134

As reported in Table 2, all significance values for both the Kolmogorov–Smirnov and Shapiro–Wilk tests exceeded the .05 threshold. This indicates that the pre-test and post-test scores for both the control and experimental groups did not significantly deviate from a normal distribution. Therefore, the assumption of normality was satisfied, and parametric statistical procedures were considered appropriate for subsequent analyses.

Homogeneity of Variance

Levene's test was conducted separately for the pre-test and post-test scores. Establishing variance equality at the pre-test stage confirms the statistical comparability of the two groups before the intervention (Table 3), whereas testing homogeneity at the post-test stage verifies whether the equal variances assumption required for the independent-samples t-test is satisfied (Table 4).

Table 3: Levene's Test for Equality of Variances (Pre-test Scores)

Variable	Levene Statistic	df1	df2	Sig.
Vocabulary Learning	0.15	1	58	0.152

Table 4: Levene's Test for Equality of Variances (Post-test Scores)

Variable	Levene Statistic	df1	df2	Sig.
Vocabulary Learning	2.041	1	58	0.161

The results in Table 3 reveal that Levene's test was not statistically significant ($p = .152 > .05$), indicating that the assumption of homogeneity of variance was satisfied for the pre-test scores. Thus, the variability of vocabulary knowledge was comparable across the control and experimental groups before the intervention.

As presented in Table 4, Levene's test for the post-test scores was not statistically significant

($p = .161 > .05$), suggesting that the assumption of equal variances was met. Consequently, the results corresponding to the "equal variances assumed" row of the independent-samples t-test were interpreted.

RQ One: The Effectiveness of Spaced versus Massed Vocabulary Learning through Digital Flashcards

To address the first research question—whether spacing technical vocabulary learning through digital flashcards is more effective than massed learning—both within-group and between-group comparisons were conducted.

Changes in Vocabulary Performance: Control Group

To determine whether the control group demonstrated significant improvement over time, a paired-samples t-test was conducted comparing their pre-test and post-test scores. The results are presented in Table 5.

As shown in Table 5, the paired-samples t-test revealed no statistically significant difference between the control group's pre-test and post-test scores [$t(29) = -0.267, p = .801$]. The 95% confidence interval for the mean difference included zero, further confirming the absence of a significant change over time. These findings indicate that vocabulary learning without structured spaced intervals did not lead to measurable improvement in the control group during the study period.

Changes in Vocabulary Performance: Experimental Group

To examine whether the experimental group demonstrated significant improvement following the intervention, a paired-samples t-test was conducted comparing pre-test and post-test scores. The results are presented in Table 6.

Table 5: Paired-Samples t-Test for the Control Group

Table 1. Paired sample t-test for the control group								
	Mean	Std. Deviation	Std. Error Mean	Paired difference		T	Df	Sig. (2-tailed)
				95% confidence interval of the difference				
				Lower	Upper			
Pair pretest-posttest	-0.16	2.989	0.589	-1.40	1.10	-0.267	29	0.801

Table 6: Paired-Samples t-Test for the Experimental Group

Table 6: Paired samples t-Test for the Experimental Group								
Paired difference								
	Mean	Std. Deviation	Std. Error Mean	95% confidence interval of the difference		T	Df	Sig.(2-tailed)
				Lower	Upper			
Pair pretest-posttest	-5.36	4.431	0.866	-7.48	-3.26	-6.325	29	0.001

As demonstrated in Table 6, the paired-samples t-test revealed a statistically significant difference between the experimental group's pre-test and post-test scores, $t(29) = -6.325$, $p < .001$. The 95% confidence interval for the mean difference did not include zero, indicating a reliable improvement following the intervention. The negative mean difference reflects higher post-test scores compared to pre-test scores. These findings demonstrate that participation in digitally scheduled spaced practice led to a substantial gain in technical vocabulary knowledge among learners in the experimental group.

Between-Group Comparison: Gain Score Analysis

While the within-group comparisons demonstrated that only the experimental group achieved significant pre-to-post improvement, comparing two separate p-values does not constitute a valid statistical test of between-group differences. A group may show a non-significant p-value not because it truly failed to improve but because of higher variability or smaller effect size. Therefore, to directly compare the magnitude of vocabulary gains

between the two groups, gain scores were calculated for each participant by subtracting pre-test scores from post-test scores. Descriptive statistics for the gain scores are presented in Table 7.

Table 7: Descriptive Statistics for Gain Scores

Group	N	Mean Gain	Std. Deviation	Std. Error Mean
Control	30	0.16	2.99	0.546
Experimental	30	5.48	4.43	0.809

As presented in Table 7, the experimental group demonstrated a substantially larger mean gain ($M = 5.48$, $SD = 4.43$) compared to the control group ($M = 0.16$, $SD = 2.99$), indicating that learners who followed the structured spaced schedule achieved considerably greater improvement in technical vocabulary knowledge. Before conducting the between-group comparison, Levene's test was performed to assess the homogeneity of variances for the gain scores. The results are presented in Table 8.

Table 8: Levene's Test for Equality of Variances (Gain Scores)

Variable	Levene Statistic	df1	df2	Sig.
Gain Scores	3.214	1	58	.078

The result of Levene's test was not statistically significant ($p = .078 > .05$), indicating that the assumption of equal variances was met for the gain scores. Consequently, the equal variances assumed condition of the independent-samples t-test was interpreted. An independent-samples t-test was conducted to compare the gain scores of the control and experimental groups. The results are presented in Table 9.

As shown in Table 9, the independent-samples t-test revealed a statistically significant difference between the gain scores of the control and experimental groups, $t(58) = -5.456$, $p < .001$. The 95% confidence interval for the mean difference ranged from -7.27 to -3.37 , indicating that the experimental group's improvement was reliably and substantially greater than that of the control group. These results confirm that digitally scheduled spaced vocabulary practice produced significantly greater vocabulary gains compared to non-spaced practice, thereby providing a robust affirmative answer to the first research question.

This gain score analysis addresses a critical methodological concern: although the pre-test means of the two groups were similar (control: $M = 17.88$; experimental: $M = 18.52$), they were not identical. By analyzing gain scores rather than raw post-test scores, the comparison directly captures the amount of change each participant experienced, thereby controlling for any baseline differences and providing a more precise estimate of the intervention effect.

RQ Two: Learners' Perceptions of Spaced Retrieval Implementation

To address the second research question—what are the perceptions of learners in the experimental group regarding the implementation of spaced retrieval—a post-intervention questionnaire was administered to the 30 participants in the experimental group. Responses were collected on a five-point Likert scale (1 = Strongly Agree to 5 = Strongly Disagree). Descriptive statistics were calculated to determine the distribution of responses across items, and one-sample t-tests were conducted to compare the mean score of each item against the neutral midpoint of the scale ($M = 3$). The distribution of responses is presented in Table 10.

Table 9: Independent-Samples t-Test for Comparing Gain Scores between Groups

	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% CI Lower	95% CI Upper
Equal variances assumed	-5.456	58	.001	-5.32	0.975	-7.27	-3.37
Equal variances not assumed	-5.456	50.4	.001	-5.32	0.975	-7.28	-3.36

Table 10: Detailed Questionnaire Results

Survey questions	1	2	3	4	5
	%	%	%	%	%
1- Spatial repetition improves my word recall.	56.67	23.33	13.33	6.67	0
2- Spaced learning lessons help me retain more knowledge.	60	26.67	13.33	0	0
3- I can remember spaced vocabulary longer and faster on tests.	63.33	13.33	23.33	0	0
4- I can observe an improvement in my vocabulary through spaced repetitions.	46.67	30	16.67	6.67	0
5- Spaced-out lessons help me understand things more clearly.	40	26.67	30	3.33	0
6- Spaced-out lessons help me learn more quickly.	33.33	40	16.67	6.67	3.33
7- When topics are spaced out, I pay greater attention.	30	40	23.33	6.67	0
8- When lessons are spaced out, it inspires me more.	16.67	50	16.67	3.33	13.33
9- When learning topics are spaced out, I get less bored.	33.33	6.67	43.33	16.67	0
10- I'm pleased that spaced practice has made vocabulary study enjoyable for me.	40	10	30	20	0
11- Spaced-out classes make vocabulary learning more enjoyable.	40	33.33	13.33	13.33	0
12- I appreciate repeating actions over and over again.	16.67	60	16.67	6.67	0
13- I prefer to acquire words by spaced practice from now on.	66.67	13.33	16.67	3.33	0
14- In general, I agree that lessons should be spaced out.	50	36.67	3.33	0	0

Note. 1 = Strongly Agree; 2 = Agree; 3 = No Idea; 4 = Disagree; 5 = Strongly Disagree.

As illustrated in Table 10, the distribution of responses indicates a predominantly positive perception of spaced vocabulary instruction. A substantial proportion of participants selected “Strongly Agree” or “Agree” for items related to improved recall (Item 1), enhanced retention (Item 2), faster retrieval during assessments (Item 4), and noticeable vocabulary development (Item 5). Furthermore, the majority of learners expressed a preference for

continuing to use spaced practice in future vocabulary learning (Item 14), reflecting a high level of acceptance of the instructional approach.

To determine whether these positive perceptions were statistically significant, one-sample t-tests were conducted to compare the mean score of each questionnaire item against the neutral midpoint of the scale ($M = 3$). The results are presented in Table 11.

Table 11: One-Sample t-Test Results for Questionnaire Items (Test Value = 3)

Item	Mean	SD	T	Df	Sig. (2-tailed)	Mean Difference
1	1.70	0.95	-7.49	29	.001	-1.30
2	1.53	0.73	-11.03	29	.001	-1.47
3	1.60	0.86	-8.91	29	.001	-1.40

Item	Mean	SD	T	Df	Sig. (2-tailed)	Mean Difference
4	1.83	0.95	-6.74	29	.001	-1.17
5	1.97	0.93	-6.07	29	.001	-1.03
6	2.07	1.01	-5.04	29	.001	-0.93
7	2.07	0.91	-5.60	29	.001	-0.93
8	2.47	1.17	-2.48	29	.020	-0.53
9	2.43	1.10	-2.83	29	.008	-0.57
10	2.30	1.18	-3.25	29	.003	-0.70
11	2.00	1.05	-5.22	29	.001	-1.00
12	2.13	0.78	-6.10	29	.001	-0.87
13	1.57	0.86	-9.11	29	.001	-1.43
14	1.53	0.57	-14.12	29	.001	-1.47

Note. Mean scores below 3 indicate agreement (positive perception). Mean Difference = Item Mean – 3.

The results of the one-sample t-tests confirmed that the mean scores of all 14 questionnaire items were significantly lower than the neutral midpoint ($p < .05$), indicating statistically significant positive attitudes toward spaced repetition across all dimensions assessed. The strongest agreement was observed for Items 2 and 14 ($M = 1.53$), reflecting learners' strong beliefs that spaced learning enhances knowledge retention and their overall endorsement of spaced instruction. Items 3 ($M = 1.60$) and 13 ($M = 1.57$) also yielded notably low means, indicating that learners perceived improved recall speed and expressed a clear preference for adopting spaced practice in the future. While all items reached statistical significance, Items 8 ($M = 2.47$, $p = .020$) and 9 ($M = 2.43$, $p = .008$) had means closer to the midpoint compared to other items, suggesting that although learners held positive views toward the motivational and boredom-reducing effects of spacing, these perceptions were relatively more moderate. This may indicate that while the cognitive benefits of spaced repetition were strongly perceived, its affective impact on sustained interest varied among learners.

Overall, the findings demonstrate that

learners held favorable cognitive and attitudinal perceptions of digitally scheduled spaced vocabulary learning. When considered alongside the statistically significant performance gains observed in the experimental group, these results provide converging evidence for the effectiveness of the intervention.

RQ Three: Learners' Attitudes toward Using Quizlet Digital Flashcards with Spaced Intervals

To address the third research question—what are the ESP learners' attitudes toward using Quizlet digital flashcards with specific intervals for learning technical vocabulary—semi-structured online interviews were conducted with 10 participants from the experimental group following the intervention. The interviews explored learners' experiences through open-ended questions focusing on key areas such as motivation, engagement, perceived learning outcomes, and the overall experience of using scheduled intervals. All interviews were audio-recorded, transcribed verbatim, and subjected to thematic content analysis. The analysis resulted in the identification of four recurrent themes

reflecting learners' experiences with the intervention. These themes and their frequency of occurrence are presented in Tables 12 and 13.

Table 12: Interview Themes Identified Through Content Analysis

Interview themes	Respondents
Motivation	5
Improved Engagement	4
Creating a Competing Environment	3
Improving the capacity for vocabulary learning	4

Table 13: Representative Quotations for Each Theme

Theme	Participant	Representative Quotation
Motivation	P2	"I felt motivated to keep going because I knew the next review session was already planned. It pushed me to prepare better each time."
	P5	"The intervals gave me something to look forward to. I wanted to see if I could remember more words than the last time."
	P7	"Honestly, before this method, I used to just memorize words the night before the exam. But with spacing, I felt more driven to study regularly because I didn't want to fall behind."
Improved Engagement	P1	"Every time I reviewed the flashcards, I noticed I was paying more attention to the details of each word—like spelling and how it's used in a sentence—because I had seen it before and could focus on deeper things."
	P4	"The different activities on Quizlet—matching, writing, listening—kept me involved. I didn't just passively look at words; I actually worked with them each session."
	P9	"I found myself spending more time on the flashcards than I expected. The spaced schedule made each session feel manageable, so I didn't skip any."
Creating a Competitive Environment	P3	"When we had timed activities, it felt like a challenge. I kept trying to beat my own score, and that made me focus more."
	P6	"I liked that there was time pressure. It made me take the practice seriously, almost like a game. I competed with myself to get faster."
	P10	"Seeing my progress over the sessions was motivating. I wanted to do better each round, and the time limits made it more exciting."
Improving the Capacity for Vocabulary Learning	P1	"After a few weeks, I realized I could recall architectural terms without struggling. The repeated exposure at different times really helped the words stick in my memory."
	P4	At first, the technical words seemed impossible to remember. But after reviewing them several times with gaps in between, they became familiar. It was like my brain had more room for new words."
	P8	"I noticed that I could handle more vocabulary items by the end. The spacing made it less overwhelming—I didn't feel like I was cramming everything at once."
	P5	"The intervals helped me process each word better. By the third or fourth review, I didn't even need to think hard—the meaning just came to me naturally."

Theme 1. Motivation: Motivation emerged as the most frequently mentioned theme, reported by five out of ten participants. Learners described the scheduled intervals as stimulating and energizing, explaining that the structured timing of review sessions increased their willingness to remain involved in vocabulary practice. As P2 explained, knowing that review sessions were pre-planned created a sense of purpose and encouraged more consistent preparation. P7 highlighted a shift from last-minute memorization habits toward regular, distributed study, attributing this change to the accountability created by the spaced schedule. Participants generally conveyed that the predictability and structure of the intervals transformed vocabulary study from a burdensome task into an achievable routine.

Theme 2. Improved Engagement: Improved engagement was another prominent theme, mentioned by four participants. Learners indicated that the spaced format encouraged consistent interaction with vocabulary items and supported deeper processing of word meanings, spelling, and contextual usage. P1 noted that repeated encounters with the same items allowed attention to shift from surface-level recognition to more detailed processing of usage and form. P4 emphasized the role of Quizlet's varied activity modes—such as matching, writing, and listening exercises—in sustaining active involvement across sessions. P9 remarked that because each spaced session felt manageable in length, the likelihood of skipping practice was reduced, which contributed to sustained engagement over the six weeks.

Theme 3. Creating a Competitive Environment: The theme of a competitive learning environment emerged in three interviews. Participants described the time constraints embedded in certain Quizlet

activities as creating a sense of challenge, which fostered focus and persistence. Rather than perceiving the time limits as restrictive, learners viewed them as motivating elements that enhanced their involvement in the learning process. P3 and P6 both described competing against their own previous scores as a source of motivation, while P10 noted that tracking visible progress over sessions reinforced a sense of achievement and encouraged continued effort.

Theme 4. Improving the Capacity for Vocabulary Learning: Four participants reported that structured spaced repetition expanded their perceived capacity for learning technical vocabulary. P1 described a noticeable reduction in the effort required to recall architectural terminology after several spaced review cycles. P4 reported that words that initially seemed difficult gradually became familiar through repeated encounters distributed over time, reducing the sense of cognitive overload. P8 emphasized that spacing made the learning process less overwhelming by distributing the vocabulary load across manageable sessions rather than concentrating it within a single study period. P5 described a shift toward more automatic retrieval, noting that after multiple spaced reviews, meanings surfaced without deliberate effort.

Overall, the qualitative findings corroborate the quantitative questionnaire and test results. Learners not only demonstrated measurable improvement in technical vocabulary acquisition but also articulated positive cognitive and motivational experiences associated with digitally scheduled spaced practice. The convergence of performance data and thematic evidence strengthens the overall interpretation that structured spaced repetition can effectively enhance both vocabulary learning outcomes and learner engagement in ESP contexts.

Discussion

The present study examined the impact of scheduled spaced intervals implemented through Quizlet digital flashcards on ESP learners' acquisition of technical vocabulary. The findings demonstrated that although both groups improved over the six-week intervention, the experimental group—who practiced vocabulary at predetermined intervals—outperformed the control group significantly. These results provide empirical support for the superiority of spaced practice over non-scheduled or massed digital review in ESP vocabulary learning contexts.

The quantitative findings demonstrated that the experimental group achieved significantly greater vocabulary gains than the control group, as confirmed by the independent-samples t-test on gain scores, $t(58) = -5.456$, $p < .001$. The mean gain of the experimental group ($M = 5.48$) was substantially larger than that of the control group ($M = 0.16$), indicating that structured spaced intervals were the primary factor driving vocabulary improvement. This interpretation is consistent with cognitive research indicating that retrieval distributed over time strengthens consolidation processes and supports durable retention [12-24].

Beyond achievement scores, the questionnaire results revealed that learners perceived spaced digital learning as more efficient, less cognitively overwhelming, and more enjoyable. Participants reported greater autonomy, flexibility, and sustained engagement when using Quizlet with defined intervals. These affective findings are particularly significant in ESP contexts, where technical vocabulary is often perceived as demanding and demotivating. Research in mobile-assisted and technology-enhanced language learning similarly suggests that structured digital environments can increase

motivation and self-regulated engagement when learning sequences are pedagogically organized [28-29].

Although the present study did not directly measure constructs from the Technology Acceptance Model (TAM) or the Theory of Planned Behavior (TPB), the results appear theoretically consistent with these frameworks. Learners' positive perceptions of structured Quizlet use suggest enhanced perceived usefulness and perceived ease of use, two central determinants of technology adoption in TAM. Moreover, the increased willingness to continue using the application may reflect strengthened behavioral intention, a key component of TPB. Therefore, while TAM and TPB were not empirically tested in this study, the findings provide indirect support for their explanatory relevance in technology-mediated ESP learning environments.

Qualitative interview data further enriched these interpretations. Participants described the spaced sessions as engaging, competitive, and cognitively manageable. Features such as repeated exposure across different activity modes (e.g., matching, listening, writing, and live games) appeared to facilitate retrieval strength and response speed. Importantly, learners emphasized that spacing reduced feelings of overload and enhanced confidence in using newly acquired architectural terminology. These perceptions correspond with the quantitative improvements observed in post-test scores.

The present findings extend the results of Lotfolahi and Salehi [19], who demonstrated the long-term advantages of spaced practice over massed learning among young EFL learners. Unlike their study, however, the current research situates spacing within a digital ESP environment and integrates affective dimensions through survey and interview data. Similarly, the results are consistent with Nakata

[18], who reported learners' positive perceptions toward spaced schedules in computer-assisted vocabulary learning. The findings also resonate with Serfaty and Serrano [20], who found that the interval between Quizlet practice sessions influenced the retention of newly learned foreign-language vocabulary.

In the present study, the combination of academic relevance, structured intervals, and interactive digital tools appears to have strengthened both retention and learner motivation. Furthermore, consistent with research highlighting the positive attitudinal impact of technology integration [30-29-32], participants expressed increased enjoyment and reduced resistance toward vocabulary learning when technology was purposefully structured.

Overall, the study demonstrates that the pedagogical value of digital flashcards does not lie merely in their technological features, but in how they are strategically integrated into instructional design. Structured spacing, rather than unsystematic repetition, appears to be the critical factor enhancing technical vocabulary acquisition in ESP contexts.

Conclusions

Aiming to determine the efficacy of spaced repetition in technical vocabulary learning, this study investigated the impact of digitally scheduled review on Iranian undergraduate ESP learners in Architecture. The findings confirm that a structured two-day interval schedule significantly enhances retention compared to unstructured digital practice, reinforcing the cognitive principle that distributed retrieval strengthens memory consolidation. These results extend existing evidence on spaced repetition to the specific domain of digitally mediated ESP instruction. Furthermore, the

study highlights that learners not only achieve superior academic outcomes but also hold strongly positive perceptions of this approach, viewing it as a valuable and engaging tool. Consequently, integrating spaced repetition algorithms into ESP curricula appears to be a pedagogically sound and learner-friendly method for fostering durable vocabulary knowledge.

Beyond the primary performance metrics, the study explored learner perceptions, revealing a strong consensus on the efficacy of spaced repetition in retaining technical vocabulary. While cognitive benefits such as improved recall speed and long-term memory consolidation were universally acknowledged, affective factors like motivation and engagement displayed a nuanced pattern, varying slightly across individuals. Qualitative insights deepened this understanding by highlighting four pivotal themes: heightened motivation, sustained engagement, a competitive learning atmosphere, and expanded vocabulary capacity. Participants emphasized that the structured intervals instilled a sense of accountability, shifting their approach from superficial recognition to deep, contextual processing of architectural terminology. Moreover, the time-bound nature of the digital tasks fostered a healthy competitive spirit that maintained focus, while the distributed practice significantly alleviated cognitive load, rendering complex concepts more manageable. Ultimately, these findings suggest that integrating spaced repetition into ESP curricula not only optimizes retention but also cultivates a psychologically supportive environment that encourages persistent and meaningful learning.

Synthesizing the quantitative and qualitative evidence, this study concludes that the pedagogical efficacy of digital flashcards hinges not on their technological features, but on the

strategic integration of cognitive mechanisms like spaced retrieval. When these tools are designed around theoretical principles rather than used as ad hoc resources, they significantly enhance vocabulary retention and foster positive learner attitudes. These findings resonate with the Technology Acceptance Model and the Theory of Planned Behavior, underscoring that perceived usefulness and behavioral control are pivotal in sustaining engagement with learning technologies.

These findings offer critical implications for ESP pedagogy and curriculum design. First, technical vocabulary acquisition in specialized fields requires intentional instruction paired with structured spaced repetition, rather than relying solely on incidental learning. Second, digital platforms like Quizlet and Anki are effective for implementing these principles, provided review intervals are systematically planned by instructors rather than left to learner discretion. Third, educators should embed spaced scheduling as a core syllabus component, treating technology as an essential instructional tool rather than an optional supplement. Finally, the positive learner perceptions suggest that this approach can mitigate the affective barriers of dense terminology, thereby enhancing learner autonomy and sustaining motivation.

Several limitations warrant acknowledgment. First, the use of convenience sampling from a single institution restricts the generalizability of findings to other contexts. Second, the sample size of 60 participants, while sufficient for large effects, limits statistical power. Third, the quasi-experimental design using intact groups, despite baseline equivalence, leaves room for uncontrolled pre-existing differences. Finally, the exclusive focus on receptive vocabulary via multiple-choice items overlooks productive skills (speaking/writing), potentially underestimating

the full scope of lexical acquisition. Fifth, the six-week intervention lacked a delayed post-test, leaving long-term retention effects unverified. Sixth, the control group used Quizlet without structured spacing; thus, the study isolates the spacing variable but limits conclusions regarding the broader efficacy of digital flashcards versus traditional methods. Seventh, qualitative data relied on self-reports, which may be influenced by social desirability bias. Eighth, instruction by a single instructor, while controlling for teacher variability, may constrain ecological validity if specific instructor characteristics drove the outcomes. Finally, administering the questionnaire only to the experimental group post-intervention prevented comparative analysis of perceptions between groups and pre-post attitude changes.

To address the limitations and extend findings, future research should prioritize investigating the transfer of spaced repetition benefits to productive vocabulary skills, such as speaking and writing. Longitudinal designs incorporating delayed post-tests at intervals of several months are essential to assess the durability of these learning effects. To enhance generalizability, subsequent studies ought to employ larger, multi-institutional samples across diverse ESP disciplines, including engineering and medicine, to determine if disciplinary context moderates retention. Furthermore, researchers should systematically compare various digital flashcard platforms and spacing algorithms to identify optimal configurations and explore how spaced repetition interacts with broader pedagogical frameworks like task-based or communicative language teaching. Finally, methodological rigor can be strengthened by administering pre-test questionnaires to both groups, adapting post-tests to capture the control group's experiences, and supplementing self-reports

with objective engagement metrics, such as platform usage analytics.

Authors' Contribution

All authors contributed equally to this work. Each author was actively involved in the conception and design of the study, data collection, analysis, and interpretation of the results. They collaboratively drafted, reviewed, and revised the manuscript to ensure intellectual accuracy and clarity. All authors read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

Acknowledgements

The authors would like to express their sincere gratitude to all individuals and institutions who supported this work. We thank our colleagues and reviewers for their valuable feedback and constructive suggestions, which greatly improved the quality of the manuscript.

Conflict of Interest

There was no conflict of interest among the authors.

References

- [1] Lai C, Zheng D. Self-directed use of mobile devices for language learning beyond the classroom. *ReCALL*. 2018;30(3):299-318. doi:10.1017/S0958344017000258.
- [2] Yu A, Trainin G. A meta-analysis examining technology-assisted L2 vocabulary learning. *ReCALL*. 2022;34(2):235-252. doi:10.1017/S0958344021000239.
- [3] Granić A, Marangunić N. Technology acceptance model in educational context: a systematic literature review. *Br J Educ Technol*. 2019;50(5):2572-2593. doi:10.1111/bjet.12864.
- [4] Yang YF. Self-directed learning to develop autonomy in an online ESP community. *Interact Learn Environ*. 2016;24(7):1629-1646. doi:10.1080/10494820.2015.1041402.
- [5] Godwin-Jones R. Evolving technologies for language learning. *Lang Learn Technol*. 2021;25(3):6-26. doi:10.64152/10125/73443.
- [6] Webb S, Yanagisawa A, Uchihara T. How effective are intentional vocabulary-learning activities? A meta-analysis. *Mod Lang J*. 2020;104(4):715-738. doi:10.1111/modl.12671.
- [7] Hyland K, Jiang F. Delivering relevance: the emergence of ESP as a discipline. *Engl Specif Purp*. 2021; 64:13-25. doi:10.1016/j.esp.2021.06.002.
- [8] Dang TN, Webb S. The lexical profile of academic spoken English. *Engl Specif Purp*. 2014;33:66-76. doi:10.1016/j.esp.2013.08.001.
- [9] Schmitt N, Schmitt D. Vocabulary in language teaching. 2nd ed. Cambridge: Cambridge University Press; 2020. doi:10.1017/9781108569057.
- [10] Nation ISP. Learning vocabulary in another language. 2nd ed. Cambridge: Cambridge University Press; 2013. doi:10.1017/CBO9781139858656.
- [11] Carpenter SK, Pan SC, Butler AC. The science of effective learning with spacing and retrieval practice. *Nat Rev Psychol*. 2022;1(9):496-511. doi:10.1038/s44159-022-00089-1.
- [12] Kang SHK. Spaced repetition promotes efficient and effective learning: policy implications for instruction. *Policy Insights Behav Brain Sci*. 2016;3(1):12-19. doi:10.1177/2372732215624708.
- [13] Cepeda NJ, Vul E, Rohrer D, Wixted JT, Pashler H. Spacing effects in learning: a temporal ridgeline of optimal retention. *Psychol Sci*. 2008;19(11):1095-1102. doi:10.1111/j.1467-9280.2008.02209.x.
- [14] Rawson KA, Dunlosky J, Sciarrelli SM. The power of successive relearning: improving performance on course exams and long-term retention. *Educ Psychol Rev*. 2013;25(4):523-548. doi:10.1007/s10648-013-9240-4.
- [15] Rogers J, Cheung A. Input spacing and the learning of L2 vocabulary in a classroom context. *Lang Teach Res*. 2020;24(5):616-641. doi:10.1177/1362168818805251.
- [16] Xodabande I, Iravi Y, Mansouri B, Matinparsa H. Teaching academic words with digital flashcards: investigating the effectiveness of mobile-assisted vocabulary learning for university students. *Front Psychol*. 2022; 13:893821. doi:10.3389/fpsyg.2022.893821.
- [17] Nakata T. Does repeated practice make perfect? The effects of within-session repeated retrieval on second language vocabulary learning. *Stud Second Lang Acquis*. 2017;39(4):653-679. doi:10.1017/S0272263116000280.
- [18] Nakata T. Effects of expanding and equal spacing on second language vocabulary learning: does gradually increasing spacing increase vocabulary learning? *Stud Second Lang Acquis*. 2015;37(4):677-711. doi:10.1017/S0272263114000825.

- [19] Lotfolahi AR, Salehi H. Spacing effects in vocabulary learning: young EFL learners in focus. *Cogent Educ.* 2017;4(1):1287391. doi:10.1080/2331186X.2017.1287391.
- [20] Serfaty J, Serrano R. Lag effects for foreign language vocabulary learning through Quizlet. *Lang Learn Technol.* 2024;28(1):1-21. doi:10.64152/10125/73567.
- [21] Scherer R, Siddiq F, Tondeur J. The technology acceptance model (TAM): a meta-analytic structural equation modeling approach explaining teachers' adoption of digital technology in education. *Comput Educ.* 2019;128:13-35. doi:10.1016/j.compedu.2018.09.009.
- [22] Al-Emran M, Mezhyuev V, Kamaludin A. Technology acceptance model in m-learning context: a systematic review. *Comput Educ.* 2018;125:389-412. doi:10.1016/j.compedu.2018.06.008.
- [23] Ajzen I. The theory of planned behavior: frequently asked questions. *Hum Behav Emerg Technol.* 2020;2(4):314-324. doi:10.1002/hbe2.195.
- [24] Soderstrom NC, Bjork RA. Learning versus performance: an integrative review. *Perspect Psychol Sci.* 2015;10(2):176-199. doi:10.1177/1745691615569000.
- [25] Coxhead A. Vocabulary and English for specific purposes research: quantitative and qualitative perspectives. London: Routledge; 2018. doi:10.4324/9781315146478.
- [26] Arnó-Macià E. The role of technology in teaching languages for specific purposes courses. *Mod Lang J.* 2012;96(S1):89-104. doi:10.1111/j.1540-4781.2012.01299.x.
- [27] Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol.* 2006;3(2):77-101. doi:10.1191/1478088706qp063oa.
- [28] Duman G, Orhon G, Gedik N. Research trends in mobile assisted language learning from 2000 to 2012. *ReCALL.* 2015;27(2):197-216. doi:10.1017/S0958344014000287.
- [29] Yu X. The English as a foreign language learners' psychological and emotional perceptions on technology integration in language classrooms. *Front Psychol.* 2022;13:906750. doi:10.3389/fpsyg.2022.906750.
- [30] Webb M, Doman E. Impacts of flipped classrooms on learner attitudes towards technology-enhanced language learning. *Comput Assist Lang Learn.* 2020;33(3):240-274. doi:10.1080/09588221.2018.1557692.
- [31] Yu A, Trainin G. A meta-analysis examining technology-assisted L2 vocabulary learning. *ReCALL.* 2022;34(2):235-252. doi:10.1017/S0958344021000239.
- [32] Zakian M, Xodabande I, Valizadeh M, Yousefvand M. Out-of-the-classroom learning of English vocabulary by EFL learners: investigating the effectiveness of mobile-assisted learning with digital flashcards. *Asian Pac J Second Foreign Lang Educ.* 2022;7:16. doi:10.1186/s40862-022-00143-8.

Appendix

Semi- Structured Interview Questions: The following questions were used to guide the interviews with participants from the experimental group:

- 1- How did the use of Quizlet with scheduled intervals affect your **motivation** to learn the technical vocabulary?
- 2- Can you describe your level of **engagement** with the tool? Did the specific timing make you more or less involved in the learning process?
- 3- Did you experience any sense of **challenge or competition** due to the time constraints? How did this influence your focus?
- 4- In your opinion, how did this spaced repetition method impact your **capacity to learn and retain** the new words compared to other methods?

AUTHOR(S) BIOSKETCHES

Dr. Zahra Cheraghi is an assistant professor in General Linguistics at the English Department, Faculty of Humanities, Shahid Rajaei Teacher Training University, Tehran, Iran. Her research interests include Syntax, Semantics, and ESP/EAP.

Cheraghi, Z., Assistant Professor, General Linguistics, English Department, Faculty of Humanities, Shahid Rajaei Teacher Training University, Tehran, Iran.

✉ z.cheraghi@sru.ac.

Omranpour, H., MA, TEFL, English Department, Faculty of Humanities, Shahid Rajaei Teacher Training University, Tehran, Iran.

✉ Hengameh.Omranpour@yahoo.com.

Motaharinezahad, A., MA, TEFL, English Department, Faculty of Humanities, Shahid Rajaei Teacher Training University, Tehran, Iran.

✉ Negar.Motaharinezahad@gmail.com.

Citation (Vancouver): Cheraghi Z, Omranpour H, Motaharinezahad A. [The power of time: how spacing techniques revolutionize ESP vocabulary learning online] *Tech. Edu. J.* 2026; 20(1): 43-64

 <https://doi.org/10.22061/tej.2026.13001.3374>





ORIGINAL RESEARCH PAPER

Technological beliefs, knowledge structures, and individual characteristics: determinants of technology integration in the classroom

S. Bibak, S. Asadian*

Department of Educational Sciences, Faculty of Education and Psychology, Azarbaijan Shahid Madani University, Tabriz, Iran

ABSTRACT

Received: 17 July 2025
Reviewed: 27 August 2025
Revised: 01 November 2025
Accepted: 21 December 2025

KEYWORDS:

Technology Integration
Individual Characteristics
Knowledge Structures
ICT Beliefs
Secondary School Teachers

* Corresponding author
dr.sasadian@gmail.com
① (+98912)5269860

Background and Objectives: The accelerating pace of technological change has rendered the effective integration of technology into education not merely desirable, but essential for preparing students for the demands of the 21st century. Educational systems worldwide have invested substantially in technological infrastructure to facilitate this integration. Yet, despite these considerable investments, the actual use of technology by teachers in classroom practice often remains below expectations. This persistent gap between infrastructure availability and meaningful technology integration suggests that access alone is insufficient. Prior research has identified teachers' beliefs, knowledge structures, and individual characteristics as key determinants of this phenomenon. Teachers' pedagogical beliefs function as cognitive filters that shape their decisions about whether and how to incorporate technology into their teaching. Their knowledge structures, particularly regarding how to integrate technology with subject content and pedagogical approaches, determine their capacity for effective implementation. Additionally, individual characteristics such as gender, age, teaching experience, and educational attainment may influence teachers' readiness to adopt technological innovations. However, studies simultaneously examining the roles of these variables within a comprehensive model remain scarce, particularly in the Iranian educational context. Accordingly, this study was conducted to elucidate the roles of technological beliefs, knowledge structures, and individual characteristics in technology integration among secondary school teachers in Tabriz, thereby addressing this significant gap in the literature.

Materials and Methods: This quantitative, applied study followed a descriptive-correlational design. The statistical population comprised all secondary school teachers in Tabriz during the 2023-2024 academic year ($N = 4,973$), representing diverse subject areas and educational districts. Using the Krejcie and Morgan table, a sample of 357 participants was selected through proportionate stratified random sampling to ensure representation across the city's five educational districts. Data were collected via four validated instruments: (1) a researcher-developed demographic questionnaire collecting information on gender, age, teaching experience, and educational attainment; (2) a 17-item knowledge structures questionnaire, measuring three dimensions (perceived technological knowledge, perceived knowledge for technology integration, and pedagogical uses of ICT) on a 5-point Likert scale; (3) a 14-item technological beliefs questionnaire inspired by Digital Pedagogical Beliefs framework; and (4) the 19-item technology integration questionnaire. Validity was established through confirmatory factor analysis and expert judgment by a panel of specialists in educational technology. Reliability coefficients (Cronbach's α) exceeded 0.70 for all instruments, indicating acceptable internal consistency. Data were analyzed using descriptive statistics and structural equation modeling (SEM) with Smart PLS 4 software.

Findings: The results revealed that technological beliefs were the strongest positive and significant predictor of classroom technology integration ($\beta = 0.388, p < 0.01$), consistent with theoretical frameworks emphasizing the role of teachers' perceptual filters in adopting educational innovations. Knowledge structures emerged as the second most influential factor ($\beta = 0.287, p < 0.01$), underscoring the centrality of the TPACK framework in meaningful technology integration. Among individual characteristics, only educational attainment

showed a positive, significant association ($\beta = 0.094$, $p < 0.05$), whereas gender, age, and teaching experience had no statistically significant effects. This finding reinforces the notion that the capacity for technology integration is broadly distributed across the teaching force and not confined to specific demographic subgroups. The proposed model demonstrated excellent fit (NFI = 0.93, CFI = 0.96, RMSEA = 0.056) and explained 68% of the variance in technology integration ($R^2 = 0.68$), indicating that the independent variables collectively account for a substantial proportion of predictive power.

Conclusions: The findings affirm that successful technology integration hinges less on demographic variables and more on the evolution of teachers' professional beliefs and the growth of integrated pedagogical-technological-content knowledge. This underscores the necessity of redefining teacher professional development programs—not merely as technical skill workshops, but as initiatives aimed at nurturing positive beliefs about technology's role in meaningful learning and cultivating TPACK-based knowledge structures grounded in authentic classroom challenges. Educational policymakers should prioritize interventions that target belief transformation and knowledge integration rather than focusing exclusively on infrastructure provision or basic digital literacy training.



COPYRIGHTS

© 2026 The Author(s). This is an open-access article distributed under the terms and conditions of the Creative Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) (<https://creativecommons.org/licenses/by-nc/4.0/>)



NUMBER OF REFERENCES
39



NUMBER OF FIGURES
1



NUMBER OF TABLES
3

مقاله پژوهشی

باورهای فناورانه، ساختار دانش و ویژگی‌های فردی: عوامل شکل‌دهنده ادغام فناوری در کلاس درس

سعید بی‌باک، سیروس اسدیان*

گروه علوم تربیتی، دانشکده علوم تربیتی و روان‌شناسی، دانشگاه شهید مدنی آذربایجان، تبریز، ایران

چکیده

پیشینه و اهداف: سرعت شتابان تحولات فناوری، یکپارچه‌سازی مؤثر فناوری در آموزش را نه صرفاً یک امر مطلوب، بلکه به ضرورتی اجتناب‌ناپذیر برای آماده‌سازی دانش‌آموزان جهت مواجهه با نیازهای قرن بیست و یکم تبدیل کرده است. نظام‌های آموزشی در سراسر جهان سرمایه‌گذاری قابل‌توجهی در زیرساخت‌های فناوری برای تسهیل این یکپارچه‌سازی انجام داده‌اند. بااین‌حال، علی‌رغم این سرمایه‌گذاری‌های چشمگیر، استفاده واقعی معلمان از فناوری در کلاس‌های درس اغلب پایین‌تر از حد انتظار باقی می‌ماند. این شکاف پایدار بین دسترسی به زیرساخت‌ها و یکپارچه‌سازی معنادار فناوری نشان می‌دهد که دسترسی به‌تنهایی کافی نیست. پژوهش‌های پیشین، باورها، ساختارهای دانش و ویژگی‌های فردی معلمان را به‌عنوان عوامل کلیدی این پدیده شناسایی کرده‌اند. باورهای پداگوژیک معلمان به‌مثابه فیلترهای شناختی عمل می‌کنند که تصمیمات آن‌ها را درباره چگونگی و چرایی استفاده از فناوری در تدریس شکل می‌دهند. ساختارهای دانش آن‌ها، به‌ویژه در مورد چگونگی یکپارچه‌سازی فناوری با محتوای درسی و رویکردهای پداگوژیک، ظرفیت آن‌ها را برای اجرای مؤثر تعیین می‌کند. علاوه بر این، ویژگی‌های فردی نظیر جنسیت، سن، سابقه تدریس و سطح تحصیلات ممکن است بر آمادگی معلمان برای پذیرش نوآوری‌های فناورانه تأثیرگذار باشد. بااین‌حال، مطالعاتی که به بررسی هم‌زمان نقش این متغیرها در قالب یک مدل جامع بپردازند، به‌ویژه در بافت آموزشی ایران، اندک است. ازاین‌رو، پژوهش حاضر باهدف تبیین نقش باورهای فناورانه، ساختارهای دانش و ویژگی‌های فردی در یکپارچه‌سازی فناوری توسط دبیران دوره متوسطه شهر تبریز و به‌منظور پرکردن این شکاف پژوهشی انجام شد.

تاریخ دریافت: ۲۶ تیر ۱۴۰۴
تاریخ داوری: ۰۵ شهریور ۱۴۰۴
تاریخ اصلاح: ۱۰ آبان ۱۴۰۴
تاریخ پذیرش: ۳۰ آذر ۱۴۰۴

واژگان کلیدی:

ادغام فناوری، ویژگی‌های فردی، ساختارهای دانش، باورهای فناوری، اطلاعات و ارتباطات، معلمان دوره متوسطه.

* نویسنده مسئول

dr.sasadian@gmail.com

۰۹۱۲-۵۲۶۹۸۶۰ (۱)

روش‌ها: این پژوهش از نوع کمی، کاربردی و با طرح توصیفی-همبستگی انجام شد. جامعه آماری شامل تمامی دبیران دوره متوسطه شهر تبریز در سال تحصیلی ۱۴۰۳-۱۴۰۲ (۴۹۷۳ نفر) بود که حوزه‌های درسی و نواحی آموزشی متنوعی را نمایندگی می‌کردند. با استفاده از جدول کرجسی و مورگان، نمونه‌ای به حجم ۳۵۷ نفر از طریق نمونه‌گیری تصادفی طبقه‌ای متناسب انتخاب شد که توزیع معلمان در پنج ناحیه آموزشی شهر را پوشش می‌داد. داده‌ها با استفاده از چهار ابزار معتبر گردآوری شد: (۱) پرسش‌نامه محقق ساخته جمعیت‌شناختی برای جمع‌آوری اطلاعات جنسیت، سن، سابقه تدریس و سطح تحصیلات؛ (۲) پرسش‌نامه ۱۷ گویه‌ای ساختارهای دانش با سه زیرمقیاس (دانش فنی ادراک‌شده، دانش ادراک‌شده برای یکپارچه‌سازی فناوری و کاربردهای آموزشی فناوری اطلاعات و ارتباطات) در طیف ۵ درجه‌ای لیکرت؛ (۳) پرسش‌نامه ۱۴ گویه‌ای باورهای فناورانه با الهام از چارچوب باورهای پداگوژیک دیجیتال؛ و (۴) پرسش‌نامه ۱۹ گویه‌ای یکپارچه‌سازی فناوری. روایی ابزارها از طریق تحلیل عاملی تأییدی و قضاوت خبرگان تأیید شد. ضرایب پایایی (آلفای کرونباخ) برای تمامی ابزارها بالای ۰/۷۰ بود که نشان‌دهنده پایایی درونی قابل قبول است. داده‌ها با استفاده از آمار توصیفی و مدل‌یابی معادلات ساختاری در نرم‌افزار PLS4 تجزیه و تحلیل شد.

یافته‌ها: نتایج نشان داد که باورهای فناورانه قوی‌ترین پیش‌بین مثبت و معنادار یکپارچه‌سازی فناوری در کلاس درس هستند ($\beta = 0/388$ ، $p < 0/01$) که با چارچوب‌های نظری تأکیدکننده بر نقش فیلترهای ادراکی معلمان در پذیرش نوآوری‌های آموزشی همسوست. ساختارهای دانش به‌عنوان دومین عامل تأثیرگذار شناسایی شدند ($\beta = 0/287$ ، $p < 0/01$) که اهمیت چارچوب (TPACK) را در یکپارچه‌سازی معنادار فناوری برجسته می‌سازد. در میان ویژگی‌های فردی، تنها سطح تحصیلات دارای رابطه مثبت و معنادار بود ($\beta = 0/094$ ، $p < 0/05$)، درحالی‌که جنسیت، سن و سابقه تدریس اثر معناداری نشان ندادند. این یافته تأکید می‌کند که ظرفیت یکپارچه‌سازی فناوری در سراسر جامعه معلمان به طور گسترده توزیع شده و محدود به زیرگروه‌های جمعیت‌شناختی خاصی نیست. مدل پیشنهادی برازش عالی را نشان داد ($R^2 = 0/68$ ، $NFI = 0/96$ ، $CFI = 0/96$ ، $RMSEA = 0/056$) و ۶۸ درصد از واریانس یکپارچه‌سازی فناوری را تبیین کرد ($R^2 = 0/68$) که بیانگر آن است که متغیرهای مستقل به طور جمعی سهم قابل توجهی در قدرت پیش‌بینی دارند.

نتیجه‌گیری: یافته‌ها تأیید می‌کند که موفقیت در یکپارچه‌سازی فناوری بیش از آنکه به متغیرهای جمعیت‌شناختی وابسته باشد، به تحول باورهای حرفه‌ای معلمان و توسعه دانش یکپارچه پداگوژیک-فناورانه-محتوایی آن‌ها مرتبط است. این امر بر ضرورت بازتعریف برنامه‌های توسعه حرفه‌ای معلمان تأکید دارد؛ برنامه‌هایی که نه صرفاً کارگاه‌های مهارت‌های فنی، بلکه ابتکاراتی هدفمند برای پرورش باورهای مثبت نسبت به نقش فناوری در یادگیری معنادار و ایجاد ساختارهای دانش مبتنی بر چارچوب باتکیه بر چالش‌های اصیل کلاسی باشند. سیاست‌گذاران آموزشی باید مداخلات معطوف به تحول باورها و یکپارچه‌سازی دانش را در اولویت قرار دهند و صرفاً تأمین زیرساخت‌ها یا آموزش‌های پایه‌ای سواد دیجیتال را مدنظر قرار ندهند.

Introduction

The rapidly accelerating pace of technological advancement has compelled educational institutions and systems to revisit traditional instructional approaches and harness emerging tools to enhance the teaching–learning process. In this context, the integration of new technologies is no longer viewed as a supplementary enhancement but as a fundamental requirement for fostering dynamic, effective learning environments. Purposeful technology use can boost student motivation, strengthen teacher–learner interaction, enable meaningful and lasting learning, and cultivate 21st-century

competencies—including critical thinking, creativity, and the intelligent application of digital tools.

Nevertheless, the extent and effectiveness of technology adoption in educational settings vary considerably and are shaped by numerous interrelated factors. A central challenge—particularly in secondary education—is that, despite substantial budgetary allocations for technological infrastructure and equipment, the actual implementation of these tools by teachers often falls short of expectations. Over the past decades, the adoption of Information and Communication Technologies (ICT) in education has raised significant concerns, with their deployment increasingly regarded as

indispensable for systemic educational transformation [1]. Even when teachers demonstrate confidence and ease in using ICT, their pedagogical application remains limited [2]. Moreover, extensive efforts have been made to support teachers in classroom technology integration by identifying facilitating and inhibiting factors. However, empirical evidence consistently indicates that teachers' ICT use remains constrained and insufficient [3]. This clearly demonstrates that mere access to technology does not guarantee its effective or meaningful integration into teaching and learning [4]. Instead, success depends on multiple factors, including teachers' digital skills, pedagogical beliefs, and consistent institutional support [5].

Teachers' use of ICT significantly influences student learning outcomes not only by enhancing motivation but also by improving students' ability to utilize these technologies more effectively [6]. Consequently, researchers have undertaken numerous studies to identify factors that either facilitate or hinder technology integration in teaching practices. Among the most prominent factors identified are teachers' attitudes, self-efficacy, prior experiences, and digital competencies [7, 8]. Findings from some studies further indicate that technology integration in educational settings is shaped by a combination of individual teacher characteristics, school-level conditions, and broader systemic structures [9]. Lai and Bower emphasize the complexity of the technology integration process within educational contexts [10], while Bower [11] highlights the critical importance of understanding the dynamic interplay among beliefs, knowledge, practices, and the instructional environment in educational technology adoption. Thus, to navigate a world characterized by intricate socio-technical dynamics, teachers must acquire the necessary

competencies to identify and deploy appropriate technological tools effectively in fulfilling their instructional responsibilities. For instance, teacher characteristics associated with classroom technology use include age, teaching experience, subject area, and class size [12]. Additionally, factors such as pedagogical knowledge, personal perceptions, access to resources, individual attributes, and disciplinary culture all significantly influence teachers' decisions regarding technology integration [13].

Technology integration in education refers to the purposeful application of digital tools to facilitate learning and strengthen critical thinking and problem-solving skills. This approach goes beyond merely teaching computer literacy or providing basic familiarity with digital instruments; rather, it emphasizes the meaningful use of technology in contexts where it offers the greatest support for the learning process. Realizing this vision requires structural transformations within schools—such that all members of the educational community (students, parents, teachers, and administrators) collectively recognize technology as an inseparable component of daily educational life [14]. Moreover, this integration entails the purposeful use of digital tools in instruction, which can yield significant educational benefits. By fostering the development of innovative teaching methodologies, it enables the creation of more engaging and effective learning environments (e.g., through videos, interactive software, and virtual reality), deepens conceptual understanding, allows for more precise assessment of student progress, cultivates essential digital competencies for life and work in the modern era, and enhances teachers' access to up-to-date and expansive educational resources [15].

A central domain of technology integration involves the use of digital platforms and tools—

such as Learning Management Systems (LMS), educational media, and instructional software—which enable personalized learning experiences, real-time assessment, and enhanced communication among teachers, students, and parents. Over recent decades, technology integration has emerged as a transformative force in education, with research evidence pointing to its positive impact on student learning outcomes, particularly in developing countries [16]. This trend was dramatically accelerated by the COVID-19 pandemic, which rendered digital technologies an indispensable component of teaching and learning [17]. In practice, this integration has manifested in diverse forms, including: (a) the adoption of LMS platforms that facilitate personalized learning and instant feedback; (b) the integration of mobile devices into everyday instruction; (c) the application of advanced technologies—such as virtual and augmented reality—in specialized subject areas; and (d) the development of AI-driven educational systems capable of adapting to individual learner needs [18]. Despite these advancements, the path forward is fraught with significant challenges: Concerns regarding digital equity and the accessibility gap [19]; Insufficient professional preparedness among teachers; Ethical dilemmas associated with AI in education; and Infrastructure and budgetary constraints [20].

Despite the significant transformative potential of digital tools in education, a fundamental question persists: Why does technology integration continue to face widespread challenges? The answer lies not in surface-level deficiencies, but in deeper layers of the teaching process—particularly teachers' beliefs and attitudes. While infrastructure and access to tools are necessary preconditions for transformation, they are ultimately insufficient on their own. Teachers' beliefs determine how,

in what contexts, and to what quality technology is employed in the teaching–learning process.

Teachers' pedagogical beliefs function as cognitive filters that shape technology integration in the classroom. According to Nespor [21], such beliefs provide a framework for problem definition and task interpretation, serving as key predictors of teaching behavior. A prevalent belief regarding ICT, for instance, is its capacity to enhance productivity and efficiency—a perception that has driven widespread adoption of digital tools across sectors, including education [21, 22]. Another influential belief concerns ICT's potential to democratize access to information, positioning the internet as an empowering conduit for equitable knowledge distribution [23]. This perceived affordance has significantly informed large-scale investments in digital infrastructure.

Ultimately, teachers' perspectives on learning and the role of technology directly influence both the quality and quantity of its classroom use [14]. Therefore, successful technology integration depends less on technical equipment and more on transforming teachers' professional attitudes and beliefs. However, beliefs alone are insufficient; they must be operationalized through coherent, integrated knowledge structures.

Teachers' professional knowledge structure—particularly the Technological Pedagogical Content Knowledge (TPACK) framework introduced by Mishra and Koehler [24]—plays a pivotal role in technology integration. TPACK posits that successful integration requires the dynamic synthesis of three domains: content, pedagogical, and technological knowledge. Effective use does not depend on isolated mastery of each domain, but on an integrated knowledge base emerging at their intersection [24]. For instance, using a simulation tool effectively requires

understanding both its impact on students' conceptual grasp and how to adapt instruction accordingly. This integrated knowledge enables teachers to move beyond superficial use and leverage technology to deepen learning. Torani and Jafari corroborate this, noting that teachers' digital literacy enhances both effective tool use and meaningful instructional interactions [25].

A vital dimension of this knowledge structure is Pedagogical Content Knowledge (PCK), originally conceptualized by Shulman [26]. PCK refers to teachers' unique ability to transform specialized subject knowledge into forms comprehensible to students with diverse backgrounds and abilities [26]. When technology is incorporated into this framework—forming TPACK—teachers with strong PCK are better equipped to identify which technological tools can address specific learning challenges or simplify complex concepts. For instance, a chemistry teacher with robust PCK recognizes that molecular modeling software can enhance students' visual understanding of chemical bonding, whereas another tool might prove ineffective [26].

Authoritative international reports reinforce the importance of cultivating this complex knowledge structure. The OECD's Teaching and Learning International Survey explicitly stresses that effective professional development must transcend technical skill training and instead focus on how to integrate such skills with pedagogical approaches and subject-specific content [20]. The report cautions that technology-focused training disconnected from specific curricular contexts yields limited impact on actual classroom practice. Consequently, meaningful technology integration requires investment in programs that foster integrated TPACK development among teachers. However, the formation and enactment of this sophisticated knowledge are themselves

influenced by a constellation of individual and contextual teacher characteristics—which can either facilitate or impede its realization in practice [20].

Individual teacher characteristics—including gender, age, and teaching experience—are regarded as influential factors shaping how teachers perceive, accept, and enact integrated TPACK in educational settings. These attributes not only affect teaching styles and classroom interactions, but also critically influence teachers' attitudes toward educational innovations (e.g., technology integration) and their capacity to synthesize the three knowledge domains effectively. Research indicates that teacher gender can impact student engagement and achievement: for instance, the OECD's Programme for International Student Assessment notes a common perception—though context-dependent—that female students in mathematics and science may relate more effectively to female teachers (see OECD international assessment reports). Moreover, studies suggest that female teachers tend to favor more collaborative instructional methods. Age and teaching experience are also highly influential. Veteran teachers typically demonstrate stronger classroom management and organizational skills. However, the International Computer and Information Literacy Study (ICILS) reveals a learning curve: novice teachers may bring greater energy and novel ideas for technology integration, whereas more experienced teachers possess deeper content knowledge and refined classroom expertise (see IEA comparative studies on digital literacy).

Review of the Related Literature

A review of both domestic and international literature reveals diverse findings. Domestically, Khadem-Nia et al. [27] found a

significant positive correlation between teachers' media literacy, epistemological beliefs, and technology acceptance. Najafzadeh et al. [28] concluded that teachers' digital technology acceptance and integration depend on individual, environmental, technological, and organizational factors. Similarly, Maleki Dastjerdah et al [29] emphasized that motivational beliefs, self-efficacy, attitudes toward technology, and teachers' technological knowledge are key drivers in adopting novel technologies, with digital literacy acting as a mediating factor. Internationally, Ifinedo, Rikala, and Hamalainen [30], in a study of Nigerian teachers, identified three variables—perceived technological knowledge, teacher knowledge, and perceived knowledge for technology integration—as direct predictors of technology integration. Qaddumi et al [31] investigated Palestinian in-service teachers' beliefs regarding ICT integration in English language teaching, finding that while teachers recognized ICT's potential and felt equipped, significant implementation barriers remained, highlighting a demand for targeted in-service training. Similarly, Peng, Razak, and Halili [32], in a Chinese context, reported that attitudes, self-efficacy, digital competence, and digital tool usage significantly influenced ICT integration among in-service trainers. Their study further revealed that gender, age, and teaching experience moderate these factors; for instance, female teachers showed higher positive attitudes and digital competence, while teachers aged 31–35 and those with less than three years of experience demonstrated stronger digital abilities and integration practices compared to older or more experienced counterparts.

Recent cross-cultural studies further enrich this understanding: Abedi, Prestridge, and Hodge [33], in a qualitative study in Ghana, found that teachers predominantly hold

teacher-centred beliefs about technology, viewing it primarily as a productivity tool rather than a catalyst for pedagogical transformation. Similarly, Peretti et al. [34] examined Italian early childhood teachers' beliefs and reported that self-efficacy and outcome expectations were significant internal predictors of technology integration intentions. Collectively, these studies underscore the complex interplay between psychological, knowledge-based, and demographic factors in technology integration across diverse educational contexts.

In light of the theoretical foundations and empirical literature reviewed, it is evident that while numerous factors influencing technology integration have been identified, research simultaneously examining the roles of individual characteristics, knowledge structures, and technological beliefs within a comprehensive model—particularly in the Iranian educational context—remains scarce. Therefore, this study seeks to fill this gap by addressing the central research question: Do technological beliefs, knowledge structures, and individual characteristics play a role in technology integration in the classroom among secondary school teachers? Answering this question can clarify the relative contribution of key determinants, thereby informing policymakers, school leaders, and teachers in efforts to enhance instructional technology use.

Method

Participants

This study employed a *quantitative* approach and is categorized as *applied* in terms of purpose and *descriptive-correlational* in nature and data collection method. The statistical population consisted of all secondary school teachers in Tabriz (N = 4,973). Using the Krejcie and Morgan table, a sample size of 357 was determined. Participants were then selected via

proportionate stratified random sampling, aligned with the distribution of teachers across the city's five educational districts.

Instruments

Data collection utilized multiple questionnaires. The instruments comprised four sections.

A researcher-developed demographic questionnaire: It consisted of information on gender, age, teaching experience, and educational attainment.

A knowledge structures questionnaire: This questionnaire was adapted from Chai and Tsai and was designed with 17 items across three dimensions [35]: perceived technological knowledge, perceived knowledge for technology integration, and pedagogical uses of technology. It was administered using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Confirmatory factor analysis confirmed validity, and reliability (Cronbach's α) was 0.831.

It is important to clarify that while these three dimensions are not direct one-to-one equivalents of the specific TPACK intersections (i.e., TPK, TCK, and TPACK), they serve as operational indicators of teachers' perceived levels of technological-pedagogical knowledge. Aligning with Chai and Tsai's framework [35], Perceived Technological Knowledge (PTK) constitutes the foundational layer corresponding to Technological Knowledge (TK) in Mishra and Koehler's model [24]. Perceived Knowledge for Technology Integration (PKTI) captures the intersection of pedagogical and technological knowledge (TPK), while Pedagogical Uses of ICT (PU-ICT) aligns more closely with the contextualized core of TPACK. This hierarchical approach to measuring integrated knowledge has been empirically validated by Ifinedo et al. [30], confirming these constructs as robust predictors of classroom technology integration.

The technological beliefs questionnaire: It was inspired by Prestidge [36], comprised 14 items, and was administered using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Validity was confirmed via confirmatory factor analysis, and reliability (Cronbach's α) was 0.727.

Schmidt et al.'s Technology Integration questionnaire [37]: It consisted of 19 items and was administered using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). This instrument has demonstrated established validity and reliability in multiple domestic and international studies.

Face and content validity of all instruments were confirmed by expert judgment. Reliability was assessed using Cronbach's alpha, with all constructs exceeding $\alpha = 0.70$ —indicating acceptable internal consistency. Specifically, for the researcher-developed technological beliefs questionnaire, while Cronbach's alpha was 0.727, the Composite Reliability (CR) exceeded 0.90 (Table 1), confirming robust internal consistency suitable for PLS-SEM analysis. Items were retained to maintain theoretical coverage based on Prestidge's framework [36], as removing items solely to inflate alpha could compromise the construct's content validity.

Content validity was ensured through a systematic expert review process: three specialists in educational technology and measurement evaluated all items for relevance, clarity, and alignment with the theoretical framework, and revisions were made based on their feedback. This qualitative validation approach, supplemented by Confirmatory Factor Analysis (CFA) and convergent validity indices ($AVE > 0.50$), aligns with established methodological practices in educational technology research where theory-driven item development and expert judgment are prioritized alongside statistical validation of the measurement model [30],[35].

Table 1: Composite reliability and convergent validity estimates

Construct	Cronbach's α	CR	AVE
Technology Integration	0.909	0.921	0.581
Technological Beliefs	0.885	0.904	0.504
Knowledge Structures	0.899	0.915	0.576
Pedagogical Uses of Technology	0.863	0.901	0.646

Data Analysis

Data analysis employed both descriptive and inferential statistics. Descriptive statistics included frequency, percentage, mean, and standard deviation. To address the research question, structural equation modeling (SEM) was performed using Smart PLS 4. This method comprises two components: the measurement model (assessing composite reliability, convergent validity, and discriminant validity) and the structural model (examining path coefficients and model fit indices).

Results and Findings

Following data collection from 357 secondary school teachers, findings are presented in two sections: descriptive and inferential (SEM) statistics. Table 2 displays the means and standard deviations of key variables. As shown, the highest mean pertains to Technological Beliefs ($M = 4.11$), while the lowest belongs to Perceived Technological Knowledge ($M = 3.79$). The dependent variable, Technology Integration, yielded a mean of 4.02—indicating a generally favorable level of integration among participants.

Prior to hypothesis testing, measurement model reliability and validity were assessed

using Composite Reliability (CR) and Average Variance Extracted (AVE). Results are presented in Table 1. All CR values exceeded 0.70, and all AVE values surpassed 0.50—indicating adequate internal consistency and convergent validity.

To address the research question—Do technological beliefs, knowledge structures, and individual characteristics influence technology integration among secondary school teachers?—the structural model was tested using bootstrapping. Path coefficients (β), t-values, and significance levels are reported in Table 3.

Overall model fit indices were: Normed Fit Index (NFI): 0.93; Comparative Fit Index (CFI): 0.96; and Root Mean Square Error of Approximation (RMSEA): 0.056. The NFI and CFI values exceed the 0.90 threshold, and RMSEA is below 0.08—indicating acceptable model fit. Moreover, the model explained 68% of the variance in technology integration ($R^2 = 0.68$), suggesting that the independent variables collectively account for a substantial proportion of predictive power. In summary, the findings indicate that:

- Technological beliefs ($\beta = 0.388$) emerged as the strongest predictor of technology integration;
- Knowledge structures ($\beta = 0.287$) ranked second in importance;
- Among individual characteristics, only educational attainment showed a positive, significant relationship ($\beta = 0.094$); gender, age, and experience were non-significant;
- The model exhibited excellent fit and explained 68% of the variance in technology integration

Table 2: Descriptive statistics of the study's variables

Measure	Mean	Standard Deviation	Variance	Min	Max
Perceived Technological Knowledge	3.79	0.64	0.41	2	5
Perceived Knowledge for Technology Integration	3.99	0.61	0.31	1.83	5
Pedagogical Uses of Technology	4.00	0.70	0.50	1.80	5
Technological Beliefs	4.11	0.61	0.37	2	5
Technology Integration	4.02	0.52	0.27	1.42	5

Table 3: Path analysis results and hypothesis testing

Relationship	Path Coefficient (β)	t-value	p-value	Outcome
Technological Beliefs $\rightarrow$ Technology Integration	0.388	8.92	$p < 0.01$	Significant
Knowledge Structures $\rightarrow$ Technology Integration	0.287	6.45	$p < 0.01$	Significant
Educational Attainment $\rightarrow$ Technology Integration	0.094	2.12	$p < 0.05$	Significant
Gender $\rightarrow$ Technology Integration	0.021	0.89	$p > 0.05$	Not Significant
Age $\rightarrow$ Technology Integration	0.032	1.12	$p > 0.05$	Not Significant
Teaching Experience $\rightarrow$ Technology Integration	0.045	1.34	$p > 0.05$	Not Significant

These results unequivocally demonstrate that advancing technology integration in classrooms requires primary focus on strengthening teachers' positive technological beliefs and developing their specialized knowledge structures. Figure 1 presents the structural equation model with standardized path coefficients. The path coefficients (β) displayed on the arrows indicate the direct effects of each predictor on technology integration. Consistent with the findings in Table 3, the model highlights the dominant role of technological beliefs ($\beta = 0.388$) as the most influential factor, followed by knowledge structures ($\beta = 0.287$) and educational attainment ($\beta = 0.094$). The non-significant paths for gender, age, and teaching experience are represented with dashed lines, indicating their lack of statistical contribution to the model. The R^2 value of 0.68 inside the endogenous construct (technology integration) denotes that the model explains 68% of its variance, underscoring the collective predictive power of the included variables. This visual representation complements the

numerical details in Table 3 by illustrating the relative strength and structure of the relationships.

Discussion

This study aimed to examine the roles of individual characteristics, knowledge structures, and ICT-related beliefs in technology integration among secondary school teachers. The findings clearly indicate that teachers' positive technological beliefs constitute the most critical factor in predicting their success in integrating technology into instruction. Following beliefs, teachers' level of knowledge—particularly their understanding of technology and how to integrate it meaningfully with subject content—ranked second in importance. Among individual characteristics, only educational attainment showed a significant positive association with technology integration, whereas gender, age, and teaching experience exhibited no notable effects.

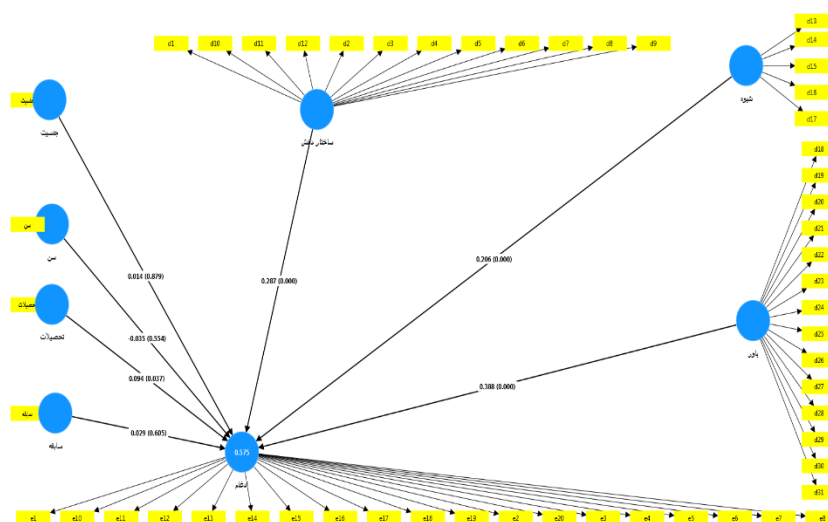


Fig. 1: Structural model with standardized path coefficients

The results robustly confirm that technological beliefs serve as the strongest predictor of successful classroom technology integration. This aligns with Nespor's [21] theoretical framework and corroborates Ertmer's [5] and Koç's [14] emphasis on the role of teachers' perceptual and cognitive filters in adopting educational innovations. Teachers who deeply believe technology can enrich teaching and learning demonstrate greater motivation and perseverance in overcoming technical and organizational barriers. This finding resonates with Zeytounly, Ghorbani, and Robotjazy et al.'s [34] study in the Iranian context, which reported satisfactory levels of technology use despite infrastructural limitations, largely explainable via the Technology Acceptance Model. It also aligns with Khadem-Nia et al. [27], who highlighted the positive link between epistemological beliefs and technology acceptance.

The second significant construct, knowledge structures, corroborates the TPACK framework [24], affirming that technical knowledge alone (TK) is insufficient for effective integration. Rather, teachers require integrated knowledge spanning content, pedagogy, and technology. This finding aligns with Ifinedo et al. [30] and

the OECD's TALIS report [20], both of which recommend professional development programs focused on integrating these knowledge domains rather than merely providing technical training. The critical importance of such integrated knowledge becomes especially evident when considering Zeytounly et al.'s [38] finding that Iranian students explicitly cited instructors' inadequate guidance in selecting appropriate tools and strategies as a primary barrier.

Regarding individual characteristics, only educational attainment showed a significant positive relationship with technology integration. This may be attributable to higher exposure to theoretical foundations and specialized training at advanced academic levels. More importantly, the non-significance of gender, age, and experience constitutes a highly encouraging finding. It suggests that the capacity for technology integration is not confined to specific demographic subgroups. This is directly supported by Zeytounly et al. [38], who found no significant gender differences in students' expectations or actual ICT use, and by Jafari et al. [39], who reported no meaningful association between demographic variables and teachers' digital

competencies. This convergence indicates that in the Iranian context, psychological-professional factors (beliefs, knowledge) hold precedence over demographic ones.

Conclusions

This study contributes to the existing literature by simultaneously examining the roles of individual characteristics, knowledge structures, and technological beliefs within a comprehensive model in the educational context. The model's 68% explanatory power underscores its high predictive validity, demonstrating that the combination of technological beliefs, knowledge structures, and educational attainment provides a robust framework for understanding technology integration. This confirms that accelerating educational transformation through technology demands a shift beyond purely technical approaches toward human-centered, capacity-building strategies.

In light of these findings, several practical implications are offered. First, professional development programs should prioritize developing integrated TPACK and transforming teachers' beliefs about technology's role in meaningful learning, rather than focusing exclusively on technical tool operation. Second, establishing professional learning communities among teachers can help teachers share successful integration experiences, thereby reinforcing collective positive beliefs. Third, schools should foster a progressive organizational culture that encourages innovative practice and views errors as integral to the learning process. Finally, ensuring ongoing in-school technical and pedagogical support is crucial to help teachers navigate implementation challenges.

While this study provided valuable insights, it acknowledged that the operationalization of "individual characteristics" was limited to gender, age, experience, and educational attainment. Future research could expand this construct to include psychological variables such as technology self-efficacy, intrinsic motivation, and learning styles, which have been identified as significant predictors of technology adoption in prior literature. Additionally, longitudinal studies are recommended to examine how changes in beliefs and knowledge structures over time influence integration practices, thereby complementing the cross-sectional design of the present study. Furthermore, replicating this model in different educational contexts and levels would enhance the generalizability of the findings.

Authors' Contribution

The first author completed this research under the guidance and supervision of the second author.

Acknowledgments

This article is derived from the master's thesis entitled "The Role of Individual Characteristics, Knowledge Structures and Beliefs of Information and Communication Technology on the Technologies Integration of High School Teachers," defended at Azarbaijan Shahid Madani University in 2025. We hereby deem it necessary to express our gratitude to all those who contributed to the research process.

Conflicts of Interest

The authors declare no conflict of interest.

References

- [1] LeTendre G. Globalization and the impact of ICT on teacher's work and professional status. In: Menter I, editor. *The Palgrave handbook of teacher education research*. Cham: Palgrave Macmillan; 2022. p. 1–22. doi:10.1007/978-3-030-59533-3_83-1.

- [2] Pham ST, Sampson PM. The development of artificial intelligence in education: a review in context. *J Comput Assist Learn.* 2022;38(5):1408–1421. doi:10.1111/jcal.12696.
- [3] Cabero-Almenara J, Guillén-Gámez FD, Ruiz-Palmero J, Palacios-Rodríguez A. Digital competence of higher education professor according to DigCompEdu: statistical research methods with ANOVA between fields of knowledge in different age ranges. *Educ Inf Technol.* 2021;26(4):4691–4708. doi:10.1007/s10639-021-10476-5.
- [4] UNESCO. Global education monitoring report 2023: technology in education: a tool on whose terms? Paris: United Nations Educational, Scientific and Cultural Organization; 2023.
- [5] Ertmer PA. Addressing first- and second-order barriers to change: strategies for technology integration. *Educ Technol Res Dev.* 1999;47(4):47–61. doi:10.1007/BF02299597.
- [6] Aidoo B, Macdonald MA, Vesterinen VM, Pétursdóttir S, Gísladóttir B. Transforming teaching with ICT using the flipped classroom approach: dealing with the COVID-19 pandemic. *Educ Sci.* 2022;12(6):421. doi:10.3390/educsci12060421.
- [7] Zhao Y, Frank KA. Factors affecting technology uses in schools: an ecological perspective. *Am Educ Res J.* 2003;40(4):807–840. doi:10.3102/00028312040004807.
- [8] Schepers J, Wetzels M. A meta-analysis of the technology acceptance model: investigating subjective norm and moderation effects. *Inf Manag.* 2007;44(1):90–103. doi:10.1016/j.im.2006.10.007.
- [9] Taimalu M, Luik P. The impact of beliefs and knowledge on the integration of technology among teacher educators: a path analysis. *Teach Teach Educ.* 2019;79:101–110. doi:10.1016/j.tate.2018.12.012.
- [10] Lai JW, Bower M. How is the use of technology in education evaluated? A systematic review. *Comput Educ.* 2019;133:27–42. doi:10.1016/j.compedu.2019.01.005.
- [11] Bower M. Technology-mediated learning theory. *Br J Educ Technol.* 2019;50(3):1035–1048. doi:10.1111/bjet.12771.
- [12] Gil-Flores J, Rodríguez-Santero J, Torres-Gordillo JJ. Factors that explain the use of ICT in secondary-education classrooms: the role of teacher characteristics and school infrastructure. *Comput Human Behav.* 2017;68:441–449. doi:10.1016/j.chb.2016.11.057.
- [13] Burke PF, Schuck S, Aubusson P, Kearney M, Frischknecht B. Exploring teacher pedagogy, stages of concern and accessibility as determinants of technology adoption. *Technol Pedagog Educ.* 2018;27(2):149–163. doi:10.1080/1475939X.2017.1387602.
- [14] Koç M. Implications of learning theories for effective technology integration and preservice teacher training: a critical literature review. *J Turk Sci Educ.* 2005;2(1):2–18.
- [15] Kilag OK, Miñoza J, Comighud E, Amontos C, Damos M, Abendan CF. Empowering teachers: integrating technology into livelihood education for a digital future. *Excellencia Int Multidiscip J Educ.* 2023;1(1):30–41.
- [16] Bulman G, Fairlie RW. Technology and education: computers, software, and the Internet. In: Hanushek EA, Machin S, Woessmann L, editors. *Handbook of the economics of education.* Vol. 5. Amsterdam: Elsevier; 2016. p. 239–280. doi:10.1016/B978-0-444-63459-7.00005-1.
- [17] Williamson B, Eynon R, Potter J. Pandemic politics, pedagogies and practices: digital technologies and distance education during the coronavirus emergency. *Learn Media Technol.* 2020;45(2):107–114. doi:10.1080/17439884.2020.1761641.
- [18] Cheung ACK, Slavin RE. How methodological features affect effect sizes in education. *Educ Res.* 2016;45(5):283–292. doi:10.3102/0013189X16656615.
- [19] Reich J. Teaching our way to digital equity. *Educ Leadersh.* 2019;76(5):30–35.
- [20] Organisation for Economic Co-operation and Development. TALIS 2018 results. Volume I, Teachers and school leaders as lifelong learners. Paris: OECD Publishing; 2019. doi:10.1787/1d0bc92a-en.
- [21] Nespor J. The role of beliefs in the practice of teaching. *J Curric Stud.* 1987;19(4):317–328. doi:10.1080/0022027870190403.
- [22] Brynjolfsson E, McAfee A. The business of artificial intelligence: what it can—and cannot—do for your organization. *Harv Bus Rev [Internet].* 2017 Jul 18.
- [23] Loader BD, Mercea D. Networking democracy? Social media innovations and participatory politics. *Inf Commun Soc.* 2011;14(6):757–769. doi:10.1080/1369118X.2011.592648.
- [24] Mishra P, Koehler MJ. Technological pedagogical content knowledge: a framework for teacher knowledge. *Teach Coll Rec.* 2006;108(6):1017–1054. doi:10.1111/j.1467-9620.2006.00684.x.
- [25] Toorani H, Jafari A. Investigating the mediating role of teachers' digital literacy in the relationship between e-learning and instructional interactions in elementary schools in Tehran. *Tech Edu J.* 2025;19(1):179–194. [In Persian] doi:10.22061/tej.2025.10164.2952.
- [26] Shulman LS. Knowledge and teaching: foundations of the new reform. *Harv Educ Rev.* 1987;57(1):1–22. doi:10.17763/haer.57.1.j463w79r56455411.
- [27] Khadem Nia R, Alavi Langarudi SK, Zandvakilian A, Hemmati H. The relationship between media literacy and epistemological beliefs with technology acceptance among teachers in Yazd. *J Inf Commun Technol Educ Sci.* 2023;13(3):143–163. [In Persian]

[28] Najafzadeh B, Barghi I, Ghasemzadeh A. A step to validate the model of acceptance and use of digital technology by teachers. *Res Teach*. 2022;10(3):23–45. [In Persian] doi:10.34785/J012.2022.037.

[29] Maleki Dastjerdeh M, Maleki N, Shorkaei R. Investigating the role of teachers in adopting new technologies in the educational process. In: *Proceedings of the Second International Conference on Educational Sciences, Counseling, Psychology, and Social Sciences*; 2023; Hamedan, Iran. [In Persian]

[30] Ifinedo E, Rikala J, Hämäläinen T. Factors affecting Nigerian teacher educators' technology integration: considering characteristics, knowledge constructs, ICT practices and beliefs. *Comput Educ*. 2020;146:103760. doi:10.1016/j.compedu.2019.103760.

[31] Qaddumi H, Smith M, Masd K, Bakeer A, Abu-Ulbeh W. Investigating Palestinian in-service teachers' beliefs about the integration of information and communication technology (ICT) into teaching English. *Educ Inf Technol*. 2023;28:12785–12805. doi:10.1007/s10639-023-11689-6.

[32] Peng R, Razak RA, Halili SH. Investigating the factors affecting ICT integration of in-service teachers in Henan Province, China: structural equation modeling. *Humanit Soc Sci Commun*. 2023;10:380. doi:10.1057/s41599-023-01871-z.

[33] Abedi EA, Prestridge S, Hodge S. Teachers' beliefs about technology integration in Ghana: a qualitative study of teachers', headteachers' and education officials' perceptions. *Educ Inf Technol*. 2024;29(5):5857–5877. doi:10.1007/s10639-023-12049-0.

[34] Peretti S, Kubiato M, Caruso F, Di Mascio T, Giancola M, D'Amico S, et al. #InstaMind: teachers' beliefs on educational technology to promote seamless technology integration in early education. *Front Educ*. 2024;9:1399807. doi:10.3389/educ.2024.1399807.

[35] Chai CS, Koh JHL, Tsai CC. A review of technological pedagogical content knowledge. *Educ Technol Soc*. 2013;16(2):31–51.

[36] Prestridge S. The alignment of digital pedagogy to current teacher beliefs. In: *Proceedings of the ACEC2010 Digital Diversity Conference*; 2010 Apr 6–9; Melbourne, Australia. Melbourne: Australian Council for Computers in Education; 2010.

[37] Schmidt DA, Baran E, Thompson AD, Mishra P, Koehler MJ, Shin TS. Technological pedagogical content knowledge (TPACK): the development and validation of an assessment instrument for preservice teachers. *J Res Technol Educ*. 2009;42(2):123–149. doi:10.1080/15391523.2009.10782544.

[38] Zeitounly M, Ghorbani MR, Robotjazy MA. Exploring Iranian university students' expectations and technology use for out-of-class English language learning. *Tech Edu J*. 2025;19(1):271–292. [In Persian] doi:10.22061/tej.2025.11598.3170.

[39] Jaafari E, RezaeiZadeh M, Shahverdi R, Bandali B, Abolghasemi M. Evaluating teachers' digital competencies during the COVID-19 pandemic. *Tech Edu J*. 2024;18(3):527–548. [In Persian] doi:10.22061/tej.2024.10320.2996.

AUTHOR(S) BIOSKETCHES

Saed Bibak is a graduate of the Master's program in Curriculum Studies at Azarbaijan Shahid Madani University. He is interested in conducting research in his specialized field, including the teaching-learning process of students and the quality of their curricula.

Saed Bibak, M.A. in Curriculum Studies, Azarbaijan Shahid Madani University, Tabriz, Iran.

✉ saeedbibak25@gmail.com

Sirous Asadian holds a Ph.D. in Curriculum Studies from Allameh Tabataba'i University and is an Associate Professor in the Department of Education at Azarbaijan Shahid Madani University. His academic credentials include the publication of two specialized books and over fifty research articles in scientific journals, as well as dozens of papers presented at national and international conferences. His research interests focus on the quality and characteristics of curricula across various educational levels and the teaching-learning process.

Asadian, S. Associate Professor, curriculum studies, Azarbaijan Shahid Madani University, Tabriz, Iran.

✉ dr.sasadian@gmail.com

Citation (Vancouver): Bibak S, Asadian S. [Technological beliefs, knowledge structures, and individual characteristics: determinants of technology integration in the classroom] *Tech. Edu. J*. 2026; 20(1): 65-78

 <https://doi.org/10.22061/tej.2026.12755.3333>





ORIGINAL RESEARCH PAPER

The mediating role of academic engagement in the relationship between social support and student satisfaction in online learning environments

A. Taghizade^{*1}, A. Akbari Balootbangan²

¹ Department of Educational Sciences, Farhangian University, P.O. Box14665-889, Tehran, Iran

² Department of Psychology and Counseling, Farhangian University, P.O. Box14665-889, Tehran, Iran

ABSTRACT

Received: 05 June 2025
Reviewed: 23 July 2025
Revised: 06 September 2025
Accepted: 06 November 2025

KEYWORDS:

Social Support
Academic Engagement
Learner Satisfaction
Online Learning

* Corresponding author

A.Taghizade@cfu.ac.ir

(+98936) 4882375

Background and Objectives: Perceived social support is a critical factor in enhancing academic engagement and satisfaction in online learning environments. However, the mechanisms through which social support influences satisfaction, particularly the mediating role of distinct dimensions of academic engagement, remain underexplored. So, the current study seeks to develop and test a structural model that explores how academic engagement, specifically its affective and behavioral components, mediates the relationship between perceived social support and satisfaction among master's students enrolled in online learning environments within Iranian higher education institutions.

Materials and Methods: A total of 391 master's students from several universities in Iran participated in this study through an online survey conducted in April 2024. Participants completed validated Persian versions of three instruments: the Online Social Support Questionnaire, the Online Student Engagement Questionnaire, and the Satisfaction with E-learning Scale. Structural equation modeling (SEM) was employed to assess the fit of the hypothesized structural model. Bootstrapping procedures (5,000 resamples) were subsequently used to test the significance of the indirect (mediating) effects.

Findings: The results revealed that social support had a significant positive direct effect on satisfaction ($\beta = 0.37, p < 0.01$). Additionally, social support significantly predicted both affective engagement ($\beta = 0.90, p < 0.001$) and behavioral engagement ($\beta = 0.92, p < 0.001$). Both affective engagement ($\beta = 0.41, p < 0.001$) and behavioral engagement ($\beta = 0.25, p < 0.05$) positively influenced satisfaction. Mediation analyses confirmed that affective engagement ($\beta = 0.37, 95\% \text{ CI } [0.26, 0.64]$) and behavioral engagement ($\beta = 0.23, 95\% \text{ CI } [0.05, 0.57]$) partially mediated the relationship between social support and satisfaction, with affective engagement demonstrating a stronger mediating effect. The proposed structural model exhibited good fit to the data ($\text{CMIN/df} = 3.34, \text{CFI} = 0.92, \text{RMSEA} = 0.07, \text{SRMR} = 0.05$).

Conclusions: Perceived social support enhances e-learning satisfaction both directly and indirectly through academic engagement. Affective engagement mediates this relationship more strongly than behavioral engagement, highlighting the critical role of emotional connection, particularly in collectivist cultural contexts. To enhance student satisfaction, eLearning environments should be deliberately designed to cultivate supportive interpersonal dynamics and foster meaningful academic engagement alongside active participation.



COPYRIGHTS

© 2026 The Author(s). This is an open-access article distributed under the terms and conditions of the Creative Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) (<https://creativecommons.org/licenses/by-nc/4.0/>)



NUMBER OF REFERENCES

73



NUMBER OF FIGURES

2



NUMBER OF TABLES

4

مقاله پژوهشی

نقش میانجی مشغولیت تحصیلی در رابطه میان حمایت اجتماعی و رضایت‌مندی دانشجویان در محیط‌های یادگیری آنلاین

عباس تقی زاده^{*}،^۱، افضل اکبری بلوط بنگان^۲^۱ گروه آموزش علوم تربیتی، دانشگاه فرهنگیان، کد پستی ۱۴۶۶۵-۱۸۸۹، تهران، ایران^۲ گروه آموزش روان‌شناسی و مشاوره، دانشگاه فرهنگیان، کد پستی ۱۴۶۶۵-۱۸۸۹، تهران، ایران

چکیده

پیشینه و اهداف: حمایت اجتماعی ادراک‌شده یکی از عوامل حیاتی در افزایش مشغولیت تحصیلی و رضایت‌مندی فراگیر در محیط‌های یادگیری آنلاین محسوب می‌شود. با این حال، سازوکارهایی که از طریق آن‌ها حمایت اجتماعی بر رضایت‌مندی تأثیر می‌گذارد، به‌ویژه نقش واسطه‌ای ابعاد متمایز مشغولیت تحصیلی هنوز به طور کافی بررسی نشده است؛ بنابراین، پژوهش حاضر باهدف تدوین و آزمون یک مدل ساختاری انجام شد تا نقش میانجی مؤلفه‌های عاطفی و رفتاری مشغولیت تحصیلی در رابطه میان حمایت اجتماعی ادراک‌شده و رضایت‌مندی دانشجویان کارشناسی‌ارشد شاغل به تحصیل در محیط‌های یادگیری آنلاین در مؤسسات آموزش عالی ایران مورد کاوش قرار گیرد.

روش‌ها: در این پژوهش، ۳۹۱ نفر از دانشجویان کارشناسی‌ارشد چندین دانشگاه در ایران از طریق یک پیمایش برخط که در فروردین‌ماه سال ۱۴۰۳ انجام شد، شرکت کردند. شرکت‌کنندگان سه ابزار را تکمیل نمودند: پرسش‌نامه حمایت اجتماعی در محیط‌های یادگیری آنلاین، پرسش‌نامه مشغولیت تحصیلی در محیط‌های یادگیری آنلاین، و پرسش‌نامه رضایت‌مندی از یادگیری الکترونیکی. برای ارزیابی برازش مدل ساختاری مفروض از مدلیابی معادلات ساختاری (SEM) استفاده شد. سپس، به‌منظور آزمون معناداری اثرات غیرمستقیم (واسطه‌ای)، از روش بوت‌استرپ (با ۵۰۰۰ بازنموده) بهره گرفته شد.

یافته‌ها: نتایج به‌دست‌آمده نشان داد که حمایت اجتماعی دارای اثر مستقیم مثبت و معنادار بر رضایت‌مندی فراگیر است ($\beta = 0.37$ ، $p < 0.01$). افزون بر این، حمایت اجتماعی به طور معناداری هم مشغولیت عاطفی ($\beta = 0.90$ ، $p < 0.001$) و هم مشغولیت رفتاری ($\beta = 0.92$ ، $p < 0.001$) را پیش‌بینی می‌کند. هر دو مؤلفه مشغولیت عاطفی ($\beta = 0.41$ ، $p < 0.001$) و مشغولیت رفتاری ($\beta = 0.25$ ، $p < 0.05$) تأثیر مثبتی بر رضایت‌مندی داشتند. تحلیل میانجی نشان داد که مشغولیت عاطفی ($\beta = 0.37$)، بافاصله اطمینان ۹۵٪ (۰/۲۶، ۰/۶۴) و مشغولیت رفتاری ($\beta = 0.23$)، بافاصله اطمینان ۹۵٪ (۰/۰۵، ۰/۵۷) به طور جزئی رابطه میان حمایت اجتماعی و رضایت‌مندی را میانجی‌گری می‌کنند که در این میان مشغولیت عاطفی دارای اثر میانجیگری قوی‌تری است. مدل ساختاری پیشنهادی از برازش مطلوبی ($SRMR = 0.05$ ، $RMSEA = 0.07$ ، $CFI = 0.92$ ، $CMIN/df = 3/34$) با داده‌ها برخوردار بود.

نتیجه‌گیری: حمایت اجتماعی ادراک‌شده به طور مستقیم و همچنین به واسطه مشغولیت تحصیلی، رضایت‌مندی از یادگیری الکترونیکی را افزایش می‌دهد. مشغولیت عاطفی این رابطه را باقدرت بیشتری نسبت به مشغولیت رفتاری واسطه‌گری می‌کند که حاکی از نقش حیاتی پیوند عاطفی، به‌ویژه در بافت‌های فرهنگی جمع‌گرا، است. به‌منظور افزایش رضایت‌مندی دانشجویان، باید محیط‌های یادگیری الکترونیکی با طراحی هدفمند، به‌گونه‌ای ساماندهی شوند که پویایی‌های میان‌فردی حمایت‌کننده و نیز مشغولیت تحصیلی معنادار را در کنار مشارکت فعال، پرورش دهند.

نویسنده مسئول

A.Taghizade@cfu.ac.ir

۰۹۳۶-۴۸۸۲۳۷۵ ①

Introduction

The widespread integration of digital tools into education, coupled with the forced transition to remote learning during the COVID-19 pandemic, has permanently reshaped higher education. What once served as a substitute for in-person instruction has now become a lasting

and essential mode of academic delivery [1]. This evolution has pushed certain psychological and pedagogical concepts to the forefront of educational research, as institutions seek to better understand and enhance the conditions that foster meaningful online learning experiences [2]. Within this context, student satisfaction continues to be regarded as a

fundamental marker of quality in e-learning environments. It captures both the cognitive judgments and emotional responses of learners regarding the degree to which their academic expectations and personal needs are fulfilled [3].

In light of persistent concerns tied to online learning, such as social isolation, student disengagement, and higher dropout rates, identifying what drives satisfaction has become an urgent priority for educators and researchers alike [2]. A central factor influencing how students evaluate their satisfaction in online learning is their level of academic engagement. Across higher education, engagement is widely regarded as a key predictor of academic achievement and degree completion. When students fail to engage meaningfully with their studies, the consequences often include lower academic performance, as well as reduced retention and graduation rates at the institutional level [4]. Early identification of learners who may be disengaging or are at risk of dropping out is therefore a critical task, one that demands a solid grasp of the engagement construct and its underlying dimensions [5–7]. Underlying this concern is the growing awareness that many students feel a heightened sense of isolation and marginality in online academic settings, conditions that can further weaken their connection to the learning process [8].

Alongside the focus on engagement, social support has increasingly been recognized as a critical element in shaping how students navigate and experience online learning. In e-learning environments, where learners must often grapple with unfamiliar technologies, manage complex platforms, and acquire course content with limited real-time access to instructors or peers, the presence of support becomes particularly vital. Encouragement and assistance received from family members,

peers, and educators can contribute meaningfully to learners' motivation, academic self-confidence, and overall satisfaction, ultimately enhancing their performance in virtual settings [9]. Beyond these direct effects, social support also plays a role in strengthening students' self-esteem, which can translate into greater commitment and sustained effort in academic tasks. Some scholars suggest that this support influences achievement and satisfaction indirectly, by shaping the degree to which students engage with their learning [10]. It is important to note, however, that the nature of social support in online courses may differ considerably from what is typically observed in face-to-face classrooms.

The absence of physical presence and non-verbal cues, combined with the asynchronous rhythm of much online communication, can shift how learners perceive and interpret supportive behaviors. These contextual differences highlight the need to examine social support specifically within e-learning settings, where the quality and frequency of interaction diverge from those found in conventional social networks or traditional classrooms [11]. Although a substantial body of research has sought to link social support to various online learning outcomes [12–13], a more nuanced understanding requires distinguishing between two related but distinct forms of support: general emotional support and what may be termed educational support. The latter refers to the provision of informational and practical assistance that directly aids the learning process, such as when an instructor clarifies a difficult concept or classmates share relevant resources.

This type of support helps reduce obstacles to completing academic tasks, fosters a sense of ease with digital tools, and promotes both active participation and self-directed learning [14]. Although scholarly attention to the factors

that shape the quality of online education, particularly social support, student engagement, and satisfaction, has grown considerably in recent years, several important gaps persist in the literature. First, while previous studies have generally confirmed positive relationships among these variables [15], relatively few have explored the underlying processes through which social support contributes to learner satisfaction [3]. Second, despite theoretical arguments positioning engagement as a potential mediator between contextual conditions and academic outcomes, empirical evidence examining this mediating role, especially with attention to distinct forms of engagement such as affective and behavioral dimensions, remains limited within the context of online learning. Third, graduate students, who often navigate unique academic and personal circumstances in virtual settings, have been largely overlooked in this line of inquiry. Finally, little research has investigated these dynamics in collectivist cultural environments such as Iran, where interpersonal connections and emotional ties may carry particular weight in shaping educational experiences and perceptions. In light of these gaps, the current study seeks to develop and test a structural model that explores how academic engagement, specifically its affective and behavioral components, mediates the relationship between perceived social support and satisfaction among master's students enrolled in online learning environments within Iranian higher education institutions. By doing so, the research aims to generate practical insights that can inform the design of more supportive online learning environments, ultimately fostering greater engagement and higher levels of student satisfaction.

Review of the Related Literature

Social support and satisfaction

Broadly understood as the assistance and reassurance individuals draw upon when confronting challenging circumstances [16], social support has long been recognized as a factor closely tied to psychological health and overall well-being [17–19]. Early conceptualizations tended to frame it primarily in terms of interpersonal exchanges and observable behaviors [17], but more recent studies have expanded this lens to include e-learning environments [20–21]. Drawing on Self-Determination Theory, researchers have observed that in online educational settings, instructors are particularly well-positioned to support learners' needs for autonomy and competence, while peers often contribute more substantially to satisfying the need for relatedness [22]. Although social support may not always offer direct solutions to academic difficulties, it plays an indispensable role in addressing learners' psychological needs, reducing feelings of isolation, and enhancing satisfaction in virtual learning contexts [21][23]. Despite its recognized importance, the study of social support within e-learning environments remains relatively underexplored [11][24]. Early efforts, such as those by Weng et al., drew attention to its relevance for technology acceptance in education, revealing the distinct contributions of peers, supervisors, and family members [24]. In a similar vein, Hsu et al. found that social support can bolster learners' resilience, deepen cognitive engagement, and contribute to more meaningful educational experiences online [11]. While these studies underscore the value of social support, they tend to approach it as a unified construct, offering limited insight into how its various dimensions may function differently within the

context of online learning. Based on the above empirical evidence, H1 is formulated as follows:

H1. Higher education students' social support has a positive effect on their satisfaction.

Social support and learning engagement

The central role of engagement in shaping educational outcomes has been consistently emphasized across both face-to-face and online learning contexts [25–27]. As Bergdahl and colleagues observed, engagement in digitally mediated environments differs in meaningful ways from what occurs in traditional classrooms, largely due to technological features such as real-time interaction and the absence of nonverbal cues, factors that call for renewed theoretical and empirical examination [28]. From the standpoint of the self-system motivational perspective, engagement is understood to emerge from students' ongoing interactions with their learning environment [7]. It is therefore considered responsive to contextual shifts and is characterized by the energy, focus, and sustained effort learners invest in academic tasks [6]. Within this motivational framework, engagement is conceptualized as a multidimensional construct encompassing behavioral, cognitive, social, and affective components [6][29]. Given that the present study centers on the behavioral and affective dimensions of engagement, each is described in greater detail below. Behavioral engagement refers to the extent to which students take part in academic activities, demonstrate appropriate conduct, and refrain from behaviors that disrupt the learning process [30]. Affective engagement, by contrast, concerns students' emotional responses to their learning experiences, including feelings of enjoyment, interest, and connection as well as their attitudes toward classmates, course content, and the broader

educational context [31–32]. This dimension has previously been captured through indicators such as joy, pleasure, excitement, and the sense of rapport students perceive with instructors and peers [33]. In a related vein, Hernandez et al. define social support as any form of assistance or help extended to an individual by others, noting that positive relationships are often built around the exchange of such support. Within educational settings, the primary sources of this support tend to be teachers, classmates, and family members. Their findings indicate that social support exerts a meaningful positive influence on university students' academic engagement [34]. Support from guardians, in particular, has been shown to help students remain engaged in their studies and achieve stronger academic outcomes [35]. Moreover, the presence of supportive relationships with both peers and educators increases the likelihood that adolescents will exhibit higher levels of behavioral engagement in the classroom [36]. Among these sources, the support provided by teachers, particularly when perceived as accessible and reliable, appears to play an especially critical role in sustaining and nurturing students' academic engagement over time [37]. In summary, hypothesis H2 and H3 are proposed as following:

H2. Higher education students' social support has a positive effect on higher education students' Affective engagement.

H3. Higher education students' social support has a positive effect on their Behavioral engagement.

Student engagement and learner satisfaction

Among the most frequently cited indicators of quality in online education is student satisfaction, widely regarded as a fundamental component of effective and successful learning experiences [38–39]. Generally defined,

academic satisfaction refers to learners' assessment of the extent to which their expectations, needs, and personal goals have been fulfilled throughout their educational journey [40]. A growing body of research has drawn attention to the positive association between satisfaction and both academic performance and student engagement [41-42]. With specific regard to the relationship between engagement and satisfaction, empirical studies have consistently pointed to a positive directional link. In an investigation involving 347 university students, Gao et al. found that both playfulness and emotional engagement contributed significantly to learners' satisfaction, suggesting that a well-designed and stimulating online platform can enhance students' overall contentment with their courses.

Notably, emotional engagement emerged as a mediating variable between several platform-related factors such as perceived usefulness, ease of use, and interactivity and satisfaction. This finding implies that students' emotional responses are shaped by their perceptions of the learning environment. Interestingly, the same study reported that cognitive engagement did not exert a significant influence on satisfaction, indicating that learners may derive greater fulfillment when their engagement is effectively and emotionally anchored rather than purely intellectual [43]. Further support for the engagement-satisfaction link comes from Yousaf et al., who examined the role of course evaluation and digital platforms in shaping online learning experiences. Drawing on data from 652 university students, their findings confirmed a meaningful relationship between engagement and satisfaction [44]. In a related study, Fisher et al. observed, based on a sample of 348 students, that both blended and flipped learning approaches enhanced participants'

perceptions of engagement, academic performance, and satisfaction. of particular interest was the finding that engagement within flipped learning contexts directly contributed to satisfaction, even in cases where students did not perceive noticeable gains in performance [45].

Taken together, these studies offer compelling evidence that student engagement and satisfaction are closely intertwined. They also suggest that specific dimensions of engagement, particularly emotional engagement, may serve as mediating mechanisms through which various forms of support influence learners' satisfaction in online settings. Nevertheless, relatively few studies have systematically examined how the affective and behavioral dimensions of engagement function as mediators in the relationship between perceived social support and overall satisfaction with online learning. In view of this research gap, we set out to examine these relationships and hypothesize the following:

H4. Higher education students' Affective engagement has a positive effect on their satisfaction.

H5. Higher education students' Behavioral engagement has a positive effect on their satisfaction.

H6. Affective engagement plays a mediating effect in the relationship between higher education students' social support and their Satisfaction.

H7. Behavioral engagement plays a mediating effect in the relationship between higher education students' social support and their Satisfaction.

Proposed structural model

Based on these hypotheses generated from the above literature review, our proposed structural model is presented in Figure 1.

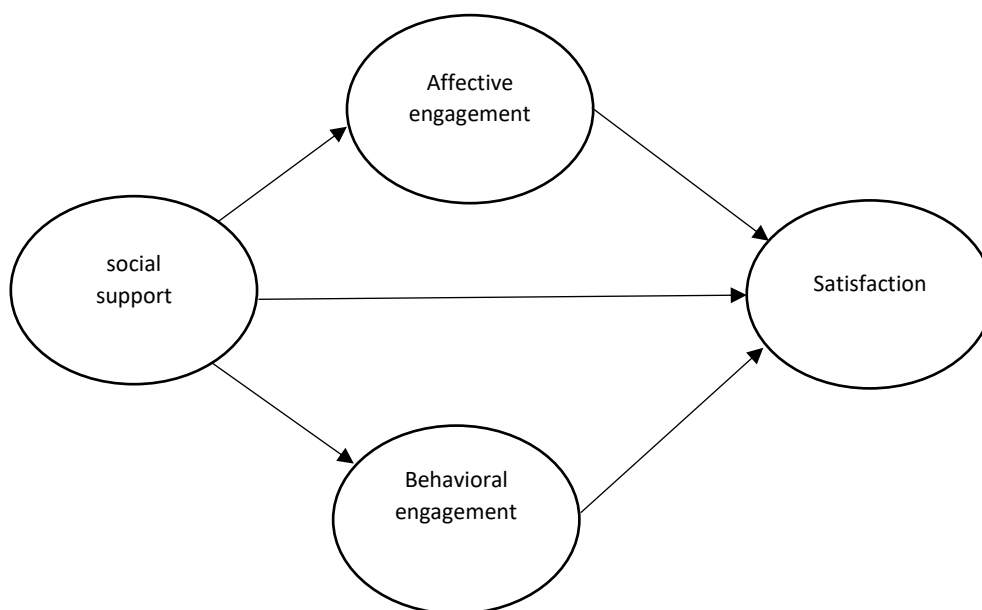


Fig. 1: Hypothesized Structural Model

Method

Participants

The present investigation employed an exploratory design, utilizing structural equation modeling to examine the complex interrelationships among perceived social support, affective engagement, behavioral engagement, and satisfaction within the context of online learning. This methodological approach is particularly well-suited for research aimed at developing a more nuanced understanding of specific phenomena, especially in situations where the researcher exercises limited control over data collection procedures and the variables of interest emerge from naturally occurring educational settings [46].

Data collection for the study was conducted in April 2024, using an online survey administered to graduate students across several universities in Iran. These universities provided a variety of programs in the humanities, engineering, and basic sciences. In addition to their online programs, they also provided in-person courses. Initially, 397

master's students were recruited using a convenience sampling method, considering factors such as availability, voluntary participation, and active engagement in online courses. After removing outliers, the sample was refined to 391 participants. Before data gathering, participants were informed about the study's objectives, with an emphasis on the confidentiality and anonymity of their responses. They were also made aware that they could withdraw from the research at any time without any consequences.

Data collection was carried out via an online survey. The minimum required sample size for this study was determined using the Soper sample size calculator for structural equation modeling [47]. Considering an anticipated effect size of 0.3, a desired statistical power level of 0.80, 4 latent variables, 22 observed variables, and a probability level of 0.05, the calculator indicated a minimum sample size of 240-260 respondents. The final sample of 391 participants exceeded this threshold, confirming its adequacy for subsequent SEM analysis [47]. The demographic distribution of the participants is detailed in Table 1.

Table 1: Demographic characteristics of participants

Variable	Subcategory	Frequency	%
Gender	Female	129	33%
	Male	262	67%
Year of Study	First-year student	102	26%
	Second-year student	156	40%
	Third-year student and above	133	34%
	22–26	121	31%
Age Range	27–31	113	29%
	32–36	78	20%
	37–41	47	12%
	42–46	20	5%
	47–51	12	3%
Field of Study	Engineering	211	54%
	Social sciences and humanities	180	46%

It should be noted that all universities involved in this research operated under a nationally standardized instructional design framework for the development and delivery of their online courses. This model incorporates both synchronous and asynchronous modes of instruction, with course content and learning activities delivered through the Moodle platform. Multimedia learning materials, along with formative and summative assessment tools such as quizzes and assignments, are developed by subject matter specialists with the aim of fostering student engagement and monitoring academic progress. In addition, real-time interactive sessions are facilitated through BigBlueButton, allowing for live communication and immediate feedback between instructors and learners.

Instruments

Online Social Support Questionnaire

To evaluate learners' social support in online courses, the 15-item self-report questionnaire, developed by the researchers and adapted from five previously validated instruments [24,52,53], assesses the students' perceived educational and emotional social support in online courses. Items are rated on a 5-point Likert scale (1=strongly disagree, 5=strongly agree), with higher scores indicating higher perceived social support. The instrument

evaluates the social support provided by family, peers, and teachers and was adapted by Taghizade et al. to fit the Iranian educational context [54]. For this research, educational social support items were used (9 items). These items are rated on a 5-point Likert scale, where higher scores indicate greater levels of perceived educational social support. In this study, the reliability of the Online Social Support was established with a Cronbach's alpha value of 0.92.

Online Student Engagement Questionnaire

To evaluate learners' engagement in online courses, the OSEQ [55] was used as the main questionnaire. It comprises 16 self-report items measuring four types of engagement (cognitive, behavioral, social, and affective engagements). Each item is rated on a 5-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = moderately agree, 4 = agree, and 5 = strongly agree), and higher scores indicate higher engagement levels. For this research, affective and behavioral engagement, which consists of 8 five-point, Likert-type items, adapted by Taghizade et al. to fit the Iranian educational context, was employed [56]. This adaptation involved necessary cultural and linguistic modifications to ensure its suitability and effectiveness. The reliability of this culturally adapted version was confirmed in the study, as

evidenced by a high Cronbach's alpha value of 0.86 (affective engagement) and 0.81 (behavioral engagement).

Satisfaction with e-learning

The Learner Satisfaction Survey (LSS), developed by Chang [57], was utilized to evaluate students' satisfaction with e-learning. This survey has undergone various validations in different contexts. For instance, Taghizade et al. translated it into Farsi and validated its reliability for use in the Iranian educational context [58]. The current study also used this translated version. The LSS comprises 25 items that assess four types of interaction (learner-content, learner-instructor, learner-learner, and learner-technology) as well as overall satisfaction. In this study, general satisfaction items were used (5 items). These items are rated on a 4-point Likert scale, where higher scores indicate greater levels of satisfaction. In this study, the reliability of the LSS was established with a Cronbach's alpha value of 0.90.

Data analysis

The SPSS software (version 27) was utilized to provide a descriptive analysis of the data. For the path analysis and model fit assessment, the AMOS module (Version 26) was employed. To evaluate the overall fit of the model, several recommended indices were calculated in this study: Chi-Square Minimum per degree of freedom $CMIN/df$, the goodness of fit index (GFI), the adjusted goodness of fit index (AGFI), the normed fit index (NFI), the comparative fit index (CFI), the root-mean-square error of approximation (RMSEA), the Root-mean-square residual (RMR), and Incremental Fit Index (IFI) [48].

Based on recommended thresholds in the literature, the acceptable level for the model fit indicators in the current study were defined as follows: $CMIN/DF$ between 3 and 5, $GFI > 0.90$,

$AGFI > 0.80$, [49]; RMSEA between 0.05 and 0.08, CFI between 0.90 and 0.95, and $RMR < 0.05$ [50]; and an adequate level for IFI [51]. To assess the significance of indirect effects in mediation models, bootstrapping procedures were employed using 5,000 resamples drawn from the original dataset. This approach generates bias-corrected confidence intervals for each estimated indirect effect, with mediation considered statistically significant when the resulting interval does not include zero.

Results and Findings

Preliminary analyses

Table 2 presents the means, standard deviations, skewness, kurtosis, and correlations between all research variables. The results indicate that all measures met the standard for univariate normality, with skewness and kurtosis values ranging from -0.17 to -0.44, which fall within the acceptable range of -1.96 to +1.96 at a significance level of .05 [49]. The Durbin-Watson statistic (1.76) fell within the acceptable range of 1.5–2.5, indicating no significant autocorrelation, while VIF (< 5) and tolerance (> 0.2) values indicated no substantial multicollinearity [49]. These findings indicate that the prerequisites for SEM were met.

Measurement model

The confirmatory factor analysis of the overall measurement model revealed a satisfactory model fit ($CMIN/df = 663/203 = 3.27$, $p < 0.000$; $IFI = 0.93$; $GFI = 0.86$; $AGFI = 0.83$; $NFI = 0.90$; $CFI = 0.93$; $RMSEA = 0.07$; $RMR = 0.05$). The results showed that the factor loadings of the latent variables (social support, affective engagement, behavioral engagement, and satisfaction) in the measurement model ranged from 0.53 to 0.86, all of which are well above the acceptable threshold of 0.30 as suggested by Kline [48].

Table 2: Descriptive statistics for focal variables

Factors	Mean	SD	Skewness	Kurtosis	TOL	VIF	1	2	3	4
1. Social Support	2.89	0.88	-0.31	-0.43	0.31	3.24	1			
2. Affective Engagement	2.95	0.93	-0.31	-0.17	0.36	2.80	0.67**	1		
3. Behavioral Engagement	3.01	0.88	-0.37	-0.29	0.34	2.92	0.68**	0.64**	1	
4. Satisfaction	2.87	0.94	-0.25	-0.44	-	-	0.73**	0.73**	0.72**	1

$p < .05$; ** $p < .01$; SD = Standard Deviation; TOL = Tolerance; VIF = Variance Inflation Factor

The construct validity was evaluated by analyzing both convergent and discriminant validity. Convergent validity was assessed using average variance extracted (AVE). In this analysis, the AVEs of all the constructs were above the threshold of 0.50, indicating good convergent validity [49]. Discriminant validity was also assessed to ensure that the constructs are distinct from one another. According to Fornell and Larcker, discriminant validity is demonstrated when the square root of the AVE for each construct exceeds the correlations between that construct and other constructs, indicating that all constructs in the model have achieved discriminant validity, confirming the uniqueness of each construct in the measurement model [59]. Furthermore, construct reliability was assessed using composite reliability (CR) and Cronbach's alpha, indicating satisfactory reliability for all six observed variables, with values exceeding the 0.70 threshold [48] (Table 3).

Structural model

We analyzed the structural model to investigate the research hypotheses. As hypothesized, the structural model offered a good fit to the data (CMIN /df = 681/204 = 3.34, $p < 0.000$; IFI = 0.92; GFI = 0.86; AGFI = 0.83; NFI = 0.90; CFI = 0.92;

RMSEA = 0.07; RMR = 0.05). As shown in Figure 2, the findings indicated that increasing social support had a positive effect on improving students' satisfaction ($\beta = 0.37$, $p = 0.01$), which confirmed our first research hypothesis (i.e., H1). The findings also showed that increasing students' social support had a positive and significant effect on increasing affective engagement ($\beta = 0.90$, $p = 0.000$), which confirms the second hypothesis (i.e., H2). Moreover, the results of the analysis showed that increasing students' social support had a positive effect on increasing behavioral engagement ($\beta = 0.92$, $p = 0.000$). So, the third hypothesis of the study, i.e., H3, was also confirmed.

Also, the results of the analysis showed that increasing students' affective engagement had a positive effect on increasing satisfaction ($\beta = 0.41$, $p = 0.000$). So, the fourth hypothesis of the study, i.e., H4, was also confirmed. Also, the results of the analysis showed that increasing students' behavioral engagement had a positive effect on increasing satisfaction ($\beta = 0.25$, $p = 0.02$). So, the fifth hypothesis of the study, i.e., H5, was also confirmed. Table 4 demonstrates the summary of the direct, indirect, and total effects of the proposed relationships.

Table 3: The measurement model

Constructs	α	CR	AVE	1	2	3	4
1. Social Support	0.92	0.92	0.56	(0.75)			
2. Affective Engagement	0.86	0.86	0.61	0.67	(0.78)		
3. Behavioral Engagement	0.81	0.82	0.54	0.68	0.64	(0.73)	
4. Satisfaction	0.90	0.90	0.65	0.73	0.73	0.72	(0.81)

Note: The square roots of AVEs from observed variables are on the diagonal and within parentheses; off-diagonal numbers are correlations among observed variables. α = Cronbach alpha; CR = Composite Reliability; AVE = Average Variance Extracted

Table 4: The summary of direct, indirect, and total effects

Hypotheses	Proposed relationship	Direct effect	Indirect effect	Total effect
H1	Social support → Satisfaction	.37	0.60	.97
H2	Social support → Affective engagement	.90	-	.90
H3	Social support → Behavioral engagement	.92	-	.92
H4	Affective engagement → Satisfaction	.41	-	.41
H5	Behavioral engagement → Satisfaction	.25	-	.25
H6	Social support → Affective engagement → Satisfaction	.37	.37	.74
H7	Social support → Behavioral engagement → Satisfaction	.37	.23	.60

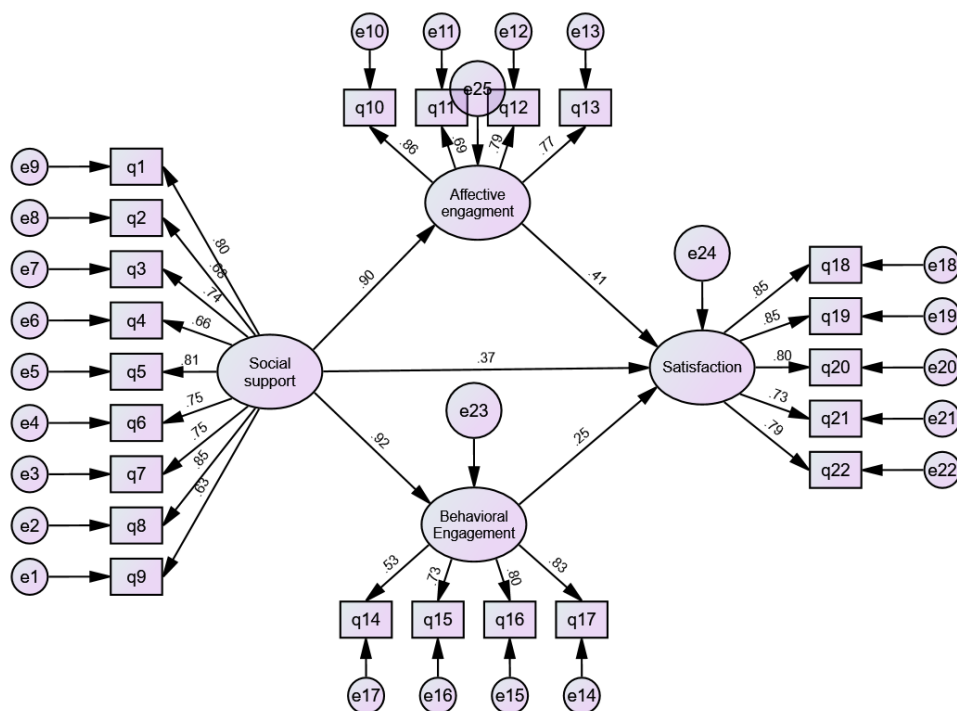


Fig. 2: Final empirical structural model

Mediation analyses

To examine whether affective and behavioral engagement function as mediators in the relationship between perceived social support and student satisfaction, a bootstrapping procedure with 5,000 resamples was conducted. This analytical strategy was selected

based on recommendations in recent methodological literature, which advocate for bootstrapping as a particularly robust approach to testing mediation, especially in studies involving relatively large sample sizes [60].

The results showed that the standardized direct effect of social support on satisfaction

was $\beta = 0.37$, $p = 0.01$. The indirect effect of social support on students' satisfaction with the mediating role of affective engagement was $\beta = 0.37$, wherein the CI was between the range of 0.26–0.64, and the 95% CI did not include zero. Moreover, the indirect effect of social support on students' satisfaction with the mediating role of behavioral engagement was $\beta = 0.23$, wherein the CI was between the range of 0.05–0.57, and the 95% CI did not include zero. This result indicates that the indirect effect between social support and satisfaction through affective and behavioral engagements is significant. After including affective and behavioral engagements as intermediate variables, the association between social support and satisfaction was reduced, but it still remained significant. This shows that affective and behavioral engagements partially mediated the effect of social support on satisfaction; hence, hypotheses H4 and H5 were supported. The indirect effect of social support on satisfaction through affective and behavioral engagements was significant. Thus, considering the confirmation of the research hypotheses and the significant effects of the research variables on each other, it can be concluded that the proposed research model was approved as the final model (see Fig. 2).

Discussion

The primary objective of this research was to examine whether academic engagement, specifically its affective and behavioral dimensions, mediates the relationship between perceived social support and satisfaction with online learning among master's students. Analysis of the data confirmed all seven hypotheses proposed in the study, demonstrating both direct and indirect pathways through which the variables of interest are interconnected.

Taken together, these findings contribute to theoretical understandings of how engagement functions within digital learning contexts while also offering practical implications for the design and facilitation of online educational experiences that foster student satisfaction. First, the results confirmed that social support has a positive and significant direct effect on students' satisfaction (H1: $\beta = 0.37$, $p < 0.01$). This finding is consistent with previous studies that have underscored the value of supportive interpersonal exchanges, especially those involving instructors and fellow students, in shaping learners' satisfaction within online educational settings [15] [61]. By fostering a sense of belonging and alleviating the isolation often experienced in digitally mediated environments, social support contributes meaningfully to the maintenance of student satisfaction [62]. Second, social support was found to significantly predict both affective engagement (H2: $\beta = 0.90$, $p < 0.001$) and behavioral engagement (H3: $\beta = 0.92$, $p < 0.001$). These findings are in line with the self-system motivational perspective, which holds that when contextual conditions are supportive, students' engagement is strengthened through the satisfaction of fundamental psychological needs, namely, autonomy, competence, and relatedness [63–64]. Within online learning environments, where physical distance can leave students feeling disconnected, the presence of social support becomes an especially valuable resource, one that encourages both active participation and positive emotional involvement in academic tasks. Third, both affective engagement (H4: $\beta = 0.41$, $p < 0.001$) and behavioral engagement (H5: $\beta = 0.25$, $p < 0.05$) were found to positively influence satisfaction.

These results align with earlier research establishing engagement as a significant

predictor of both satisfaction and academic achievement in higher education contexts [15][30][65]. Affective engagement captures the emotional bonds students form with their learning experiences, fostering greater intrinsic motivation and genuine enjoyment of academic tasks. Behavioral engagement, by contrast, is reflected in the effort learners invest, their persistence in the face of challenges, and their active involvement in course activities, each of which contributes to a more rewarding and meaningful educational journey [66]. The mediation analyses revealed that affective engagement (H6: $\beta = 0.37$, 95% CI [0.26, 0.64]) and behavioral engagement (H7: $\beta = 0.23$, 95% CI [0.05, 0.57]) partially mediated the relationship between social support and satisfaction. Taken together, these findings point to a dual role for social support in shaping student satisfaction, operating both directly and indirectly through its influence on engagement. This mediating pathway finds theoretical support in engagement-mediated models of academic success, which contend that contextual variables shape educational outcomes largely by shaping how students engage with their learning [67]. Consistent with this perspective, recent investigations into online and blended learning environments have reported comparable patterns, with engagement functioning as a bridge between supportive conditions and favorable academic results [15].

The observation that affective engagement exerted a stronger mediating influence than its behavioral counterpart may reflect the particular salience of emotional connection in shaping how social support translates into satisfaction within the Iranian cultural setting. This pattern could be understood in light of the collectivist orientation that characterizes Iranian society, where interpersonal ties and emotional bonds carry considerable weight

[68]. In such a context, the support individuals receive from others may contribute to satisfaction less by prompting observable actions and more by nurturing positive emotional experiences and reinforcing a sense of belonging. From a methodological perspective, the application of bootstrapping techniques with 5,000 resamples yielded reliable estimates of the indirect effects under investigation, with confidence intervals confirming the statistical significance of the proposed mediation pathways. This analytical approach is extensively endorsed in the methodological literature as a preferred strategy for testing mediation within structural equation modeling frameworks, particularly in situations involving non-normal data distributions or models of considerable complexity [69–70].

Conclusions

The present research adds to the expanding scholarly conversation surrounding student engagement and satisfaction in online learning contexts through the empirical examination of a mediation model linking social support, affective and behavioral engagement, and satisfaction. The results offer confirming evidence that social support functions as a significant predictor of both engagement and satisfaction, while also revealing that engagement operates as a central mechanism through which support exerts its influence on learners' overall contentment. Taken together, these findings carry important implications for the design of digital learning environments, highlighting the value of cultivating supportive interpersonal dynamics and deliberately fostering conditions that encourage meaningful student engagement.

While the present study employed rigorous analytical procedures, several limitations should be considered when interpreting its

findings. First, the use of cross-sectional survey data introduces certain constraints inherent to this methodological approach. Reliance on self-reported measures raises the possibility of response bias, as participants may not always accurately recall or articulate their experiences [71]. Future research would benefit from incorporating both subjective and objective indicators, alongside qualitative methods such as interviews, to develop a more nuanced understanding of the relationships identified here [72]. Second, the cross-sectional design precludes any definitive claims about causal direction. To establish causality and trace how these dynamics unfold over time, longitudinal or experimental designs would be necessary [73]. Third, the sample was restricted to graduate students enrolled in Iranian institutions, which may limit the extent to which findings can be generalized to other educational levels or cultural settings.

Based on the findings and limitations of the present study, several suggestions for future research can be offered. Replicating this work across diverse populations and national contexts would help clarify whether and how cultural factors moderate the observed relationships. In addition, future investigations might extend the scope of inquiry by examining other facets of engagement such as cognitive and agentic dimensions as well as additional outcome variables including academic performance and student retention. Exploring the potential moderating influence of individual differences, such as learners' self-regulation abilities or digital literacy, could also offer valuable insights into the conditions under which support and engagement most effectively contribute to positive outcomes. In sum, this research highlights the central role that social support and academic engagement play in shaping students' satisfaction with online learning. By cultivating supportive

relationships and fostering meaningful engagement, educators and institutions can contribute to the creation of online learning environments that are not only more satisfying for students but also more conducive to their academic success.

Authors' Contribution

Author 1 conceptualized and designed the research, supervised the overall process, and prepared the initial draft of the manuscript. Author 2 was responsible for data collection and execution of the study. Both authors collaborated on revising and editing the final version. All authors have read and approved the submitted manuscript.

Acknowledgments

We extend our sincere thanks to everyone who has contributed to the successful completion of this paper.

Conflicts of Interest

There are no conflicts of interest to declare.

References

- [1] Maican CI, Cazan AM, Cocoradă E, Dovleac L, Lixăndroiu RC, Maican MA, et al. The role of contextual and individual factors in successful e-learning experiences during and after the pandemic: a two-year study. *J Comput Educ.* 2025;12(2):589–624. doi:10.1007/s40692-024-00323-0.
- [2] Mensah C, Kugbonu MA, Appietu ME, Nti GA, Forson MA. Social support, computer self-efficacy, online learning engagement and satisfaction among undergraduate hospitality students. *Cogent Educ.* 2024;11(1):2335803. doi:10.1080/2331186X.2024.2335803.
- [3] Singh A, Ishrat A. The role of social support in enhancing self-efficacy and learning satisfaction in online education among secondary school students. *On Horiz.* 2025;33(3):320–37. doi:10.1108/OTH-03-2025-0033.
- [4] Sanders LD, Daly AP, Fitzgerald K. Predicting retention, understanding attrition: a prospective study of foundation year students. *Widening Particip Lifelong Learn.* 2016;18(2):50–83. doi:10.5456/WPLL.18.2.50.

- [5] Henrie CR, Halverson LR, Graham CR. Measuring student engagement in technology-mediated learning: a review. *Comput Educ.* 2015;90:36–53. doi:10.1016/j.compedu.2015.09.005.
- [6] Miller CJ, Perera HN, Maghsoudlou A. Students multidimensional profiles of math engagement: Predictors and outcomes from a self-system motivational perspective. *Br J Educ Psychol.* 2021;91(1):261–85. doi:10.1111/bjep.12358.
- [7] Wang MT, Fredricks JA, Ye F, Hofkens TL, Linn JS. The math and science engagement scales: scale development, validation, and psychometric properties. *Learn Instr.* 2016;43:16–26. doi:10.1016/j.learninstruc.2016.01.008.
- [8] Dixon MD. Measuring student engagement in the online course: the Online Student Engagement scale (OSE). *Online Learn.* 2015;19(4). doi:10.24059/olj.v19i4.561.
- [9] Toor KK. Parent-child relationship and students' academic achievement: a study of secondary school students. *MIER J Educ Stud Trends Pract.* 2018;8(1):38–56. doi:10.52634/mier/2018/v8/i1/1418.
- [10] Pfeifer MA, Cordero JJ, Stanton JD. What I wish my instructor knew: how active learning influences the classroom experiences and self-advocacy of STEM majors with ADHD and specific learning disabilities. *CBE Life Sci Educ.* 2023;22(1):ar2. doi:10.1187/cbe.21-12-0329.
- [11] Hsu JY, Chen CC, Ting PF. Understanding MOOC continuance: an empirical examination of social support theory. *Interact Learn Environ.* 2018;26(8):1100–18. doi:10.1080/10494820.2018.1446990.
- [12] Apker J. College student accounts of coping and social support during COVID-19-impacted learning. *Commun Q.* 2022;70(3):296–316. doi:10.1080/01463373.2022.2051574.
- [13] Tannert S, Gröschner A. Joy of distance learning? How student self-efficacy and emotions relate to social support and school environment. *Eur Educ Res J.* 2021;20(4):498–519. doi:10.1177/14749041211024784.
- [14] Federici RA, Skaalvik EM. Students' perception of instrumental support and effort in mathematics: the mediating role of subjective task values. *Soc Psychol Educ.* 2014;17(3):527–40. doi:10.1007/s11218-014-9264-8.
- [15] Kok XF, Pua CY, Puah S, Devilly OZ, Wang PC, Chua EC. The mediating role of student engagement in the relationship between teacher and digital support and learner satisfaction in blended learning environments at higher education. *Br Educ Res J.* 2025;51(3):1313–41. doi:10.1002/berj.4123.
- [16] Wortman CB, Dunkel-Schetter C. Conceptual and methodological issues in the study of social support. In: Baum A, Singer JE, editors. *Handbook of psychology and health.* Vol. 5, Stress. Hillsdale (NJ): Lawrence Erlbaum Associates; 1987. p. 63–108.
- [17] Cohen S, Hoberman HM. Positive events and social supports as buffers of life change stress. *J Appl Soc Psychol.* 1983;13(2):99–125. doi:10.1111/j.1559-1816.1983.tb02325.x.
- [18] Hu X, Song Y, Zhu R, He S, Zhou B, Li X, et al. Understanding the impact of emotional support on mental health resilience of the community in social media during the COVID-19 pandemic. *J Affect Disord.* 2022;308:360–8. doi:10.1016/j.jad.2022.04.105.
- [19] Lin TC, Hsu JSC, Cheng HL, Chiu CM. Exploring the relationship between receiving and offering online social support: a dual social support model. *Inf Manag.* 2015;52(3):371–83. doi:10.1016/j.im.2015.01.003.
- [20] Liu C, Ma J. Social support through online social networking sites and addiction among college students: the mediating roles of fear of missing out and problematic smartphone use. *Curr Psychol.* 2020;39(6):1892–9. doi:10.1007/s12144-018-0075-5.
- [21] Yao Z, Tang P, Fan J, Luan J. Influence of online social support on the public's belief in overcoming COVID-19. *Inf Process Manag.* 2021;58(4):102583. doi:10.1016/j.ipm.2021.102583.
- [22] Vasconcellos D, Parker PD, Hilland T, Cinelli R, Owen KB, Kapsal N, et al. Self-determination theory applied to physical education: a systematic review and meta-analysis. *J Educ Psychol.* 2020;112(7):1444–69. doi:10.1037/edu0000420.
- [23] Yan L, Tan Y. Feeling blue? Go online: an empirical study of social support among patients. *Inf Syst Res.* 2014;25(4):690–709. doi:10.1287/isre.2014.0538.
- [24] Weng C, Tsai CC, Weng A. Social support as a neglected e-learning motivator affecting trainees' decisions of continuous intentions of usage. *Australas J Educ Technol.* 2015;31(2):177–92. doi:10.14742/ajet.1311.
- [25] Wong L. Student engagement with online resources and its impact on learning outcomes. *J Inf Technol Educ Innov Pract.* 2013;12:129–46. doi:10.28945/1829.
- [26] Lin LC, Hung IC, Kinshuk, Chen NS. The impact of student engagement on learning outcomes in a cyber-flipped course. *Educ Technol Res Dev.* 2019;67:1573–91. doi:10.1007/s11423-019-09698-9.
- [27] Wang C, Mirzaei T, Xu T, Lin H. How learner engagement impacts non-formal online learning outcomes through value co-creation: an empirical analysis. *Int J Educ Technol High Educ.* 2022;19(1):32. doi:10.1186/s41239-022-00341-x.

- [28] Bergdahl N, Nouri J, Fors U, Knutsson O. Engagement, disengagement and performance when learning with technologies in upper secondary school. *Comput Educ.* 2020;149:103783. doi:10.1016/j.compedu.2019.103783.
- [29] Wang MT, Peck SC. Adolescent educational success and mental health vary across school engagement profiles. *Dev Psychol.* 2013;49(7):1266–76. doi:10.1037/a0030028.
- [30] Fredricks JA, Blumenfeld PC, Paris AH. School engagement: potential of the concept, state of the evidence. *Rev Educ Res.* 2004;74(1):59–109. doi:10.3102/00346543074001059.
- [31] Deng R, Benckendorff P, Gannaway D. Learner engagement in MOOCs: scale development and validation. *Br J Educ Technol.* 2020;51(1):245–62. doi:10.1111/bjet.12810.
- [32] Fredricks JA, Hofkens TL, Wang MT. Addressing the challenge of measuring student engagement. In: Renninger KA, Hidi SE, editors. *The Cambridge handbook of motivation and learning.* Cambridge: Cambridge University Press; 2019. p. 689–712. doi:10.1017/9781316823279.029.
- [33] Fredricks JA, McColskey W. The measurement of student engagement: a comparative analysis of various methods and student self-report instruments. In: Christenson SL, Reschly AL, Wylie C, editors. *Handbook of research on student engagement.* New York: Springer; 2012. p. 763–82. doi:10.1007/978-1-4614-2018-7_37.
- [34] Hernandez D, Jacomino G, Swamy U, Donis K, Eddy SL. Measuring supports from learning assistants that promote engagement in active learning: evaluating a novel social support instrument. *Int J STEM Educ.* 2021;8(1):22. doi:10.1186/s40594-021-00286-z.
- [35] Quin D. Longitudinal and contextual associations between teacher-student relationships and student engagement: a systematic review. *Rev Educ Res.* 2017;87(2):345–87. doi:10.3102/0034654316669434.
- [36] Wentzel KR, Muenks K, McNeish D, Russell S. Peer and teacher supports in relation to motivation and effort: a multilevel study. *Contemp Educ Psychol.* 2017;49:32–45. doi:10.1016/j.cedpsych.2016.11.002.
- [37] Havik T, Westergård E. Do teachers matter? Students' perceptions of classroom interactions and student engagement. *Scand J Educ Res.* 2020;64(4):488–507. doi:10.1080/00313831.2019.1577754.
- [38] Basith A, Rosmayadi R, Triani SN, Fitri F. Investigation of online learning satisfaction during COVID-19: in relation to academic achievement. *J Educ Sci Technol.* 2020;6(3):265–75. doi:10.26858/est.v1i1.14803.
- [39] Barrutia I, Danielli JJ, Seminario R, Monzón P. Qualitative analysis of the level of satisfaction with virtual education in university students in times of pandemic. *New Trends Qual Res.* 2021;7:220–8. doi:10.36367/ntqr.7.2021.220-228.
- [40] Moore JC, Shelton K. The Sloan Consortium pillars and quality scorecard. In: Shattuck K, editor. *Assuring quality in online education: practices and processes at the teaching, resource, and program levels.* Sterling (VA): Stylus Publishing; 2014. p. 40–9.
- [41] Meyer KA. Student engagement in online learning: what works and why. *ASHE High Educ Rep.* 2014;40(6):1–114. doi:10.1002/aehe.20018.
- [42] Croxton RA. The role of interactivity in student satisfaction and persistence in online learning. *J Online Learn Teach.* 2014;10(2):314–24.
- [43] Gao BW, Jiang J, Tang Y. The effect of blended learning platform and engagement on students' satisfaction: the case from tourism management teaching. *J Hosp Leis Sport Tour Educ.* 2020;27:100272. doi:10.1016/j.jhlste.2020.100272.
- [44] Fisher R, Perényi A, Birdthistle N. The positive relationship between flipped and blended learning and student engagement, performance and satisfaction. *Act Learn High Educ.* 2021;22(2):97–113. doi:10.1177/1469787418801702.
- [45] Yousaf HQ, Rehman S, Ahmed M, Munawar S. Investigating students' satisfaction in online learning: the role of students' interaction and engagement in universities. *Interact Learn Environ.* 2023;31(10):7104–21. doi:10.1080/10494820.2022.2061009.
- [46] Swedberg R. Exploratory research. In: Elman C, Gerring J, Mahoney J, editors. *The production of knowledge: enhancing progress in social science.* Cambridge: Cambridge University Press; 2020. p. 17–41. doi:10.1017/9781108762519.002.
- [47] Soper DS. A priori sample size calculator for structural equation models [Internet].
- [48] Kline RB. *Principles and practice of structural equation modeling.* 5th ed. New York: Guilford Press; 2023.
- [49] Hair JF Jr, Black WC, Babin BJ, Anderson RE. *Multivariate data analysis.* 7th ed. Upper Saddle River (NJ): Pearson Prentice Hall; 2010.
- [50] Hu LT, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Struct Equ Modeling.* 1999;6(1):1–55. doi:10.1080/10705519909540118.

- [51] Bollen KA. Structural equations with latent variables. New York: John Wiley & Sons; 1989.
- [52] Malecki CK, Demaray MK. What type of support do they need? Investigating student adjustment as related to emotional, informational, appraisal, and instrumental support. *Sch Psychol Q.* 2003;18(3):231–52. doi:10.1521/scpq.18.3.231.22576.
- [53] Tan JS, Hurd NM, Albright JN. Attachment, appraisal support, and the transition to college among underrepresented students. *Emerg Adulthood.* 2019;7(1):52–8. doi:10.1177/2167696817745454.
- [54] Taghizade A, Hosseini Largani M. Psychometric properties of the Persian version of the Social Support Questionnaire in online courses: a transcultural adaptation and psychometric study. *Interdiscip J Virtual Learn Med Sci.* 2025;16(3):254–68. doi:10.30476/ijvlms.2025.107766.1346.
- [55] Hoi VN, Le Hang H. The structure of student engagement in online learning: a bifactor exploratory structural equation modelling approach. *J Comput Assist Learn.* 2021;37(4):1141–53. doi:10.1111/jcal.12551.
- [56] Taghizade A, Musavian SS, Hosseinik SS. Psychometric properties of the Persian version of the Online Student Engagement Questionnaire: a transcultural adaptation and psychometric study. *Interdiscip J Virtual Learn Med Sci.* 2024;15(3):226–40. doi:10.30476/ijvlms.2024.102125.1299.
- [57] Chang KY. Factors affecting student satisfaction in different learning deliveries [dissertation]. Normal (IL): Illinois State University; 2011.
- [58] Taghizade A, Safdari Z, Saedi N. Psychometric properties of the Persian version of Learner Satisfaction Survey in online courses: a transcultural adaptation and psychometric study. *Interdiscip J Virtual Learn Med Sci.* 2023;14(1):47–59. doi:10.30476/ijvlms.2023.97699.1203.
- [59] Fornell C, Larcker DF. Evaluating structural equation models with unobservable variables and measurement error. *J Mark Res.* 1981;18(1):39–50. doi:10.1177/002224378101800104.
- [60] Mehrvarz M, Heidari E, Farrokhnia M, Noroozi O. The mediating role of digital informal learning in the relationship between students' digital competence and their academic performance. *Comput Educ.* 2021;167:104184. doi:10.1016/j.compedu.2021.104184.
- [61] Cho MH, Cho Y. Instructor scaffolding for interaction and students' academic engagement in online learning: mediating role of perceived online class goal structures. *Internet High Educ.* 2014;21:25–30. doi:10.1016/j.iheduc.2013.10.008.
- [62] Rovai AP. Building sense of community at a distance. *Int Rev Res Open Distrib Learn.* 2002;3(1):1–16. doi:10.19173/irrodl.v3i1.79.
- [63] Connell JP, Wellborn JG. Competence, autonomy, and relatedness: a motivational analysis of self-system processes. In: Gunnar MR, Sroufe LA, editors. *Self processes and development: Minnesota Symposium on Child Psychology.* Vol. 23. Hillsdale (NJ): Lawrence Erlbaum Associates; 1991. p. 43–77.
- [64] Skinner E, Furrer C, Marchand G, Kindermann T. Engagement and disaffection in the classroom: part of a larger motivational dynamic? *J Educ Psychol.* 2008;100(4):765–81. doi:10.1037/a0012840.
- [65] Kuh GD, Cruce TM, Shoup R, Kinzie J, Gonyea RM. Unmasking the effects of student engagement on first-year college grades and persistence. *J Higher Educ.* 2008;79(5):540–63. doi:10.1353/jhe.0.0019.
- [66] Reeve J. A self-determination theory perspective on student engagement. In: Christenson SL, Reschly AL, Wylie C, editors. *Handbook of research on student engagement.* New York: Springer; 2012. p. 149–72. doi:10.1007/978-1-4614-2018-7_7.
- [67] Reschly AL, Christenson SL. Jingle, jangle, and conceptual haziness: evolution and future directions of the engagement construct. In: Christenson SL, Reschly AL, Wylie C, editors. *Handbook of research on student engagement.* New York: Springer; 2012. p. 3–19. doi:10.1007/978-1-4614-2018-7_1.
- [68] Hofstede G. Culture's consequences: comparing values, behaviors, institutions, and organizations across nations. 2nd ed. Thousand Oaks (CA): Sage Publications; 2001.
- [69] Hayes AF. Introduction to mediation, moderation, and conditional process analysis: a regression-based approach. New York: Guilford Press; 2013.
- [70] Zhao X, Lynch JG Jr, Chen Q. Reconsidering Baron and Kenny: myths and truths about mediation analysis. *J Consum Res.* 2010;37(2):197–206. doi:10.1086/651257.
- [71] Cole JS, Gonyea RM. Accuracy of self-reported SAT and ACT test scores: implications for research. *Res High Educ.* 2010;51(4):305–19. doi:10.1007/s11162-009-9160-9.
- [72] Akyol Z, Garrison DR. Understanding cognitive presence in an online and blended community of inquiry: assessing outcomes and processes for deep approaches to learning. *Br J Educ Technol.* 2011;42(2):233–50. doi:10.1111/j.1467-8535.2009.01029.x.
- [73] Cole DA, Maxwell SE. Testing mediational models with longitudinal data: questions and tips in the use of structural

equation modeling. *J Abnorm Psychol.* 2003;112(4):558–77. doi:10.1037/0021-843X.112.4.558.

✉ A.Taghizade@cfu.ac.ir

AUTHOR(S) BIOSKETCHES

Abbas Taghizade is an assistant professor at Farhangian University, Iran. He has authored numerous scientific papers in journals and conferences. His research interests include instructional design, e-learning, AI applications in education, and social network analysis.

Taghizade, A., Assistant Professor, Department of Educational Sciences, Farhangian University, P.O. Box14665-889, Tehran, Iran.

Afzal Akbari Balootbangan is an assistant professor at Farhangian University, Iran. He has contributed numerous scholarly papers to academic journals and conferences. His research interests include educational psychology, psychometrics, and related fields such as assessment and evaluation, psychological measurement, and research methodology in educational settings.

Akbari Balootbangan, A., Assistant Professor, Department of Psychology and Counseling, Farhangian University, P.O. Box14665-889, Tehran, Iran.

✉ Akbariafzal@cfu.ac.ir

Citation (Vancouver): Taghizade A, Akbari Balootbangan A. [The Mediating Role of Academic Engagement in the Relationship between Social Support and Student Satisfaction in Online Learning Environments] *Tech. Edu. J.* 2026; 20(1): 79-96



<https://doi.org/10.22061/tej.2026.113160.3395>





ORIGINAL RESEARCH PAPER

ICT self-efficacy, ICT engagement and teaching enjoyment among Iranian EFL teachers: an age-moderated model

R. Nejati

English Department, Faculty of Humanities, Shahid Rajaee Teacher Training University, Tehran, Iran

ABSTRACT

Received: 01 August 2025
Reviewed: 16 September 2025
Revised: 09 November 2025
Accepted: 26 December 2025

KEYWORDS:

Age
EFL Teachers
ICT Self-efficacy
ICT Engagement
Teaching Enjoyment

* Corresponding author

✉ reza.nejati@sru.ac.ir

☎ (+9821) 22970035

Background and Objectives: The integration of information and communication technologies (ICTs) into English as a foreign language (EFL) instruction is now a routine aspect of educational practice. It may be related to teachers' motivation, emotional experiences, and professional well-being. Previous research has mainly focused on issues such as technology adoption, technical skills and attitudes toward ICT. Much less attention has been paid to the emotional consequences of technology use. In particular, positive emotions such as teaching enjoyment remain underexplored. Age may be especially relevant in this respect. The present study examined the relationships among ICT self-efficacy, ICT engagement, and teaching enjoyment among Iranian high school EFL teachers. The study tested whether ICT engagement mediates the relationship between ICT self-efficacy and teaching enjoyment. It also investigated whether age moderates both the direct and indirect associations among these variables.

Materials and Methods: A cross-sectional correlational design was employed. Participants comprised 194 Iranian high school EFL teachers recruited through purposive sampling via social networking platforms. Participation was voluntary and anonymous. Teachers completed three self-report questionnaires assessing ICT self-efficacy, ICT engagement, and foreign language teaching enjoyment. All instruments were administered in Persian following a rigorous translation, back-translation, and content validation procedure. Teaching enjoyment was measured using a scale capturing personal enjoyment, student-related enjoyment, and collegial enjoyment. ICT engagement assessed teachers' behavioral, cognitive, motivational, and social involvement with digital technologies. ICT self-efficacy measured teachers' perceived capability to use ICT for instructional, professional, and communicative purposes. Age was operationalized as a categorical variable. Before analysis, data were screened for normality, multicollinearity, and suitability for parametric procedures. Structural equation modeling and regression-based analyses were conducted to test mediation, moderation, and moderated mediation associations. Indirect associations were evaluated using bootstrapped confidence intervals to ensure robust estimation of conditional relationships.

Findings: The results indicated that ICT self-efficacy was positively associated with both ICT engagement and teaching enjoyment. ICT engagement was also positively associated with teaching ICT self-efficacy and teaching enjoyment. Age significantly moderated the relationship between ICT engagement and teaching enjoyment. Among younger teachers, higher levels of ICT engagement were associated with greater teaching enjoyment. Among older teachers, this relationship was weak and not statistically significant. ICT self-efficacy was negatively related to ICT engagement among older teachers. Moderated mediation analyses further showed that ICT engagement mediated the relationship between ICT self-efficacy and teaching enjoyment only among younger teachers. For older teachers, the indirect association did not reach statistical significance. After accounting for engagement, the relationship between ICT self-efficacy and teaching enjoyment is partially moderated by age.

Conclusions: These findings suggest that ICT engagement plays a crucial role in translating teachers' ICT self-efficacy into teaching enjoyment, but this process is partially moderated by age. For younger teachers, engagement with technology appears to be an emotionally meaningful activity through which confidence in ICT use is associated with teaching enjoyment. For older teachers, ICT use may be more selective or instrumental, carrying less

affective significance. The results underscore the importance of adopting an age-sensitive perspective in professional development and technology integration policies. Teaching enjoyment is associated with more than improving technical skills. It is also associated with meaningful, autonomy-supportive forms of ICT engagement that align with teachers' pedagogical values and professional identities. Limitations include reliance on self-report measures, non-probability sampling and a cross-sectional design that precludes causal inference. Future research would benefit from longitudinal designs to explore how technology-related emotions are associated across teachers' age groups and how contextual factors shape these experiences in diverse educational settings.



COPYRIGHTS

© 2026 The Author(s). This is an open-access article distributed under the terms and conditions of the Creative Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) (<https://creativecommons.org/licenses/by-nc/4.0/>)



NUMBER OF REFERENCES

72



NUMBER OF FIGURES

0



NUMBER OF TABLES

5

مقاله پژوهشی

خودکارآمدی فناوری، درگیری با فناوری و لذت تدریس در میان معلمان زبان انگلیسی ایران: مدلی با نقش تعدیل‌گری سن

رضا نجاتی

گروه زبان انگلیسی، دانشکده علوم انسانی، دانشگاه تربیت دبیر شهید رجایی، تهران، ایران

چکیده

پیشینه و اهداف: ادغام فناوری‌های اطلاعاتی و ارتباطی در آموزش زبان انگلیسی به‌عنوان زبان خارجی امروزه به بخشی عادی از شیوه‌های آموزشی تبدیل شده است. این ادغام می‌تواند با انگیزه معلمان، تجربه‌های هیجانی و آسایش شغلی آنان مرتبط باشد. پژوهش‌های پیشین عمدتاً بر موضوعاتی مانند پذیرش فناوری، مهارت‌های فنی و نگرش نسبت به فناوری آموزش تمرکز داشته‌اند، درحالی‌که به پیامدهای هیجانی استفاده از فناوری توجه بسیار کمتری شده است. به‌ویژه، هیجان‌های مثبت مانند لذت تدریس کمتر مورد بررسی قرار گرفته‌اند. سن معلم در این زمینه می‌تواند اهمیت بسزایی داشته باشد. پژوهش حاضر روابط میان «خودکارآمدی فناوری»، «درگیری با فناوری» و لذت تدریس را در میان دبیران زبان انگلیسی دبیرستان‌ها در ایران بررسی کرد. این مطالعه نقش «درگیری با فناوری» را به‌عنوان میانجی بین رابطه «خودکارآمدی فناوری» و لذت تدریس و نقش سن را به‌عنوان متغیر تعدیل در رابطه سه متغیر مذکور بررسی کرده است.

روش‌ها: در این پژوهش از طرح همبستگی استفاده شد. شرکت‌کنندگان شامل ۱۹۴ دبیر زبان انگلیسی دبیرستان‌های ایران بودند که از طریق نمونه‌گیری هدفمند و با استفاده از سکوها شبکه‌های اجتماعی جذب شدند. مشارکت داوطلبانه و ناشناس بود. معلمان سه پرسش‌نامه خوداظهاری را برای سنجش «خودکارآمدی فناوری»، «درگیری با فناوری» و لذت تدریس زبان خارجی تکمیل کردند. همه ابزارها پس از اجرای دقیق فرایند ترجمه، بازترجمه و اعتبارسنجی محتوایی به زبان فارسی اجرا شدند. لذت تدریس با مقیاسی سنجیده شد که لذت شخصی، لذت مرتبط با دانش‌آموز و لذت تعامل با همکاران را در بر می‌گرفت. «درگیری با فناوری» میزان مشارکت رفتاری، شناختی، انگیزشی و اجتماعی معلمان با فناوری‌های دیجیتال را ارزیابی می‌کرد. «خودکارآمدی فناوری» نیز توان ادراک‌شده معلمان برای استفاده آموزشی، حرفه‌ای و ارتباطی از فناوری را می‌سنجید. سن به‌صورت متغیر مقوله‌ای عملیاتی شد. پیش از تحلیل، داده‌ها از نظر نرمال بودن، هم‌خطی چندگانه و مناسب بودن برای آزمون‌های پارامتریک بررسی شدند. برای آزمون روابط میانجی‌گری، تعدیل‌گری و «میانجی‌گری تعدیل‌شده» از مدل‌یابی معادلات ساختاری و تحلیل‌های مبتنی بر رگرسیون استفاده شد.

تاریخ دریافت: ۱۰ مرداد ۱۴۰۴
تاریخ دوری: ۲۵ شهریور ۱۴۰۴
تاریخ اصلاح: ۱۸ آبان ۱۴۰۴
تاریخ پذیرش: ۰۵ دی ۱۴۰۴

واژگان کلیدی:

سن
دبیران زبان انگلیسی
خودکارآمدی فناوری
درگیری با فناوری
لذت تدریس

* نویسنده مسئول

Reza.nejati@sru.ac.ir

۰۲۱-۲۲۹۷۰۰۳۵ ①

روابط غیرمستقیم با بهره‌گیری از فاصله‌های اطمینان «بوت‌استرپ» ارزیابی شدند تا برآوردی دقیق از روابط شرطی حاصل شود.

یافته‌ها: نتایج نشان داد که «خودکارآمدی فناوری» با هر دو متغیر «درگیری با فناوری» و لذت تدریس رابطه مثبت دارد. «درگیری با فناوری» نیز با «خودکارآمدی فناوری» و لذت تدریس رابطه مثبت نشان داد. سن معلمان رابطه میان «درگیری با فناوری» و لذت تدریس را به طور معنادار تعدیل کرد. در میان معلمان جوان‌تر، سطوح بالاتر «درگیری با فناوری» با لذت تدریس بیشتر همراه بود؛ اما در میان معلمان مسن‌تر، این رابطه ضعیف و از نظر آماری معنادار نبود. «خودکارآمدی فناوری» در میان معلمان مسن‌تر با «درگیری با فناوری» رابطه منفی داشت. تحلیل‌های میانجی‌گری تعدیل‌شده همچنین نشان داد که تنها در میان معلمان جوان‌تر «درگیری با فناوری» در رابطه بین «خودکارآمدی فناوری» و لذت تدریس نقش میانجی دارد. برای معلمان مسن‌تر، رابطه غیرمستقیم به سطح معناداری آماری نرسید. پس از تثبیت سهم «درگیری با فناوری»، رابطه میان «خودکارآمدی فناوری» و لذت تدریس در حد بسیار کم توسط عامل سن تعدیل می‌شود.

نتیجه‌گیری: این یافته‌ها نشان می‌دهد که «درگیری با فناوری» نقش محوری در تبدیل «خودکارآمدی فناوری» معلمان به لذت تدریس ایفا می‌کند، اما این فرایند تا حدی توسط سن تعدیل می‌شود. به نظر می‌رسد برای معلمان جوان‌تر، «درگیری با فناوری» فعالیتی هیجانی باشد که از طریق آن، اعتماد به استفاده از فناوری با لذت تدریس پیوند می‌یابد. برای معلمان مسن‌تر، استفاده از فناوری ممکن است گزینشی‌تر یا ابزاری‌تر باشد و بار عاطفی کمتری داشته باشد. نتایج بر اهمیت اتخاذ رویکردی حساس به سن در برنامه‌های تربیت‌معلم و سیاست‌های ادغام فناوری تأکید می‌کند. لذت تدریس صرفاً به بهبود مهارت‌های فنی محدود نمی‌شود؛ بلکه به‌صورت معنادار و حمایت‌کننده و اختیاری با «درگیری با فناوری» نیز مرتبط است که با ارزش‌های آموزشی و هویت‌های حرفه‌ای معلمان هم‌راستا باشند. محدودیت‌های پژوهش شامل اتکا به ابزارهای خوداظهاری، نمونه‌گیری غیرتصادفی و طرح مقطعی است که استنباط علی را غیرممکن می‌کند. پژوهش‌های آینده می‌توانند با طرح‌های طولی هیجان‌های مرتبط با فناوری در گروه‌های سنی مختلف معلمان را بررسی و عوامل زمینه‌ای این تجربه‌ها را در محیط‌های آموزشی متنوع کشف کنند.

Introduction

The expansion of information and communication technologies (ICTs) in EFL contexts has altered how English is taught, extending its impact beyond instructional techniques. Research suggests that ICT adoption also bears on teachers' motivational states, emotional responses, and psychological experiences [1,2]. While early research emphasized access to digital tools and technical skills, recent studies suggest that effective ICT integration depends more critically on teachers' engagement with technology, their self-efficacy beliefs, and affective outcomes such as teaching enjoyment [3–6]. These psychological factors are particularly important, as technology adoption alone does not guarantee instructional effectiveness or teacher well-being.

From the Uses and Gratifications Theory (UGT) perspective, teachers' engagement with

ICT is driven by the intention to meet specific professional and instructional demands, such as supporting student learning, obtaining instructional materials, and facilitating classroom management tasks [7–9]. Moving beyond explanations centered solely on needs, the Technology Acceptance Model (TAM) highlights perceived usefulness and perceived ease of use as central determinants of teachers' continued involvement with technological tools [10,11]. However, TAM's rationalist focus may underrepresent motivational and affective processes, while UGT-based studies often remain descriptive, limiting insight into the psychological mechanisms that sustain engagement over time [12,13].

Closely related to ICT engagement is ICT self-efficacy, rooted in Bandura's [14] Social Cognitive Theory, which holds that teachers with higher ICT self-efficacy are more tending to adopt digital tools, implement innovative instructional practices, and persist when facing

technological challenges [15,16]. From a Self-Determination Theory (SDT) perspective, perceived competence supports intrinsic motivation and autonomy, thereby fostering engagement and well-being [17–19].

Teaching enjoyment has emerged as a theoretically important affective dimension of teachers' engagement with ICT, particularly in EFL contexts [20,21]. Teaching enjoyment refers to a positive and enduring emotional state associated with satisfaction and engagement in instructional activities [22–24]. According to Flow Theory, teachers experience enjoyment when the challenges they face in instruction are well matched to their perceived skills, leading to intense involvement and intrinsic satisfaction [25–27]. From the perspective of Broaden-and-Build Theory, enjoyment functions as a resource-generating emotion that broadens teachers' cognitive and behavioral capacities, promoting upward spirals of engagement and strengthening self-efficacy [28,29]. However, empirical models that integrate ICT engagement, self-efficacy, and teaching enjoyment—particularly in EFL settings—remain limited [30].

Individual differences, notably age, may moderate these relationships. Research indicates that older teachers often report lower levels of ICT self-efficacy, potentially reflecting differential exposure, variations in digital fluency, or stronger reliance on established instructional routines [31,32]. From a lifespan perspective, age may influence how teachers render ICT engagement and efficacy beliefs into affective experiences, such as enjoyment. Yet age is rarely modeled as a moderator in these psychological pathways, leaving important developmental and contextual dynamics insufficiently understood [33].

Review of the Related Literature

ICT self-efficacy refers to teachers' beliefs in their ability to use digital tools effectively for instructional purposes [14,15,33]. These beliefs influence how teachers approach new technologies, respond to challenges, and integrate ICT into classroom routines. Self-efficacy is partly technical and partly pedagogical; however, dominant frameworks often foreground operational skills (e.g., navigating software, troubleshooting) over relational or instructional uses of technology, reflecting what scholars describe as technorationalist framings of teacher competence [34].

Older teachers often report lower ICT self-efficacy than younger colleagues, a pattern frequently attributed to later exposure to digital technologies and professional socialization in pre-digital instructional contexts [35,36]. For many, ICT competence developed reactively in response to institutional mandates rather than through exploratory or self-initiated use, which may influence how technology is integrated into established pedagogical routines [32].

Iranian EFL research similarly indicates that younger teachers tend to report higher confidence and greater engagement with multimedia tools and digital platforms than older colleagues [37]. These differences appear to reflect variations in professional socialization rather than simple skill deficits.

Importantly, lower ICT self-efficacy does not necessarily indicate lower technical skill. Rather, efficacy beliefs are shaped by professional identity and accumulated pedagogical experience, which may influence how digital practices are emotionally appraised, particularly among older teachers [14,2].

ICT engagement is generally viewed as a multidimensional construct that encompasses teachers' behavioral, cognitive, and emotional involvement with technology [38]. It refers not only to how often teachers use digital tools, but also to the depth and meaningfulness of their interactions with them [39]. ICT engagement involves activities such as exploring and experimenting with digital resources, thereby sustaining their use over time, and integrating them purposefully into pedagogical practice.

Age moderates ICT engagement partly because teachers' motivational dispositions, professional priorities and identity concerns evolve across the life span [40,41]. Younger teachers often approach technology with curiosity, ambition and identity-building motives. As such, ICT competence is viewed as an indicator of modern pedagogy and professional legitimacy within contemporary educational contexts [42,30]. For many young teachers, digital proficiency is closely tied to aspirations for innovation and recognition [43].

As teachers accumulate experience, ICT engagement tends to become more selective and pragmatic. Mid-career teachers, who frequently balance intensified teaching demands alongside administrative responsibilities and family commitments, are more likely to evaluate technology use in terms of cost–benefit considerations, asking whether the effort invested yields tangible pedagogical returns [41,44]. In later career stages, teachers often rely on instructional approaches that have demonstrated effectiveness over time, which can lead to more cautious or skeptical orientations toward ICT adoption, particularly when new technologies are perceived as disruptive to established practices rather than supportive of them [45].

Iran's educational system has experienced some technology reforms, often structured through centralized, top-down policy initiatives

that seek to modernize teaching and learning (e.g., adoption of national educational ICT platforms and infrastructure programs) but whose implementation varies widely across regions (e.g., connectivity, access to devices) [46,47].

Teaching enjoyment is a positive emotional experience that emerges when teachers feel effective, connected, and productive [48,49]. Enjoyment matters because it supports persistence, creativity and pedagogical risk-taking. Research shows that technology can increase enjoyment by diversifying instructional materials, enabling interactive tasks and enhancing communication [50]. However, ICT can also erode enjoyment when it introduces technical problems, cognitive overload, or unfamiliar routines—particularly for teachers with lower ICT self-efficacy.

Teachers' emotional reactions to technology can be effectively explored by integrating insights from both Self-Determination Theory (SDT) and the Technology Acceptance Model (TAM). SDT posits that positive feelings and intrinsic motivation toward professional activities emerge when individuals experience autonomy, competence, and relatedness [18]. In technology-rich teaching settings, these needs are more likely to be satisfied when teachers feel capable of using ICT, perceive choice in its implementation, and maintain meaningful interactions with students and colleagues [2]. TAM emphasizes that perceived usefulness and ease of use shape attitudes toward technology and intentions to adopt it [10,11]. Empirical research suggests that age and teaching experience may relate to teachers' attitudes towards ICT use, although these relationships are typically modest and highly context-dependent rather than uniformly linear [51]. In addition to age, alignment between technological tools and teachers' pedagogical values, instructional goals, and classroom

interaction patterns appears central to fostering positive emotional engagement. Mohammadi & Yousofi [52] highlight the importance of relational, narrative and culturally mediated pedagogical practices in shaping teachers' affective experience.

The literature consistently links ICT self-efficacy to teachers' engagement with digital technologies, which in turn shapes their enjoyment of teaching. This association, however, is indirect and varies with age. Conceptualizing ICT engagement as a mediating variable between self-efficacy and teaching enjoyment, with age as a moderator, provides a lens for understanding why digitalization produces uneven emotional outcomes among Iranian EFL teachers.

From a Social Cognitive and Self-Determination perspective, ICT self-efficacy reflects perceived competence as a core driver of autonomous engagement [14,18]. Teachers who are competent in using ICT tend to explore and integrate digital tools. Nevertheless, self-efficacy alone does not guarantee enjoyment. Positive affect arises when engagement is meaningful, pedagogically aligned, and voluntary. Imposed tasks may reduce enjoyment even among competent users.

The Flow Theory clarifies this mediating role: enjoyment emerges when ICT challenges match teachers' skills [53]. Younger teachers, familiar with digital routines, more readily experience flow, reinforcing both engagement and self-efficacy. Older teachers often encounter a mismatch between task demands and established teaching schemas, which may trigger anxiety and weaken the self-efficacy–enjoyment link.

Research on teacher technology adoption suggests that positive ICT experiences can broaden educators' thought-action repertoires—expanding their cognitive flexibility and behavioral options for classroom

innovation—while repeated negative experiences (such as system instability or coercive implementation) may narrow engagement and diminish perceived competence, particularly among older teachers who face steeper learning curves [29,33].

These patterns align with Fredrickson's Broaden-and-Build Theory, which postulates that positive emotions broaden momentary thought-action repertoires and build enduring personal resources over time, whereas negative emotions narrow attention and behavioral options. While originally developed in positive psychology, this framework has been applied to technology contexts to explain how emotional responses to ICT shape long-term engagement trajectories.

TAM identifies perceived usefulness and perceived ease of use as major factors of technology adoption [10]. Empirical studies applying TAM to educational contexts have found that age-related differences in these perceptions are often mediated by prior experience rather than age itself and can influence adoption decisions among teachers [11]. Notably, self-efficacy is not a construct in the original TAM but appears in extended models (e.g., TAM2) and related frameworks like the Unified Theory of Acceptance and Use of Technology (UTAUT).

The Uses and Gratifications Theory offers a complementary lens by examining how teachers actively select technologies to satisfy specific professional needs (e.g., efficiency, student engagement), rather than passively responding to system features [8]. This theory does not address ease of use or self-efficacy but helps explain why educators pursue particular technologies based on anticipated gratifications.

The Broaden-and-Build Theory highlights how experiences with ICT build over time. Positive experiences can expand teachers'

thinking and actions, encouraging creativity and more engagement. On the other hand, early negative experiences such as unstable systems or top-down mandates can lower engagement and reduce feelings of competence, especially for older teachers. The Uses and Gratifications Theory and the Technology Acceptance Model add that age can shape how teachers see the usefulness and ease of digital tools. These perceptions, in turn, affect how self-efficacy leads to engagement and teaching enjoyment.

In Iranian EFL contexts, where teaching is deeply relational and professional authority is tied to experience, ICT self-efficacy does not automatically yield teaching enjoyment; rather, its emotional payoff depends on whether ICT engagement aligns with teachers' autonomy, competence, and pedagogical values [54]. Phenomenological evidence also shows that teacher enjoyment connects with perceptions of control and efficacy in instructional roles [52]. When engagement satisfies these personal and contextual needs, teachers experience more positive emotions, but when it conflicts with established pedagogical identities or relational values, enjoyment may diminish or even turn into frustration. Empirical evidence from Iranian EFL research supports mediated paths wherein engagement explains part of the link between competence-related constructs and work motivations or affect [55]. These patterns support a moderated mediation framework in which ICT engagement mediates the self-efficacy–enjoyment relationship and age (or experience level) moderates both the strength of engagement and its emotional outcome, helping explain why digitalization energizes some teachers while challenging others (e.g., age/experience differences in technology perception reported in teacher ICT attitude studies; see Clipa et al. [56]). The present study proposes the following questions.

- Does ICT engagement mediate the relationship between ICT self-efficacy and teaching enjoyment?
- Does age moderate the relationship between ICT self-efficacy and ICT engagement?
- Does age moderate the indirect relationship between ICT self-efficacy and teaching enjoyment through ICT engagement?

Method

Participants

The study focused on Iranian high school EFL teachers. Because there is no complete national registry of teachers and the population is geographically dispersed, participants were recruited through a mix of purposive and snowball sampling. Initial invitations were shared on popular social media platforms such as Telegram, WhatsApp, and Eitaa. Each recipient was encouraged to share the survey link with colleagues, facilitating a chain-referral recruitment process that has been shown to be effective for accessing dispersed professional communities [57].

A total of 194 teachers took part in the study. While non-probability sampling limits the generalizability of the findings, it remains a practical and accepted strategy in educational research when random sampling is unfeasible [58]. Screening analyses confirmed that the data were appropriate for parametric procedures: distributions showed acceptable skewness and kurtosis, linearity was evident in scatterplots, and variance inflation factors (VIFs) were below 5 [59]. Sample size guidelines for mediation and SEM analyses generally suggest a minimum of 200–250 participants [60]; accordingly, the present sample size can be considered adequate for examining the proposed associations and indirect pathways. Nevertheless, the use of digital platforms for recruitment may have favored teachers with

higher levels of technological competence, which could be reflected in relatively high levels of ICT engagement and teaching enjoyment in the sample.

Instruments

Data were collected using three questionnaires, namely, Foreign Language Teaching Enjoyment (FLTE), ICT Engagement, and ICT Self-Efficacy.

Teachers' language teaching enjoyment was quantified using the 10-item FLTE scale adapted from Dewaele and Li [55]. This instrument is grounded in positive psychology principles [61]. It assesses enjoyment across three dimensions, namely personal (Items 1, 4, 7, 10), student-centered (Items 2, 5, 8), and collegial enjoyment (Items 3, 6, 9). Responses were rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Reliability for the Persian adaptation was satisfactory ($\alpha = .88$), consistent with prior reports ($\alpha = .85-.89$; [55,62]).

The 21-item ICT Engagement Scale [1] measured teachers' attitudes, motivations, and behavioral patterns regarding technology use. The scale includes four subscales, namely interest in ICT (Items 1–6), perceived competence (Items 7–11), autonomy in ICT use (Items 12–17), and ICT as a social topic (Items 18–21). Participants indicated how frequently they engaged with each activity on a 5-point scale (1 = never, 5 = every day). Reliability of this questionnaire in the present sample was strong ($\alpha = .91$) and comparable to values reported in previous studies ($\alpha = .76-.89$; [1,63,64]).

Teachers' efficacy in using ICT was assessed with an 18-item scale developed by Compeau and Higgins [15], which evaluates self-efficacy across four domains, namely basic ICT operations and troubleshooting (Items 1–5), instructional use (Items 6–9), support for student-centered learning (Items 10–14), and professional communication (Items 15–18).

Items were rated on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). Reliability in this sample was excellent ($\alpha = .95$), consistent with prior research [65–66].

Age was operationalized as a categorical variable measured in self-reported years. Following recommendations in educational technology and organizational psychology research, age was modeled as a moderator through interaction terms with ICT engagement and ICT self-efficacy to test developmental and cohort-based differences in teaching enjoyment [67,68,69]. To examine the robustness of findings, supplementary analyses recoded age into two categories (20–40, ≥ 41 years), consistent with prior work on generational differences in technology use in educational contexts [70].

Procedure

All instruments were translated into Persian using a multi-step translation procedure. Two bilingual EFL instructors independently produced initial translations, which were subsequently synthesized by a third instructor. A panel of three experts evaluated the translations for semantic, conceptual, and cultural fidelity. After finalizing the items, they were combined into a single Google Form. All items were obligatory to prevent missing responses [71].

The questionnaires were distributed via Telegram, WhatsApp, and Eitaa. Participation was voluntary, and respondents were free to withdraw at any stage. At the beginning, participants reviewed an information sheet outlining the study's objectives, confidentiality and data protection procedures. Responses were automatically saved in a Google Drive folder, then exported to Excel for analysis. Ethical approval for the study was obtained from the author's institutional Research Ethics Committee (Ref: SRTTU-REC-2024-087).

Structural equation modeling (SEM) was employed to assess the validity of the measurements. Mediation analyses were used to test the indirect association between ICT self-efficacy and teaching enjoyment through ICT engagement, with bootstrapped confidence intervals used to estimate the indirect effect. Moderation analyses examined whether age was associated with variation in the modeled pathways and moderated mediation analyses assessed whether the indirect association between ICT self-efficacy and teaching enjoyment via ICT engagement differed across age groups. This method enabled the simultaneous examination of direct, indirect and conditional relationships among the variables, offering a rigorous evaluation of the study's conceptual framework [69].

Design

This paper adopted a quantitative, cross-sectional correlational design to examine the relationships among ICT self-efficacy, ICT engagement, and teaching enjoyment among Iranian EFL teachers, with age tested as a moderating variable. Data were collected through three self-administered online questionnaires.

Results and Findings

A total of 194 Iranian high school EFL teachers completed three questionnaires: an 18-item ICT self-efficacy scale, a 10-item instrument assessing Foreign Language Teaching Enjoyment, and a 21-item ICT engagement assessment. Data were analyzed using PROCESS 4 through descriptive statistics and mediation and moderation modeling.

The descriptive information for all measured constructs is displayed separately for younger teachers (20–40 years) and older teachers (≥ 41 years) in Table 1. Among younger teachers ($n = 130$), the mean teaching enjoyment score was 44.19 ($SD = 6.33$), the mean ICT engagement score was 85.98 ($SD = 10.19$), and the mean ICT self-efficacy score was 75.79 ($SD = 12.92$). Skewness and kurtosis values for these variables ranged from -1.35 to 1.12 . These values suggest acceptable departures from normality for parametric analyses. For older teachers ($n = 64$), the mean enjoyment score was 44.06 ($SD = 4.96$), the mean ICT engagement score was 75.3 ($SD = 15.46$), and the mean ICT self-efficacy score was 67.41 ($SD = 18.63$).

Table 1: Descriptive Statistics

Variable	Age Group	n	Min	Max	Mean	SD	Skewness	Kurtosis
Enjoyment	20–40	130	28	50	44.19	6.33	−0.9	−0.42
ICT engagement	20–40	130	59	105	85.68	10.19	−0.47	−0.23
ICT efficacy	20–40	130	33	90	75.79	12.92	−1.35	1.12
Enjoyment	41+	64	36	50	44.06	4.96	−0.23	−1.38
ICT engagement	41+	64	48	103	75.30	15.46	−0.05	−0.91
ICT efficacy	41+	64	25	90	67.41	18.63	−0.91	0.10

Skewness and kurtosis values were within conventional bounds (−1.38 to 0.10), indicating reasonably symmetric distributions. Younger teachers reported higher ICT engagement and lower self-efficacy than older teachers, whereas enjoyment scores were similar across age groups.

The measurement model was evaluated before examining the associations among constructs. As shown in Table 2, the three instruments exhibited satisfactory reliability and an acceptable factorial structure. Teaching Enjoyment demonstrated a high level of internal consistency ($CR = 0.91$) and satisfactory shared variance among its indicators ($AVE = 0.51$). Comparable patterns were observed for ICT Self-Efficacy, which yielded a composite reliability of 0.97 and an AVE of 0.66. ICT Engagement also showed strong convergent validity ($AVE = 0.86$), accompanied by an exceptionally high composite reliability coefficient ($CR = 0.99$). In general, reliability estimates for all constructs were above the threshold of 0.70. ICT engagement correlated moderately with Teaching Enjoyment ($r = .31$) and ICT Self-Efficacy ($r = .67$). These indices render the measurement model appropriate. Construct distinctiveness was examined using the Fornell–Larcker criterion. In each case, the square root of the AVE was larger than the corresponding correlations with other latent variables, all of which were below 0.72. These results indicate that the constructs were not unduly overlapping.

Notwithstanding these acceptable measurement properties, the composite reliability estimate for ICT engagement warrants careful consideration. Although high

reliability coefficients are typically viewed as advantageous, values that approach unity may signal item overlap or an excessively restrictive representation of the construct. As noted by Hair et al. [72], composite reliability values exceeding .95 should be interpreted with caution, as they can indicate semantic redundancy rather than superior measurement accuracy. Accordingly, future research may benefit from further scale refinement, including the removal of overlapping items to achieve greater parsimony.

Age was coded as 1 = younger teachers and 2 = older teachers. In this coding scheme, the reported coefficient for Age reflects the difference in the outcome between older and younger teachers: positive values indicate higher scores for older teachers and negative values indicate lower scores. Interactions involving age indicate whether the association between a predictor (e.g., ICT engagement or ICT self-efficacy) and the outcome differs across the two age groups. Moderated regression analyses were then run to examine whether the associations among ICT self-efficacy, ICT engagement, and teaching enjoyment varied across age groups.

The first model examined teaching enjoyment as the outcome (Table 3). The model was statistically significant, $F(4, 189) = 14.09$, $p < .001$ and explained approximately 19% of the variance in enjoyment ($R^2 = .19$). ICT engagement was positively associated with enjoyment ($b = 0.07$, $SE = 0.03$, $p < .00$), as was ICT self-efficacy, although the latter association was smaller ($b = 0.46$, $SE = 0.10$, $p < .00$). Age was not associated with enjoyment ($b = 1.27$, $SE = 0.88$, $p < .15$).

Table 2: Measurement Model Validity Statistics (N = 194)

Construct	CR	AVE	VAVE	Correlations
Teaching Enjoyment	0.91	0.51	0.716	$r = .31$ (efficacy), $.32$ (engagement)
ICT Self-Efficacy	0.97	0.66	0.716	$r = .31$ (enjoyment), $.67$ (engagement)
ICT Engagement	0.99	0.86	0.774	$r = .32$ (enjoyment), $.67$ (efficacy)

Table 3: Moderated Regression Analysis Predicting Teaching Enjoyment

Predictor	<i>b</i>	SE	<i>t</i>	<i>p</i>	95% CI
ICT Self-Efficacy	0.07	0.03	2.16	.032	[0.01, 0.14]
ICT Engagement	0.46	0.10	4.68	0.000	[0.26, 0.65]
AGE	1.27	0.88	1.44	0.15	[-0.47, 3.01]
ICT Engagement $\times$ AGE	-0.23	0.06	-4.07	0.000	[-0.34, -0.12]

Model summary. $R = .43$, $R^2 = .19$, $F(4, 189) = 14.09$, $p < .001$.
 Conditional associations of ICT engagement

	<i>b</i>	SE	<i>t</i>	<i>p</i>	95% CI
AGE					
Younger teachers	0.23	0.05	4.54	0.000	[0.13, 0.33]
Older teachers	0.00	0.04	0.06	.95	[-0.08, 0.09]

Note. AGE is a dichotomous age grouping variable coded as 1 = younger teachers and 2 = older teachers. Coefficients represent unstandardized associations. Confidence intervals are based on 95% limits.

The interaction between ICT engagement and age was statistically significant ($b = -0.23$, $SE = 0.06$, $p < .00$). It amounts to saying that the association between ICT engagement and teaching enjoyment was moderated by age. Conditional association analyses indicated a positive association for younger teachers ($b = 0.23$, $SE = 0.05$, $p < .001$), but not significant for older teachers ($b = -0.00$, $SE = 0.04$, $p = .95$). These findings suggest that higher ICT engagement tends to co-occur with greater teaching enjoyment primarily among younger teachers (Table 3).

The second model examined ICT engagement as the outcome (Table 4). The model was statistically significant, $F(3, 190) = 56.46$, $p < .001$, explaining approximately 50% of the variance ($R^2 = .50$). ICT self-efficacy was positively associated with ICT engagement ($b = 0.38$, $SE = 0.14$, $p < .001$). This indicates that higher perceived ICT capability tended to co-occur with higher engagement. Age group was

negatively associated with ICT engagement, with older teachers reporting lower levels of engagement ($b = -5.91$, $SE = 1.67$, $p < .001$). The interaction between ICT self-efficacy and age group was not statistically significant ($b = 0.09$, $SE = 0.09$, $p = .328$). This suggests that the association between self-efficacy and engagement was not moderated by age groups.

To examine whether ICT engagement mediated the relationship between ICT self-efficacy and teaching enjoyment and whether this indirect pathway differed by age group, a moderated mediation analysis was conducted (Table 5). Results indicated a significant direct association between ICT self-efficacy and teaching enjoyment ($b = 0.07$, $SE = 0.03$, $p = .032$). This shows that teachers reporting greater confidence in their ICT capabilities also tended to report higher levels of teaching enjoyment irrespective of their actual ICT engagement.

Table 4: Moderated Regression Analysis Predicting ICT Engagement

Predictor	<i>b</i>	SE	<i>t</i>	<i>p</i>	95% CI
ICT Self-Efficacy	0.38	0.14	2.77	< .006	[0.11, 0.65]
AGE	-5.91	1.67	-3.54	< .001	[-9.02, -2.62]
ICT Self-Efficacy × AGE	0.09	0.09	0.98	.328	[-0.09, 0.28]

Model summary. $R = .70$, $R^2 = .50$, $F(3, 190) = 56.46$, $p < .001$.

Note. AGE is a dichotomous age-group variable coded as 1 = younger teachers and 2 = older teachers. Coefficients are unstandardized and represent associations. CI = confidence interval.

ICT self-efficacy was also positively associated with ICT engagement, while age group was negatively associated with engagement. The interaction between self-efficacy and age group in predicting engagement was not significant, indicating that age did not moderate the self-efficacy–engagement association.

Despite this, the conditional indirect association between ICT self-efficacy and teaching enjoyment via ICT engagement differed by age group. Among younger teachers, ICT self-efficacy was positively associated with enjoyment through engagement (indirect effect = 0.11, BootSE = 0.02, 95% CI [0.08, 0.14]). In contrast, the indirect association among older teachers was small and not statistically significant (indirect association = 0.00, BootSE = 0.01, 95% CI [-0.02, 0.03]). The index of moderated mediation was statistically significant (index = -0.11, BootSE = 0.02, 95% CI [-0.14, -0.07]), indicating that the strength of the indirect association varied systematically across age groups (Table 5). These findings suggest that ICT engagement functions as a meaningful correlate linking ICT self-efficacy to teaching enjoyment primarily among younger teachers. However, this indirect pathway is absent among older

teachers.

Discussion

The present study considered associations among ICT self-efficacy, ICT engagement, and teaching enjoyment in Iranian high school EFL teachers, with age as a moderating factor. The findings are interpreted in relation to teachers' engagement behaviors and career-stage differences.

Consistent with prior research [14,15,2], ICT self-efficacy was positively associated with teaching enjoyment, suggesting that the teachers' perceived digital competence tends to co-occur with more favorable affective experiences in professional contexts. From the perspective of Self-Determination Theory, having confidence in one's digital skills may support the fulfillment of the basic psychological need for competence, which is typically associated with intrinsic motivation and positive emotional experiences [18]. Teachers who perceive themselves as capable of using digital tools may therefore report greater autonomy and creative involvement in instructional tasks, alongside higher levels of teaching enjoyment.

Table 5: Direct and Conditional Indirect Associations Between ICT Self-Efficacy and Teaching Enjoyment

Direct Association						
Path		<i>b</i>	SE	<i>t</i>	<i>p</i>	95% CI
ICT Self-Efficacy → Enjoyment		0.07	0.03	2.16	.032	[0.01, 0.14]
Conditional Indirect Associations via ICT Engagement						
Age Group	Indirect Effect	BootSE	95% Boot CI			
Younger teachers	0.11	0.03	[0.06, 0.16]			
Older teachers	0.00	0.02	[−0.05, 0.05]			
Moderated Mediation						
Index		BootSE	95% Boot CI			
Index of moderated mediation (AGE)		−0.11	[−0.17, −0.04]			

Note. AGE is a dichotomous age-group variable coded as 1 = younger teachers and 2 = older teachers. Indirect effects are estimated using bootstrap confidence intervals (95%). Coefficients represent unstandardized associations and should not be interpreted causally.

Nevertheless, the association between ICT self-efficacy and teaching enjoyment was relatively modest when compared with the association involving ICT engagement, indicating that perceived competence alone may be insufficient to account for variation in emotional experiences. This pattern resonates with Flow Theory [26] and Broaden-and-Build Theory [29], both of which emphasize the role of sustained engagement, skill–challenge alignment, and positive affective cycles rather than competence perceptions in isolation. In this sense, teaching enjoyment appears to be more closely linked to teachers' ongoing meaningful engagement with digital tools than to confidence alone.

The findings suggest that ICT engagement functions as a relevant mediating variable in the association between ICT self-efficacy and teaching enjoyment, with this indirect pattern varying by age. Among younger teachers (20–40 years), ICT self-efficacy was positively associated with ICT engagement, and engagement, in turn, showed a positive association with teaching enjoyment. This configuration is broadly consistent with propositions from Self-Determination Theory, which links perceived competence with autonomous, intrinsically oriented activity, and Flow Theory, which emphasizes the experiential value of perceived alignment between skills and

task demands [25,18]. From a Broaden-and-Build perspective, positive affect accompanying engagement may be associated with broader cognitive and behavioral repertoires that co-occur with sustained involvement in ICT-related practices [29]. Taken together, these theoretical lenses help contextualize why ICT engagement tends to show a stronger association with enjoyment among younger teachers.

By contrast, among older teachers (≥ 41 years), the indirect association between ICT self-efficacy and teaching enjoyment via ICT engagement was negligible. This pattern is consistent with previous research indicating that later-career teachers often relate to technology in more selective or instrumental ways, associated with career-stage priorities and well-established pedagogical identities [35,40]. Even when older teachers report moderate to high levels of ICT self-efficacy, engagement levels may vary due to perceived misalignment between digital practices and instructional values, institutional constraints, or earlier experiences with technology [34,45]. Such contextual and experiential factors may help explain why ICT use carries less emotional salience for some later-career teachers, which is consistent with the observed absence of a significant indirect association in this age group.

Overall, this pattern underscores the relevance of age as a moderator variable in technology-related affective processes. Although ICT self-efficacy mirrors teachers' confidence in their digital capabilities, its association with teaching enjoyment appears to be associated with engagement behaviors that are themselves shaped by career-stage expectations, professional identity, and contextual affordances.

From the Uses and Gratifications perspective, younger teachers may be more inclined to engage with ICT in ways that correspond with preferences for novelty, social interaction, and professional development, while older teachers may orient toward technology in more instrumental or stability-focused ways [7,8]. Explanations grounded in the Technology Acceptance Model, which emphasize perceived usefulness and ease of use, also help contextualize these differences [10,11], though such models place less emphasis on motivational and affective dimensions.

Despite lower ICT engagement among older teachers, overall enjoyment levels were comparable across age groups, suggesting that teaching enjoyment may be sustained through alternative sources such as pedagogical mastery and relational competence [42,52]. Taken together, these findings highlight that ICT engagement represents one of several pathways associated with positive affective experiences in teaching and that technology-related engagement is neither a necessary nor a uniformly salient correlate of teaching enjoyment across age groups.

The results are consistent with an integrative framework in which psychological needs, engagement experiences, and contextual affordances jointly shape teachers' emotional responses to ICT.

Conclusions

The present study explored associations among ICT self-efficacy, ICT engagement, and teaching enjoyment among Iranian high school EFL teachers, with age examined as a moderating variable. The findings show that ICT self-efficacy is positively associated with both ICT engagement and teaching enjoyment; however, the strength and configuration of these associations vary across age groups. For younger teachers, ICT engagement displayed a stronger association with teaching enjoyment, and the indirect association between self-efficacy and enjoyment via engagement was evident only within this group. Among older teachers, ICT engagement was weakly associated with enjoyment, and the indirect pattern was negligible. Together, these results suggest that the emotional correlates of ICT use are not uniform and appear to be linked not only to perceived competence but also to how digital practices align with teachers' pedagogical routines, motivational orientations, and available emotional resources. The findings highlight the importance of considering career-stage differences when examining the affective dimensions of ICT use.

In practical terms, the findings point to several considerations for policy and teacher development. Professional learning initiatives may benefit from greater sensitivity to career stage: younger teachers tend to report higher engagement with ICT, whereas older teachers may prefer more structured and pedagogically aligned forms of digital integration. Beyond the development of technical skills, professional support may place greater emphasis on meaningful engagement, autonomy-supportive practices, and opportunities for intrinsically rewarding use of technology. Ensuring equitable access to digital resources and

allowing flexibility in how ICT is adopted may help address age-related differences in engagement and emotional experience.

Future studies might build on this work by using longitudinal or mixed-method designs to explore how ICT self-efficacy, engagement and teaching enjoyment evolve together. Further attention to institutional culture, resource conditions and professional identity may also clarify the contextual factors in teachers' affective experiences with technology. Focusing on these dimensions could help provide a more nuanced insight into the ways ICT relates to both teaching practices and enjoyment in EFL contexts.

Authors' Contribution

The corresponding author assumed the responsibility for all aspects of this research. This includes the conception and design of the study, data acquisition, and interpretation of the data. The corresponding author was also solely responsible for drafting the manuscript, performing critical revisions for important intellectual content, and conducting the statistical analysis. All tasks related to obtaining funding, providing administrative, technical, or material support, and supervision were carried out exclusively by the corresponding author.

Acknowledgements

The researcher extends gratitude to the teachers who kindly took part in this study. Special thanks are also due to colleagues whose careful efforts in the back-translation of the questionnaires ensured precision and reliability in the translated instruments.

Conflict of Interest

The author has no personal or financial interests that could potentially influence this work.

References

- [1] Kunina-Habenicht O, Goldhammer F. ICT engagement: a new construct and its assessment in PISA 2015. *Large Scale Assess Educ.* 2020;8:8. doi:10.1186/s40536-020-00084-z.
- [2] Scherer R, Siddiq F, Tondeur J. The technology acceptance model (TAM): a meta-analytic structural equation modeling approach explaining teachers' adoption of digital technology in education. *Comput Educ.* 2019;128:13-35. doi:10.1016/j.compedu.2018.09.009.
- [3] Paetsch J, Franz S, Wolter I. Changes in early career teachers' technology use for teaching: the roles of teacher self-efficacy, ICT literacy, and experience during COVID-19 school closure. *Teach Teach Educ.* 2023;135:104318. doi:10.1016/j.tate.2023.104318.
- [4] Chaaban Y, Ellili-Cherif M. Technology integration in EFL classrooms: a study of Qatari independent schools. *Educ Inf Technol.* 2017;22(5):2433-2454. doi:10.1007/s10639-016-9552-8.
- [5] Hammou YA, Elfatihi M. Moroccan teachers' level of ICT integration in secondary EFL classrooms. *Int J Lang Lit Stud.* 2019;1(3):1-19. doi:10.36892/ijlls.v1i3.65.
- [6] Moradi H. The role of language teachers' perceptions and attitudes in ICT integration in higher education EFL classes in China. *Humanit Soc Sci Commun.* 2025;12:208. doi:10.1057/s41599-025-04524-5.
- [7] Katz E, Blumler JG, Gurevitch M. Uses and gratifications research. *Public Opin Q.* 1973;37(4):509-523. doi:10.1086/268109.
- [8] Ruggiero TE. Uses and gratifications theory in the 21st century. *Mass Commun Soc.* 2000;3(1):3-37. doi:10.1207/S15327825MCS0301_02.
- [9] Quan-Haase A, Young AL. Uses and gratifications of social media: a comparison of Facebook and instant messaging. *Bull Sci Technol Soc.* 2010;30(5):350-361. doi:10.1177/0270467610380009.
- [10] Davis FD. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Q.* 1989;13(3):319-340. doi:10.2307/249008.
- [11] Teo T. Factors influencing teachers' intention to use technology: model development and test. *Comput Educ.* 2011;57(4):2432-2440. doi:10.1016/j.compedu.2011.06.008.
- [12] Lee ASH, Thi LS, Lin MH. Affective technology acceptance model: extending technology acceptance model with positive and negative affect. In: *Knowledge management strategies and applications*. London: IntechOpen; 2017. p. 147-165.

- [13] Venkatesh V, Thong JYL, Xu X. Unified theory of acceptance and use of technology: a synthesis and the road ahead. *J Assoc Inf Syst.* 2016;17(5):328-376. doi:10.17705/1jais.00428.
- [14] Bandura A. Self-efficacy: the exercise of control. New York: WH Freeman; 1997.
- [15] Compeau DR, Higgins CA. Computer self-efficacy: development of a measure and initial test. *MIS Q.* 1995;19(2):189-211. doi:10.2307/249688.
- [16] Han J, Gao C. University teachers' well-being in ICT-enhanced teaching: the roles of teacher self-efficacy and teaching support. *Australas J Educ Technol.* 2023;39(6):89-104. doi:10.14742/ajet.8868.
- [17] Chiu TKF, Falloon G, Song Y, Wong VWL, Zhao L, Ismailov M. A self-determination theory approach to teacher digital competence development. *Comput Educ.* 2024;214:105017. doi:10.1016/j.compedu.2024.105017.
- [18] Deci EL, Ryan RM. The "what" and "why" of goal pursuits: human needs and the self-determination of behavior. *Psychol Inq.* 2000;11(4):227-268. doi:10.1207/S15327965PLI1104_01.
- [19] Salikhova NR, Lynch MF, Salikhova AB. Psychological aspects of digital learning: a self-determination theory perspective. *Contemp Educ Technol.* 2020;12(2):ep280. doi:10.30935/cedtech/8584.
- [20] Durmuş RI, Akman-Yeşilel DB. Foreign language teaching enjoyment: in-service English language teacher perspectives. *J Qual Res Educ.* 2025;(43):164-185. doi:10.14689/enad.43.1901.
- [21] Azari Noughabi M, Yüce E, Fekri N. Developing foreign language teacher enjoyment among Iranian and Turkish EFL teachers: a cross-cultural study. *System.* 2024;123:103308. doi:10.1016/j.system.2024.103308.
- [22] Collie RJ, Shapka JD, Perry NE. School climate and social-emotional learning: predicting teacher stress, job satisfaction, and teaching efficacy. *J Educ Psychol.* 2012;104(4):1189-1204. doi:10.1037/a0029356.
- [23] Frenzel AC, Goetz T, Lüdtke O, Pekrun R, Sutton RE. Emotional transmission in the classroom: exploring the relationship between teacher and student enjoyment. *J Educ Psychol.* 2009;101(3):705-716. doi:10.1037/a0014695.
- [24] Frenzel AC, Daniels LM, Burić I. Teacher emotions in the classroom and their implications for students. *Educ Psychol.* 2021;56(4):250-264. doi:10.1080/00461520.2021.1985501.
- [25] Bakker AB. Flow among music teachers and their students: the crossover of peak experiences. *J Vocat Behav.* 2005;66(1):26-44. doi:10.1016/j.jvb.2003.11.001.
- [26] Csikszentmihalyi M. Flow: the psychology of optimal experience. New York: Harper & Row; 1990.
- [27] Mierzwa E. Foreign language learning and teaching enjoyment: teachers' perspectives. *J Educ Cult Soc.* 2019;10(2):170-188. doi:10.15503/jecs20192.170.188.
- [28] Burić I, Slišković A, Sorić I. Teachers' emotions and self-efficacy: a test of reciprocal relations. *Front Psychol.* 2020;11:1650. doi:10.3389/fpsyg.2020.01650.
- [29] Fredrickson BL. The role of positive emotions in positive psychology: the broaden-and-build theory of positive emotions. *Am Psychol.* 2001;56(3):218-226. doi:10.1037/0003-066X.56.3.218.
- [30] Tondeur J, van Braak J, Ertmer PA, Ottenbreit-Leftwich A. Understanding the relationship between teachers' pedagogical beliefs and technology use in education: a systematic review of qualitative evidence. *Educ Technol Res Dev.* 2017;65(3):555-575. doi:10.1007/s11423-016-9481-2.
- [31] O'Bannon BW, Thomas K. Teacher perceptions of using mobile phones in the classroom: age matters! *Comput Educ.* 2014;74:15-25. doi:10.1016/j.compedu.2014.01.006.
- [32] Vanderlinde R, Aesaert K, van Braak J. Institutionalized ICT use in primary education: a multilevel analysis. *Comput Educ.* 2014;72:1-10. doi:10.1016/j.compedu.2013.10.007.
- [33] Howard SK, Tondeur J, Ma J, Yang J. What to teach? Strategies for developing digital competency in preservice teacher training. *Comput Educ.* 2021;165:104149. doi:10.1016/j.compedu.2021.104149.
- [34] Selwyn N. Is technology good for education? Cambridge: Polity Press; 2016.
- [35] Cuban L. Oversold and underused: computers in the classroom. Cambridge (MA): Harvard University Press; 2001.
- [36] Hatlevik IKR, Hatlevik OE. Examining the relationship between teachers' ICT self-efficacy for educational purposes, collegial collaboration, lack of facilitation, and the use of ICT in teaching practice. *Front Psychol.* 2018;9:935. doi:10.3389/fpsyg.2018.00935.
- [37] Barjestesh H, Vijayaratnam P, Sabzevari M, Fatehi Rad N, Rabani K, Manoochehrzadeh M. Digital literacy of Iranian English as a foreign language (EFL) teachers: teaching experience in focus. *Forum Linguist Stud.* 2025;7(1):163-171. doi:10.30564/fls.v7i1.7244.
- [38] Fredricks JA, Blumenfeld PC, Paris AH. School engagement: potential of the concept, state of the evidence. *Rev Educ Res.* 2004;74(1):59-109. doi:10.3102/00346543074001059.

- [39] Joo YJ, Park S, Lim E. Factors influencing preservice teachers' intention to use technology: TPACK, teacher self-efficacy, and technology acceptance model. *J Educ Technol Soc.* 2018;21(3):48-59.
- [40] Day C, Gu Q. Variations in the conditions for teachers' professional learning and development: sustaining commitment and effectiveness over a career. *Oxf Rev Educ.* 2007;33(4):423-443. doi:10.1080/03054980701450746.
- [41] Huberman AM. *The lives of teachers.* London: Cassell; 1993.
- [42] Kelchtermans G. Who I am in how I teach is the message: self-understanding, vulnerability and reflection. *Teach Teach.* 2009;15(2):257-272. doi:10.1080/13540600902875332.
- [43] Howard SK, Mozejko A. Teachers: technology, change and resistance. In: Knezek G, Christensen R, editors. *Teaching and digital technologies.* Cambridge: Cambridge University Press; 2015. p. 307-317.
- [44] Scherer R, Teo T. Unpacking teachers' intentions to integrate technology: a meta-analysis. *Educ Res Rev.* 2019;27:90-109. doi:10.1016/j.edurev.2019.03.001.
- [45] Vongkulluksn VW, Xie K, Bowman MA. The role of value on teachers' internalization of external barriers and externalization of personal beliefs for classroom technology integration. *Comput Educ.* 2018;118:70-81. doi:10.1016/j.compedu.2017.11.009.
- [46] Aref A, Aref K. The barriers of educational development in rural areas of Iran. *Indian J Sci Technol.* 2012;5(2):2191-2193.
- [47] Ahmadi S, Hosseini SM, Shirbagi N. A systematic literature review of ICT in the educational system of Iran. *Sch Adm.* 2023;10(4):109-135.
- [48] Al-Dosari SM, Mohsen MA, Curle S. Enjoyment in the foreign language teaching environment: Saudi teachers' perspectives. *Psycholinguistics.* 2022;32(1):29-50. doi:10.31470/2309-1797-2022-32-1-29-50.
- [49] Frenzel AC. Teacher emotions. In: Linnenbrink-Garcia EA, Pekrun R, editors. *International handbook of emotions in education.* New York: Routledge; 2014. p. 494-519.
- [50] Guo H, Gao W, Shen Y. L2 enjoyment of English as a foreign language students: does teacher verbal and non-verbal immediacy matter? *Front Psychol.* 2022;13:897698. doi:10.3389/fpsyg.2022.897698.
- [51] Sørebo Ø, Eide H, Hatlevik IH, Kristiansen R. Motivating factors, resources and patterns of using information and communication technology among preservice teachers. *Comput Educ.* 2009;53(4):1157-1170. doi:10.1016/j.compedu.2009.05.001.
- [52] Mohammadi V, Yousofi N. A phenomenological inquiry into supporting and hindering factors of foreign language teaching enjoyment (FLTE) among Iranian EFL teachers. *Discov Psychol.* 2025;5:165. doi:10.1007/s44202-025-00526-1.
- [53] Gil-Flores J, Rodríguez-Santero J, Ortiz-de-Villate C. Teaching practices and organizational aspects associated with the use of ICT. *Large Scale Assess Educ.* 2024;12:26. doi:10.1186/s40536-024-00215-w.
- [54] Mossafaie M, Alibakhshi G, Tabrizi HH. Iranian EFL teachers' self-efficacy: structural equation modeling of the consequences. *Asian Pac J Second Foreign Lang Educ.* 2024;9:42. doi:10.1186/s40862-024-00264-2.
- [55] Dewaele JM, Li C. Emotions in second language acquisition: a critical review and research agenda. *Foreign Lang World.* 2020;196(1):34-49.
- [56] Clipa O, Delibas CS, Măță L. Teachers' self-efficacy and attitudes towards the use of information technology in classrooms. *Educ Sci.* 2023;13(10):1001. doi:10.3390/educsci13101001.
- [57] Noy C. Sampling knowledge: the hermeneutics of snowball sampling in qualitative research. *Int J Soc Res Methodol.* 2008;11(4):327-344. doi:10.1080/13645570701622220.
- [58] Etikan I, Musa SA, Alkassim RS. Comparison of convenience sampling and purposive sampling. *Am J Theor Appl Stat.* 2016;5(1):1-4. doi:10.11648/j.ajtas.20160501.11.
- [59] Tabachnick BG, Fidell LS. *Using multivariate statistics.* 7th ed. Harlow: Pearson Education; 2019.
- [60] Kline RB. *Principles and practice of structural equation modeling.* 5th ed. New York: Guilford Press; 2023.
- [61] Seligman MEP, Csikszentmihalyi M. Positive psychology: an introduction. *Am Psychol.* 2000;55(1):5-14. doi:10.1037/0003-066X.55.1.5.
- [62] Tao J, Xu Y, Wang S, Gao XA. The emotions of language teachers: a systematic review of studies between 2015 and 2024. *Lang Teach.* 2025;58(4):450-473. doi:10.1017/S0261444825000205.
- [63] Ma Y, Qin X. Measurement invariance of information, communication and technology (ICT) engagement and its relationship with student academic literacy: evidence from PISA 2018. *Stud Educ Eval.* 2021;68:100982. doi:10.1016/j.stueduc.2020.100982.
- [64] Korukluoğlu P, Alcı B, Rubach C. Reliability and validity of the Turkish version of the teachers' basic ICT competence beliefs scale. *Int J Assess Tools Educ.* 2023;10(1):29-55. doi:10.21449/ijate.995005.

[65] Bakar NSA, Maat SM, Rosli R. A systematic review of teachers' self-efficacy and technology integration. *Int J Acad Res Bus Soc Sci*. 2018;8(8):540-557. doi:10.6007/IJARBS/v8-i8/4611.

[66] Sang G, Valcke M, van Braak J, Tondeur J. Explaining teachers' intention to use technology: a path analysis model. *Educ Inf Technol*. 2010;15(4):301-319. doi:10.1007/s10639-010-9119-2.

[67] Aiken LS, West SG. Multiple regression: testing and interpreting interactions. Thousand Oaks (CA): Sage Publications; 1991.

[68] Hayes AF. Introduction to mediation, moderation, and conditional process analysis: a regression-based approach. 3rd ed. New York: Guilford Press; 2022.

[69] Teo T, Milutinovic V. Modelling the intention to use technology for teaching mathematics among preservice teachers in Serbia. *Australas J Educ Technol*. 2015;31(4):423-439. doi:10.14742/ajet.1668.

[70] Šabić J, Baranović B, Rogošić S. Teachers' self-efficacy for using information and communication technology: the interaction effect of gender and age. *Inform Educ*. 2022;21(2):353-373. doi:10.15388/infedu.2022.11.

[71] DeVellis RF. Scale development: theory and applications. 4th ed. Thousand Oaks (CA): Sage Publications; 2016.

[72] Hair JF, Hult GTM, Ringle CM, Sarstedt M. A primer on partial least squares structural equation modeling (PLS-SEM). 3rd ed. Thousand Oaks (CA): Sage Publications; 2022.

AUTHOR(S) BIOSKETCHES

Reza Nejati is an associate professor of Teaching English as a Foreign Language (TEFL) at Shahid Rajaei Teacher Training University. His research interests include teaching and assessing language skills.

Nejati, R., Associate Professor, TEFL. English Department, Shahid Rajaei Teacher Training University, Tehran, Iran.

✉ reza.nejati@sru.ac.ir

Citation (Vancouver): Nejati R. [ICT Self-efficacy, ICT Engagement and Teaching Enjoyment among Iranian EFL Teachers: An Age-moderated Model] *Tech. Edu. J*. 2026; 20(1): 97-114

 <https://doi.org/10.22061/tej.2026.12990.3369>





ORIGINAL RESEARCH PAPER

Are self-directed learners the authors of their learning? The role of AI in transforming students' cognitive agency

A. Ramezani

Department of Educational Administration, Farhangian University, Tehran, Iran

ABSTRACT

Received: 24 July 2025
Reviewed: 12 September 2025
Revised: 08 October 2025
Accepted: 19 December 2025

KEYWORDS:

AI
Students
Self-Directed Learning
Colaizzi's Method
Cognitive Agency

* Corresponding author

✉ a.ramezani@cfu.ac.ir

☎ (+98912) 5411015

Background and Objectives: The rapid advancement of AI (AI) in higher education, particularly through adaptive learning systems, intelligent tutoring agents, and generative AI tools, has catalyzed a paradigm shift in traditional teaching and learning models. Also, the increased use of AI in higher education in many different fields offers a more personalized, responsive, and effective learning experience. Yet, as AI systems increasingly determine how students interact with and process knowledge, and create knowledge outputs, it is important to answer both basic questions about learner agency in relation to the very paradigm of the autonomous learner that underpins theories of adult and higher education. This article considers whether AI-enhanced learning environments support or deter learners' sense of cognitive authorship.

Methods: This study used a qualitative method that is a mixture of conceptual and empirical inquiry to show pressing issues related to educational theory and emerging technologies: in the age of AI, are self-directed learners still authors of their learning? The philosophical method examines issues about the ontological and epistemic grounds of cognitive agency in an AI-mediated context using semi-structured interviews with 23 students in different fields at Tehran universities. It includes the question of the lived experience of university students who are engaging with AI to be educated. To increase methodological precision Colaizzi's seven step was used; this was chosen because of its specificity and effective depth for interpretation, as well as its fit with a focus on phenomenology in its aim to examine how 'agency', 'authorship', and 'self-direction' of students are lived in an algorithmic context that is mediating cognitive agency. This method includes seven steps: 1) Reading and re-reading all the transcribed interviews to make sense of them, 2) Extracting significant statements. These are phrases or sentences that directly pertain to the investigated phenomenon, 3) Giving meaning to the statements: During the process pertinent quotes are categorized the themes are generated based on multiple statements that convey similar meaning, 4) Repeating step 1-3 for each interview, then the researcher can begin to create theme based on the formulated meaning, 5) Gathering an exhaustive description of everything generated in step 1-4, 6) Summarizing the exhaustive description so that there is an identification of the fundamental structure of the phenomenon and 7) Ensuring the credibility of the data through member checking.

Findings: Results indicated that using AI in different fields has both negative and positive effects on learning and cognitive agency of students. Central outcomes on the positive side include cognitive scaffolding, increased access to complex knowledge, the ability of AI as a cognitive extension, co-authorship with AI through critical engagement, increasing critical thinking, and improving self-learning through simulation and interactive environments. On the other hand, it has some challenges such as: Ambiguous intellectual authorship, Erosion of epistemic self-Trust, Illusion of mastery, Passive deference to algorithmic authority, and ethical dissonance and academic guilt.

Conclusions: Based on these findings and different aspects of AI in student cognitive agency, the paper proposes a framework for self-directed learning in the age of AI in which authorship is not isolated, as the learner is still the one who makes learning; however, this issue needs basic changes in pedagogical, curricular, and philosophical perspectives.



COPYRIGHTS

© 2026 The Author(s). This is an open-access article distributed under the terms and conditions of the Creative Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) (<https://creativecommons.org/licenses/by-nc/4.0/>)



NUMBER OF REFERENCES

32



NUMBER OF FIGURES

2



NUMBER OF TABLES

3

مقاله پژوهشی

آیا یادگیرندگان خود راهبر عامل یادگیری خود هستند؟ بررسی نقش هوش مصنوعی در تغییر عاملیت شناختی دانشجویان

عباس رضانی

گروه مدیریت آموزشی، دانشگاه فرهنگیان، تهران، ایران

چکیده

پیشینه و اهداف: پیشرفت سریع سامانه‌های هوش مصنوعی در آموزش عالی به‌ویژه از طریق سامانه‌های یادگیری تطبیقی، عوامل آموزش هوشمند و ابزارهای تولیدی هوش مصنوعی تحولی پارادایمی در مدل‌های سنتی تدریس و یادگیری ایجاد کرده است. استفاده گسترده از هوش مصنوعی در رشته‌های مختلف، یادگیری شخصی‌سازی شده، پاسخگو و اثربخش‌تری را به ارمغان می‌آورد. اما با گسترش نقش سامانه‌های هوش مصنوعی در تعیین نحوه تعامل دانشجویان با دانش و پردازش آن، سؤال‌های اساسی دربارهٔ عاملیت یادگیرنده و پارادایم یادگیرنده خود راهبر که پایهٔ نظریه‌های آموزش بزرگسالان و آموزش عالی بوده و از اهمیت بالایی برخوردار است، پیش می‌آید. پژوهش حاضر به بررسی نقش دوگانهٔ محیط‌های یادگیری مجهز به هوش مصنوعی را در عاملیت شناختی یادگیرندگان خود راهبر می‌پردازد؛ اینکه این سامانه‌ها چه چالش‌ها و فرصت‌هایی را برای دانشجویان فراهم می‌نمایند.

روش‌ها: رویکرد پژوهش حاضر از نوع کیفی بود تا با بررسی دیدگاه‌ها و تجارب دانشجویان مسائل مهم مرتبط با نظریه آموزشی و فناوری‌های نوظهور را نشان دهد و به این سؤال که «در عصر هوش مصنوعی، آیا یادگیرندگان خود راهبر هنوز عامل یادگیری خود هستند؟» بپردازد. این روش فلسفی به بررسی مبانی وجودی و معرفتی عاملیت شناختی در زمینهٔ واسطه‌گری هوش مصنوعی پرداخته و از مصاحبه‌های نیمه‌ساختاریافته با ۲۳ دانشجو در رشته‌های مختلف دانشگاه‌های تهران استفاده نمود. این پرسش در مورد تجارب زیسته دانشجویانی که با هوش مصنوعی برای آموزش درگیر هستند، مطرح شد. به‌منظور تجزیه و تحلیل داده‌ها و افزایش دقت روش شناختی، روش هفت‌مرحله‌ای کولایزی به کار گرفته شد؛ این روش به دلیل خاصیت و عمق تفسیری مؤثر خود و تطبیق با پدیدارشناسی برای بررسی «عاملیت»، «مالکیت فکری» و «خودراهبری» دانشجویان در زمینه الگوریتمی عصر حاضر انتخاب شد. این روش شامل هفت مرحله است: (۱) خواندن و بازخوانی تمام مصاحبه‌های نوشته شده برای درک آن‌ها، (۲) استخراج عبارات معنی‌دار که مستقیماً به پدیده مورد بررسی مربوط می‌شوند، (۳) معنابخشی به عبارات: در این فرایند نقل‌قول‌های مرتبط دسته‌بندی می‌شوند و تم‌ها بر پایه چندین عبارت با معانی مشابه شکل می‌گیرند، (۴) تکرار گام‌های ۱ تا ۳ برای هر مصاحبه و سپس ایجاد تم بر اساس معانی شکل گرفته، (۵) جمع‌آوری توصیف جامع از تمام موارد تولید شده در گام‌های ۱-۴، (۶) تلخیص جامع برای شناسایی ساختار بنیادی پدیده، و (۷) اطمینان از اعتبار داده‌ها از طریق بررسی اعضا.

یافته‌ها: نتایج نشانگر این موضوع بودند که استفاده از هوش مصنوعی در حوزه‌های مختلف تأثیرات مثبت و منفی بر یادگیری و عاملیت شناختی دانشجویان دارد. مهم‌ترین یافته‌ها در بخش فرصت‌ها شامل این موضوع بودند که هوش مصنوعی می‌تواند به تقویت ساختار شناختی، دسترسی بیشتر به دانش پیچیده، تعمیق دانش شناختی، همکاری مشترک با هوش مصنوعی از طریق مشارکت فعال، تقویت تفکر انتقادی و بهبود خودآموزی از طریق شبیه‌سازی و محیط تعاملی کمک کند. از سوی دیگر، چالش‌هایی نظیر ابهام در مالکیت فکری، کاهش اعتماد معرفتی به خود، توهم تسلط، تسلیم ذهنی به اقتدار الگوریتمی، ناهماهنگی اخلاقی و احساس گناه علمی استخراج شدند.

تاریخ دریافت: ۰۲ مرداد ۱۴۰۴
تاریخ داوری: ۲۱ شهریور ۱۴۰۴
تاریخ اصلاح: ۱۶ مهر ۱۴۰۴
تاریخ پذیرش: ۲۸ آذر ۱۴۰۴

واژگان کلیدی:

هوش مصنوعی
دانشجویان
یادگیری خود راهبر
روش کلایزی
عاملیت شناختی

* نویسنده مسئول

a.ramezani@cfu.ac.ir

© ۱۵۰۴۱۱۰۵-۰۹۱۲

نتیجه‌گیری: بر پایه این یافته‌ها و جنبه‌های متنوع هوش مصنوعی در عاملیت شناختی دانشجویان، پژوهش حاضر، چارچوبی برای یادگیری خود راهبر در عصر هوش مصنوعی ارائه می‌دهد، به نحوی که مالکیت فکری جدا انگاشته نمی‌شود و دانشجویان عامل یادگیری خود در تعامل با هوش مصنوعی باقی می‌مانند و هم‌زمان از آن استفاده نیز می‌نمایند، اما این موضوع نیازمند تغییرات جدی و اساسی در مباحث آموزشی، برنامه‌ریزی و فلسفی است.

Introduction

Artificial intelligence (AI) is considered one of the most influential technologies of the 21st century [1]. The integration of AI into educational systems is reshaping traditional teaching methods by providing tools that enable learners to effectively engage with complex problems [2]. The development of technologies and the increase in virtual learning opportunities have led to a change in people's understanding of the ways of learning [3]. In the traditional perspective, 'teacher' was seen as the only source of knowledge, but today, sources of information have become very diverse. Therefore, as information has become easier to access, the nature of learning has also changed. In the past, it was essential to memorize information, but now, it has become fundamental to gain skills related to where information can be accessed and how to learn it [4]. Specifically, people are expected to acquire the skills of learning to learn subjects. Individuals who do not have the ability to learn and who cannot organize their own learning processes fall behind in many areas in the globalizing world where technology is increasingly improving [5]. In this part, the concept of self-directed learning emerged.

The concept of the self-directed learner has been central to adult and higher education theory for many years. A fundamental aspect of this orientation of self-directed learning is cognitive agency, related to the learner's ability to be the agent of their own understanding, think independently, and articulate their claims to knowledge with epistemic integrity. Built on humanist and constructivist traditions, this

model holds that adult learners are self-regulated individuals who plan their learning goals, find resources, and assess their progress [6]. Self-directed learners make plans by determining their learning goals. They organize how to access learning resources. They are also open to learning, curiosity, autonomy, and taking the initiative to learn in a self-controlled manner [7]. However, this humanist ideal is coming under challenge from the rapid introduction of AI into the university learning space. From various generative chatbots that draft essays and solve equations, to adaptive platforms that curate personalized learning pathways, AI systems have gone from being peripheral tools to becoming active agents in the cognitive processes of students. This represents a significant change, and alongside these developments comes an important question. In an era where algorithms are co-constructing knowledge, is the self-directed learner still the author of their learning?

Although issues regarding academic integrity and plagiarism [8] in academic discussions of educational technology are ongoing, ontological and epistemological issues have been sidelined. In fact, not only is AI changing how students might learn, but also changing who is learning and what it means to know. As Williamson and Eynon investigated, AI-facilitated educational infrastructures are performing a 'silent reconfiguration of the learner-subject', whereby agency is being redistributed across human-technological assemblages in ways that are largely opaque even to learners and educators [9]. This exploration addresses these gaps through a philosophical-qualitative inquiry of the lived

experiences of university students as they learn using AI, including an emphasis on the transformation of cognitive agency and epistemic authorship.

While the utilization of generative AI is widespread in higher education, 78% of university students say they 'often' utilize generative AI in their studies [10]. There is little existing literature, philosophy, and empirically informed literature that addresses their implications for learner autonomy. Existing research literature often resides at one of two poles: techno-optimism, which claims that AI represents a potential force for democratization [11], or the grim story of 'outsourcing of thought' [12]. Neither achieves the nuance and irony of learners' engagement with AI in everyday learning.

More critically, studies rarely engage with the phenomenology of agency, that is, how students feel, perceive, and make sense of their own role as knowers when AI is involved. Without this experiential grounding, theoretical debates about autonomy risk becoming abstract and disconnected from the realities of the contemporary classroom. It is impossible to design ethical AI pedagogies if there was misunderstanding learners' experience of agency in AI-rich environments [9].

This research aims to take a step toward answering the following question: *'In what ways do university students experience agency in cognition while learning with AI, and therefore, to what extent do they view themselves as authors of their understanding?'* In an attempt to privilege student voices (as previously noted), this work shifts focus from traditional figurative frameworks that categorize AI only as either an empowering or threatening presence and instead starts to unpack the nuanced, even contradictory ways agency is negotiated in practice. This study is based on an interdisciplinary conceptual

framework that draws upon three related areas of scholarship: (1) self-determination learning philosophy (2) posthuman and socio-material theories on distributed cognition, and (3) critical approaches to AI in education

First, the study investigates the humanist self-directed learning (SDL) framework elaborated by Knowles [13] and Candy [14], which celebrates the learner's autonomy, inherent desire to learn, and epistemic obligation to take responsibility as a learner. But rather than situating SDL as a static or normative ideal, we explore SDL's assumptions about the affordances and constraints of AI [12]. It contends that the historically situated and particular construct of an autonomous, rational learner as the central construct of humanist pedagogy becomes an increasing source of dissonance in algorithmically mediated societies.

Next, it takes posthuman and sociomaterial positions that present a challenge to the concept of a bounded, self-sufficient learner. Accordingly, later in this part, the study draws on Hayles's [15] notion of cognitive assemblages and Fenwick's [16] conception of sociomaterial entanglements in learning, to reframe cognition as always already distributed across networks of human and non-human actors. In this sense, AI systems are not regarded simply as external tools, but are entangled actants that create knowledge in the network of learning [9]. This ontological shift brings the focus of analysis from a narrative of loss of 'agency' to one that more quickly considers how 'agency' is redistributed and reconfigured in human-AI relationships.

The article also draws upon critical AI studies in education that center on the ways algorithmic systems infuse and reproduce relations of power, epistemic bias, and assumptions about normative ways of knowing and learning. For example, Polat et al. caution

that many AI platforms act as "black-box epistemic authorities" in that they conceal the logics of their decision-making and the sources of their content in a way that constrains students' abilities to critique what they are engaging with [17]. Similarly, Holmes et al. point out that AI-based tutoring systems tend to privilege measurable performance rather than an understanding of conceptual relationships, and our study takes up this tension that is enacted through the phenomenological concept of "illusion of mastery" when students confuse their outputs scaffolded by the algorithmic process as understanding [18].

Collectively, these theoretical perspectives provide a robust and multi-layered scaffold for analyzing AI not simply as a neutral pedagogical tool, but as a socio-technical mediator that actively shapes subjectivity, knowledge production, and the very conditions of agency within contemporary higher education. Building upon these, this study aims to explore the evolving nature of learner agency in the context of AI-mediated education. As AI systems increasingly participate in processes of knowledge construction, the boundaries between human cognition and machine assistance become blurred, prompting questions about autonomy, authorship, and responsibility in learning. Therefore, this research seeks to understand how university students experience and negotiate their cognitive agency and authorship of understanding while learning with AI systems within contemporary higher-education environments.

Review of the Related Literature

AI has become a cornerstone of modern education, offering students unprecedented opportunities to enhance critical thinking and self-learning. The integration of AI into educational systems is reshaping traditional

teaching methods by providing tools that enable learners to effectively engage with complex problems. The capacity to simulate various scenarios, provide accurate analysis, and deliver personalized feedback makes it an invaluable asset in nurturing cognitive skills such as critical thinking and self-directed learning.

At this time, because of the widespread use of AI across the world, there are studies about different aspects of AI in higher education. Integrating AI in higher education is also the most noticeable in the previous studies. Namdarian et al. indicated that there is a positive relationship between using AI and improving the outcomes of students, and AI use can lead to personalized learning, improved educational processes, and enhanced access to education for all students [19]. Khabarehin's study showed that AI serves as a transformative force in the field of education, playing a central role in improving the quality and personalization of the learning process [20]. Williamson and Eynon examined how AI-facilitated educational tools are performing a "silent reconfiguration of the learner-subject," whereby agency is being redistributed across human-technological gathering [9]. Rezaei et al. indicated AI as an important factor for transforming education [23]. Moreover, AI can speed up the process of learning by providing personalized feedback and allowing learners to use their critical thinking when faced with incorrect information. In another study, Hwang et al. showed that creating comprehensive AI literacy programs is essential to ensure that learners and educators can navigate the AI landscape effectively [24].

Although the use of AI is widespread in higher education, based on research, 78% of university students say they 'often' utilize generative AI in their studies [10]. Furthermore, providing personalized educational content

based on learners' preferences using the profile expansion technique significantly reduces the cognitive load during learning [23], and using AI in education facilitates the process of learning [24]. It is indicated that AI learning services can provide personalized learning based on students' level [25]. Other studies, like Wang et al., emphasized the competence of using AI [26], while Sadeghi and Naser approved the effectiveness of AI in the 21 centuries [1]. Ramazani and Talebi indicated that technology has an important role to play in regulating society's lifestyle [27]. These studies admitted the urgent need for the use of AI and that using AI can positively increase and improve the quality of students' learning. However, most of these studies have only shown the positive effects or the learning outcomes after using AI without considering whether, in this widespread use of AI, students are the authors of their learning or whether the machine gives them some clues and then gives them authorship. Because of this important need and question, the current study aims to examine the challenges and opportunities AI can provide for students' cognitive agency in the process of learning.

Moreover, research in the field of AI in education indicates that AI tools play an active role in shaping learning processes. These developments challenge the traditional view of learner agency, which emphasized individual autonomy [27]. On the other hand, the concept of Self-Directed Learning (SDL), emphasizing learner autonomy and self-regulation, faces new challenges with the integration of AI into educational settings. While AI offers the potential for personalized learning and helpful guidance, this might come at the cost of reduced independent cognitive effort and an abdication of authorship to the AI. Studies examining the impact of emerging technologies on cognitive and social skills highlight the

importance of balancing technology utilization with the preservation of learner agency [20]. This situation demands a re-evaluation of our understanding of the self-directed learner in light of novel AI interactions.

Much existing research focuses on the practical benefits of AI in education, such as improved performance and content personalization [28-29]. However, there remains a significant research gap in comprehensively examining students' cognitive agency and their role as authors of learning within these novel environments. Fewer studies delve deeply into the process of agency allocation and distribution between students and AI, rarely addressing how students maintain their sense of authorship and exercise cognitive agency when presented with AI suggestions, and whether this ultimately enhances or diminishes self-directed learning.

Method

Participants

The participants of this study were 23 undergraduate and graduate students. A purposive sampling strategy was employed to recruit 23 undergraduate and graduate students from diverse academic fields, including humanities, empirical sciences, and social sciences, across various research-intensive universities in Tehran. The primary selection criterion was participants' demonstrable, ongoing engagement with generative AI tools (such as ChatGPT, Gemini, Microsoft Copilot) or adaptive learning environments (like Khanmigo, Gradescope) for academic purposes within the preceding six months. The snowball method was utilized to identify and recruit additional participants who met these criteria, ensuring a sample that could comprehensively address the core themes of the study. Data saturation was achieved by the

conclusion of interviews with the 23 selected participants. This point was determined when subsequent interviews yielded no new significant themes or novel insights related to the students' experiences with AI in their academic work. The iterative process of data collection and preliminary analysis allowed the researchers to identify the emergence of recurring patterns and concepts, indicating that the sample size was sufficient to capture the breadth of experiences relevant to the research questions.

Table 1: Descriptive data of participants

Code	Gender	Age
SP1	Male	22
SP2	Female	24
SP3	Female	31
SP4	Male	27
SP5	Female	24
SP6	Female	28
SP7	Male	20
SP8	Male	24
SP9	Female	25
SP10	Male	30
SP11	Female	27
SP12	Female	29
SP13	Female	22
SP14	Male	23
SP15	Female	21
SP16	Male	29
SP17	Male	22
SP18	Female	25
SP19	Male	24
SP20	Female	27
SP21	Female	29
SP22	Male	32
SP23	Female	20

Instruments

The research study employed a qualitative approach; therefore, the instrument for gathering the required data was semi-structured questions.

Design

This study adopts a philosophical-qualitative approach, integrating interpretive phenomenology with both conceptual and empirical inquiry. This hybrid methodology is essential for addressing the pressing issues at the intersection of educational theory and emerging technologies, specifically the question: In the age of AI, is the self-directed learner an author of their learning? The conceptual and philosophical inquiry component delves into the theoretical underpinnings of key concepts such as cognitive agency, authorship, and self-direction. It seeks to establish a framework for understanding these constructs in the context of AI-mediated learning. Simultaneously, the empirical inquiry, conducted through in-depth interviews with university students, grounds these philosophical explorations in lived experience. By examining how students *actually* engage with AI tools for academic purposes, this component provides rich, contextual data on how they perceive and enact their agency and authorship.

Combining these approaches allows us to bridge the gap between abstract educational ideals and the practical realities shaped by AI. The philosophical lens offers critical depth for analyzing the implications of technology on learning, while empirical data provides the necessary validation and nuanced understanding of student experiences. This integrated approach is crucial for a comprehensive understanding of the complex dynamics at play, and for generating relevant insights into the evolving role of the learner in an AI-infused educational landscape. The philosophical inquiry examines issues about the ontological and epistemic grounds of cognitive agency in an AI-mediated context. This inquiry situates the question in the lived experience of university students who are engaging with AI to

be educated. To enhance methodological specificity and precision, as well as fidelity to the subjective experience of the participant, the phenomenological approach of [30] is used. Colaizzi's seven-step process for measuring human experience was chosen because of its specificity and effective depth for interpretation, as well as its fit with a focus on phenomenology in its aim to examine how 'agency', 'authorship', and 'self-direction' of students are lived in an increasingly algorithmic context that is mediating cognitive agency.

Procedure

Participants provided informed consent, and institutional review board approval was obtained. Interviews were approximately 45-60 minutes in length, audio-recorded, and transcribed word-for-word. The interview guide was designed to elicit rich descriptions of participants' experiences with AI and to invite consideration of moments when students felt either empowered, dependent, confused, or clarified their thinking about intellectual ownership. Prompts requested stories from the students to reflect on questions such as: when you are using AI to help write or work through a problem, do you feel you are still the author of your own work? Or briefly describe a time that you noticed AI help prompt your thinking - what was that like?

Data analysis

Analysis followed Colaizzi's seven-step process [30]. First, each transcript was read multiple times to achieve a sense of holistic familiarity with the participant's story. Second, all of the stated important statements relating to the phenomenon, namely those that expressed feelings, judgments, or experiences relating to agency, feelings of control, or authorship in AI-mediated learning, were extracted. Third, these statements were then interpreted to create

their underlying psychological and experiential meanings (e.g., *"I just accepted what it gave me"* was interpreted as a surrender of epistemic vigilance). Fourth, through iterative comparison and repeating steps 1-3 over again, the meanings that were formulated were then clustered into emergent thematic categories that generated themes such as Delegated Intellectual Labor, Ambivalent Trust in Algorithmic Guidance, and The Erosion of Epistemic Responsibility. Fifth, compiling an exhaustive description of everything generated in steps 1- 4 is done in this step. A rich descriptive narrative was detailed that captured all of the themes and added descriptive depth to the total experience for learning with AI. Sixth, from this rich narrative description, the fundamental structure of the essential, invariant essence of the phenomenon was distilled; namely, that AI will make cognitive agency different not by obfuscating it, but by redistributing cognitive agency through a human-technology assemblage where the learners' role as the epistemic author is conditional, negotiable, and often cloaked. Finally, to enhance credibility, preliminary findings were shared with a subset of participants in member-checking sessions, allowing them to confirm or refine the researchers' interpretations. Figure 1 shows these steps.

To ensure the trustworthiness of this study, procedures were implemented throughout the research process. Continuous reflexivity was practiced by the researcher to critically examine personal biases, assumptions, and potential influences on data collection and analysis. This involved maintaining a research journal to document reflections on the research process, including the evolving understanding of the participants' experiences and the researcher's role in shaping the inquiry. These reflections were used to ensure that interpretations

remained grounded in the data and were not unduly influenced by preconceptions. Also, a comprehensive audit trail was meticulously maintained to document all stages of the research. This included: (1) verbatim transcripts of all interviews; (2) a complete log of the coding process, including the development of codebooks, initial codes, and the refinement of themes; (3) memos documenting analytical decisions and the rationale behind thematic groupings; and (4) field notes capturing contextual details during data collection.

The phenomenological analysis proceeded in theoretical dialogue throughout the study. It led to a better understanding of how to connect the identified themes through the philosophical lens. For instance, fragmented authorship was understood through the lens of narrative identity, that is, the idea that the self is a result of the stories we tell about our actions. When, for instance, the AI aided in drafting these stories, the learner's identity was not coherent. In the same way, students' representations of 'AI as an invisible tutor' that minimally aids their learning were filtered through Foucault's

understanding of autonomy as self-discipline, in which people are made to want to govern themselves. By interweaving empirical phenomenology with critical philosophy, it aspires to remain grounded in lived experience while also contributing toward contemporary theoretical dialogue on autonomy and post-human forms of self-directed learning.

To ensure qualitative trustworthiness, several techniques were employed. Prolonged data analysis and triangulation with the reflective field notes, as well as participant checking, increased study credibility. Transferability was supported by the thick description of the participant sample and institutional context. Confirmability was aided by researcher reflexivity, particularly through maintaining a bracketing journal (Husserl's epoché) to identify and set aside preconceptions about AI in education. In this way, they seek not only to describe how students experience AI in learning but also to identify what this means for the idea of the self-directed learner.

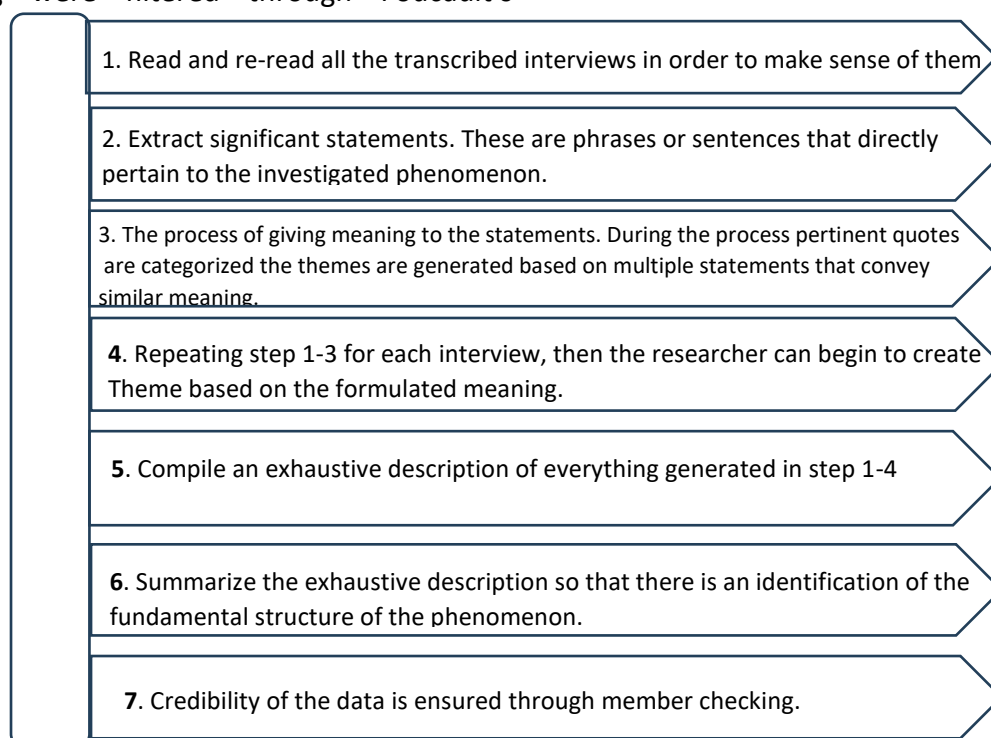


Fig. 1: Colaizzi's seven-step process [30]

Results and Findings

The data analysis using Colaizzi's methodology [30] resulted in the lived experiences of the participants being organized into nine themes.

Notably, the themes formed two broad categories of experiential aspects: (1) challenges to cognitive agency and (2) opportunities for cognitive agency. Tables 2 and 3 present themes, experiential meanings, and some representative open codes.

Table 2: Challenges and problems that threaten cognitive agency with AI

Main theme	Experiential meaning	Open Codes	Indicators
Ambiguous Intellectual Authorship	Learners experience a fractured sense of ownership over their ideas, as AI blurs the boundary between self-generated and algorithmically suggested thought.	I can't say this was my idea- it feels like I'm wearing someone else's thoughts. Whose voice is this in my essay? - I edited it, but the thinking wasn't mine.	SP1, SP8, SP12, SP18, SP9, SP7, SP23
Erosion of Epistemic Self-Trust	Students increasingly doubt their own cognitive reliability and defer to AI as an external authority, weakening their internal epistemic compass.	I don't trust my answers unless AI confirms them. - I second-guess everything I think now. - My brain feels lazy without it.- If the AI disagrees, I assume it's right.	SP3, SP9, SP2, SP19
Illusion of Mastery	AI-generated outputs create a convincing but superficial sense of competence, masking a lack of deep understanding or internalization.	I got an A, but I'd fail if tested today. - It looks like I know it, but I don't. - The AI learned it, not me. - I can reproduce it, but not explain it.	SP1, SP10, SP14
Passive Deference and Over-reliance on Algorithmic Authority	Cognitive fatigue or time pressure leads to uncritical acceptance of AI content, suspending reflective judgment and verification. Students use AI in many and all conditions, feeling that without AI they cannot solve anything	If it sounds smart, I assume it's right. - I don't have the energy to fact-check a machine. - I just copy-paste and hope. - It's fluent, so it must be true.-I feel that without AI, I cannot solve any issues.- I think that if I know a thing, I should check it with AI; without AI, I cannot do my homework and projects.	SP1, SP10, SP116, SP12, SP4
Ethical Dissonance and Academic Guilt	Despite institutional ambiguity, students feel moral discomfort, perceiving AI use as a betrayal of the ideal of self-earned knowledge.	It feels like I'm stealing my own education. - I know it's allowed, but it doesn't feel honest. - Am I still a real student if AI thinks? - I'm cheating myself, not the professor.	SP2, SP11, SP6, SP4
Reducing human interaction	Reduction in communication with other people in the real world, ignoring human interaction	When I use AI for many hours, it is just me and AI, not other people. I do not interact or ask questions of other people because I ask and interact with AI for hours. I think that we do not need other people's ideas when AI is with us.	SP19, SP7, SP12, SP21

Challenges to Cognitive Agency

Ambiguous Intellectual Authorship

A sense of intellectual identity was often broken, as students often reported a sense of total confusion about the source of their ideas when utilizing AI. This vagueness was not so much concerning plagiarism but had to do with the loss of narrative sense in their learning process. *"I used ChatGPT to write my colonialism essay", as SP7 said: "I rephrased all the sentences, yet the argument structure simply seemed borrowed. I would have liked to tell my professor that it was not me when he complimented the original insight. My real voice, I now do not know what."* Such an experience indicates a phenomenological crisis: the self is no longer perceived as the exclusive source of thinking, but as a part of an unequal dialogue with an unseen algorithmic other. This perspective is also admitted by SP1 and SP9, SP8, SP12, SP18, and SP23.

Erosion of Epistemic Self-Trust

There was a silent but widespread loss of confidence in one's own mental judgment that developed in the fields. Even students who had good academic performance said they were ceding the truth to AI as an adjudicator of truth, which weakened the internal epistemic cue of truth. A Master's student, SP2, responded: *"Last week, I worked out a problem in genetics by myself and correctly provided a solution, but I have checked it using an AI solver. And when the AI answered otherwise, I panicked. I relied on the machine, rather than my own judgment, though I had studied that subject for weeks"*. This change represents a restructuring of epistemic power, from the individual to the apparatus in which algorithmic proficiency is confused with truth. Also, SP19, SP3, and SP9 emphasized this fact.

Illusion of Mastery

Numerous respondents created quality academic work with the help of AI and did not have a profound grasp of it, which created a gap between performance and competence. SP3 breathed this contradiction: *"I wrote a perfect solution with the assistance of AI, and I got full marks. However, during the exam, when they varied one of the parameters, I got paralyzed. I understood that I had not been taught the logic; I had been taught to activate the AI in the right way. The knowledge was not a real grade; the grade was real"*. This theme emphasizes the possibility of AI replicating the learning experience without encouraging the cognitive change, which is internal and characteristic of true mastery. SP10 also said: *"I had such an experience, and it led to a lower grade on the final exam; because of this, he said that we must know the logic and the knowledge itself, and then we can use AI correctly"*. Moreover, SP14 and SP1 admitted these responses.

Passive Deference and Over-reliance on Algorithmic Authority

Students tend to interrupt critical thinking and accept AI outputs without doubt under conditions of cognitive overload or fatigue. SP9 confessed: *"During finals, I was so tired that I was no longer questioning what the AI said. In case it referred to one of the studies published in 2023 or contained academic terminology, I simply believed that it was credible. I lacked the mental capacity to check, and frankly, I was no longer interested"*. This is an attitude of passivity that is indicative of a normalization of epistemic outsourcing in which efficiency replaces intellectual vigilance.

Many respondents said that they are dependent on AI in different situations, from quite tiny issues to important things in their lives or projects. SP10 said: *"I need AI for all my projects and lessons; I think that without it I*

cannot handle my projects, especially my homework that professors give us". Also, SP1 indicated a project in paper and said that "all of these things were written by AI, and then I checked it and learned that I cannot give up using it at this time of technology in the world". Moreover, SP12, SP16, and SP4 admitted this dependency.

Ethical Dissonance and Academic Guilt

Regardless of institutional acceptance, a lot of students felt morally uneasy due to a perceived transgression of the spirit of self-acquired knowledge. The inner conflict described by SP4,

who is an MA student, was as follows: "I know my department has been accepting AI in brainstorming, but as I use it, I always feel like I am depriving myself of the challenge that makes learning interesting. It is not about rules, but it is about integrity. Do I remain a thinker when I outsource my thinking?" This is not a feeling of guilt caused by fear of punishment, but rather a break in the moral connection of the learner with the knowledge. SP2 said: "Sometimes I feel guilty when using AI, and it causes different academic problems and issues for me". Also, SP11 and SP6 emphasized this fact, and they agree with these issues.

Table 3: Opportunities of AI for cognitive agency

Main theme	Experiential meaning	Open Codes	Indicator
Cognitive scaffolding	AI provides timely emotional and intellectual support during periods of overload, reducing anxiety and enabling task initiation.	It holds my hand when I'm overwhelmed. - ChatGPT gives me breathing room. - It helps me start when I'm stuck. - Without it, I'd just shut down."	SP7, SP22, SP5
Enhanced access	AI democratizes learning by translating, simplifying, or contextualizing advanced material, especially for non-native speakers or those with gaps in foundational knowledge. Some students experience AI as a seamless, integrated extension of their own cognition, enhancing fluency, creativity, and problem-solving speed.	It explains things my professor assumed I knew. - As a non-native speaker, it helps me sound academic. - I finally understand quantum basics thanks to AI. - It fills the holes in my prior education.	SP5, SP9, SP23
Critical Co-authorship with AI as a Cognitive Extension	Reflective learners actively interrogate, challenge, and refine AI outputs, transforming passive consumption into a dialogic, agentic learning practice.	It's part of how I think now. - My ideas flow faster with it. - It's like a prosthetic for my brain. - I don't feel disabled; I feel augmented. I treat AI like a debate partner. - I always ask: 'Why is this true? I challenge its answers to stay in charge. - I use it to test my thinking, not replace it."	SP10, SP3, SP6, SP4
Enhancing critical thinking	Using feedback for different issues quickly engages the ability of thinking with providing different feedback, distinguishing different voices of feedbacks	I use AI to improve my ability to think, like when I ask questions over and over to get the reasons- I use it and ask it many and many questions to identify the voices that it uses and why it uses.	SP6, SP11, SP2, SP18, SP8
Facilitating learning with simulation and interactive environments	A learning environment with AI facilitates the way of learning, preparing for different communication	I use AI for learning because it helps me with different interactions, and I can ask many questions for learning just one issue- simulation is important, I think, because I think that I am there in real.	SP10, SP12, SP3, SP8

Reducing Human Interaction

Using AI in different issues and subjects also changes the ways of human interactions; many respondents highlighted this issue by saying the rate of using ai and reducing communication with others. SP19 said: *"I use AI for all questions that I have, all things that I need, even for my emotional matters; it is not important for me to say my private feelings to others"*. SP7 also said that *"using AI leads me to have no more interaction with others, even with my parents and siblings at home"*. Furthermore, SP12 and SP 21 confirm this limited interaction with others.

Opportunities for Cognitive Agency

Cognitive Scaffolding

According to the test, AI was heavily perceived as a supportive cognitive partner that soothes the feeling of overwhelm and allows one to start work at a time of high stress. This relief was mentioned by SP7, a third-year social science student: *"When I do my homework, I find myself overwhelmed with information. The moment I request AI to encapsulate a 40-page guideline into bullet points, it feels as though somebody has given me a life raft. It does not substitute for my learning; it merely does not allow me to sink so I can actually get down to the material"*. In this regard, AI does not substitute agency, but is a scaffold that temporarily performs the role of restoring the ability of the learner to act. This was admitted by SP5 and SP22 as well.

Enhanced Access

In the case of students with language barriers or knowledge gaps, AI was a democratizing power that opened up new content that was not available before. SP5, a doctoral student, said: *"In giving a lecture at university, I enter lecture notes into the AI and have it provided me with simpler explanations of concepts or analogies.*

Quantum entanglement suddenly seems to be logical. In its absence, I would be lost and too shy to ask". The theme highlights how AI could foster epistemic inclusion within various academic settings. Also, SP9 AND SP23 were concerned about this issue.

Critical Co-authorship with AI as a Cognitive Extension

Other students did not view AI as an external device but saw it as a natural continuation of their personal thinking, as a way of improving their fluency and problem-solving skills. Reflecting on SP10, a senior student in social science, said: *"It feels like I have a second brain that does not get tired whenever using Copilot. It proposes solutions to my problems when I am debugging that I have not thought of, but it is up to me whether to take them. It is not detached from me; it is a part of my workflow, just like a calculator or a notebook. I am not inferior to be human; I am more competent"*. This view fits in with the extended mind theories in which technology is constitutive of thinking.

A subgroup of reflective learners proactively turned AI engagement into a dialogic form and retained agency by critical questioning. This position was characterized by SP3, a BA student who said: *"I do not always take AI at its face value when it comes to analysis. In questions or scenarios, I request that you present a case on both sides, and then I dismantle its argument. At one time, it was probably wrong, but that comes in handy! It makes me defend my position more strictly. That way, it is not my assistant: it is my sparring partner"*. This is a posthuman kind of self-direction: agency is not natural but is reasserted in a conscious negotiation with non-human others. It was also admitted by SP4 and SP6.

Enhancing Critical Thinking

Using AI can challenge the ability of students' way of thinking through different feedback that they produce. SP6 said: *"I use AI because I think it empowered my capability of thinking with different norms and feedback that was given to me"*. Also, SP3 said: *"I like AI for the reason of different and varied feedback that helps me to think more"*. This issue was approved by SP11, SP2, SP17, and SP8.

Facilitating Learning with Simulation and Interactive Environments

Leveraging AI simulation in the way of learning, and also the interaction in this way, can be one of the most important opportunities of AI. SP10 said: *"The environment- no, let me say the real environment of learning that AI gives us is so helpful for learning"*. Also, SP12 supported this by saying that: *"I used AI because of its interesting algorithms of interaction in a real-*

like learning environment". Moreover, SP3 and SP8 admitted this practical aspect of using AI.

Discussion

The results of this paper demonstrate a dramatic restructuring of cognitive agency in AI-mediated higher education, rather than just an erosion. Although the humanist vision of the self-directed learner, based on the notions of autonomy and epistemic responsibility introduced by Knowles [13] and Candy [14], assumes a limited, sovereign subject who is the author of his or her own knowledge, the lived experiences of participants indicate a more distributed, negotiated, and usually disputed agency. This change is in line with what Williamson and Eynon refer to as the datafication of learning, in which algorithmic systems no longer support cognition but instead distinctly define epistemic pathways, often unintentionally [9].

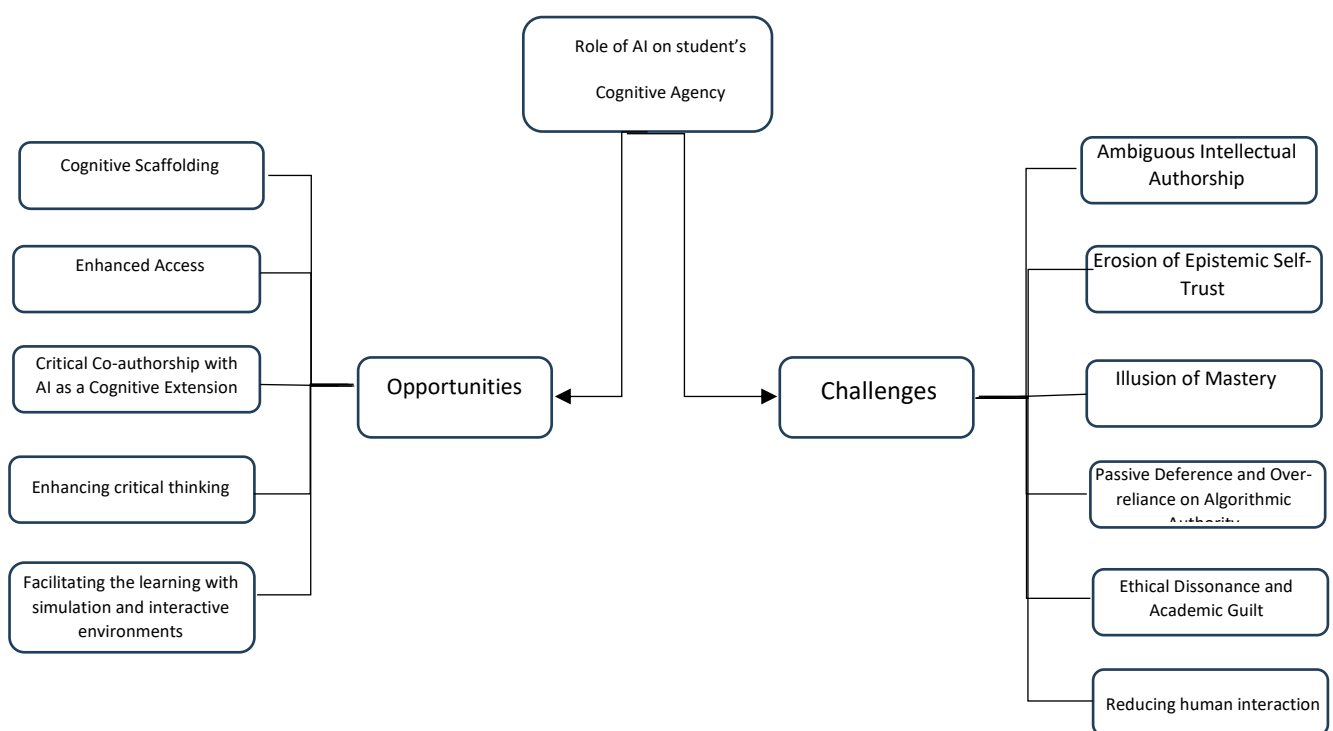


Fig. 2: Challenges and benefits of AI in students' cognitive agency

The argument of uncertain intellectual authorship and the weakening of epistemic self-confidence can be highly relatable to the recent discourse on the epistemic authority of AI. According to Polat et al., generative AI is an epistemic agent that acts as a black box, i.e., it hides its origins and logic, pushing the learner out of the critical assessment of knowledge claims [17]. This is not only a technical displacement, but an existential one: when they consult AI instead of personally acquired knowledge, the students are performing what Biesta describes as a crisis of subjectification, a loss of becoming a subject capable of defending his or her own judgments [12].

However, it would be a simplistic approach to think of AI only as a threat to agency. Our results on AI as a cognitive extension and negotiated co-authorship resemble posthuman and sociometrical views that refute the myth of the autonomous learner. Basing our arguments on the recent publication on cognitive assemblages [15], we observe that cognition has never been localized to any particular tool or environment, and AI is no exception, but a magnification of that state of affairs. Agency can also be enhanced and not substituted when learners actively incorporate AI in their cognitive ecology, as the reflection that *"I am not less human, I am more capable"*, by SP1 implies.

The duality of AI as prosthesis and parasite reflects the ambivalence [31] is recognized in educational AI, as it can make more things available to everyone (as in our motif of greater access to complicated knowledge) and at the same time increase epistemic dependency. The most important distinction our information points to is that of critical AI literacy. Individuals who negotiated co-authorship (e.g., PS9, the law student who presented AI as a sparring partner) are instances of what Williamson and Eynon describe as an approach to

instrumentalism reflexively- in other words, employing AI strategically and retaining epistemic dominance [9].

Importantly, this state of ethical dissonance and academic guilt experienced by many students is a harbinger of the fact that the issue is not AI, but rather the absence of pedagogical systems to maneuver around its use. According to Rapanta et al., universities have been keen to integrate AI without considering assessment or designing learning. These tensions are left to be resolved by our participants individually, and these systemic failures are usually absorbed into individualized moral inadequacies [32]. This stresses the invitation by Williamson and Eynon to education that creates the capacity to be in the world in a manner that is not entirely prescribed by that which is given; it has a capacity which must be consciously trained in AI-saturated settings [9].

Lastly, the illusion of mastery and passive deference themes display the underlying pedagogical crisis of the confusion of performance with learning. With the growing trend of outcome-based education, AI can use this loophole to maximize results instead of knowledge. According to a warning that Holmes et al. give, AI tutors can teach students how to achieve in school, but not how to think (SP11) [18]. Our evidence supports this danger--but also its remedy: scaffolding struggle (not removing it) through the use of AI, as SP5 explained, may rehabilitate the learner's ability of the learner in genuine engagement.

To move beyond a descriptive account of AI integration, this study proposes a formal framework of 'Critical Co-authorship.' This framework conceptualizes agency not as a static attribute of the individual, but as a dynamic, negotiated process within a distributed cognitive assemblage. Critical Co-authorship is defined by three essential dimensions: First, Epistemic Oversight, which

requires the learner to maintain 'epistemic dominance' by treating the AI not as an oracle, but as a fallible interlocutor. This involves the reflexive interrogation of the AI's 'black-box' logic to prevent the passivity of deference. Second, Dialectical Engagement, wherein the learner employs AI as a 'sparring partner' to stimulate higher-order thinking. Rather than using AI to bypass cognitive effort, the learner utilizes it to facilitate what the findings term 'scaffolding struggle' using the tool to introduce complex perspectives or structural frameworks that the learner must then critically wrestle with to achieve genuine understanding. Third, Architectural Authorship, which shifts the definition of authorship from the mechanical production of text to the strategic design of inquiry. In this mode, the learner remains the primary agent by directing the cognitive ecology, ensuring that the AI serves as a prosthetic extension of their intellect rather than a parasitic substitute for it.

The study's contribution lies in its movement beyond the binary discourse of AI as either an existential threat or a mere cognitive tool. By reframing the impact of AI as a 'dramatic restructuring of cognitive agency' rather than a simple erosion, this research demonstrates that the current academic crisis is not a direct result of AI integration, but of a systemic pedagogical failure to address the 'prosthetic/parasitic' duality of these tools. Most importantly, it posits a normative shift: instead of aiming for a return to traditional, autonomous humanism, the study identifies 'scaffolding struggle' as the essential pedagogical intervention necessary to cultivate critical agency in AI-saturated environments.

Conclusions

In conclusion, the emergence of AI necessitates a redefinition of the self-directed learner. The

traditional model of the isolated, autonomous subject is increasingly untenable in an era of co-produced cognition. This paper has advocated for a posthuman framework where agency is understood as a reflective negotiation between human intent and algorithmic suggestion. By fostering 'critical co-authorship,' higher education can prepare students to treat AI as a collaborator in thought while upholding rigorous standards of accountability. Implementing this requires a fundamental restructuring of pedagogy, curriculum, and philosophical inquiry. This paper argues that the traditional paradigm of the self-directed learner is not becoming obsolete, but requires a fundamental ontological redefinition. The Cartesian ideal of the autonomous, self-contained knower is increasingly incompatible with a contemporary epistemic landscape where cognition is co-produced within human-machine assemblages. Instead, it proposes a posthuman framework of self-directed learning, wherein agency is understood not as a possessional attribute of the individual, but as a continuous, reflective negotiation between human intentionality and algorithmic agency. Within this framework, authorship is reimagined as a participatory and morally alert process. It is no longer an isolated act of production, but a conversational engagement that demands a new form of competence: critical co-authorship. This competence entails the ability to utilize AI as a cognitive collaborator while maintaining rigorous accountability for the epistemic claims produced. Despite its significant findings, the study has some limitations, like the utilizing qualitative approach and the issue of generalizability of the findings. To operationalize the framework, the paper proposes a tripartite shift in higher education:

- Pedagogical Shift: Moving from outcome-based assessments toward process-oriented

designs, such as reflective portfolios and documented AI-interaction logs, to capture the "scaffolding struggle."

- Curricular Shift: Integrating disciplinary-specific AI literacy that emphasizes the interrogation of algorithmic logic, bias, and the limits of machine reasoning.

- Philosophical Shift: Transitioning from a humanist binary of autonomy vs. dependence toward an assemblage-based understanding of agency, recognizing the distributed nature of modern intellect.

Ultimately, as AI becomes ubiquitous in academic settings, the central challenge for higher education is not the regulation of tool use, but the cultivation of a way of thinking that is enhanced by, rather than substituted by, algorithmic mediation. The goal is to equip learners not merely to achieve academic performance, but to maintain the capacity for critical, independent thought within an increasingly automated epistemic ecology. In the future, researchers can use quantitative or mixed methods to conduct this research in extended society and test the generalizability.

Authors' Contribution

All of the process of this manuscript was done by Abbas Ramezani.

Acknowledgments

Thanks to all those who have participated in this research.

Conflict of Interest

The author has no conflicts of interest.

References

[1] Sadeghi H, Naser M. Legal-ethical challenges of the EU regulation on artificial intelligence performance in the health domain. *Bioeth J.* 2021;10(35):1–14. [In Persian] doi:10.22037/bioeth.v10i35.27500.

[2] Ramezani A, Sharifi M. Investigating the relationship between the use of artificial intelligence and critical thinking through the mediation of self-learning: a case study of high school students. *Res Instr Methods.* 2025;3(3):65–90. [In Persian]. doi:10.22091/jrim.2025.11934.1171.

[3] Farrell O. Review of Veletsianos G. Learning online: the student experience. *TechTrends.* 2021;65(2):236–7. doi:10.1007/s11528-021-00582-z.

[4] Facer K, Sandford R. The next 25 years? Future scenarios and future directions for education and technology. *J Comput Assist Learn.* 2010;26(1):74–93. doi:10.1111/j.1365-2729.2009.00337.x.

[5] Taşkın Alkan B, Tüzün H. A narrative of meeting a computer: a cognitive-ethnographic study of self-directed computer learning. *Educ Inf Technol.* 2024;29(17):23089–119. doi:10.1007/s10639-024-12748-2.

[6] Merriam SB, Caffarella RS, Baumgartner LM. Learning in adulthood: a comprehensive guide. 3rd ed. San Francisco: Jossey-Bass; 2007.

[7] du Toit-Brits C, van Zyl CM. Self-directed learning characteristics: making learning personal, empowering and successful. *Afr Educ Rev.* 2017;14(3–4):122–41. doi:10.1080/18146627.2016.1267576.

[8] Eke DO. ChatGPT and the rise of generative AI: threat to academic integrity? *J Responsible Technol.* 2023;13:100060. doi:10.1016/j.jrt.2023.100060.

[9] Williamson B, Eynon R. Historical threads, missing links, and future directions in AI in education. *Learn Media Technol.* 2020;45(3):223–35. doi:10.1080/17439884.2020.1798995.

[10] Lo CK. What is the impact of ChatGPT on education? A rapid review of the literature. *Educ Sci.* 2023;13(4):410. doi:10.3390/educsci13040410.

[11] Zawacki-Richter O, Marín VI, Bond M, Gouverneur F. Systematic review of research on artificial intelligence applications in higher education—where are the educators? *Int J Educ Technol High Educ.* 2019;16:39. doi:10.1186/s41239-019-0171-0.

[12] Biesta G. The integrity of education and the future of educational studies. *Br J Educ Stud.* 2023;71(5):493–515. doi:10.1080/00071005.2023.2242452.

[13] Knowles MS. Self-directed learning: a guide for learners and teachers. New York: Association Press; 1975.

[14] Candy PC. Self-direction for lifelong learning: a comprehensive guide to theory and practice. San Francisco: Jossey-Bass; 1991.

[15] Hayles NK. *Unthought: the power of the cognitive nonconscious.* Chicago: University of Chicago Press; 2017.

[16] Fenwick T. Sociomaterial practices in education: knowing, doing, and materiality. In: Billett S, Harteis C, Gruber H, editors.

International handbook of research in professional and practice-based learning. Dordrecht: Springer; 2014.

[17] Polat M, Karataş İH, Varol N. Ethical artificial intelligence in educational leadership: literature review and bibliometric analysis. *Leadersh Policy Sch.* 2025;24(1):46–76. doi:10.1080/15700763.2024.2412204.

[18] Holmes W, Bialik M, Fadel C. Artificial intelligence in education: promises and implications for teaching and learning. Boston: Center for Curriculum Redesign; 2019.

[19] Namdarian L, Armanfar M, Khedmatgozar H. The functions of artificial intelligence technologies in higher education learning systems: aligning with the global evolution of learning. *Technol Educ J.* 2025;19(2):389–412. [In Persian] doi:10.22061/tej.2025.11335.3135.

[20] Khabareh K. Identifying the opportunities of artificial intelligence for teacher leadership in the education process. *Technol Educ J.* 2024;19(1):233–52. [In Persian] doi:10.22061/tej.2025.11612.3171.

[21] Talan T. Artificial intelligence in education: a bibliometric study. *Int J Res Educ Sci.* 2021;7(3):822–37. doi:10.46328/ijres.2409.

[22] Rajabiyan Dehzireh M. Identifying the challenges and capabilities of artificial intelligence in teaching and learning by providing solutions. *Technol Educ J.* 2024;18(4):921–50. [In Persian]. doi:10.22061/tej.2024.10777.3058.

[23] Rezaei M, Pazouki E, Ebrahimpour R. Development of an intelligent mechanism for comparing personalized education in the context of an interactive educational system. *Technol Educ J.* 2024;18(3):697–714. [In Persian] doi:10.22061/tej.2024.10465.3012.

[24] Hwang GJ, Xie H, Wah BW, Gašević D. Vision, challenges, roles and research issues of artificial intelligence in education. *Comput Educ Artif Intell.* 2020;1:100001. doi:10.1016/j.caeai.2020.100001.

[25] Organisation for Economic Co-operation and Development. Trustworthy AI in education: promises and challenges [Internet]. Paris: OECD; 2020 [cited 2026 Aug 28].

[26] Wang B, Rau PLP, Yuan T. Measuring user competence in using artificial intelligence: validity and reliability of an artificial intelligence literacy scale. *Behav Inf Technol.* 2023;42(9):1324–37. doi:10.1080/0144929X.2022.2072768.

[27] Ramazani A, Talebi Z. A consideration of the roles of preservice teachers' information literacy, digital literacy, and ICT self-efficacy in teaching. *Technol Educ J.* 2023;18(1):271–86. [In Persian]. doi:10.22061/tej.2024.10254.2979.

[28] Crawford K. Atlas of AI: power, politics, and the planetary costs of artificial intelligence. New Haven: Yale University Press; 2021.

[29] Fawns T. An entangled pedagogy: looking beyond the pedagogy-technology dichotomy. *Postdigit Sci Educ.* 2022;4(3):711–28. doi:10.1007/s42438-022-00302-7.

[30] Colaizzi PF. Psychological research as the phenomenologist views it. In: Valle RS, King M, editors. Existential-phenomenological alternatives for psychology. New York: Oxford University Press; 1978. p. 48–71.

[31] Selwyn N. Education and technology: key issues and debates. 3rd ed. London: Bloomsbury Academic; 2022.

[32] Rapanta C, Bhatt I, Bozkurt A, Chubb LA, Erb C, Forsler I, et al. Critical GenAI literacy: postdigital configurations. *Postdigit Sci Educ.* 2025;7(4):1296–333. doi:10.1007/s42438-025-00573-w.

AUTHOR(S) BIOSKETCHES

Abbas Ramezani is an assistant professor in the Department of Educational Administration at Farhangian University. He holds a PhD in Educational Management from Shahid Beheshti University in Tehran. Dr. Ramezani has supervised over 45 master's and doctoral theses and presented approximately 80 scientific articles in journals and scientific conferences. He has been actively involved in the scientific committee and review of several scientific journals and conferences. His areas of expertise include educational management, higher education, educational technology, literacy, and comparative education.

Ramezani, A., Assistant Professor, Educational Management. Farhangian University, Tehran, Iran

✉ a.ramezani@cfu.ac.ir

Citation (Vancouver): Ramezani A. [Are self-directed learners the author of their learning? The role of ai in transforming students' cognitive agency] *Tech. Edu. J.* 2026; 20(1): 115-132

 <https://doi.org/10.22061/tej.2026.12892.3354>





ORIGINAL RESEARCH PAPER

Future opportunities for teaching “career and technology” textbooks in lower secondary school education in Iran based on technological trends: a futures studies approach

M. Keshavarz Turk

Department of Art Education, Farhangian University, P.O. Box 14665-889, Tehran, Iran

ABSTRACT

Received: 26 June 2025
Reviewed: 14 August 2025
Revised: 12 October 2025
Accepted: 06 December 2025

KEYWORDS:

Educational Opportunity
Futures Studies
Work and Technology
Technological Trends
Lower Secondary School

* Corresponding author

✉ Mustafa.Keshavarzturk@cfu.ac.ir

📞 (+9821) 88477432

Background and Objectives: 'Career and Technology' Textbooks have the vital role in education in equipping students with technical skills, creativity, and digital literacy. The review of international studies highlights the rapid pace of technological change driven by digital transformation and new technologies like AI, VR/AR, 3D printing, and IoT. The paper argues that these trends challenge traditional teaching methods and create unprecedented opportunities for personalized and interactive learning. This study, using futures studies methods with a foresight approach—which constitutes a systematic, anticipatory, and analytical process for anticipating future changes and threats—identifies key technological trends and emerging educational opportunities in the 'Career and Technology' course. It aims to align the content of this course with future educational needs and skill requirements.

Methods: The research employed a mixed-methods (quantitative-qualitative) exploratory approach. The process was executed in three distinct stages: Step 1: Identifying Technological Trends: A systematic review of academic literature and educational reports was conducted to identify 11 key technological trends with the potential to influence 'Career and Technology' education. Step 2: Prioritizing Trends: A questionnaire was developed to rank the identified trends based on their potential to create opportunities in the next 5-7 years. The survey was sent to 60 experts, with 48 valid responses collected. The data were analyzed using SPSS26 and the Friedman test to rank the trends. Step 3: Identifying and Classifying Opportunities: Semi-structured interviews were conducted with 24 experts (university professors and teachers) to understand the benefits and impacts of the prioritized trends. The interview transcripts were analyzed using qualitative content analysis with ATLAS.ti software.

Findings: The Friedman test results (Chi-Square = 392.912, df=10, $p < 0.000$) showed significant differences in the experts' rankings. The top three trends, based on their potential to create future opportunities, were: Artificial Intelligence (AI) (Average Rank: 9.84), Online Learning (Average Rank: 9.64), and Internet of Things (IoT) (Average Rank: 9.40). The qualitative analysis process generated 362 initial codes, which were then synthesized into 44 main themes representing the key opportunities. Key future-oriented opportunities identified include enhancing cognitive activity, blending hard and soft skills, and creating smart workshops, as well as personalizing learning, intelligent assessment, and safe, low-cost simulation. Additionally, updating the role of teachers, designing engaging technology-based content, automating processes, digital collaboration, real-world projects, virtual visits, and AI-assisted entrepreneurship education are highlighted, aligning the 'Career and Technology' course with future needs. Finally, the analysis categorizes the impact of the prioritized technological trends across the four essential domains of teaching and learning: Content Design and Production, Presentation and Teaching, Performance Assessment, and Learning Environment Management

Conclusion: The research affirms that technology is a key driver for transforming the "Career and Technology" course. The coming years should focus on personalized and deep learning (driven by AI) and facilitating safe, practical learning (driven by VR/AR and IoT). These opportunities are crucial for developing the hard and soft skills students need for the future project-based economy. Such comprehensive integration is essential for

teaching these courses, equipping students with skills in adaptability, teamwork, and problem-solving, while simultaneously nurturing their ability in creative inquiry, data-driven decision-making, and effective collaboration within smart, technology-enriched environments. These are, in fact, the very competencies that fully align with the future-oriented opportunities identified by experts.



COPYRIGHTS

© 2026 The Author(s). This is an open-access article distributed under the terms and conditions of the Creative Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) (<https://creativecommons.org/licenses/by-nc/4.0/>)



NUMBER OF REFERENCES

65



NUMBER OF FIGURES

1



NUMBER OF TABLES

7

مقاله پژوهشی

فرصت‌های آینده آموزش کتب «کار و فناوری» دوره متوسطه اول ایران مبتنی بر روندهای فناورانه: رویکردی آینده‌پژوهانه

مصطفی کشاورز ترک

گروه آموزش هنر، دانشگاه فرهنگیان، صندوق پستی ۱۱۹-۱۴۶۶۵، تهران، ایران

چکیده

پیشینه و اهداف: کتاب‌های درسی «کار و فناوری» نقش حیاتی در آموزش، تجهیز دانش‌آموزان به مهارت‌های فنی، خلاقیت، و سواد دیجیتال ایفا می‌کنند. مرور مطالعات بین‌المللی بر سرعت بالای تغییرات فناورانه که توسط تحول دیجیتال و فناوری‌های نوظهور مانند هوش مصنوعی، واقعیت مجازی و افزوده، پرینت سه‌بعدی و اینترنت اشیا هدایت می‌شوند، تأکید دارد. این مقاله استدلال می‌کند که این روندها، روش‌های تدریس سنتی را به چالش می‌کشند و فرصت‌های بی‌سابقه‌ای را برای یادگیری شخصی‌سازی شده و تعاملی ایجاد می‌کنند. این پژوهش با بهره‌گیری از روش‌های آینده‌پژوهی (با رویکرد آینده‌نگاری) که یک فرایند نظام‌مند، پیش‌نگر و تحلیلی برای پیش‌بینی تغییرات و تهدیدات آینده است، به شناسایی روندهای کلیدی فناوری و فرصت‌های آموزشی نوظهور در درس «کار و فناوری» می‌پردازد. هدف آن، همسوسازی محتوای این درس با مهارت‌ها و نیازهای آموزشی آینده است.

روش‌ها: این پژوهش از یک رویکرد اکتشافی آمیخته (کمی - کیفی) استفاده کرده که در سه مرحله‌ی متمایز اجرا شده است: گام نخست، شناسایی روندهای فناورانه از طریق مرور نظام‌مند ادبیات و گزارش‌های آموزشی که منجر به شناسایی ۱۱ روند کلیدی شد. گام دوم، اولویت‌بندی روندها با توسعه و ارسال یک پرسش‌نامه به ۶۰ متخصص (با ۴۸ پاسخ معتبر) برای رتبه‌بندی پتانسیل ایجاد فرصت در ۵ تا ۷ سال آینده، و تحلیل داده‌ها با SPSS26 و آزمون فریدمن. گام سوم، شناسایی و طبقه‌بندی فرصت‌ها با انجام مصاحبه‌های نیمه‌ساختاریافته با ۲۴ متخصص و تحلیل محتوای کیفی با نرم‌افزار ATLAS.ti صورت گرفت.

یافته‌ها: یافته‌ها نشان داد که آزمون فریدمن ($\chi^2 = 392/912$, $df = 0/000$) تفاوت‌های معناداری در رتبه‌بندی متخصصان را تأیید کرد و سه روند برتر از نظر پتانسیل ایجاد فرصت‌های آتی عبارت بودند از: هوش مصنوعی میانگین رتبه (۹/۸۴)، یادگیری آنلاین میانگین رتبه (۹/۶۴) اینترنت اشیا میانگین رتبه (۹/۴۰) در بخش کیفی، تحلیل منجر به تولید ۳۶۲ کد اولیه شد که در نهایت در ۴۴ تم اصلی (فرصت‌های کلیدی) سنتز شدند. فرصت‌های کلیدی آینده‌محور شناسایی شده شامل تقویت فعالیت شناختی، ترکیب مهارت‌های سخت و نرم، و ایجاد کارگاه‌های هوشمند تا شخصی‌سازی یادگیری، ارزیابی هوشمند، و شبیه‌سازی ایمن و کم‌هزینه و همچنین به‌روزرسانی نقش معلمان، طراحی محتوای جذاب مبتنی بر فناوری، خودکارسازی فرایندها، همکاری دیجیتال، پروژه‌های واقعی، بازدهی‌های مجازی، و آموزش کارآفرینی با کمک

تاریخ دریافت: ۰۵ تیر ۱۴۰۴
تاریخ داوری: ۲۳ مرداد ۱۴۰۴
تاریخ اصلاح: ۲۰ مهر ۱۴۰۴
تاریخ پذیرش: ۱۵ آذر ۱۴۰۴

واژگان کلیدی:

فرصت آموزشی
آینده‌پژوهی
کار و فناوری
روندهای فناورانه
متوسطه اول

* نویسنده مسئول

Mustafa.Keshavarzturk@cfu.ac.ir

۰۲۱-۸۸۴۷۷۴۳۲۱

هوش مصنوعی است که جهت‌گیری درس «کار و فناوری» را با نیازهای آینده هماهنگ می‌کنند. و در نهایت تأثیر روندها را در چهار حوزه اساسی تدریس و یادگیری طبقه‌بندی کردند: طراحی و تولید محتوا، ارائه و تدریس، ارزیابی عملکرد، مدیریت محیط یادگیری.

نتیجه‌گیری: این تحقیق تأیید می‌کند که فناوری، محرک اصلی برای تحول درس «کار و فناوری» است. سال‌های آتی باید بر یادگیری شخصی‌سازی‌شده و عمیق (ناشی از هوش مصنوعی) و تسهیل یادگیری عملی و ایمن ناشی از واقعیت مجازی و اینترنت اشیا تمرکز کنند. این فرصت‌ها برای توسعه مهارت‌های سخت و نرم موردنیاز دانش‌آموزان برای اقتصاد مبتنی بر پروژه آینده، حیاتی هستند چنین یکپارچه‌سازی همه‌جانبه‌ای برای آموزش این دروس ضروری است که دانش‌آموزان را به مهارت‌های سازگاری، کار تیمی و مسئله‌یابی مجهز کند، و هم‌زمان توانایی آنان را در زمینه کاوش خلاق، تصمیم‌گیری مبتنی بر داده، و همکاری مؤثر در بستر محیط‌های هوشمند و فناورانه پرورش دهد در واقع این موارد همان ویژگی‌هایی هستند که کاملاً با فرصت‌های آینده‌محور شناسایی‌شده توسط خبرگان همخوانی دارد.

Introduction

Effective education is considered the foundation for economic, social, and cultural development in any society, and its primary mission is to cultivate a generation equipped with the necessary skills for the future [1]. In this context, the *Career and Technology* courses in the first grade of secondary school play a central role in developing students' practical competencies, technical skills, design thinking, and technological literacy, serving as a bridge between theoretical knowledge and practical application in daily life and future work environments. This course covers processes such as familiarity with tools and materials, the design and production process, project management, and product evaluation. The competencies acquired in this course are essential not only for success in higher educational stages but also for employability in the future job market, which is heavily influenced by technology [2].

The teaching-learning processes in this course, according to the evaluation standards of The Association for Educational Communications and Technology (AECT), as cited by Barto and Conklin [3], can be separated and analyzed into four main areas that technology can revolutionize: 1) Content Design and Production: Includes the creation of digital resources, simulations, and multimedia tools;

2) Presentation and Instruction: Includes the use of active, interactive, and personalized methods (such as flipped learning); 3) Performance Assessment: Includes measuring practical competencies instead of theoretical knowledge and providing precise feedback; and 4) Learning Environment Management: Includes the organization of resources, scheduling, and the safe management of workshops and projects. Since the 2000s, with the acceleration of the digital transformation phenomenon and the emergence of new technologies such as Artificial Intelligence (AI), Virtual and Augmented Reality (VR and AR), 3D printing, and the Internet of Things (IoT), all aspects of life, including educational systems, have undergone fundamental changes [4]. These technological trends have challenged traditional teaching methods and provided unique opportunities for personalizing learning, simulating complex environments, and making content interactive [5].

The Career and Technology course, due to its practical and technical nature, is particularly affected by these transformations. New technological tools have the potential to convert traditional workshop environments into virtual and interactive laboratories, allowing for the practice of complex or dangerous skills without physical limitations or high costs. These developments not only necessitate a review of the content and

educational tools for this course but also directly lead to the emergence of innovative opportunities in the design of teaching aids, specialized practical assessment platforms, and the production of intelligent content. These educational-technological opportunities represent a combination of innovation in content, teaching methods, and the utilization of advanced technologies that can lead to increased effectiveness and attractiveness of the Career and Technology course, and ultimately, enhance students' skills to face the challenges of the Fourth Industrial Age.

Futures studies allows organizations, including educational institutions, to focus on desirable futures, not just those that are more probable. Desirable futures relate to what we, individually or collectively, want to happen in the future. Foresight helps educational leaders move from a passive, reactive mode (merely observing trends) to an active, transformative mode (shaping technologies and educational programs). Its vital role is to anticipate future threats and opportunities that affect complex systems in the long term [6]. Foresight goes beyond speculation; it is defined as a systematic, future-oriented, analytical, and interactive process. This systematic nature makes it a credible tool for "the systematic examination of future developments" [7].

Given the necessity of adapting educational content to the accelerating pace of technological change, the main goal of this research is to use a foresight approach and its tools to identify, analyze, and prioritize emerging educational opportunities in the Career and Technology courses of the first stage of secondary school, which will be shaped by future technological trends. This research seeks to answer these key questions:

- What are the technological trends with the greatest impact on Career and Technology education in the future?

- What educational and content opportunities will be formed for this course based on these trends?

This research can help educational technology specialists, textbook authors, and educational policymakers to design the path for transforming the content of Career and Technology courses with deeper insight, ensuring students are prepared for future job and skill requirements.

Review of the Related Literature

A significant portion of recent domestic literature focuses on the potential of technologies to enhance learning in higher education. The article by Hosseini Moghaddam [8] emphasizes the impact of global trends on higher education and the derived priorities for foresight in Iran. Using foresight methods, it identifies and analyzes four key areas—social accountability, national reputation and influence, transformation in education, and participatory governance—as foresight priorities for higher education in Iran. In the article by Olyaei et al. [9], a comprehensive review of the applications, opportunities, and challenges of Artificial Intelligence (AI) in universities is conducted, using a literature review approach and the experiences of pioneering global universities. The study shows that AI is gradually penetrating the educational, research, and administrative domains, playing an enabling role in the core processes of the university. Based on the evaluations, the research provides specific policy recommendations for the effective and sustainable utilization of AI in Iranian universities, emphasizing the enhancement of digital literacy, infrastructure development, and the formulation of data governance frameworks.

The research by Fazeli et al. [10], using a foresight approach, analyzes the probable scenarios of emerging trends in the teaching and learning of *Ma'arif* (Islamic Studies/Humanities) courses in universities. This aims to identify and improve teaching methods and learning models in this vital area in the face of rapid technological developments. The results of this study indicated that over the next ten years, learning trends will move toward creating dynamic learning environments, personalizing learning with adaptive technologies, increasing learner ownership, and reducing the formality of the learning environment, which necessitates comprehensive planning. Salimi et al. [11], in a systematic study using a qualitative approach and content analysis method, examined the effects of new technologies on future educational trends. The findings were categorized into two main themes: Positive Impact of Technology on Education, which included 40 sub-themes such as increased efficiency, reduced costs, and improved teaching processes; and Challenges of Technology and Education, which included 34 sub-themes such as incompatibility of standards, need for new infrastructure, management of complexity, and cultural impacts. Ultimately, this study concludes that attention and planning for a systemic change in the future educational system are essential, considering reciprocal interaction and smart learning.

The review of credible foreign articles clearly emphasizes novel technologies in education. Dorota et al. [12] presented a systematic review on AR, emphasizing that AR has become a credible and growing educational technology, particularly after the COVID-19 pandemic, due to increased interaction and better learning outcomes. Despite challenges such as cost and the need for technical skills, this research

examined the current trends, benefits, and concerns related to the integration of AR in various educational fields such as life sciences, engineering, and health, and stressed the necessity of utilizing the superior features of this technology for positive educational outcomes. Chen et al. [13] conducted research with the aim of analyzing and mapping the evolution of topics and hidden trends in the field of educational technologies over four decades. They analyzed all articles published in the prestigious journal *Computers & Education* between 1976 and 2018. To achieve this goal, the Structural Topic Modeling (STM) method was applied to 3,963 articles to identify and compare research focal points, annual trends, connections between topics, and the main concerns of the countries/regions active in this field. The article by Burbules et al. [14] emphasizes that education is the main key to sustainable development and the improvement of human quality of life worldwide. It examines how education is being transformed in the information age by novel digital technologies. The current research summarizes five main trends of change in education (including goals, ecology, teaching-learning processes, and educational governance) in light of new technologies and warns that these reforms will only succeed with awareness of the potential risks of technology and by abandoning traditional approaches.

The use of *futures studies* concepts to map the future of education, especially the concept of future educational trends, has received considerable attention in recent years. The article by Dube and Wen [15] aimed to map out the changing trends of educational technologies in schools by analyzing and evaluating the predictions of the Horizon reports from 2011 to 2021 and examining their accuracy using bibliometric analysis. The research results indicated that mobile

technologies and data analytics were consistently highlighted throughout this period, and the technology industry and market, rather than pedagogical or theoretical approaches, have been the main drivers of these technological trends in schools.

The Joint Research Centre of the European Commission, citing Tuomi et al. [16], prepared a report with the aim of identifying emerging trends (especially AI in education), predicting risks, and extracting potential opportunities. This is to help policymakers develop educational systems that are effective, human-centered, and compatible with new technologies. The report posits that the European Union is striving to adapt its educational system to this changing information environment with the goal of achieving the "Digital Decade" and the dual digital and green transition by 2030. In this research, digital technologies (such as Big Data, Blockchain, AI, and new generations of virtual worlds) are introduced as high-potential technologies that are creating a new social-technical revolution with high speed and transformative power.

The main objective of Mosad's [17] research was to review the recent literature in the field of educational technology to compile its latest trends in 2018. This research was conducted using a descriptive method, and its results presented 30 new trends in technology and education for that year. The ultimate goal of this compilation was to assist Egyptian students, researchers, and academic staff specializing in educational technology, as the transformations in educational technology are constantly revolutionizing teaching methods and creating new learning experiences. According to a study by Thompson et al. [18], the most important trends identified in 2021 included remote learning or work, the widening digital divide, and mental health issues (social);

the adoption of blended learning (technological); and reduced higher education budgets and uncertainty in economic models (economic). The authors emphasize that despite institutional slowness in universities to respond to these trends and delays in research sharing (especially after COVID-19), new trends in technology, methodology, and educational practices continue to emerge. This article addresses the importance of trends in educational technology in higher education, noting that trends (which are both measurable and emerging) influence decisions regarding budgeting, infrastructure, and curriculum design.

The article by Akhmadoev et al. [19] examines the use of innovative technologies in the educational process, including VR simulations and AI algorithms. The main objective is to explore the capacity of these technologies to transform education globally and increase accessibility for students of all ages and backgrounds. Furthermore, this article reviews current trends and the future outlook for technology education and offers practical recommendations for teachers on the best way to utilize these tools in classrooms. Wang et al. [20] conducted a study using the Delphi method to identify research trends and priorities in the field of educational technology from the perspective of scientific journal editors. After conducting three rounds of surveys with 25 editors, the final results indicated five main themes for trends and priorities: focus on computer-related aspects, teaching and learning, online and digital education, social aspects, and research and theory. The goal of this study was to provide valuable insights for better understanding the field and to help researchers publish high-quality, relevant articles.

Methods

Participants

The participant selection for this mixed-methods study was conducted in two distinct phases using non-probability purposeful sampling to ensure the inclusion of information-rich cases. For the quantitative phase, a sample of 60 experts was selected based on strict criterion sampling, requiring candidates to hold advanced academic degrees in educational or educational technology fields and possess a minimum of one year of relevant professional experience. This selection aimed to gather a qualified consensus for trend prioritization. The demographic characteristics of the research experts are summarized in Table 1.

Subsequently, the qualitative phase involved 24 specialized experts chosen through purposeful sampling for in-depth, semi-structured interviews. This smaller, focused sample was instrumental in achieving data saturation and obtaining rich, nuanced insights necessary to explore the underlying effects and ultimately categorize the identified technological opportunities within the curriculum. Table 2 presents the demographic characteristics of the research experts in the qualitative phase.

Table 2: Demographic characteristics of experts (Interviews)

Characteristic group	Number	Frequency (%)
Age		
25-35 years	15	62
35-45 years	7	30
Above 45 years	2	8
Education		
Bachelor's degree	5	21
Master's degree	12	50
PhD degree	7	29
Experience in the university/education sector		
1-3 years	7	29
4-7 years	14	58
More than 7 years	3	13

Instruments

Quantitative Instrument: Questionnaire

The core data collection tool for the study's quantitative phase (Prioritizing Trends) was a dedicated measurement questionnaire meticulously developed based on the foundational research. This instrument was crucial for moving beyond trend identification toward strategic prioritization. Its design and content development originated from the key technological trends (e.g., AI, VR, and Gamification) established through the comprehensive literature review in Step 1.

Table 1: Demographic characteristics of research experts (Questionnaire)

Characteristic	Group	Number of experts	Frequency (Percentage)
Age	25 - 35 years old	21	44
	36 - 45 years old	18	37
	Above 45 years old	9	19
Education	Bachelor's Degree	23	48
	Master's Degree	10	21
	Ph.D Degree	15	31
Experience in education	1 - 3 years	12	25
	4 - 7 years	28	58
	More than 7 years	8	17

The questionnaire was structured not merely to list these trends, but to explicitly assess their potential role in creating tangible educational and learning opportunities within the specific context of the Career and Technology curriculum over a defined 5-to-7-year foresight horizon.

To ensure the instrument's scientific rigor and relevance, its content validity was systematically established through a formal process of expert judgment. A preliminary draft of the questionnaire, complete with instructions and scaling mechanisms, was sent to 6 university professors' email addresses with expertise in educational technology and curriculum development. These academics were tasked with reviewing the tool based on three critical criteria: Relevance (the extent to which items measured the intended construct), Clarity (the unambiguous wording of items and instructions), and Completeness (the comprehensive coverage of all identified trends). Following their detailed feedback, which often involved suggested rephrasing or restructuring, the questionnaire underwent rigorous revision and refinement. This iterative

process ensured that the final version, used for data collection from the 60 experts, possessed high content fidelity and academic consensus.

As shown in Table 3, the overall mean score of the experts' evaluations was 4.26 out of 5, and the face and content validity coefficient was calculated as 0.85. These results indicate that the measurement tool possesses adequate and acceptable validity. Therefore, the designed questionnaire was deemed valid in terms of linguistic style, alignment with theoretical literature, consistency with research objectives, and coverage of research dimensions. Following the implementation of minor suggested revisions, the instrument is ready for use in the main phase of the study. To assess the reliability of the measurement instrument, Cronbach's Alpha coefficient was employed. The results from the pilot test of the questionnaire on a small sample indicated a Cronbach's Alpha coefficient of 0.81 for all items. This value exceeds the standard threshold (typically 0.70), signifying a high degree of internal consistency among the questionnaire's items.

Table 3: Face and content validity assessment of the pilot questionnaire (Six experts)

Evaluation indices	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6
Linguistic alignment with Persian writing conventions	4	5	5	4	5	4
Alignment of questions with existing literature indices	4	3	5	5	5	4
Consistency of items with research dimensions	4	5	4	4	5	4
Reliability of questions in addressing research objectives	5	3	4	3	5	4
Necessity of adding or deleting items	3	5	4	5	3	4
Mean score of each expert	4	4.4	4.4	4.2	4.6	4

Qualitative Instrument: Semi-structured Interview

The primary instrument for the qualitative phase (Identifying and categorizing opportunities) was a semi-structured interview protocol. This protocol was indispensable for eliciting deep, contextualized expert insights that quantitative data could not provide. The interview questions were designed strategically to specifically follow up on the results of the quantitative phase; they focused on gaining a broader and deeper understanding of the benefits, effects, and practical applicability of the prioritized technological trends (as determined in the previous step). The structure of the protocol was intentionally semi-structured to maintain focus on the research objectives—ensuring consistent coverage of core themes across all 24 interviews—while also allowing for sufficient flexibility to pursue emergent ideas and capture the specialized, unique perspectives of the experts. Before implementation, the entire interview protocol, including the sequencing and wording of the core questions, was reviewed by subject matter experts. This review process confirmed the protocol's appropriateness, comprehensiveness, and alignment with the study's goal of identifying and categorizing the innovative potentials, thereby ensuring that the extracted data would be rich and directly relevant for the subsequent thematic analysis.

Design

The present study employed a sequential exploratory mixed-methods design, utilizing a combination of quantitative and qualitative approaches to identify and prioritize future

educational-technological opportunities in the Career and Technology curriculum. Foresight methodologies are considered a vital tool for discovering creative potentials in the teaching of Career and Technology curriculum topics. The importance of this approach is amplified, especially when facing the increasing and variable advancements in the field of technology [21]. This design was chosen as it allows for an initial broad exploration of the field (qualitative/literature review), followed by systematic prioritization (quantitative), and a final, deeper qualitative exploration of the results. The overall process followed a sequential flow of phases, as illustrated in Figure 1.

Procedure

The methodology was executed in a clear sequential manner:

Step 1: Identifying Technology Trends (Exploratory phase). This step involved a systematic review of articles searched for future technological trends in the educational field, resulting in the identification and analysis of 43 relevant sources. A precise review and monitoring of these sources were conducted to extract 11 emerging trends highly relevant to education and learning.

Step 2: Prioritizing Trends (Quantitative phase). Utilizing the 11 identified trends, an expert-specific questionnaire was designed. The process involved assessing the validity and reliability of the instrument (as previously detailed, involving six university professors for content validity). The instrument was then used to collect the opinions of specialists and experts for the final prioritization of the trends ($n = 48$ valid responses).

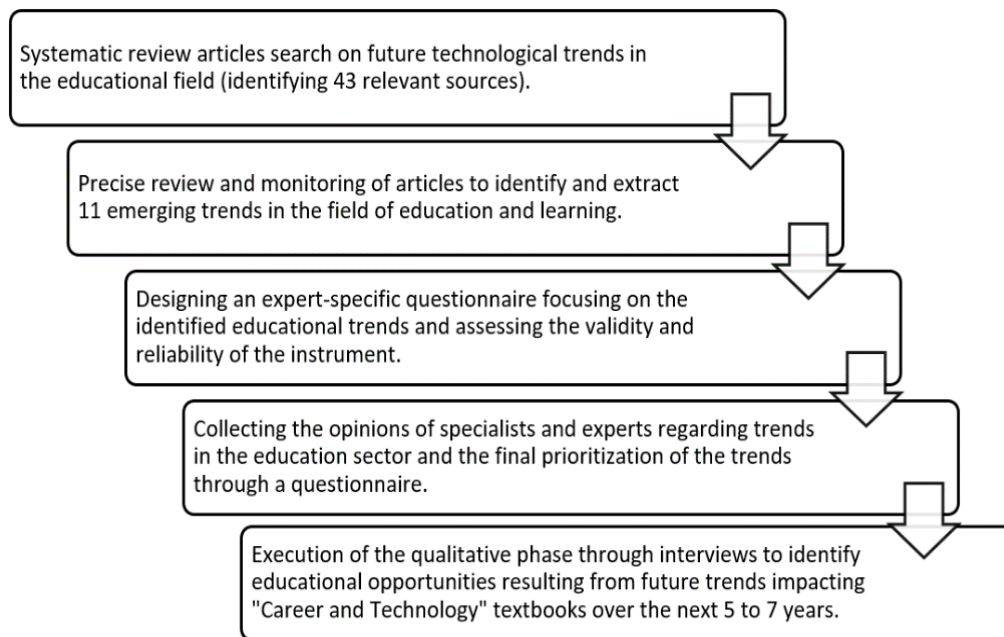


Fig. 1: Research flowchart and sequential design steps for educational-technological opportunity identification

Step 3: Identifying and Categorizing Opportunities (Qualitative follow-up). The final step involved the execution of the qualitative phase through semi-structured interviews with 24 experienced experts. This phase focused on identifying detailed educational opportunities resulting from the future trends prioritized in Step 2, specifically those impacting Career and Technology textbooks over the next 5 to 7 years.

Data Analysis

The analysis was conducted in two distinct stages, corresponding to the quantitative and qualitative phases of the design. In quantitative data analysis (Step 2), data gathered from the 48 valid questionnaires were analyzed using SPSS version 26. Given the objective of comparing the ranking or consensus among different categories of technological trends, the non-parametric Friedman test was employed. The primary goal of this analysis was to calculate and compare the average rankings of the 11 emerging trends to systematically

determine which held the highest potential for creating innovative educational opportunities in the Iranian context. In qualitative data analysis (Step 3), the data extracted from the 24 semi-structured expert interviews were analyzed using thematic analysis. This rigorous procedure began with an initial process of text coding, during which 362 initial concepts were systematically extracted from the interview transcripts. Through subsequent aggregation, refinement, and synthesis, these concepts were ultimately consolidated into 44 thematic categories (core subjects). These 44 themes represent the most critical potentials for curricular improvement, teaching aids, and novel teaching methods within the subject of Career and Technology.

Results and Findings

This section presents the results obtained from executing the two main stages of the methodology (identifying and prioritizing

trends, and identifying opportunities through interviews).

Identification and Prioritization of Technological Trends

The present study employed a rigorous Systematic Review (SR) methodology to comprehensively analyze the existing academic literature concerning "Technology" and "Education". This method, chosen to ensure a transparent and bias-free synthesis of findings, began with the precise formulation of the research question: "What are the effective technologies in education?" A subsequent search strategy was executed across the Google Scholar database, utilizing the key combination: (Technology) AND (education) AND (systematic review) in both English and Persian. The search scope was strictly limited by inclusion criteria, focusing only on full-text, peer-reviewed journal articles published between 2015 and 2025, while excluding items such as technical reports and industrial studies.

Following the initial search, the two-stage screening process—involving the removal of duplicates and an assessment of titles and abstracts by researchers—resulted in the selection of 79 articles. A final, meticulous assessment of the full texts led to a core sample of 33 articles deemed compatible with the study's objectives. Data extraction from these final articles included details on publication year, research approach, and key findings. The synthesized data were then subjected to Inductive Content Analysis, where initial codes were generated and grouped into sub-categories. This rigorous process ultimately yielded 11 technological trends (see Table 4) that were identified as having the potential to influence teaching-learning processes, especially in practical subjects like Career and Technology.

Table 4: Technological trends impacting the future of the education sector

Row	Technological trend in education	Sources
1	AI	[22]; [23]; [24]; [25]; [26]; [27]
2	IoT	[28]; [29]; [30]; [31]
3	3D printing	[32]; [33]; [34]
4	AR and VR	[12]; [35]; [36]; [37]; [38]
5	Blockchain technology	[39]; [40]; [41]; [42]
6	Online learning	[43]; [44]; [45]
7	Gamification	[46]; [47]; [48]; [49]
8	Wearable technology	[50]; [51]; [52]; [46]
9	Cloud-based learning	[53]; [54]; [55]; [56]
10	Social networks and collaborative learning	[57]; [58]; [59]
11	Metaverse in education	[60]; [61]; [62]; [63]; [64]; [65]

Table 5 reflects the prioritization carried out regarding the likely and high-potential technological developments. Based on these findings, experts predict that over the next 5 to 7 years, technologies focusing on AI, Online Learning, and the IoT will be the main trends shaping innovative opportunities in the education of Career and Technology courses (see Table 6).

Table 5: Implementation of the Friedman Test for ranking educational technological trends

Test	Chi-Square value	Degrees of freedom	Significance level
Friedman Test	392.912	10	0.000

Table 6 presents the ranked importance of the 11 identified technological trends based on the experts' opinions, as determined by the Friedman test.

Table 6: Output and analysis results of the Friedman Test

Technology trend	Mean rank	Mean	Standard deviation	Priority
AI	9.84	4.87	0.334	1
Online learning	9.64	4.77	0.592	2
IoT	9.40	4.69	0.803	3
AR and VR	6.96	3.83	0.694	4
Gamification	6.90	3.72	0.706	5
Social networks and collaborative learning	6.68	3.81	0.606	6
Metaverse in education	4.73	2.93	0.665	7
Wearable Technology	4.72	2.95	0.459	8
3D printing	2.79	2.04	0.459	9
Blockchain technology	2.74	2.01	0.617	10
Cloud-based learning	1.61	1.25	0.729	11

In this research, with a focus on education, AI and Machine Learning technology were identified as the most important trend for creating educational-technological opportunities, which indicates the significance of personalized learning and adaptive assessment in the future of Career and Technology education.

Identification of Educational Opportunities (Interview Analysis)

To identify the educational-technological opportunities arising from the prioritized trends, 24 semi-structured interviews were conducted with experts (including faculty members and high school teachers). By executing the coding steps, 362 initial codes were extracted from the 24 expert interviews during the open coding phase. These interviews were conducted semi-structurally. The coding process was performed with the help of ATLAS.ti software. Based on this, the information was initially grouped, and the ideas derived from the open coding were organized into 44 categories or groups. Subsequently, the phrases extracted during the open coding were merged based on content alignment (or similarity).

Discussion

The findings of this study, underpinned by the Friedman test (Chi-Square = 392.912, $df=10$, $p<0.000$), indicate statistically significant differences in how experts perceive the potential of various technological trends to shape future opportunities in teaching “career and technology” at the lower secondary school level in Iran. This strong statistical significance underscores a consensus among experts regarding the differential impact of these emerging technologies on the educational landscape.

Of particular note, AI, online learning, and the IoT emerged as the leading trends, garnering the highest average ranks from the experts. The paramount importance assigned to AI (Average Rank: 9.84) suggests a widespread recognition of its transformative capabilities within education. This aligns with a substantial body of literature [22-27] in our review, which consistently highlights AI’s potential to personalize learning experiences, automate administrative tasks, and provide intelligent tutoring systems. For the context of Iranian lower secondary education, this implies a critical need to integrate AI concepts and tools

into the curriculum and teacher training, preparing students for an AI-driven future

workforce and equipping educators with AI-enhanced pedagogical strategies.

Table 7: Opportunities for teaching-learning processes extracted from interview analysis

Opportunity code	Opportunity (Theme)	Gamification	VR/AR	IoT	Online learning	AI	Opportunity related to the teaching of Career and Technology textbooks
401	Activating cognitive activity	*	*		*	*	AI-powered tools force students to ask better and more precise questions, which accelerates the process of acquiring knowledge and activating cognitive abilities in solving complex technical problems.
402	Blending hard and soft skills	*	*	*	*	*	Designing small entrepreneurship projects based on IoT to strengthen digital literacy skills, computational thinking, and technological entrepreneurship.
403	Creating smart workshops	*	*	*	*	*	Equipping workshops with shared 3D printers or simulation games. Access to online resources and simulators, and networking schools.
404	Reduced cost, automated solutions, and increased return	*	*	*	*	*	The cost of automated solutions decreases compared to in-person instruction, while their return increases due to accumulated learning.
405	Designing engaging educational content aligned with current technologies	*	*	*	*	*	Innovation in educational content: The teacher, freed from repetitive instruction, finds more time to design new, engaging projects relevant to labor market needs. They can design projects centered on AI, IoT, and robotics that align with student interests.
406	Preparedness for dynamic economy: Rapid synchronization with labor market demand		*		*	*	Every project in the Career and Technology course simulates a job mission. This course teaches students how to manage and execute a defined project from start (design) to finish (implementation and product delivery). The Career and Technology course transforms from a traditional unit into a skill accelerator that can rapidly incorporate new skill modules based on current market demands (such as basics of AI, IoT, or simple cybersecurity) into its curriculum.
407	Ownership over challenges: from surface learning to deep mastery of technical skills	*	*	*	*	*	Instead of following instructions, the student seeks to discover solutions and overcome technical challenges independently. This increases the sense of ownership over learning and deeply internalizes problem-solving skills.
408	Change in the competencies of managers and teachers	*	*	*	*	*	Future managers and teachers must acquire the competence to utilize technology; otherwise, they will quickly be recognized as a barrier to the learning process.
409	Passive vs. active use		*	*	*	*	Schools should focus on the active, thoughtful, and critical use of technologies, not passive consumption.

Opportunity code	Opportunity (Theme)	Gamification	VR/AR	IoT	Online learning	AI	Opportunity related to the teaching of Career and Technology textbooks
410	Transition to design thinking	*	*		*	*	Instead of relying solely on linear instructions, the course content should focus on the iterative problem-solving cycle. Students use online tools to first define the real problem, then proceed to ideation, rapid prototyping, and testing. This approach makes "Innovation and Technology" modules the core of the course.
411	Assessment of process with digital portfolio			*	*		Instead of relying solely on the final product, online platforms should be used to create a digital portfolio. This portfolio allows for the documentation of work steps, photos, programming code, and peer or self-assessment throughout the process (e.g., documenting the project in electronics and construction modules).
412	Simulation before construction	*	*	*		*	Used for the virtual design and testing of electronic or mechanical projects. This drastically reduces workshop hazards, material costs, and trial-and-error time before moving to the physical construction phase.
413	Activating textbook images		*		*	*	The student points their phone at a 2D diagram of an electric circuit, and the 3D model of that circuit, with moving currents or detachable components, appears on the screen.
414	Smart design and construction tools		*	*		*	Students can use generative AI tools to assist with initial product design, simulate trial-and-error, and automatically troubleshoot circuits or code.
415	Continuous optimization of technical content		*			*	Curriculum design based on failure and success patterns: Providing precise data to the teacher for improving project designs in future years; for example, if 90% of students fail at a specific project stage, machine learning analysis indicates that part of the content needs to change.
416	Reducing tool barriers: using applications as smart tools		*		*	*	Use of mobile applications as alternative or auxiliary tools; for instance, using Augmented Reality measuring tools for quick dimensioning, or specialized calculators and unit converters (like converting electrical units).
417	The teacher's central role shifts from information conveyor to guide		*			*	With the automation of repetitive tasks by AI and technology, the teacher's central role will shift from an information conveyor to a guide, coach, learning experience designer, and student progress analyst. Instead of focusing on repetitive, step-by-step instruction (now handled by AI and instructional videos), the teacher can dedicate their time to one-on-one coaching. They can provide specialized guidance to each student based on their specific project and help them solve technical and creative challenges.
418	Identifying difficult moments in the learning process			*	*	*	Identify difficult moments in the learning process for timely human intervention.

Opportunity code	Opportunity (Theme)	Gamification	VR/AR	IoT	Online learning	AI	Opportunity related to the teaching of Career and Technology textbooks
419	Automatic remote supervision for test Administration				*	*	Provide automatic remote supervision for test administration.
420	AI-based assessments for fairer evaluation					*	Instead of comparing students to a fixed standard, AI assesses how much each student has progressed relative to their starting point (based on initial assessment data).
421	personalized learning			*	*	*	Technologies help adjust content based on student performance, which aids in developing problem-solving and critical thinking. Adjusting the pace, content, and difficulty level of technical lessons (like teaching design software or coding modules) based on the student's individual needs and preferences. Career and Technology projects can be personalized based on each student's skill level, interest, and learning speed.
422	Facilitating answer seeking for learners		*	*	*	*	Provides practical solutions for improving learning through e-learning platforms, chatbots, and automated assessment and control systems. If a student encounters a problem while working with a tool (e.g., how to calibrate a sensor), they can receive step-by-step guidance from AI without interrupting the teacher's focus.
423	Analysis of student learning data: performance assessment based on practical behavior data in the workshop		*			*	AI reports to the teacher which students (based on initial assessment performance) are most likely to make errors or need practical assistance. This optimized focus allows the teacher to spend their time on students who genuinely need one-on-one help, rather than general supervision.
424	Automation of administrative tasks	*		*	*	*	Automation of administrative tasks, which can reduce the workload of instructors.
425	Providing automatic feedback			*	*	*	AI-based platforms can offer questions that match the individual's level of understanding and provide automatic feedback, which allows students to learn at their own pace.
426	Real-life practical projects	*	*	*		*	Building simple models of sensors, small home automation systems, or smart irrigation systems, or simple environmental sensors using educational kits.
427	Use of sensors and internet-connected devices			*		*	For data collection in the physical classroom environment (e.g., how students interact with educational tools).
428	Training sustainability engineers: Optimization of energy and			*		*	Using smart plugs or energy consumption sensors to measure and reduce resource consumption in the workshop. This teaches students skills in sustainability management and optimization of manufacturing processes.

Opportunity code	Opportunity (Theme)	Gamification	VR/AR	IoT	Online learning	AI	Opportunity related to the teaching of Career and Technology textbooks
429	material consumption Targeted teacher intervention: focusing on at-risk students before errors occur			*		*	Analyzing student data to predict which individual is currently most likely to fail the project or use a tool unsafely.
430	Facilitating group discussions, communication, and collaboration skills				*	*	Collaborative platforms such as wikis, discussion forums, and social media facilitate project-based learning and group discussions, allowing students to learn from each other and improve their communication and collaboration skills.
431	Rapid prototyping	*	*	*	*	*	Students can prototype and test their design ideas quickly and at low cost, which directly contributes to strengthening the innovation and technology modules.
432	Learner-generated educational content: sharing construction experiences				*		Students can easily share their project documentation (such as short instructional videos, construction stage images, or design files) on these networks. This turns rich content produced by the students themselves into an educational resource for future years.
433	Smart assistants		*		*	*	Smart assistants can provide precise technical guidance and help students with troubleshooting while coding for robotics projects or working with specialized software.
434	Entrepreneurship education with AI		*		*	*	Using AI tools for market analysis and identifying consumer needs, and assisting students with naming, brand design, and marketing final products for Career and Technology projects.
435	Developing digital collaboration skills: project management in a social context		*		*		Group projects, whose management and coordination are done through online collaboration tools, directly strengthen teamwork, conflict management, and effective communication skills in a technical context.
436	Safe and low-cost workshop simulation: beyond physical limitations		*	*		*	AR and VR enable the simulation of dangerous workshop environments (like working with cutting tools or electricity) without risk to life or waste of raw materials.
437	Visual guidance during construction: accelerating assembly and practical troubleshooting		*			*	Teaching the stages of assembling and troubleshooting complex devices with AI-powered instructions displayed on the real object. Using VR glasses or tablets to overlay 3D instructions onto the actual workbench. For example, when assembling an electronic circuit, VR shows the student exactly where each component is placed and which wire connects to which point. The student can view the different internal layers of a device and interactively diagnose and replace faulty parts without opening the actual device.

Opportunity code	Opportunity (Theme)	Gamification	VR/AR	IoT	Online learning	AI	Opportunity related to the teaching of Career and Technology textbooks
438	Virtual visits to factories and occupations		*	*	*		The possibility of accessing industrial and work environments that are physically or financially inaccessible through virtual tours, which deepens the student's understanding of careers and technological applications.
439	Online and remote learning of theoretical parts of the Career and Technology course				*		The theoretical parts of the course, such as design fundamentals, familiarity with tools, and production stages, can be delivered to students through online learning. This allows in-person class time to be entirely dedicated to practical and workshop tasks. The teacher can prepare short instructional videos of project stages (e.g., how to work with software or the steps to build a simple robot). These videos serve as self-study content, allowing students to progress at their own pace and review content as needed.
440	Online and blended education	*			*	*	The widespread development and adoption of blended learning models that combine in-person classes with flexible, self-paced online components to increase accessibility and flexibility in the time and location of learning. Tools (like video conferencing or online whiteboards) enable teachers and students to collaborate remotely while maintaining communication through visual cues (like body language). These tools facilitate the definition of group projects.
441	Remote collaboration				*		For group projects, students can use online tools like Google Docs for planning, designing, and project management. This can be done before the in-person work begins in the workshop.
442	Verification of student credentials and electronic certificates				*		Connecting with future careers by converting classroom achievements into real-world credentials in the job market. Providing an official and valid document for every skill acquired, which the student can use as an attestable achievement on their resume.
443	Increasing motivation and practical perseverance: skill training in game format	*	*				Converting project stages into gamified missions. Instead of 'cutting the piece,' the student receives a 'Precision cut badge.' A quick quiz or game assesses knowledge of basic tools (saw, drill, design software) or core concepts (safety, basic electricity). (Competition or game for initial assessment) VR technologies enhance student motivation and understanding by providing engaging simulations.
444	Gamified missions	*					Creating project teams that must share their knowledge and solve each other's problems to receive higher scores. Converting complex project stages (like precise cuts or electronic circuit wiring) into 'levels' or 'gamified missions.' This makes the course engaging and encourages students to perform their work with higher accuracy and speed to earn more points.

Similarly, online learning (Average Rank: 9.64) was ranked exceptionally high. The COVID-19 pandemic accelerated the adoption and acceptance of online learning globally, and our expert panel's ranking reflects its perceived sustained importance [45-50]. This trend presents significant opportunities for expanding access to quality career and technology education, particularly in geographically dispersed areas of Iran. It necessitates the development of robust digital learning platforms, engaging online content, and effective methods for facilitating online collaboration and assessment in technology-focused subjects.

The Internet of Things (Average Rank: 9.40), securing the third position, signifies a growing awareness of its potential to create practical, hands-on learning experiences. As noted in the literature [51-55], IoT enables the development of smart environments and connected devices, offering unique avenues for teaching principles of hardware, software, networking, and data analysis tangibly. For Iranian schools, leveraging IoT could involve creating 'smart classrooms' or incorporating IoT projects into technology curricula, thereby fostering crucial skills in system design, data interpretation, and problem-solving.

These top-ranked trends – AI, online learning, and IoT – collectively point towards a future where technology education is more personalized, accessible, and experiential. The strong expert consensus provides a clear directive for curriculum developers and policymakers in Iran to prioritize these areas when planning the evolution of Career and Technology textbooks and teaching methodologies.

The thematic analysis of the interviews (see Table 6) presents a comprehensive mapping of opportunities for enhancing teaching-learning processes within Career and Technology

education, as extracted from the qualitative interview analysis. The table categorizes these opportunities by theme (Opportunity Code) and cross-references them with key technological drivers, including Gamification, VR/AR, IoT, online learning, and AI. This multidimensional view illustrates how specific technological integrations can transform traditional textbook instruction into dynamic, skill-oriented learning experiences. Finally, the analysis below is presented based on how technologies impact each of the four main teaching-learning processes, with a focus on the Career and Technology course. The impact of these trends, broken down by the four key areas of teaching-learning processes, is as follows:

Content Design and Production

Virtual and Augmented Reality and online simulations are highly crucial in this area. These technologies create opportunities such as Simulation Before Construction (Opportunities 412 and 431) and the production of self-study content. Generative AI, by creating opportunities for smart design and construction tools (Opportunity 414), helps students with rapid prototyping and troubleshooting of initial designs, and shifts the teacher's central role to that of an innovative content designer (Opportunities 417 and 432).

Presentation and Instruction

Artificial Intelligence and Machine Learning (Priority Trend 1) bring about a fundamental transformation in this area. Opportunities such as facilitating individual learning and design thinking (Opportunity 410), activating cognitive activity, and personalized learning (Opportunities 421 and 401) directly stem from AI's capabilities. The teacher evolves from an information conveyor to a technical consultant and guide for student-centered projects (Opportunity 417), which is made possible by

the automation of repetitive processes by technology. The use of gamification and VR/AR for safe workshop simulation (Opportunity 436) and increasing motivation (Opportunity 437) makes learning more engaging and practical.

Performance Assessment

Big data and AI set the stage for fairer assessment (based on progress) (Opportunity 420) and process assessment with a digital portfolio (Opportunity 411). The use of the IoT and sensors creates an opportunity for data-driven performance evaluation and assessing students' practical behavior in the workshop (Opportunity 423). Furthermore, automated feedback and the continuous optimization of technical content based on student performance data (Opportunities 415 and 425) become possible.

Learning Environment Management

Online learning technology provides the main infrastructure for online and blended education (Opportunity 440) and remote collaboration (Opportunity 441), giving the Career and Technology course content flexibility (Opportunity 406) to synchronize with labor market demand. The use of IoT creates an opportunity for creating smart workshops and training sustainability engineers (by optimizing energy consumption in the workshop - Opportunity 428). Additionally, AI can assist with targeted teacher intervention for students at risk before errors occur by providing data analysis (Opportunity 429).

Conclusions

In this era of profound technological transformation, including smart and networked technologies, the nature of education, training, and the development of individual capabilities have fundamentally changed. The current suite

of technologies has created a massive shift in learning and instruction. The classic education system is becoming obsolete, and opportunities for accelerated, easier, and cheaper learning are emerging. Second-generation AI technologies have the potential to enable personalized, individual learning activities and support. A main issue, however, is that teachers are not integrating new technologies into the classroom as expected, with many merely using them as digital substitutes for old tools. The aim of this research was to identify innovative opportunities in the Career and Technology course in Iran's first stage of secondary school, based on technological trends, and to provide a desired future vision for educational policymakers, educational entrepreneurs, and Career and Technology teachers in the country.

The findings of this research indicate that the five main technologies that will have the greatest impact in shaping innovative opportunities in Career and Technology education over the next 5 to 7 years are: AI and Machine Learning, online and blended learning, IoT, VR/AR, and gamification. AI ranked first by experts; AI will have the greatest impact on the areas of Presentation and Instruction and Performance Assessment. With capabilities such as personalized learning, empowering the teacher for targeted coaching, and analyzing student learning data for timely intervention, this technology sets the stage for educational opportunities. Online and blended learning provide a flexible and scalable infrastructure for Learning Environment Management. Opportunities like online and blended instruction, remote collaboration, and process assessment with a digital portfolio are directly dependent on the capabilities of this technology. Virtual and Augmented Reality ranked in the middle; these technologies create fundamental opportunities in the areas of Content Design and Production and

Presentation and Instruction. This includes safe and low-cost workshop simulation, visual guidance during construction (with VR/AR), and virtual visits to factories to increase student motivation and understanding. Internet of Things, by enabling the collection and analysis of IoT sensor data in the workshop, creates opportunities in the Performance Assessment and Learning Environment Management sections. This technology can help educational institutions continuously optimize technical content and make data-driven decisions with a more precise view. Gamification, converting complex project stages into computerized game missions, makes the course engaging and encourages students to perform their work with higher accuracy and speed to earn more points.

The findings of this research indicate that the integration of technology into teaching approaches and the learning process for Career and Technology topics plays a central role in the transformation of these textbooks. Accordingly, business owners and educational experts can leverage these opportunities for innovation and enhancement of educational outcomes. These opportunities can have a favorable impact on students' ability to enter the project-based economy and develop hard and soft skills.

This study showed that in the coming years, the focus should be on personalized and deep learning (driven by AI) and facilitating safe and practical learning (driven by VR/AR and IoT). This focus should be at the core of the attention of educational policymakers, Career and Technology teachers, and educational entrepreneurs. By focusing on technological trends and how they influence the creation of innovation opportunities across diverse areas of Career and Technology education, this research succeeded in mapping a new and comprehensive vision. These results have the capacity to serve as a guiding document for entrepreneurs, investors, and curriculum

designers in the educational sector. Utilizing these identified opportunities, creative individuals can proceed to establish new companies or expand existing services: development of AI-based assessment platforms: to create tools for fairer assessment (based on individual progress) and provide automatic feedback in technical projects; design of VR simulation modules: to build safe and low-cost workshop simulators for practicing complex or dangerous technical skills; and development of digital collaboration tools: to create online platforms for fostering digital collaboration skills and managing group projects in the Career and Technology course.

The opportunities identified through interview analysis for optimizing teaching-learning processes. It details how various technological tools (gamification, VR/AR, IoT, online learning, and AI) align with specific educational themes to enhance the delivery and impact of Career and Technology textbooks. This paper argues for utilizing mobile applications as auxiliary tools, such as AR-based measurement tools for rapid dimensioning or specialized digital unit converters for electrical engineering modules. Also, as AI automates repetitive instruction, the teacher's role shifts from a lecturer to a coach, mentor, and learning experience designer. This transition allows educators to focus on personalized, one-on-one technical coaching and creative problem-solving guidance. If machine learning analysis identifies a high error rate (e.g., 90%) at a specific project stage, it signals a necessary curriculum adjustment. So, future Career and Technology authors could move beyond fixed standards toward AI-based assessments that measure individual progress relative to a student's unique baseline/starting point by leveraging technology to adjust the pace, complexity, and content of technical modules (e.g., coding or design software) based on

individual student performance, interests, and learning speeds. They could also use chatbots and e-learning platforms to provide immediate, step-by-step technical guidance (e.g., sensor calibration) without disrupting the teacher's instructional flow. They can also use AI to analyze practical workshop behavior and predict which students require intensive assistance, thereby optimizing the teacher's time and focus, and analyze real-time student data to predict which individuals are at highest risk of error, enabling proactive rather than reactive intervention.

The main limitation of this study was the difficulty in accessing experienced experts in education and technology. This challenge led the researchers to use a semi-structured interview method. To enhance the validity of the results, future researchers are advised to utilize alternative methodologies such as expert focus groups or scenario analysis with expert participation to discover and validate further opportunities. Conducting statistical research to measure the validity of the identified opportunities with a larger number of educational specialists.

Authors' Contribution

The research ideas, execution, article writing, and data analysis were primarily the responsibility of the first author (corresponding), Mustafa Keshavarz Turk.

Acknowledgments

The authors acknowledge and appreciate the involvement of Tehran's "Career and Technology" teachers between 2024 and 2025. Additionally, we would like to thank our colleagues in Farhangian University of Tehran for their valuable support throughout this study.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this material. Furthermore, the authors certify that this material has not previously been published and that it is not now being considered for publication elsewhere.

References

- [1] Carney S. Reimagining our futures together: a new social contract for education, by UNESCO, Paris, UNESCO, 2021, 186 pages, ISBN 978-92-3-100478-0. *Comp Educ.* 2022;58(4):568–9. doi: 10.1080/03050068.2022.2102326.
- [2] Zare P, Ojaghi N, Dinarvand P. Identifying the challenges of teaching workbook and technology from the point of view of sixth-grade teachers in Shush City in order to provide a suitable solution. *Technol Scholarsh Educ.* 2024;4(1):27–40. [In Persian] doi: 10.30473/t-edu.2024.70687.1132.
- [3] Barreto D, Conklin S. Mapping AECT standards framework: implications for instructional technology programs. *Impact Educ.* 2025;10(2):64–72. doi: 10.5195/ie.2025.461.
- [4] Mukul E, Büyüközkan G. Digital transformation in education: a systematic review of Education 4.0. *Technol Forecast Soc Change.* 2023;194:122664. doi: 10.1016/j.techfore.2023.122664.
- [5] Fullan M, Quinn J. *Coherence: the right drivers in action for schools, districts, and systems.* Thousand Oaks (CA): Corwin Press; 2015.
- [6] Hines A, Bishop PC. Framework foresight: exploring futures the Houston way. *Futures.* 2013;51:31–49. doi: 10.1016/j.futures.2013.05.002.
- [7] Iden J, Methlie LB, Christensen GE. The nature of strategic foresight research: a systematic literature review. *Technol Forecast Soc Change.* 2017;116:87–97. doi: 10.1016/j.techfore.2016.11.002.
- [8] Hoseini Moghadam M. Global trends in science and technology and the futures studies of higher education in Iran: priorities and strategies. *J Iran Futures Stud.* 2022;6(2):1–28. doi: 10.30479/jfs.2022.16183.1332.
- [9] Olyaei S, Montazer GA, Hosseini Moghaddam M. Policy recommendations for the realization of intelligent higher education in Iran based on global trends. *J Sci Technol Policy.* 2024;17(2):69–88. [In Persian] doi: 10.22034/jstp.2024.11659.1784.

- [10] Fazeli M, Moradi R, Rasouli B, Rajabian Damsizheh M. Analysis of potential scenarios of emerging trends in the teaching and learning of education courses at universities with a futures studies approach. *J Appl Res Behav Sci*. 2024;2(1). [In Persian] doi: 10.22070/tlr.2024.18653.1532.
- [11] Salimi B, Namvar Y, Rastgoo A, Soleimani T. A systematic study of the effects of new technologies on future educational trends. *Technol Educ J*. 2022;16(3):647–59. [In Persian] doi: 10.22061/tej.2022.8450.2672.
- [12] Kamińska D, Zwoliński G, Laska-Leśniewicz A, Raposo R, Vairinhos M, Pereira E, et al. Augmented reality: current and new trends in education. *Electronics*. 2023;12(16):3531. doi: 10.3390/electronics12163531.
- [13] Chen X, Zou D, Cheng G, Xie H. Detecting latent topics and trends in educational technologies over four decades using structural topic modeling: a retrospective of all volumes of *Computers & Education*. *Comput Educ*. 2020;151:103855. doi: 10.1016/j.compedu.2020.103855.
- [14] Burbules NC, Fan G, Repp P. Five trends of education and technology in a sustainable future. *Geogr Sustain*. 2020;1(2):93–7. doi: 10.1016/j.geosus.2020.05.001.
- [15] Dubé AK, Wen R. Identification and evaluation of technology trends in K–12 education from 2011 to 2021. *Educ Inf Technol*. 2022;27(2):1929–58. doi: 10.1007/s10639-021-10689-8.
- [16] Tuomi I, Cachia R, Villar-Onrubia D. On the futures of technology in education: emerging trends and policy implications. Luxembourg: Publications Office of the European Union; 2023. doi: 10.2760/079734.
- [17] Mosad AR. Recent trends of educational technology for Egypt 2018. *J Res Curric Instr Educ Technol*. 2019;5(3):187–204. doi: 10.21608/jrciet.2019.54148.
- [18] Thompson K, Corrin L, Hwang GJ, Lodge JM. Trends in education technology in higher education. *Australas J Educ Technol*. 2021;37(3):1–4. doi: 10.14742/ajet.7396.
- [19] Akhmadov A, Mutsurova Z, Beterbieva A. Innovative technologies in the educational process: trends, prospects for development. *SHS Web Conf*. 2023;172:01013.
- [20] Wang X, Hampton J, Ritzhaupt AD, Dawson K. Trends and priorities of educational technology research: a Delphi study. *Contemp Educ Technol*. 2022;14(4). doi: 10.30935/cedtech/12317.
- [21] Hines A, Bishop PJ, editors. *Thinking about the future: guidelines for strategic foresight*. Washington (DC): Social Technologies; 2006.
- [22] Wang N, Wang X, Su YS. Critical analysis of the technological affordances, challenges and future directions of generative AI in education: a systematic review. *Asia Pac J Educ*. 2024;44(1):139–55. doi: 10.1080/02188791.2024.2305156.
- [23] Ouyang F, Zheng L, Jiao P. Artificial intelligence in online higher education: a systematic review of empirical research from 2011 to 2020. *Educ Inf Technol*. 2022;27(6):7893–7925. doi: 10.1007/s10639-022-10925-9.
- [24] Zawacki-Richter O, Marín VI, Bond M, Gouverneur F. Systematic review of research on artificial intelligence applications in higher education—where are the educators? *Int J Educ Technol High Educ*. 2019;16(1):39. doi: 10.1186/s41239-019-0171-0.
- [25] Mustafa MY, Tlili A, Lampropoulos G, Huang R, Jandrić P, Zhao J, et al. A systematic review of literature reviews on artificial intelligence in education (AIED): a roadmap to a future research agenda. *Smart Learn Environ*. 2024;11(1):59. doi: 10.1186/s40561-024-00350-5.
- [26] Salas-Pilco SZ, Xiao K, Hu X. Artificial intelligence and learning analytics in teacher education: a systematic review. *Educ Sci*. 2022;12(8):569. doi: 10.3390/educsci12080569.
- [27] Rizvi S, Waite J, Sentance S. Artificial intelligence teaching and learning in K–12 from 2019 to 2022: a systematic literature review. *Comput Educ Artif Intell*. 2023;4:100145. doi: 10.1016/j.caeai.2023.100145.
- [28] Kandil O, Rosillo R, Abd El Aziz R, De La Fuente D. Investigating the impact of the Internet of Things on higher education: a systematic literature review. *J Appl Res High Educ*. 2025;17(1):254–73. doi: 10.1108/JARHE-05-2023-0223.
- [29] Mircea M, Stoica M, Ghilic-Micu B. Investigating the impact of the Internet of Things in higher education environment. *IEEE Access*. 2021;9:33396–409. doi: 10.1109/ACCESS.2021.3060964.
- [30] Chweya R, Ibrahim O. Internet of Things (IoT) implementation in learning institutions: a systematic literature review. *Pertanika J Sci Technol*. 2021;29(1). doi: 10.47836/pjst.29.1.26.
- [31] Aldowah H, Rehman SU, Ghazal S, Umar IN. Internet of Things in higher education: a study on future learning. *J Phys Conf Ser*. 2017;892(1):012017. doi: 10.1088/1742-6596/892/1/012017.
- [32] Tejera M, Galiç S, Lavicza Z. 3D modelling and printing in teacher education: a systematic literature review. *J STEM Educ Res*. 2025. doi: 10.1007/s41979-025-00147-2.
- [3] Cheng L, Antonenko PD, Ritzhaupt AD. The impact of teachers' pedagogical beliefs, self-efficacy, and technology

value beliefs on 3D printing integration in K–12 science classrooms. *Educ Technol Res Dev.* 2024;72(1):181–208. doi: 10.1007/s11423-023-10276-3.

[34] Pearson HA, Dubé AK. 3D printing as an educational technology: theoretical perspectives, learning outcomes, and recommendations for practice. *Educ Inf Technol.* 2022;27(3):3037–64. doi: 10.1007/s10639-021-10733-7.

[35] Lampropoulos G, Keramopoulos E, Diamantaras K, Evangelidis G. Augmented reality and gamification in education: a systematic literature review of research, applications, and empirical studies. *Appl Sci.* 2022;12(13):6809. doi: 10.3390/app12136809.

[36] Martin F, Dennen VP, Bonk CJ. A synthesis of systematic review research on emerging learning environments and technologies. *Educ Technol Res Dev.* 2020;68(4):1613–33. doi: 10.1007/s11423-020-09812-2.

[37] Fan M, Antle AN, Warren JL. Augmented reality for early language learning: a systematic review of augmented reality application design, instructional strategies, and evaluation outcomes. *J Educ Comput Res.* 2020;58(6):1059–100. doi: 10.1177/0735633120927489.

[38] Zhang J, Li G, Huang Q, Feng Q, Luo H. Augmented reality in K–12 education: a systematic review and meta-analysis of the literature from 2000 to 2020. *Sustainability.* 2022;14(15):9725. doi: 10.3390/su14159725.

[39] Alammary A, Alhazmi S, Almasri M, Gillani S. Blockchain-based applications in education: a systematic review. *Appl Sci.* 2019;9(12):2400. doi: 10.3390/app9122400.

[40] Haque M, Kumar VV, Singh P, Goyal AA, Upreti K, Verma A. A systematic meta-analysis of blockchain technology for the educational sector and its advancements towards Education 4.0. *Educ Inf Technol.* 2023;28(10):13841–67. doi: 10.1007/s10639-023-11744-2.

[41] Ocheja P, Agbo FJ, Oyelere SS, Flanagan B, Ogata H. Blockchain in education: a systematic review and practical case studies. *IEEE Access.* 2022;10:99525–40. doi: 10.1109/ACCESS.2022.3206791.

[42] Rani P, Sachan RK, Kukreja S. A systematic study on blockchain technology in education: initiatives, products, applications, benefits, challenges and research direction. *Computing.* 2024;106(2):405–47. doi: 10.1007/s00607-023-01228-z.

[43] Johnson CC, Walton JB, Strickler L, Elliott JB. Online teaching in K–12 education in the United States: a systematic review. *Rev Educ Res.* 2023;93(3):353–411. doi: 10.3102/00346543221105550.

[44] Akintayo OT, Eden CA, Ayeni OO, Onyebuchi NC. Evaluating the impact of educational technology on learning outcomes in the higher education sector: a systematic review. *Open Access Res J Multidiscip Stud.* 2024;7(2):52–72. doi: 10.53022/oarjms.2024.7.2.0026.

[45] Martin F, Sun T, Westine CD. A systematic review of research on online teaching and learning from 2009 to 2018. *Comput Educ.* 2020;159:104009. doi: 10.1016/j.compedu.2020.104009.

[46] Hong H, Dai L, Zheng X. Advances in wearable sensors for learning analytics: trends, challenges, and prospects. *Sensors.* 2025;25(9):2714. doi: 10.3390/s25092714.

[47] Dehghanzadeh H, Farrokhnia M, Dehghanzadeh H, Taghipour K, Noroozi O. Using gamification to support learning in K–12 education: a systematic literature review. *Br J Educ Technol.* 2024;55(1):34–70. doi: 10.1111/bjet.13335.

[48] Sailer M, Homner L. The gamification of learning: a meta-analysis. *Educ Psychol Rev.* 2020;32(1):77–112. doi: 10.1007/s10648-019-09498-w.

[49] Kalogiannakis M, Papadakis S, Zourmpakis AI. Gamification in science education: a systematic review of the literature. *Educ Sci.* 2021;11(1):22. doi: 10.3390/educsci11010022.

[50] Liu Z, Ren Y, Kong X, Liu S. Learning analytics based on wearable devices: a systematic literature review from 2011 to 2021. *J Educ Comput Res.* 2022;60(6):1514–57. doi: 10.1177/07356331211064780.

[51] Almusawi HA, Durugbo CM, Bugawa AM. Wearable technology in education: a systematic review. *IEEE Trans Learn Technol.* 2021;14(4):540–54. doi: 10.1109/TLT.2021.3107459.

[52] Chu SL, Garcia BM, Rani N. Research on wearable technologies for learning: a systematic review. *Front Educ.* 2023;8:1270389. doi: 10.3389/feduc.2023.1270389.

[53] Malkawi A. Systematic review of cloud computing studies within higher educational institutions in Saudi Arabia. *Int J Sci Res.* 2024;13(1):713–21. doi: 10.21275/SR24105185022.

[54] Eljak H, Ibrahim AO, Saeed F, Hashem IAT, Abdelmaboud A, Syed HJ, et al. E-learning-based cloud computing environment: a systematic review, challenges, and opportunities. *IEEE Access.* 2024;12:7329–55. doi: 10.1109/ACCESS.2023.3339250.

[55] Thavi R, Jhaveri R, Narwane V, Gardas B, Jafari Navimipour N. Role of cloud computing technology in the education sector. *J Eng Des Technol.* 2024;22(1):182–213. doi: 10.1108/JEDT-08-2021-0417.

[56] Samyan N, St Flour PO. The impact of cloud computing on e-learning during the COVID-19 pandemic. *Int J Stud Educ Sci.* 2021;2(2):146–72.

[57] Almukhaylid M. The actualization of the social media affordance for sociality in an informal learning environment: the case of Saudi Arabia [dissertation]. Cape Town: University of Cape Town; 2025.

[58] Almakaty SS. New trends in communication and media education in the digital age: a global analysis and comparison study [preprint]. Preprints; 2024.
doi: 10.20944/preprints202410.1022.v1.

[59] Hu X, Xu Y, Liao H, Ma J. A systematic literature review study of digital transformation in higher education: technologies, challenges and trends. In: Proceedings of the 2024 7th International Conference on Educational Technology Management; 2024 Nov. p. 146–53.
doi: 10.1145/3711403.3711424.

[60] Sidhu MS, Mousakhani S, Lee CK, Sidhu KK. Educational impact of metaverse learning environment for engineering mechanics dynamics. Comput Appl Eng Educ. 2024;32(5).
doi: 10.1002/cae.22772.

[61] Al Yakin A, Seraj PMI. Impact of metaverse technology on student engagement and academic performance: the mediating role of learning motivation. Int J Comput Inf Manuf. 2023;3(1):10–18. doi: 10.54489/ijcim.v3i1.234.

[62] Muhammad AS, Nat M, Sheikh Muse AM, Sena AZ. Exploring the horizon: a comprehensive systematic literature

review on student engagement in the metaverse. Horiz Int J Learn Futures. 2025;33(2):223–44.
doi: 10.1108/OTH-11-2024-0080.

[63] Nuryana IKD, Purwanto P, Isnanto RR. Systematic literature review: the effect of student interaction on academic achievement in online learning. SHS Web Conf. 2024;202:06001. doi: 10.1051/shsconf/202420206001.

[64] Asiksoy G. Empirical studies on metaverse-based education: a systematic review. Int J Eng Pedagogy. 2023;13(3).
doi: 10.3991/ijep.v13i3.36227.

[65] Shan S, Wang Z. Virtual learning using metaverse-based platform. Int J Educ Technol Artif Intell. 2022;1(2).

AUTHORS' BIOSKETCHES

Mustafa Keshavarz Turk holds a PhD. in Entrepreneurship from the University of Tehran. He is a faculty member at Farhangian University of Tehran. His research focuses on the intersection of entrepreneurship, technology, futures studies, and education.

Keshavarz Turk, M., Faculty Member, Entrepreneurship, Farhangian University of Tehran, Tehran, Iran

✉ Mustafa.Keshavarzturk@cfu.ac.ir

Citation (Vancouver): Keshavarz Turk M. [Future opportunities for teaching “career and technology” textbooks in lower secondary school education in iran based on technological trends: a futures studies approach] *Tech. Edu. J.* 2026; 20(1): 133-156

 <https://doi.org/10.22061/tej.2026.12671.3332>





ORIGINAL RESEARCH PAPER

Evaluating pre-service teachers' mathematical modelling task performance: a comparison with ai responses

N. Azadi¹, E. Reyhani¹, M. Ghorbani^{*1}, R. Ebrahimpour², S. Haghjoo³

¹ Department of Mathematics, Faculty of Science, Shahid Rajaee Teacher Training University, Tehran, Iran

² Center for Cognitive Science, Institute for Convergence Science and Technology (ICST), Sharif University of Technology, Tehran, Iran; School of Cognitive Sciences, Institute for Research in Fundamental Sciences (IPM), Tehran, Iran

³ Farhangian University, Bushehr, Iran

ABSTRACT

Received: 16 August 2025
Reviewed: 25 September 2025
Revised: 28 October 2025
Accepted: 19 December 2025

KEYWORDS:

Mathematical Modelling
AI (AI)
ChatGPT
PSTs

* Corresponding author

✉ mghorbani@sru.ac.ir

☎ (+98912) 4074398

Background and Objectives: Mathematical modelling has increasingly become a central component of mathematics education, as it helps students connect abstract mathematical concepts to real-world situations. Despite its importance, many elementary pre-service teachers (PSTs) face challenges when attempting to design or solve modelling problems, partly due to their limited exposure to such tasks during their teacher education programs. With the rapid development of AI (AI), new opportunities have emerged to compare human problem-solving approaches with machine-generated solutions. The purpose of this study is to examine how elementary PSTs and an AI system perform on mathematical modelling tasks. Specifically, the study seeks to understand the strengths and weaknesses of PSTs' modelling competencies, while also exploring the potential contributions of AI as a supportive tool in mathematics education. The objective is not only to evaluate performance but also to address the broader significance of integrating AI into teacher education, highlighting both opportunities and risks.

Methods: A convenience sample of 50 PSTs participated in the study. Participants were asked to complete a researcher-developed test that included mathematical modelling tasks designed to evaluate different aspects of modelling competence. The face and content validity of the instrument were reviewed and confirmed by two experts in mathematics education, ensuring the appropriateness and relevance of the items. Data were collected in written form and analyzed using both quantitative and qualitative approaches. The PSTs' responses were examined based on the competency framework, which provides structured criteria for assessing modelling skills such as understanding the problem, using mathematics, interpreting results, and validating solutions. AI-generated responses were also collected for the same tasks, and these were compared with the human responses in terms of strategy, accuracy, creativity, and solution quality. The study followed a qualitative design with deductive (directed) content analysis, which allowed the researchers to systematically code and interpret the data while drawing comparisons across human and AI performance.

Findings: The findings revealed several important patterns. Many PSTs demonstrated weaknesses in mathematical modelling, particularly in the stages of validation and interpretation. Their answers were often incomplete or lacked sufficient reasoning. However, the participants performed relatively better in the criterion of 'use of mathematics', indicating that they could carry out mathematical procedures but struggled to connect them meaningfully to real-world contexts. No statistically significant differences were found between participants based on gender or academic background, suggesting that the difficulties with modelling are widespread among elementary PSTs regardless of their demographic characteristics. In contrast, the AI system produced solutions that were generally more coherent and well-structured, particularly in terms of validation and creativity. The AI was able to provide step-by-step explanations and generate multiple approaches to solving the same problem, which could serve as a model for PSTs. Nevertheless, the AI responses were not flawless, and in some cases, over-simplifications or assumptions were made without sufficient justification.

Conclusion: The study concludes that while PSTs have some foundational skills in mathematical modelling, their overall competencies are insufficient for solving complex

modelling tasks independently. This finding points to a need for teacher education programs to place greater emphasis on developing modelling skills through practice, reflection, and guided instruction. At the same time, the study highlights the potential of AI as a valuable educational resource. AI can accelerate the learning process by providing worked examples, alternative solutions, and creative perspectives on modelling tasks. However, the findings also caution against over-reliance on AI. If PSTs depend too heavily on AI-generated solutions without critical evaluation, their own problem-solving and reasoning abilities may be undermined. Therefore, AI should be integrated into teacher education thoughtfully, with clear guidelines for its use as a supportive rather than substitutive tool. By balancing human learning with technological support, teacher educators can better prepare future teachers to engage their students in meaningful mathematical modelling activities.



COPYRIGHTS

© 2026 The Author(s). This is an open-access article distributed under the terms and conditions of the Creative Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) (<https://creativecommons.org/licenses/by-nc/4.0/>)



NUMBER OF REFERENCES

47



NUMBER OF FIGURES

3



NUMBER OF TABLES

13

مقاله پژوهشی

ارزیابی عملکرد دانشجو معلمان در تکالیف مدل سازی ریاضی: مقایسه با پاسخ های هوش مصنوعی

نفیسه آزادی^۱، ابراهیم ریحانی^۱، مجتبی قربانی^{۲*}، رضا ابراهیم پور^۳، سعید حق جو^۲

^۱ گروه ریاضی، دانشکده علوم، دانشگاه تربیت دبیر شهید رجایی، تهران، ایران

^۲ مرکز علوم شناختی، مؤسسه علوم و فناوری های همگرا (IGST)، دانشگاه صنعتی شریف، تهران، ایران؛ مدرسه علوم شناختی، پژوهشگاه دانش های بنیادی (IPM)،

تهران، ایران

^۳ دانشگاه فرهنگیان، بوشهر، ایران

چکیده

پیشینه و اهداف: مدل سازی ریاضی به طور فزاینده ای به بخش مرکزی آموزش ریاضی تبدیل شده است، زیرا به دانش آموزان کمک می کند مفاهیم انتزاعی ریاضی را به موقعیت های واقعی پیوند دهند. با وجود اهمیت آن، بسیاری از دانشجو معلمان ابتدایی در طراحی یا حل مسائل مدل سازی با چالش هایی مواجه می شوند که بخشی از آن ناشی از مواجهه محدود آنان با این گونه فعالیت ها در طول دوره های تربیت معلم است. با توسعه سریع هوش مصنوعی فرصت های تازه ای برای مقایسه رویکردهای حل مسئله انسانی با راه حل های تولید شده توسط ماشین به وجود آمده است. هدف این مطالعه بررسی نحوه عملکرد دانشجو معلمان ابتدایی و یک سامانه هوش مصنوعی در انجام تکالیف مدل سازی ریاضی است. به طور خاص، این پژوهش به دنبال درک نقاط قوت و ضعف شایستگی های مدل سازی دانشجو معلمان است، در حالی که هم زمان نقش بالقوه هوش مصنوعی به عنوان یک ابزار حمایتی در آموزش ریاضی را نیز بررسی می کند. هدف پژوهش صرفاً ارزیابی عملکرد نیست، بلکه تأکید بر اهمیت گسترده تر ادغام هوش مصنوعی در آموزش معلمان است که هم فرصت ها و هم مخاطرات آن را برجسته می سازد.

روش ها: نمونه ای در دسترس شامل ۵۰ دانشجو معلم در این پژوهش شرکت کردند. از شرکت کنندگان خواسته شد آزمون محقق-ساختی را تکمیل کنند که شامل تکالیف مدل سازی ریاضی برای ارزیابی جنبه های مختلف شایستگی مدل سازی بود. رویای صوری و محتوایی ابزار توسط دو متخصص آموزش ریاضی بررسی و تأیید شد تا تناسب و ارتباط سوالات تضمین شود. داده ها به صورت نوشتاری جمع آوری و با رویکردهای کمی و کیفی تحلیل شدند. پاسخ های دانشجو معلمان بر اساس چارچوب شایستگی گریفراس و ماس بررسی گردید؛ چارچوبی که معیارهای ساختاریافته ای برای ارزیابی مهارت های مدل سازی مانند درک مسئله، به کارگیری ریاضیات، تفسیر نتایج و اعتبارسنجی راه حل ها ارائه

تاریخ دریافت: ۲۵ مرداد ۱۴۰۴

تاریخ داوری: ۰۳ مهر ۱۴۰۴

تاریخ اصلاح: ۰۶ آبان ۱۴۰۴

تاریخ پذیرش: ۲۸ آذر ۱۴۰۴

واژگان کلیدی:

مدلسازی ریاضی

هوش مصنوعی

چت جی پی تی

دانشجو معلمان

* نویسنده مسئول

mghorbani@srui.ac.ir

۰۹۱۲-۴۰۷۴۳۹۸ ③

می‌دهد. همچنین پاسخ‌های تولیدشده توسط سامانه هوش مصنوعی برای همان تکالیف جمع‌آوری و از نظر راهبرد، دقت، خلاقیت و کیفیت راه‌حل با پاسخ‌های انسانی مقایسه شدند. پژوهش حاضر از طراحی کیفی با تحلیل محتوای استقرایی هدایت‌شده بهره گرفت که به پژوهشگران امکان داد داده‌ها را به طور نظام‌مند کدگذاری و تفسیر کنند و هم‌زمان مقایسه‌هایی میان عملکرد انسانی و هوش مصنوعی انجام دهند.

یافته‌ها: یافته‌ها الگوهای مهمی را نشان دادند. بسیاری از دانشجو معلمان ضعف‌هایی در مدل‌سازی ریاضی از خود بروز دادند، به‌ویژه در مراحل اعتبارسنجی و تفسیر. پاسخ‌های آنان اغلب ناقص یا فاقد استدلال کافی بود. باین‌حال، مشارکت‌کنندگان در معیار «به‌کارگیری ریاضیات» عملکرد نسبتاً بهتری داشتند، به این معنا که می‌توانستند فرایندهای ریاضی را اجرا کنند؛ اما در برقراری ارتباط معنادار آن‌ها با زمینه‌های واقعی مشکل داشتند. تفاوت معناداری از نظر آماری بین شرکت‌کنندگان بر اساس جنسیت یا پیشینه تحصیلی مشاهده نشد که نشان می‌دهد فارغ از ویژگی‌های جمعیت‌شناختی، دشواری‌های مربوط به مدل‌سازی در میان دانشجو معلمان ابتدایی رایج است. در مقابل، سامانه هوش مصنوعی راه‌حلی منسجم‌تر و ساختارمندتر ارائه داد، به‌ویژه در زمینه اعتبارسنجی و خلاقیت. هوش مصنوعی قادر بود توضیحات گام‌به‌گام و رویکردهای متعددی برای حل یک مسئله تولید کند که می‌تواند به‌عنوان الگو برای دانشجو معلمان مورد استفاده قرار گیرد. باین‌حال، پاسخ‌های هوش مصنوعی نیز بی‌نقص نبودند و در برخی موارد ساده‌سازی بیش از حد یا فرضیات بدون توجیه کافی در بین پاسخ‌ها مشاهده شد.

نتیجه‌گیری: نتایج نشان داد اگرچه دانشجو معلمان ابتدایی دارای برخی مهارت‌های پایه‌ای در مدل‌سازی ریاضی هستند، اما شایستگی کلی آنان برای حل مستقل تکالیف پیچیده مدل‌سازی ناکافی است. این یافته بیانگر ضرورت توجه بیشتر برنامه‌های تربیت‌معلم به توسعه مهارت‌های مدل‌سازی از طریق تمرین، بازاندیشی و آموزش هدایت‌شده است. درعین‌حال، پژوهش بر پتانسیل هوش مصنوعی به‌عنوان منبعی ارزشمند در آموزش تأکید دارد. هوش مصنوعی می‌تواند با ارائه مثال‌های حل‌شده، راه‌حل‌های جایگزین و دیدگاه‌های خلاقانه، فرایند یادگیری را تسریع کند. باین‌وجود، یافته‌ها هشدار می‌دهند که اتکال بیش از حد به هوش مصنوعی می‌تواند توانایی‌های استدلالی و حل مسئله دانشجو معلمان را تضعیف کند؛ بنابراین، هوش مصنوعی باید به‌صورت سنجیده و با دستورالعمل‌های روشن به‌عنوان ابزار حمایتی و نه جایگزین در آموزش معلمان به کار گرفته شود. با ایجاد توازن میان یادگیری انسانی و پشتیبانی فناورانه، مربیان معلم می‌توانند معلمان آینده را بهتر برای درگیرکردن دانش‌آموزان در فعالیتهای معنادار مدل‌سازی ریاضی آماده سازند.

Introduction

Teaching and learning mathematical modeling are a key area in mathematics education, enhancing students' understanding, critical thinking, problem-solving skills, and adaptability to real-world contexts [1-6]. Developing these skills early supports both academic success and future professional competencies. Mathematical modelling is challenging to teach and learn, but teachers with appropriate training and support can successfully design and implement modelling activities [7-9]. Modelling enhances understanding, retention, and positive attitudes toward mathematics [10], highlighting the need to assess PSTs' modelling competencies.

The 21st-century educational landscape has been transformed by technology, especially artificial intelligence (AI) [11]. Future math

education will likely feature blended learning environments, enhanced computational thinking, data literacy, problem-solving, critical thinking, and interdisciplinary connections [12]. Considering the importance of mathematical modelling in the education of elementary education pre-service teachers (PSTs), as well as the advancements in technology and the need to pay attention to AI as a field that impacts education, particularly in mathematics education, this study focuses on the learning process and modelling competency of elementary education PSTs in solving mathematical modelling tasks, rather than on the instruction or teaching methods of modelling. Accordingly, the study aims first to assess the modelling competency of elementary education PSTs in solving mathematical modelling tasks; then to examine the responses of ChatGPT to mathematical modelling questions; and finally, to compare

the performance of PSTs with that of AI, ChatGPT. Therefore, the research questions are stated as follows:

- How do elementary education PSTs perform in each of the seven criteria for mathematical modelling competencies?
- How does the performance of elementary education PSTs compare to that of ChatGPT in responding to different types of modelling problems?
- Is there a difference in the modelling competencies of elementary education PSTs based on gender and educational background?

Review of the Related Literature

Mathematical Modeling

Blum and Borromeo Ferri conceptualize mathematical modelling as a process of transition between the real world and the world of mathematics [3]. According to Blum and Leiß, the seven-step process of mathematical modelling can be depicted using a modelling cycle [13], as shown in Figure 1.

The modelling cycle begins with understanding the situation and constructing a situational model [13-15]. The problem is then

simplified and structured to form a real model, identifying key variables and relationships [14-15]. This real model is converted into a mathematical model for calculations and analysis, producing mathematical results that require interpretation in context. Validation follows, ensuring logical consistency and accuracy, often involving comparison of models and critical reflection [13][15]. Finally, the solution is communicated for external evaluation and discussion, completing the ideal modelling cycle, though iterative movement between stages is often necessary [16-17].

AI

Advancements in information and communication technologies have led to scientific transformations, such that in recent years, AI technology has been present in almost all scientific fields. According to Wang and Sun, AI is a new field in technology designed for researching and developing theories, methods, technologies, and application systems to simulate, enhance, and advance human intelligence [18]. Recently, initiatives and projects have been launched in various countries to introduce AI and machine learning into the education system [19].

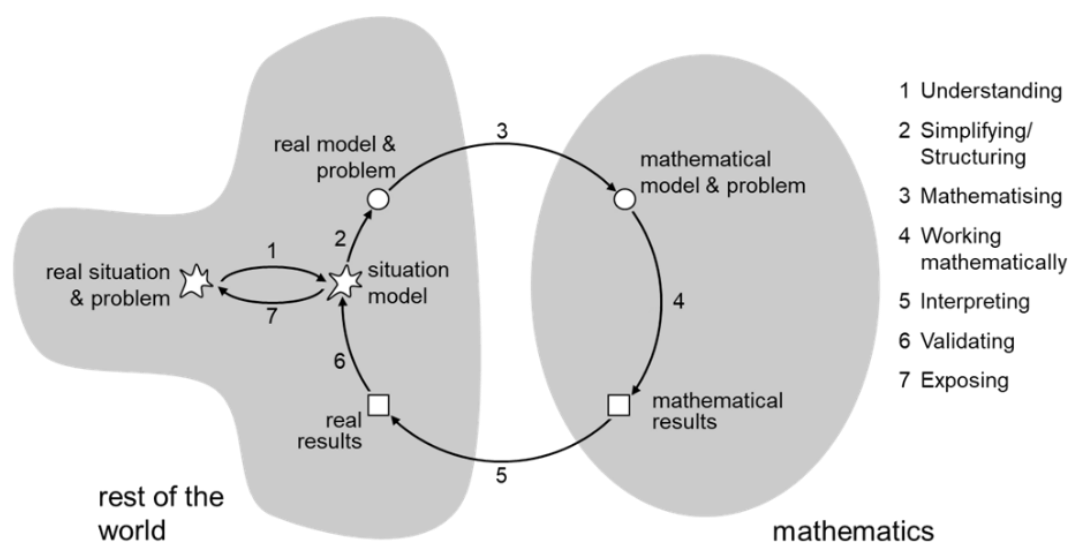


Fig. 1: Diagram of the mathematical modelling cycle proposed by [13]

One of the innovations with the potential to bring about profound changes in the education system is ChatGPT [20], which is an advanced language-processing AI developed by OpenAI [12]. ChatGPT is available in versions GPT-3, GPT-3.5, and GPT-4. Mathematics is continually employed to design innovative AI algorithms that enhance both power and efficiency. Additionally, it can aid in identifying and understanding the limitations of AI [21]. AI-based chatbots, like ChatGPT, can solve basic mathematical and logical problems, but they may not provide reliable results for more complex issues [22].

AI and Mathematics Education

AI, capable of independent thinking and creativity, enhances learning efficiency and reduces study time [18], [23]. Generative AI models like ChatGPT have transformed education, changing how students approach mathematical problem-solving [24]. Generative AI, as a pioneering technology, has challenged traditional teaching and learning methods, and the performance of AI-based chatbots like Google Bard (now Gemini), ChatGPT, and Bing Copilot (now Copilot) in solving mathematical problems, especially in educational settings, has attracted significant attention [25]. These systems have demonstrated their ability to solve basic and moderately complex math problems. However, they may not always provide the best or most efficient solution. Teachers must ensure that students benefit from this valuable technology without becoming overly reliant on it for solving complex problems [26]. It is anticipated that AI will bring significant transformations to mathematics education. Therefore, teachers and instructors must stay informed about the latest advancements and adapt to them, while remaining committed to delivering high-quality education [12].

Chatbots are increasingly recognized as effective learning tools in education. They provide quick, clear, and personalized support, helping students understand concepts, solve problems step-by-step, improve math skills, and explore unique solutions [22] [27]. Chatbots can enhance math education, enable learning at an individual pace, and make mathematics more accessible, while students take a more active role in learning. However, their use should complement, not replace, traditional learning [21].

Parra et al. showed that AI can help students explore geometry concepts under teacher supervision [25], though chatbots may struggle with real-world tasks and over-reliance may reduce human interaction [26]. Lee and Yeo developed an AI chatbot acting as a virtual student to support PSTs' questioning and teaching practice [28].

Spreitzer et al. found that different ChatGPT versions possess basic problem-solving skills, but effectiveness declines with task complexity [26]. Yang et al. reported stronger modelling competencies among German PSTs compared to China and Hong Kong [29]. Nguyen and Tran observed improvements in modelling skills among Vietnamese PSTs [30]. Geiger et al. proposed a framework to enhance teachers' modelling competencies holistically [17].

Dasari et al. showed that students relying solely on AI performed worse than those taught by teachers or assisted by ChatGPT, emphasizing both AI's potential and teachers' essential role [31]. Gerber et al. highlighted the importance of integrating technology training into teacher education [32]. Guerrero–Ortiz demonstrated that technological environments support PSTs in designing modelling tasks, understanding real-world problems, performing complex calculations, and applying mathematical concepts [33].

Research on elementary mathematical modelling, particularly teacher support and AI-related skills, remains limited [9][19]. Therefore, more research must be conducted in the area of teaching mathematical modelling at the elementary level. According to Wei et al., teaching mathematics at the elementary level is closely related to authentic real-world issues [34], which is one of the key characteristics of mathematical modelling activities.

Given the background of the present study, the key to this lies in the hands of teachers. To enhance the teaching and learning of mathematical modelling for elementary students, it is essential to develop teachers in this area. Therefore, the focus of this research is on examining the modelling competencies of pre-service elementary teachers. Additionally, the need for research in the field of AI prompted the authors to compare the responses of pre-service elementary teachers with those of advanced AI technology.

Methods

Participants

A random sample of 50 pre-service elementary teachers, from the cohorts of 2021 to 2023, was selected to answer the research questions (Table 1). Of these PSTs, 22 were female, and 28 were male. The sample consisted of 15 students from the 2021 cohort, 20 from the 2022 cohort, and 15 from the 2023 cohort of the university.

Instruments

To ensure usability, the mathematical modeling questions were reviewed by elementary education experts and pilot-tested with a small group of pre-service teachers. Necessary adjustments were made to enhance clarity, reliability, and validity, ensuring the results accurately reflect PSTs' competencies in mathematical modeling. The pilot test showed acceptable reliability (Cronbach's alpha = 0.8). Three researcher-developed problems, aligned with the mathematical modelling competency criteria, were provided to PSTs. The problems allowed multiple solution strategies. The participants had 24 hours to complete the assignments.

Procedure

The responses of PSTs to the questionnaire items were scored based on the mathematical modelling competency framework by Greefrath and Maaß [15]. Subsequently, the questions were answered by ChatGPT AI, and its responses were compared with those of the PSTs. After various descriptions were made, the significance of gender and educational background of the pre-service elementary teachers was examined, and questions one to three were answered completely. The significance of the differences was analyzed using SPSS software. Before conducting the main test, a pilot test consisting of six mathematical modelling problems (including three levels of modelling assignments) was administered.

Table 1: Number of Participants

Year of Entry	Girls	Percentage of Girls	Boys	Percentage of Boys	Total
Entry 2021	8	53%	7	47%	15
Entry 2022	6	30%	14	70%	20
Entry 2023	8	53%	7	47%	15
Total	22	44%	28	56%	50

Table 2 shows the discrimination and difficulty indices of the pilot test questions. According to Table 2, questions 1, 3, and 5 were considered for the main test with minor modifications. Table 3 shows the discrimination and difficulty indices of the pilot test questions. These indices were calculated based on the percentage of correct responses from different groups of participants, the top and bottom 25% of respondents, commonly used in item analysis. According to Table 1, questions 1, 3, and 5 were selected for the main test with minor modifications.

Table 2: Discrimination and Difficulty Index

Question	Discrimination Index	Difficulty Index
1	0.733	0.8
2	0.5	0.3
3	0.6	0.4
4	0.16	0.29
5	0.61	0.12
6	0.28	0.11

Design

This study employed a mixed-methods approach (a combination of quantitative and qualitative methods) of the sequential explanatory type. In this way, the main focus of the work is on qualitative results, and the use of quantitative results aims to shape the qualitative data [35]. This study used a qualitative design based on deductive (directed) content analysis. Qualitative content analysis is "An approach to documents that emphasizes the role of the investigator in the construction of the meaning of and in texts" [36]. "DQA is an attempt to encourage researchers to test, refine, reformulate, refute, and replace theoretical models qualitatively" [37]. In deductive qualitative content analysis, the analysis and interpretation of data are based on categories and themes that the

researcher has defined prior to data collection. In other words, the data analysis is guided by existing theoretical frameworks [38].

To evaluate the modelling competencies of pre-service teachers in this study, an analytical framework was employed that includes specific criteria for assessing performance in solving modelling tasks. In this regard, the criteria proposed by Greefrath and Maaß for evaluating modelling competencies were selected as the basis for the analysis [15]. Table 3 shows the criteria for evaluating modelling competencies presented by Greefrath and Maaß [15].

Greefrath and Maaß employed the modelling competency framework in their research [15]. As shown in Table 3, the criteria for evaluating modelling competencies used in their study include understanding, gathering information, mathematization, use of mathematics, interpretation, validation, and discussion of results.

Kang and Noh classified modelling problems into three levels based on ambiguity and information completeness [39]:

- Level 1 is clearly defined with minimal ambiguity,
- Level 2 contains some ambiguity and incomplete information, and
- Level 3 is open-ended with incomplete or excessive information, requiring students to analyze, strategize, and implement solutions.

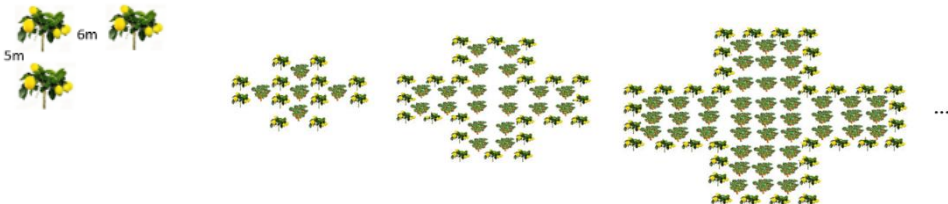
The researcher-developed questionnaire was designed according to these three levels and aligned with the mathematical modelling competency criteria [39], as detailed in Table 4.

Based on the mathematical modelling framework [15] (understanding the problem, gathering information, mathematization, using mathematics, interpretation, validation, and discussion of results), the responses were scored. The scoring followed the classification by Spreitzer et al. [26] as shown in Table 5.

Table 3: Criteria for Evaluating Modelling Competencies [15]

Competence	Description	Competence
Understanding	PSTs construct a mental model of a specific situation and understand the question.	Understanding
Gathering Information, Analyzing Resources (Transforming)	Separating important information from unimportant information in a real situation.	Gathering Information, Analyzing Resources (Transforming)
Mathematization	Translating real situations into appropriate mathematical models (sentence, equation, shape, etc.).	Mathematization
Use of Mathematics	Working with the mathematical model.	Use of Mathematics
Interpretation	Relating the results of the model to the real situation and achieving real outcomes.	Interpretation
Validation	Checking the appropriateness of real results and comparing and evaluating different models concerning a real situation.	Validation
Discussion of (Potentially) Contradictory Results	Linking the model's responses to the real situation and answering the question.	Discussion of (Potentially) Contradictory Results

Table 4: Test Questions

Row	Test Questions
1	A school with 282 students has decided to plant the maximum number of orange and lemon saplings on agricultural land with the following pattern, with the help of the students (the planting pattern for the saplings is illustrated below from left to right. The first figure of the pattern begins with four orange saplings and 12 lemon saplings surrounding them, and this continues in subsequent figures. The horizontal distance between the saplings is 6 meters, and the vertical distance between two saplings is 5 meters. Lemon saplings are placed all around the field, while orange saplings are positioned in the center of the field. It is known that the circumference of the agricultural land is 264 meters. a) How many orange and lemon saplings should the school prepare for planting in this agricultural land? b) How many students will you divide into groups for planting each sapling? 
2	The school is looking to purchase gifts for outstanding students. There are two options to choose from at the store: each pair of ping pong paddles costs 100,000 z, and a chess set costs 150,000 z. For every 5 pairs of ping pong paddles purchased, you get one pair free, and if you buy 2 chess sets, you get one chess set free. If the school needs a certain number of gifts, which option is better [40]?
3	Recently, charitable organizations have started campaigns to collect bottle caps. You might wonder why bottle caps. One reason is their small size, as they can be easily gathered without requiring a lot of space. These caps are made of high-quality materials, and after recycling, they are used in various industries to produce office and even commercial supplies. On the other hand, the body of the bottles is made of "polyethylene terephthalate" (265 degrees Celsius) [41], and the labels around them are mostly made of "PVC." However, the bottle caps are made of a different material, "PE polyethylene" (with a melting point

Row	Test Questions
	of 143.3 degrees Celsius) [42]. Each of the materials mentioned has a different melting point, and since it is not possible to predict two melting points in a recycling machine, putting them together can cause issues. Both plastic caps and plastic bottles are recyclable, but due to their different melting points, they cannot be recycled together. Considering the costs and time involved, in some cases, the relevant centers may decide against recycling the caps, and both the caps and labels end up being discarded. These factors make bottle caps unique materials that are unwanted by both the public and recyclers, while also being distinct and special materials from which good raw materials can be derived. Collecting these caps helps protect the environment, encourages citizen responsibility, and aids those in need. Many elderly individuals and patients require wheelchairs but cannot afford them. The charitable efforts that use the proceeds from bottle cap sales to purchase wheelchairs for such individuals significantly improve their lives. Engaging in charitable work and spreading this practice can enhance individuals' sense of responsibility. How many days should pass for your university to be able to procure a high-quality wheelchair for a nursing home?

Table 5: Scoring Method for PSTs' and ChatGPT's Responses

Score	0	1	2	3
Description	Not Attempted	Attempted but incorrect	Attempted but incomplete	Completed and sufficient

Based on the selected scoring method, the maximum score for the questionnaire is 84 points.

Results and Findings

Responses of the PSTs

Table 6 shows the minimum and maximum scores obtained by the PSTs, along with the standard deviation and mean. The overall mean score is 26.16, with a standard deviation of 21.53.

In Table 7, the average total scores of PSTs were compared across the two variables of

gender and academic background. It was observed that the average total score of male PSTs (27.35) was higher than that of female PSTs (24.63). The average scores of PSTs admitted in 2021 (30.46) were higher than those admitted in 2022.

Additionally, Figure 2 displays the scores of the PSTs. The highest score achieved was 68, obtained by three PSTs. Five individuals received a score of one, which is the lowest score. None of the PSTs received a score of zero. Fourteen individuals scored above half of the maximum score (i.e., a score of 42), while 36 individuals scored below half of the maximum score.

Table 6: Statistical Information of PST Teachers' Scores

Number	Minimum Score	Maximum Score	Mean	Standard Deviation
50	1	63	26.16	21.53

Table 7: The Mean and Standard Deviation of PSTs' Scores Across Different Variables

	Gender		Educational Background		
	Girl	Boy	2021	2022	2023
Mean Scores	24.63	27.35	30.46	27.1	21.78
Standard Deviation	23.08	19.72	21.47	22.64	17.85

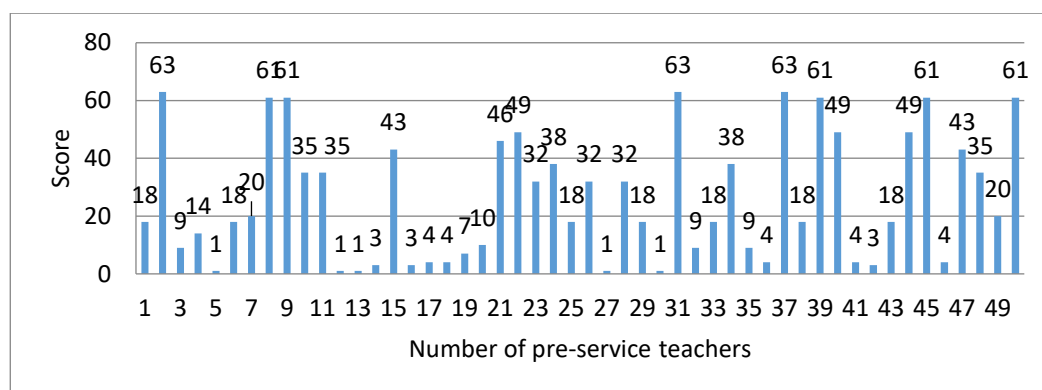


Fig. 2: Status of PSTs' Scores in the Exam

The percentage of responses from PSTs to each of the exam questions is shown in Table 8. In this analysis, since a score of zero does not reflect the ability to evaluate the thinking of the PSTs, the scores of 1, 2, and 3 were examined for each question.

Table 8 shows that PSTs performed best in the 'use of mathematics' criterion for question 2 (score 1, 48%), indicating basic procedural engagement, but overall, participation in 'validation' was extremely low (0% for questions 1b, 2, and question 3), revealing a major gap in evaluating results.

In question 1a, most PSTs scored well in 'understanding the problem', 'gathering information', and 'mathematization' (score 3, ~42%), identifying context and relevant quantities, though few articulated assumptions or reflected on alternatives. Interpretation and discussion were minimal (score 1, 2%), showing limited connection between mathematical work and real-world meaning.

Question 1b mirrored this pattern, with good scores in problem understanding (36%) but no engagement in validation. Question 2 showed frequent procedural use of mathematics (score 1, 48%), with some algorithmic reasoning but limited contextual consideration. Question 3 exhibited generally low participation, with partial engagement in criteria such as gathering information, mathematization, use of mathematics, and interpretation (score 2, 10%),

and many responses lacked coherent modeling strategies or depth.

Overall, students demonstrated stronger performance in early modeling phases like problem understanding and mathematization, but consistently struggled with validation and interpretation. This pattern suggests a fragmented understanding of the modeling cycle, where modeling is seen more as a problem-solving routine than as an iterative reasoning process.

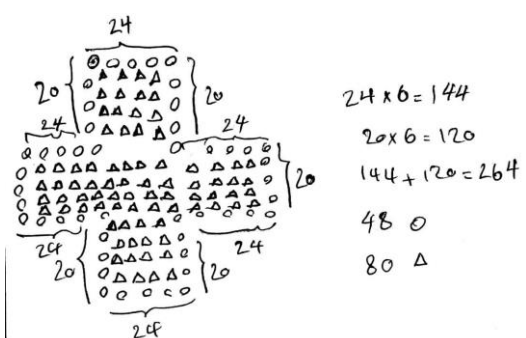
A sample of PSTs' written responses is shown in Table 9, illustrating common reasoning patterns and recurring difficulties in transitioning from mathematical formulation to meaningful interpretation.

A review of the average scores in each criterion of modeling competency, along with the qualitative analysis of PSTs' responses (Table 9), reveals that student teachers demonstrated relatively better performance in the 'use of mathematics' criterion, while their weakest area was clearly 'validation'. This finding is consistent with what emerged in Table 8, where performance across criteria appeared interrelated. In many cases, PSTs who struggled to understand the problem also faced difficulties in subsequent phases such as information gathering, mathematization, and interpretation. This pattern suggests that modeling competencies are not isolated skills but function as a connected cognitive process.

Table 8: Percentage of PSTs' Responses to the Mathematical Modelling Competency Criteria

	Mathematical Modelling Competency Criteria																				
	Understanding			Gathering Information			Mathematization			Use of Mathematics			Interpretation			Validation			Discussion		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1a	6	14	42	6	14	42	4	14	42	12	14	36	2	6	32	20	16	20	2	6	32
1b	24	2	36	10	22	30	24	8	24	24	12	20	24	18	20	0	32	20	20	18	20
2	16	22	6	32	22	6	40	14	6	48	20	6	4	24	6	0	20	6	26	20	6
3	0	8	8	0	10	6	0	10	6	0	10	6	6	10	6	0	2	6	4	6	6

Table 9: A Sample of PSTs' Responses to the Questionnaire Questions

The criteria for mathematical modelling competency.	Score	Question	Sample response from PSTs
Understanding the problem: The PST drew a model of how to plant trees according to the situation of the problem, and therefore understood the question well.	3	1a	
Gathering information: The student's response indicates a lack of complete understanding in searching for information and the ambiguous assumptions of the problem.	2	3	"We have about 1,900 students, and including the administrative staff, we are around 2,000 people in total. We are provided with drinks along with lunch twice a week, so approximately 4,000 bottle caps are collected".
Mathematization: The student-teacher did not appropriately transform the simplified real-world situation, along with the information and assumptions of the problem, into correct mathematical expressions to form a mathematical model. Since the number of gifts required for the students was not specified in the question, the student should have considered different scenarios for the number of gifts but only examined one scenario.	1	2	"The ping-pong racket is more cost-effective because the price of each one is less than 100 z, whereas the price of each chess set is 100 z. Chess: $1 + 2 = 3$ Ping-pong racket: $1 + 5 = 6$"
Use of mathematics: The student presented an incomplete solution, which ultimately did not lead to a conclusion with proper reasoning.	2	3	"The majority of bottle usage at the university is for malt drinks and yogurt drinks served with lunch, which happens twice a week. There are approximately 1,500 students, and around 3,000 bottle caps are collected weekly. Additionally, around 1,000 mineral water bottle caps can be collected occasionally. In total, 4,000 bottle caps are gathered, and it seems that within one month, a wheelchair could be purchased.

Interpretation: The student correctly solved the problem mathematically and then provided an appropriate interpretation of the mathematical results to relate them to real-world outcomes.

3 2

Ping-pong is cheaper.

Let's assume we need 10 gifts.

For ping-pong: 10 = 4 we buy + 1 free + 5 we buy.

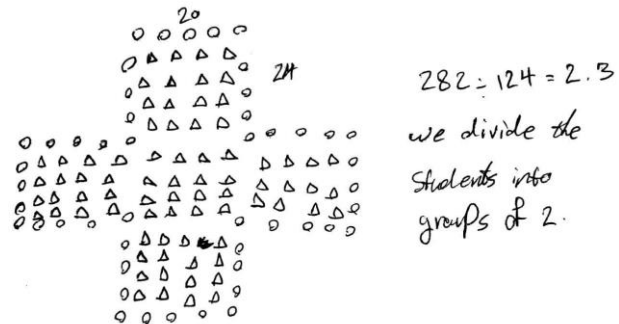
For chess: 10 = 1 we buy + 2 we buy + 1 we take + 2 we buy + 1 we take + 2 we buy.

Without using discounts, we spend 900 z on ping-pong. For chess, we have:

$$1,050 = 1,500 \times 7.$$

In the validation phase, a student grouped participants but did not check the results for real-world consistency, specify group sizes, or assess the number of groups. Proper validation requires carefully reviewing the problem and ensuring the feasibility of the solution.

2 1b



Discussion of results: The student related the obtained results to the real-world situation, thus answering the question.

3 2

5 pairs of ping-pong = 1 pair free

2 chess sets = 1 free

If we need a total of 50 gifts:

Pairs of ping-pong	free
5	1
50	10

Chess sets	free
2	1
50	25

For 7.5 million z, we get 3.7 million gifts (better).

For 5 million z spent, we get 1 million gifts.

For example, effective validation of a mathematical model depends on one's ability to interpret results meaningfully within the context. Many PSTs failed to critically evaluate the plausibility of their solutions or consider whether their model realistically represented the original situation. Instead, they often accepted the numerical output as final, without checking it against real-world expectations or proposing alternative explanations.

This lack of reflective thinking indicates a procedural view of modeling, where reaching an answer is prioritized over reasoning about the model's validity or broader implications. The responses suggest that PSTs may perceive modeling as a linear process — once the math is done, the task is complete — rather than as a cyclical inquiry where interpretation and validation guide refinements to the model. Moreover, the absence of alternative responses

or justifications in many answers points to limited metacognitive engagement. Students rarely questioned their assumptions or evaluated whether different modeling approaches could yield more realistic or insightful results. This cognitive gap leads not only to less sophisticated models but also to answers that may be mathematically correct yet practically unfeasible. The findings underscore the need for more explicit emphasis on interpretation and validation in preservice teacher training, as these components are essential for developing modeling competencies that extend beyond symbolic manipulation.

In Tables 10 and 11, the significance of the total score differences among PSTs has been examined. Since the calculated P-value is greater than 0.05, the observed differences in gender and academic background of the PSTs in

responding to the questionnaire questions are not significant.

Table 10: The significance of the gender variable in the total score

	Variable	Mann-Whitney U	P-Value
Total score	Gender	293.500	0.776

Table 11: The significance of the academic background variable in the total score

	Variable	Kruskal-Wallis H	P-Value
Total score	Academic background	1.760	0.415

ChatGPT's responses to the exam questions

To obtain more suitable responses from ChatGPT using the mathematical modelling cycle and emphasizing the criteria for mathematical modelling competency, this research utilized neutral prompts based on the study by Spreitzer et al. [26], such as 'verify your calculations', 'provide validation for the task', or 'are there alternative solutions?' to minimize the impact of external factors. At this stage, the questionnaire questions were presented to ChatGPT based on the prompts provided by Spreitzer et al. [26]. Table 12 shows the scores achieved by ChatGPT in response to the questionnaire questions.

As observed, ChatGPT achieved a total score of 54 in response to the mathematical modelling questions. Table 12 shows that ChatGPT performed poorly in responding to Question 1(a), misunderstanding the question (score of 1), which resulted in an inability to identify the correct pattern for planting saplings. This error also affected the subsequent criteria (all criteria in Question 1(a), except for the interpretation criterion, scored 1). ChatGPT's mistake in determining the appropriate pattern and number of saplings in

part (a) impacted the mathematical modelling competency criteria in Question 1(b) as well, leading to incorrect responses. Thus, while the understanding of the problem, information gathering, mathematical formulation, and interpretation were appropriately conducted, they were based on an incorrect assumption, resulting in a score of 2. The criteria for the use of mathematics (incorrect mathematical solution), validation (inadequate validation), and discussion (providing an incorrect answer) received a score of 1. In Question 2, there was only one mistake: failing to consider all scenarios for the number of gifts needed for the school, as ChatGPT only examined one scenario. However, it correctly executed this scenario and achieved a score of 2 across all mathematical modelling criteria. GPT was successful in answering question 3. It also scored 3 in all the competency criteria for modelling. The responses of GPT to the mathematical modelling questions in Table 13, along with the analysis of the answers, are provided.

Analysis of GPT's responses across the three modeling problems reveals both potential and limitations in its modeling competency, particularly when compared to PSTs. One of the most prominent weaknesses in GPT's performance was observed in Problem 1, which required identifying a visual pattern. GPT struggled to accurately process and interpret the shape-based data and misidentified the fourth pattern. This suggests a limitation in visual-spatial reasoning, a key component in pattern recognition. Furthermore, GPT incorrectly calculated the number of trees and proposed grouping students into units of 4 or 5, overlooking the requirement that 282 students be organized into groups of 2 and 3 — a sign of insufficient contextual reasoning and interpretation of constraints embedded in the problem.

Table 12: Scores achieved by ChatGPT in each criterion of mathematical modelling competency

Mathematical Modelling Competency Criteria							
	Understandi ng	Gathering Information	Mathematizati on	Use of Mathemati cs	Interpretatio n	Validatio n	Discussio n
1a	1	1	1	1	2	1	1
1b	2	2	2	1	2	1	1
2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3

Table 13: Responses of ChatGPT to the mathematical modelling exam questions.**AI Response**

1



Let's analyze the image provided and determine the number of orange and lemon seedlings, as well as how to divide the students into groups.

Part a: Number of Orange and Lemon Seedlings

From the image, it seems the arrangement of the seedlings forms a specific pattern where the lemon seedlings are placed around the perimeter and the orange seedlings are in the middle.

Counting Seedlings

1. Counting Lemon Seedlings:

- Lemon seedlings are around the edge. To count these, we need to identify the outermost layer of the grid.

2. Counting Orange Seedlings:

- Orange seedlings are in the inner part of the field, arranged in a cross pattern.

Image Analysis

By examining the image, we can count the number of seedlings manually.

- Each side of the cross pattern of orange seedlings appears to be composed of 7 seedlings.
- There are 4 sections of the cross, plus the central block.

Let's count the orange seedlings first:

- Each arm of the cross has 7 seedlings.
- There are 4 arms, so $4 \times 7 = 28$ seedlings.
- Additionally, there is a central block with 1 seedling.
- Total number of orange seedlings: $28 + 1 = 29$.

Now, counting the lemon seedlings around the perimeter:

- Each side of the square around the cross has 8 seedlings on each side of the cross, making it 9 on each straight side.

Total number of lemon seedlings:

- 4 corners, each counted twice (once for each adjoining side): $4 \times 8 = 32$.
- Subtract the 4 corners counted twice: $32 - 4 = 28$.

Part b: Dividing Students into Groups

Given:

- Total number of students: 282.
- Total number of seedlings (orange + lemon): $29 + 32 = 61$.

To plant each sapling, students are divided into groups:

- Each group should handle one seedling.
- Number of students per seedling: $\frac{282}{61} \approx 4.62$.

This means each group should consist of approximately 4 or 5 students, rounded for practical purposes.

Summary

a) Number of Seedlings:

- Lemon seedlings: 32.
- Orange seedlings: 29.

b) Groups of Students:



- Each group should ideally consist of 4 or 5 students, considering practical organization.

If there are alternative solutions or different patterns in the image that suggest a different number of seedlings, the above method provides a validated calculation based on the given distances and arrangement.

**Mathematical Modelling Competency Framework for GPT Responses**

Understanding: GPT failed to fully understand the first problem, recognizing the general placement of saplings but misjudging their number and ignoring key patterns, reflecting an incomplete grasp of the task.

Information Gathering: GPT poorly executed the information-gathering step, failing to identify the correct pattern, misusing data, and ignoring the distances between saplings.

Mathematical Formulation: As a result of the previous steps and inconsistent assumptions, the mathematical model was not well formed, and the quantities and dimensions were not used correctly.

Use of Mathematics: GPT produced inaccurate mathematical results due to incorrect data use and misunderstanding the problem, leading to errors in calculating saplings and student groupings.

Interpretation: Overall, GPT demonstrates good performance in interpretation and explanations, effectively relating mathematical results to real-world contexts.

Validation: In this problem, validation was not performed well, and alternative solutions were not provided.

Discussion: Given the incorrect results obtained from the use of assumptions and inconsistent solutions, the final answer is also incorrect.

2



Let's work through this problem step-by-step, verifying the calculations and comparing the two options to determine which is the better deal based on the given promotions.

Step 1: Clarify the Promotions and Prices

- **Ping pong paddles:**
 - Each pair costs 100,000 z.
 - For every 5 pairs of paddles, you get 1 pair free.
- **Chess sets:**
 - Each set costs 150,000 z.
 - For every 2 chess sets, you get 1 chess set free.

Step 2: Determine Effective Cost for Each Option

Option 1: Ping Pong Paddles

For every 5 pairs of paddles purchased, the school gets 1 free pair. This means that for every 6 pairs received, the school only pays for 5 pairs.

1. Cost of 6 pairs of paddles:

$$\text{Cost of 6 pairs} = 5 \times 100,000 \text{ z} = 500,000 \text{ z}$$

- So, the **effective cost per pair** of ping pong paddles (with the discount) is:

$$\text{Effective cost per pair} = \frac{500,000 \text{ z}}{6} \approx 83,333.33 \text{ z}$$

Option 2: Chess Sets

For every 2 chess sets purchased, the school gets 1 free chess set. This means for every 3 chess sets received, the school only pays for 2 sets.

1. Cost of 3 chess sets:

$$\text{Cost of 3 chess sets} = 2 \times 150,000 \text{ z} = 300,000 \text{ z}$$

- So, the **effective cost per chess set** (with the discount) is:

$$\text{Effective cost per chess set} = \frac{300,000 \text{ z}}{3} = 100,000 \text{ z}$$

Step 3: Comparison of Effective Costs

- The effective cost per pair of ping pong paddles is 83,333.33 z.
- The effective cost per chess set is 100,000 z.

Conclusion for Best Option:

- Based on the **effective cost**, ping pong paddles offer a **cheaper per-unit price** (83,333.33 z) compared to chess sets (100,000 z).
- Therefore, **ping pong paddles** would be the **better option** if the school wants to maximize the number of gifts for a given budget.

Validation and Alternative Considerations:

- If the school is concerned with **variety** or **student preference**, chess sets might still be a worthwhile option, even though they are slightly more expensive per unit.
- **Budget Constraints:** If the school has a fixed budget, the analysis would hold, as the effective cost favors ping pong paddles unless the school has a particular reason to prefer chess sets (e.g., if fewer, higher-value gifts are desirable).

Thus, the **ping pong paddles** option provides more gifts for the same amount of money due to the more favorable promotion.



Understanding: GPT understood the problem and its assumptions well but overlooked the unspecified number of students for gift preparation.

Information Gathering: GPT correctly used the relevant information except for the unspecified number of gifts needed for the students.

Mathematical Formulation: GPT failed to complete the mathematical model because it overlooked the number of students, though considering different scenarios could have led to a correct model.

Use of Mathematics: The solutions used are correct. However, not considering all possible scenarios for the number of students led to incomplete results.

Interpretation: The presentation of incomplete results led to an inadequate interpretation. However, within the scope of the obtained mathematical result, a suitable interpretation was provided.

Validation: GPT showed creativity and suggested alternative solutions in the validation section but did not consider all scenarios, making its validation incomplete.

Discussion: Given the solutions and validation of the responses, GPT could have corrected its answer and paid more attention to various scenarios regarding the number of students.

3



To determine how many days it would take for your university to procure a high-quality wheelchair for a nursing home through a bottle cap collection campaign, we can break down the process and perform some calculations. Here's how it might work:

1. Understanding the Collection Process

Assumptions:

- **Weight of a single bottle cap:** Approximately 2.5 grams.
- **Recycling value of polyethylene (PE):** Typically between \$0.50 and \$1.00 per kilogram.
- **Cost of a high-quality wheelchair:** Typically ranges from \$500 to \$1,500, depending on quality and features.

2. Calculating Funds from Bottle Caps

Let's assume your university aims to collect a significant number of bottle caps in a certain timeframe. For this example, we will consider a collection of 1 million bottle caps.

Weight Calculation:

- Total weight of caps:

$$1,000,000 \text{ caps} \times 2.5 \text{ g} = 2,500,000 \text{ g} = 2,500 \text{ kg}$$

Revenue Calculation:

- If we assume a mid-range price of \$0.75 per kilogram for recycling:

$$2,500 \text{ kg} \times 0.75 \text{ USD} = 1,875 \text{ USD}$$

3. Cost of the Wheelchair

Assuming the cost of a high-quality wheelchair is around \$1,200.

4. Timeframe for Collection

To estimate how long it would take to collect 1 million bottle caps, we need to consider:

- **Participation Rate:** How many students are involved in the collection effort.
- **Collection Rate:** How many caps can be realistically collected per student per day.

Example Estimation:

- Let's assume 100 students participate and each collects 50 caps per day.

Total caps collected per day:

$$100 \text{ students} \times 50 \text{ caps/student} = 5,000 \text{ caps/day}$$

To collect 1 million caps:

$$\frac{1,000,000 \text{ caps}}{5,000 \text{ caps/day}} = 200 \text{ days}$$

5. Validation of Task

If your university can maintain this collection rate, it would take approximately 200 days to collect enough caps to fund one wheelchair at \$1,200, assuming a stable participation rate and commitment from students.

6. Alternative Solutions

Here are some alternative methods to potentially expedite the process or raise funds more efficiently:

- **Direct Monetary Donations:** Encouraging students and faculty to donate directly could lead to faster funding for the wheelchair. For example, if 120 people donate \$10 each, you would reach \$1,200 quickly.
- **Collecting Larger Quantities of Plastics:** Expanding the campaign to include entire bottles (not just caps) can yield more revenue, as the plastic in bottles can have a higher recycling value.
- **Sponsorships or Grants:** Seeking sponsorship from local businesses or applying for grants can provide immediate funding without relying solely on bottle cap collection.
- **Awareness Campaigns:** Running awareness campaigns to motivate more students to participate or organize events that facilitate the collection can increase the number of caps collected per day.

Conclusion

To procure a high-quality wheelchair for a nursing home, it could take approximately 200 days if your university collects 1 million bottle caps at the specified rate. However, alternative methods like direct donations or expanding the recycling effort could significantly reduce the time needed to achieve this goal.



Understanding: In the first stage, GPT demonstrated its understanding by summarizing the information needed to solve the problem. Therefore, it has a suitable grasp of this issue.

Information Gathering: When writing the steps of the work, the assumptions that would be used were stated, such as the price of the wheelchair or the number of collected doors, etc.

Mathematical Formulation: In this stage, the collected information was organized and categorized correctly.

Use of Mathematics: Appropriate mathematical solutions were applied to the data.

Interpretation: Suitable interpretations were made for each stage of the mathematical results, and the results were related to the real world.

Validation: The price of the wheelchair and daily bottle use should be examined, showing GPT can guide humans in evaluating responses against reality.

Discussion: By expressing suitable statements, the result obtained in the previous section was effectively related to the real world, providing an appropriate answer to the question.

Although GPT did correctly interpret the intent that each group should plant one sapling, it failed to fully integrate this understanding into a consistent model. It also neglected spatial relationships in the diagram (such as distances between lemon and orange saplings), which

further weakened its information-gathering stage. The failure to account for relevant spatial and quantitative information led to an inadequate mathematical model and ultimately to incorrect solutions. Despite these flaws, GPT rated its own solution as valid, reflecting a lack

of metacognitive oversight — it did not question or revise its output in light of inconsistencies.

In Problem 2, GPT's performance improved. While it ignored the open-ended nature of the student population and considered only a single scenario, its use of mathematics and interpretation within that scenario was appropriate. Interestingly, GPT showed signs of creative reasoning in the validation phase — including comparing gift options, referencing economic considerations, and suggesting a bulk purchase strategy. This indicates GPT's potential to introduce alternative perspectives, although it still lacked full awareness of the problem's openness and did not explore multiple interpretations unless explicitly prompted.

Problem 3 demonstrated GPT's best performance. It correctly identified key variables such as the price of the wheelchair, the number of students, and the number of bottles used. GPT's discussion highlighted practical considerations and economic reasoning. However, it still exhibited a tendency to rely on straightforward data extraction and lacked deeper questioning or back-checking of assumptions — essential components of robust modeling.

Across the three tasks, GPT's strengths were most apparent in structured quantitative reasoning and creative validation, while its weaknesses lay in visual interpretation, flexible problem framing, and self-correction. GPT did not demonstrate the ability to identify and revise errors unless guided explicitly — a limitation for its role as an autonomous modeling agent.

When comparing GPT's responses (Table 13) with those of the PSTs (Table 8), key differences emerge. In Question 1a, PSTs outperformed GPT in problem comprehension, information gathering, and mathematization. Their written

responses showed a better grasp of visual data and a more grounded sense of realism. However, in Question 1b, GPT surpassed PSTs in mathematical formulation and interpretation, suggesting stronger algorithmic reasoning. The two groups performed similarly in validation, though GPT's validation was more imaginative while PSTs were more grounded in real-world feasibility.

In Question 2, PSTs and GPT showed comparable performance in problem understanding and validation. GPT outperformed in information use and mathematical modeling, possibly due to its ability to generate well-structured solutions, but PSTs demonstrated more critical reflection on data limitations. In Question 3, since most PSTs scored zero, GPT clearly performed better overall.

Broadly speaking, PSTs demonstrated stronger performance in using mathematics but consistently underperformed in validation — confirming the findings from earlier sections. GPT, by contrast, showed limitations in recognizing structure or patterns within problems and lacked the capacity to correct its own flawed solutions. However, its creativity in the validation stage and structured reasoning suggest that GPT can serve as a helpful guide in modeling education.

It is important to emphasize, however, that GPT's responses should not be used in isolation. While GPT can offer diverse perspectives and facilitate initial reasoning, it cannot yet simulate the full spectrum of human metacognition, flexibility, or contextual judgment. Therefore, GPT is best employed as a pedagogical tool to support PSTs, not as a replacement for critical human evaluation or collaborative reasoning. Over-reliance on its outputs could mislead students into accepting incomplete or inappropriate models without proper scrutiny.

Discussion

The study found that PSTs performed best in the 'use of mathematics' criterion but weakest in 'validation', indicating struggles with applying, evaluating, and validating results. These weaknesses may stem from limited prior knowledge and insufficient support [43]. PSTs' competencies are interdependent, suggesting that comprehensive training across all modelling skills is essential to improve their overall performance.

This study highlights AI tools like ChatGPT as practical supports in teacher education. ChatGPT can guide PSTs through mathematical modelling stages, provide step-by-step explanations, alternative approaches, timely feedback, and simulate real-world scenarios, especially supporting areas like validation, while fostering critical thinking and greater cognitive skills. Durandt et al. found that students receiving mathematical modelling instruction showed the greatest growth in competency [44]. Similarly, this study indicates that elementary PSTs have the potential to solve modelling problems and use the modelling cycle, but a lack of formal courses and resources led to incomplete answers, highlighting their weaknesses. No significant differences were observed based on gender or academic background.

Comparison of PSTs' responses with ChatGPT showed that the AI provided step-by-step answers with good explanations but struggled in Problem 1 (pattern recognition) and Question 2 (considering all scenarios), while performing well in Question 3. This highlights the interdependence of modelling competency criteria, where weaknesses in one area affect others. Although ChatGPT offered useful ideas for validation [15], it did not revise its responses accordingly. AI shows limitations in holistic understanding of geometry, as seen

in its errors with the first problem [21][25][45]. Consistent with Spreitzer et al. [26], GPT performs poorly on low- to medium-complexity modelling tasks. ChatGPT offered alternative solutions not seen in PSTs' responses, suggesting its role as a supportive tool, especially for validation. AI should complement, not replace, teachers, enhancing student engagement, learning efficiency, and critical thinking while maintaining the essential benefits of in-person classroom interaction [46-47].

Therefore, integrating AI tools like ChatGPT into teacher education curricula can provide practical and meaningful support in modelling education. For example, such tools can be used in workshops or courses to simulate modelling tasks, provide instant feedback, and encourage reflective discussions. This practical integration not only leverages AI's strengths but also maintains the essential role of human educators in guiding and contextualizing learning.

AI serves as an effective educational tool for teaching topics like mathematical modelling. According to Yang et al., AI education can enhance creative thinking and problem-solving skills in learners. In the current study, considering the creativity demonstrated by ChatGPT in solving mathematical modelling problems—especially in the validation phase—it can be argued that ChatGPT can be utilized as a complementary educational tool in teaching mathematical modelling [29]. Similarly, Spreitzer et al. identified two key outcomes for ChatGPT: assisting with simple modelling problem-solving and serving as a supplementary educational resource [26].

It can be argued that pre-service teachers can utilize ChatGPT as a supportive tool for solving modelling problems, particularly in enhancing and improving their modelling competencies. Furthermore, according to

Spreitzer et al., excessive reliance on technology, especially AI, may lead to a decrease in human interaction during the learning process [26]. Therefore, it is essential to pay special attention to the guiding role of the teacher and the cognitive abilities of students, while also reviewing the validity of AI-generated solutions.

Conclusions

The findings of this study reveal that while elementary pre-service teachers (PSTs) possess some basic competencies in mathematical modelling, they face significant challenges in areas such as validation, interpretation, and the meaningful connection of mathematical processes to real-world contexts. These weaknesses suggest that current teacher education programs may not provide sufficient opportunities for PSTs to engage with modelling tasks in a structured and reflective manner. At the same time, the analysis of AI responses shows that tools like ChatGPT can offer structured solutions, creative perspectives, and validation strategies, though they also suffer from limitations such as oversimplifications and gaps in holistic understanding. Together, these findings emphasize the need for a balanced approach in teacher education—one that develops human competencies while making strategic use of AI to scaffold learning.

In light of these insights, the integration of the mathematical modelling cycle into teacher training programs is strongly recommended, using both innovative instructional methods and AI as a supportive tool. Teacher educators should design tasks that require PSTs to reflect, validate, and critique both their own solutions and AI-generated ones, thereby fostering deeper reasoning and critical thinking. The findings also suggest that AI tools like ChatGPT

can serve as effective supportive resources by providing step-by-step guidance, creative problem-solving strategies, and immediate feedback. Educators can incorporate these tools into workshops or courses to simulate real-world modelling scenarios, encourage reflective discussions, and enhance student engagement. However, careful pedagogical guidance is necessary to prevent over-reliance on AI and ensure that human reasoning and creativity remain central in the learning process.

One limitation of the present study is the relatively small sample size, which may limit the generalizability of the findings. The study was conducted with the participation of [number] pre-service teachers, which was sufficient for qualitative analysis; however, the results should be generalized to other groups with caution. There are several suggestions for further research: use of larger, more diverse samples of pre-service teachers to improve generalizability and study demographic effects on modelling skills; conducting longitudinal research to assess long-term impacts of AI-assisted instruction on problem-solving, reasoning, and teaching; exploring different educational and cultural contexts (e.g., middle/high schools, various curricula) to test broader applicability; and running comparative studies on different AI supports (chatbots, VR, videos) to identify the most effective approaches.

Authors' Contribution

All authors have the same contribution.

Acknowledgements

The authors would like to express their sincere gratitude to Shiraz Farhangian University for their support and collaboration during this research.

Conflict of Interest

The authors have no conflicts of interest.

References

- [1] Greefrath G, Carreira S. Mathematical applications and modelling in mathematics education. In: Wang J, editor. *Proceedings of the 14th International Congress on Mathematical Education*. Vol. 1. Singapore: World Scientific; 2024. p. 417–21. doi:10.1142/9789811287152_0046.
- [2] Schukajlow S, Kaiser G, Stillman G. Empirical research on teaching and learning of mathematical modelling: a survey on the current state-of-the-art. *ZDM Math Educ*. 2018;50:5–18. doi:10.1007/s11858-018-0933-5.
- [3] Blum W, Borromeo Ferri R. Mathematical modelling: can it be taught and learnt? *J Math Model Appl*. 2009;1(1):45–58.
- [4] Fulford GR. Mathematical modelling using scenarios, case studies and projects in early undergraduate classes. *Int J Math Educ Sci Technol*. 2024;55(2):468–79. doi:10.1080/0020739X.2023.2244490.
- [5] Rosanti A, Aisyah N, Darmawijoyo, Lestari S. High school students' modelling abilities in arithmetic sequences using body weight contexts. *Al-Jabar J Pendidik Mat*. 2024;15(2):309–21. doi:10.24042/ajpm.v15i2.19372.
- [6] Oficiar JRG, Ibañez ED, Pentang JT. Metacognitive awareness as a predictor of mathematical modeling competency among preservice elementary teachers. *Int J Educ Methodol*. 2024;10(2):1079–92. doi:10.12973/ijem.10.2.1079.
- [7] Zbiek RM, Peters SA, Galluzzo B, White SJ. Secondary mathematics teachers learning to do and teach mathematical modelling: a trajectory. *J Math Teach Educ*. 2024;27(1):55–83. doi:10.1007/s10857-022-09550-7.
- [8] Vorhölter K, Greefrath G, Borromeo Ferri R, Leiss D, Schukajlow S. Mathematical modelling. In: Jahnke HN, Hefendehl-Hebeker L, editors. *Traditions in German-speaking mathematics education research*. Cham: Springer; 2019. p. 91–114. doi:10.1007/978-3-030-11069-7_4.
- [9] Turner EE, Bennett AB, Granillo M, Ponnuru N, Roth McDuffie A, Foote MQ, et al. Authenticity of elementary teacher-designed and implemented mathematical modelling tasks. *Math Think Learn*. 2024;26(1):47–70. doi:10.1080/10986065.2022.2028225.
- [10] Blum W, Galbraith PL, Henn HW, Niss M, editors. *Modelling and applications in mathematics education: the 14th ICMI Study*. New York: Springer; 2007. doi:10.1007/978-0-387-29822-1.
- [11] Vose JM, Peterson DL, Fettig CJ, Halofsky JE, Hiers JK, Keane RE, et al. Fire and forests in the 21st century: managing resilience under changing climates and fire regimes in USA forests. In: Greenberg CH, Collins BS, editors. *Fire ecology and management: past, present, and future of US forested ecosystems*. Cham: Springer; 2021. p. 465–502. doi:10.1007/978-3-030-73267-7_12.
- [12] Supriyadi E, Kuncoro KS. Exploring the future of mathematics teaching: insights with ChatGPT. *Union J Ilm Pendidik Mat*. 2023;11(2):305–16. doi:10.30738/union.v11i2.14898.
- [13] Blum W, Leiß D. Investigating quality mathematics teaching: the DISUM project. In: Bergsten C, Grevholm B, editors. *Developing and researching quality in mathematics teaching and learning*. Linköping: Swedish Society for Research in Mathematics Education; 2007. p. 3–16.
- [14] Bali M. An analysis of Grade 12 national examinations marking memoranda on the topic of measurement in Mathematical Literacy using a mathematical modelling framework [master's thesis]. Cape Town: University of the Western Cape; 2017.
- [15] Greefrath G, Maaß K. Diagnosis and evaluation in mathematical modelling. In: Greefrath G, Maaß K, editors. *Modelling competences: diagnosis and evaluation*. Cham: Springer; 2020. p. 1–19.
- [16] Borromeo Ferri R. On the influence of mathematical thinking styles on learners' modelling behaviour. *J Math Didakt*. 2010;31(1):99–118. doi:10.1007/s13138-010-0009-8.
- [17] Geiger V, Galbraith P, Niss M, Delzoppo C. Developing a task design and implementation framework for fostering mathematical modelling competencies. *Educ Stud Math*. 2022;109(2):313–36. doi:10.1007/s10649-021-10039-y.
- [18] Wang Y, Sun J. Design and implementation of virtual reality interactive product software based on AI deep learning algorithm. *Adv Multimed*. 2022; 2022:9104743. doi:10.1155/2022/9104743.
- [19] Kim S, Jang Y, Choi S, Kim W, Jung H, Kim S, et al. Analyzing teacher competency with TPACK for K–12 AI education. *KI Künstl Intell*. 2021;35(2):139–51. doi:10.1007/s13218-021-00731-9.
- [20] Rawas S. ChatGPT: empowering lifelong learning in the digital age of higher education. *Educ Inf Technol*. 2024;29(6):6895–908. doi:10.1007/s10639-023-12114-8.
- [21] Dahal N, Luitel BC, Pant BP. Exploring capabilities and limitations of generative AI chatbots in solving math algorithm problems. In: *Proceedings of the 15th International Congress on Mathematical Education*; 2024 Jul 7–14; Sydney, Australia. 2024.

- [22] Plevris V, Papazafeiropoulos G, Jiménez Rios A. Chatbots put to the test in math and logic problems: a comparison and assessment of ChatGPT-3.5, ChatGPT-4, and Google Bard. *AI*. 2023;4(4):949–69. doi:10.3390/ai4040048.
- [23] de Oliveira Fornasier M. The impact of the introduction of AI in advocacy: skills and professional ethics necessary for the future lawyer. *Rev Fac Direito UFPR*. 2021;66(2):69–94. doi:10.5380/rfdufr.v66i2.73458.
- [24] Rane N. Enhancing mathematical capabilities through ChatGPT and similar generative artificial intelligence: roles and challenges in solving mathematical problems. *SSRN Electron J*. 2023. doi:10.2139/ssrn.4603237.
- [25] Parra V, Sureda P, Corica A, Schiaffino S, Godoy D. Can generative AI solve geometry problems? Strengths and weaknesses of LLMs for geometric reasoning in Spanish. *Int J Interact Multimed Artif Intell*. 2024;8(5):65–74. doi:10.9781/ijimai.2024.02.009.
- [26] Spreitzer C, Straser O, Zehetmeier S, Maaß K. Mathematical modelling abilities of artificial intelligence tools: the case of ChatGPT. *Educ Sci*. 2024;14(7):698. doi:10.3390/educsci14070698.
- [27] Cevher AY, Yıldırım S. Design and use of chatbots for educational purposes: a study on student opinions. *İleri Teknol Çalış Derg*. 2023;1(2):76–83. doi:10.5281/zenodo.10445240.
- [28] Lee D, Yeo S. Developing an AI-based chatbot for practicing responsive teaching in mathematics. *Comput Educ*. 2022;191:104646. doi:10.1016/j.compedu.2022.104646.
- [29] Yang X, Schwarz B, Leung IK. Pre-service mathematics teachers' professional modelling competencies: a comparative study between Germany, Mainland China, and Hong Kong. *Educ Stud Math*. 2022;109(2):409–29. doi:10.1007/s10649-021-10064-x.
- [30] Nguyen ATT, Tran D. Quantitative reasoning as a lens to examine changes in modelling competencies of secondary preservice teachers. *Math Educ Res J*. 2025;37(1):27–54. doi:10.1007/s13394-023-00481-x.
- [31] Dasari D, Hendriyanto A, Sahara S, Suryadi D, Muhaimin LH, Chao T, et al. ChatGPT in didactical tetrahedron, does it make an exception? A case study in mathematics teaching and learning. *Front Educ*. 2024;8:1295413. doi:10.3389/educ.2023.1295413.
- [32] Gerber S, Quarder J, Greefrath G, Siller HS. Pre-service teachers' pedagogical content knowledge for teaching simulations and mathematical modelling with digital tools. In: Hodgen J, Geraniou E, Bolondi G, Ferretti F, editors. *Proceedings of the Twelfth Congress of the European Society for Research in Mathematics Education*. Bolzano: Free University of Bozen-Bolzano and ERME; 2022. p. 1051–8.
- [33] Guerrero-Ortiz C. Implicaciones de los ambientes digitales en los procesos de modelización. In: *Actes du septième symposium d'Étude sur le Travail Mathématique*; 2023; Strasbourg, France. Strasbourg: IREM de Strasbourg; 2023. p. 683–92. [In Spanish].
- [34] Wei Y, Zhang Q, Guo J. Can mathematical modelling be taught and learned in primary mathematics classrooms? A systematic review of empirical studies. *Educ Sci*. 2022;12(12):923. doi:10.3390/educsci12120923.
- [35] Plano Clark VL, Creswell JW. *Understanding research: a consumer's guide*. 2nd ed. Boston: Pearson; 2015.
- [36] Bryman A. *Social research methods*. 5th ed. Oxford: Oxford University Press; 2016.
- [37] Gilgun JF. Qualitative research and family psychology. *J Fam Psychol*. 2005;19(1):40–50. doi:10.1037/0893-3200.19.1.40.
- [38] Kibiswa NK. Directed qualitative content analysis (DQICA): a tool for conflict analysis. *Qual Rep*. 2019;24(8):2059–79. doi:10.46743/2160-3715/2019.3778.
- [39] Kang O, Noh J. Teaching mathematical modelling in school mathematics. In: *Proceedings of the 12th International Congress on Mathematical Education*; 2012 Jul 8–15; Seoul, South Korea. Seoul: COEX; 2012. p. 145–57.
- [40] Anhalt CO, Cortez R. Developing an understanding of mathematical modelling in secondary teacher preparation. *J Math Teach Educ*. 2016;19(6):523–45. doi:10.1007/s10857-015-9309-8.
- [41] Daubeney RDP, Bunn CW, Brown CJ. The crystal structure of polyethylene terephthalate. *Proc R Soc Lond A Math Phys Sci*. 1954;226(1167):531–42. doi:10.1098/rspa.1954.0273.
- [42] Xiao Y, Dai X, Wang K, Zhou G. High melting point of linear, spiral polyethylene nanofibers and polyethylene microspheres obtained through confined polymerization by a PPM-supported Ziegler-Natta catalyst. *ChemistryOpen*. 2020;9(11):1173–80. doi:10.1002/open.202000290.
- [43] Hwang GJ, Tu YF. Roles and research trends of artificial intelligence in mathematics education: a bibliometric mapping analysis and systematic review. *Mathematics*. 2021;9(6):584. doi:10.3390/math9060584.
- [44] Durandt R, Blum W, Lindl A. Fostering mathematical modelling competency of South African engineering students: which influence does the teaching design have? *Educ Stud Math*. 2022;109(2):361–81. doi:10.1007/s10649-021-10068-7.
- [45] Wardat Y, Tashtoush MA, AlAli R, Jarrah AM. ChatGPT: a revolutionary tool for teaching and learning mathematics. *Eurasia J Math Sci Technol Educ*. 2023;19(7):em2286. doi:10.29333/ejmste/13272.

[46] Su J, Ng DT, Chu SK. Artificial intelligence literacy in early childhood education: the challenges and opportunities. *Comput Educ Artif Intell.* 2023;4:100124. doi:10.1016/j.caeai.2023.100124.

[47] Elbanna S, Armstrong L. Exploring the integration of ChatGPT in education: adapting for the future. *Manag Sustain Arab Rev.* 2024;3(1):16–29. doi:10.1108/MSAR-03-2023-0016.

AUTHOR(S) BIOSKETCHES

Nafise Azadi is a Ph.D. student of mathematics education under the supervision of Professor Modjtaba Ghorbani.

Azadi, N., Ph.D. student, Department of Mathematics, Faculty of Science, Shahid Rajaee Teacher Training University, Tehran, I. R. Iran

 nafise.azadi@sru.ac.ir

Ebrahim Reyhani received his bachelor's degree in mathematics education from Kharazmi University, his master's degree in pure mathematics from Shahid Beheshti University, and his PhD in mathematics education from Moscow State University. He was serving as an associate professor at Shahid Rajaee Teacher Training University when he passed away in December 2024.

Reyhani, E., Associate Professor, Department of Mathematics, Faculty of Science, Shahid Rajaee Teacher Training University, Tehran, Iran

 e_reyhani@sru.ac.ir

Modjtaba Ghorbani is a professor of pure mathematics at Shahid Rajaee Teacher Training University. His interests include algebra and mathematics education.

Ghorbani, M., Professor, Department of Mathematics, Faculty of Science, Shahid Rajaee Teacher Training University, Tehran, I. R. Iran

 mghorbani@sru.ac.ir

Reza Ebrahimpour is a professor of cognitive neuroscience at the Sharif University of Technology. His interests include neuroscience, AI, and neuroeducation.

Ebrahimpour, R. Professor, Center for Cognitive Science, Institute for Convergence Science and Technology, Sharif University of Technology, Tehran, I. R. Iran

 ebrahimpour@sharif.edu

Saeid Haghjoo is currently a Lecturer in the Department of Mathematics at Farhangian University, Bushehr. His interests include teaching and learning of mathematics. He holds a Ph.D. in mathematics education from Shahid Rajaee Teacher Training University.

Haghjoo, S., PhD., Mathematics Education, lecturer at Farhangian University in Bushehr, Iran

 s.Haghjoo@sru.ac.ir

Citation (Vancouver): Azadi N, Reyhani E, Ghorbani M, Ebrahimpour R, Haghjoo S. [Evaluating pre-service teachers' mathematical modelling task performance: a comparison with ai responses] *Tech. Edu. J.* 2026; 20(1): 157-178

 <https://doi.org/10.22061/tej.2026.12519.3299>





ORIGINAL RESEARCH PAPER

Parental involvement in digital learning environments: examining school-parent communication, parental self-efficacy, and students' positive digital agency

M. Namdari-Pejman^{*1}, M. Zandian²

¹ Department of Educational Administration, Farhangian University, Tehran, Iran

² Department of Educational Management, Faculty of Psychology and Education, University of Tehran, Tehran, Iran

ABSTRACT

Received: 09 September 2025
Reviewed: 16 October 2025
Revised: 19 November 2025
Accepted: 25 December 2025

KEYWORDS:

Parental Involvement
Digital Learning Environments
School-Parent Communication
Parental Self-Efficacy
Students' Positive Digital Agency

* Corresponding author

 m.namdari@cfu.ac.ir

☎ (+9821) 87751000

Background and Objectives: The rapid advancement of digital technologies and the expansion of online learning in the wake of the COVID-19 pandemic have profoundly highlighted the critical role of parents in supporting their children's education within digital environments. Previous studies consistently show that active parental involvement contributes significantly to improvements in students' academic performance, motivation, and digital literacy. Two key factors identified as influential in this parental engagement are the quality of school-parent communication and parents' self-efficacy in the digital domain. Effective school communication acts as a vital bridge between home and school, helping to mitigate the barriers posed by the digital divide. Concurrently, parental self-efficacy—the belief in one's ability to effectively support a child's online learning—empowers parents, fostering the motivation for constructive supervision and the modeling of positive digital behaviors. Despite this background, research has focused little on an integrated examination of these factors and the mediating role of parental engagement in shaping students' positive digital agency—defined as responsible, ethical, and creative behaviors in virtual spaces. The current study aims to address this gap by testing a conceptual structural model that explores the relationships between school-parent communication, parental self-efficacy, parental digital engagement, and students' positive digital agency. A central objective is to specifically investigate the mediating role of parental digital engagement in transmitting the effects of the two antecedent factors (school communication and self-efficacy) onto the development of positive digital agency. The findings of this research aim to provide empirical evidence to inform educational policy and empower families in the digital age.

Methods: This study employed a descriptive-correlational design with a quantitative approach, utilizing covariance-based structural equation modeling (SEM). The target population consisted of parents of elementary school students in Qazvin, Iran, during the 2025-2026 academic year, all of whom had at least one year of experience with their child's digital learning. A multi-stage cluster sampling method was used. After removing incomplete or unsuitable responses, the final sample size comprised 362 participants. Data were collected using four standardized Persian questionnaires: The Parental Self-Efficacy Scale, the School-Parent Communication Scale, the Parental Digital Engagement Scale, and the Students' Positive Digital Agency Scale. Data analysis involved checking preliminary assumptions (e.g., normality), conducting confirmatory factor analysis (CFA) to validate the measurement model, and testing the structural model. The significance of direct and indirect (mediating) effects was assessed using the bootstrap method with 5000 resamples.

Findings: The conceptual model demonstrated an acceptable fit with the data (CFI = 0.96, RMSEA = 0.07). All direct paths were statistically significant: school-parent communication to parental digital engagement ($\beta = 0.60$), parental self-efficacy to parental digital engagement ($\beta = 0.26$), and parental digital engagement to students' positive digital agency ($\beta = 0.53$). The analysis of indirect effects confirmed the mediating role of parental digital engagement, indicating it functions as a full mediator in the relationship between the two predictor variables (school communication and parental self-efficacy) and the outcome variable

(students' positive digital agency). Overall, the model explained 65% of the variance in parental digital engagement and 28% of the variance in students' positive digital agency.

Conclusion: The results underscore the necessity of harmonizing environmental factors (effective school communication) and individual factors (parental self-efficacy) through practical parental digital engagement to foster students' positive digital agency. To cultivate students as responsible and creative digital citizens, schools must strengthen two-way communication channels and actively empower parents. Practical applications of these findings include the design of targeted parent training workshops focused on digital skills and supportive strategies, as well as the integration of digital citizenship education into the core school curriculum. This study's limitations include its specific geographical focus (Qazvin) and reliance on self-reported data. For future research, it is recommended to investigate the role of potential moderating variables, such as socioeconomic status, and to test practical intervention programs on a larger scale to further validate and generalize the proposed model.



COPYRIGHTS

© 2026 The Author(s). This is an open-access article distributed under the terms and conditions of the Creative Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) (<https://creativecommons.org/licenses/by-nc/4.0/>)



NUMBER OF REFERENCES

44



NUMBER OF FIGURES

1



NUMBER OF TABLES

4

مقاله پژوهشی

مشارکت والدین در محیط‌های یادگیری دیجیتال: مطالعه‌ای در مورد ارتباطات مدرسه، خودکارآمدی والدین و کنشگری مثبت دیجیتال دانش‌آموزان

مهدی نامداری پژمان^{۱*}، محسن زندیان^۲

^۱گروه مدیریت آموزشی، دانشگاه فرهنگیان، تهران، ایران

^۲گروه مدیریت آموزشی، دانشکده روان‌شناسی و علوم تربیتی، دانشگاه تهران، تهران، ایران

چکیده

پیشینه و اهداف: پیشرفت سریع فناوری‌های دیجیتال و گسترش یادگیری برخط در پی همه‌گیری کووید-۱۹، به طور برجسته‌ای نقش حیاتی والدین را در حمایت از آموزش فرزندان در محیط‌های دیجیتال پررنگ کرده است. مطالعات پیشین به طور مستمر نشان می‌دهند که مشارکت فعال والدین به بهبود معنادار عملکرد تحصیلی، انگیزش و سواد دیجیتال دانش‌آموزان کمک می‌کند. دو عامل کلیدی مؤثر در مشارکت والدین، کیفیت ارتباطات مدرسه با والدین و خودکارآمدی والدین در حیطه دیجیتال است. ارتباط مؤثر مدرسه به‌عنوان پلی حیاتی بین خانه و مدرسه عمل کرده و به کاهش موانع ناشی از شکاف دیجیتالی کمک می‌کند. هم‌زمان، خودکارآمدی والدین - یعنی باور به توانایی حمایت مؤثر از یادگیری برخط فرزند - به والدین قدرت می‌بخشد و انگیزه نظارت سازنده و الگوسازی رفتارهای مثبت دیجیتال را تقویت می‌کند. علی‌رغم این پیشینه ثابت شده، بررسی یکپارچه این عوامل و نقش میانجی‌گر مشارکت والدین در شکل‌دهی به «کنشگری مثبت دیجیتال» دانش‌آموزان - که به‌عنوان رفتارهای مسئولانه، اخلاقی مدار و خلاق در فضای مجازی تعریف می‌شود - کمتر موردتوجه قرار گرفته است. هدف این مطالعه پر کردن این شکاف از طریق آزمون یک مدل مفهومی ساختاری است که روابط بین ارتباطات مدرسه با والدین، خودکارآمدی والدین، مشارکت دیجیتال والدین و کنشگری مثبت دیجیتال دانش‌آموزان را بررسی می‌کند. هدف اصلی، بررسی ویژه‌ی نقش میانجی‌گر مشارکت دیجیتال والدین در انتقال اثرات دو عامل پیشین (ارتباط مدرسه و خودکارآمدی) به توسعه کنشگری مثبت دیجیتال است. یافته‌های این پژوهش شواهد تجربی برای اطلاع‌رسانی به سیاست‌گذاری آموزشی و توانمندسازی خانواده‌ها در عصر دیجیتال ارائه می‌کند.

تاریخ دریافت: ۱۸ شهریور ۱۴۰۴

تاریخ داوری: ۲۴ مهر ۱۴۰۴

تاریخ اصلاح: ۲۸ آبان ۱۴۰۴

تاریخ پذیرش: ۰۴ دی ۱۴۰۴

واژگان کلیدی:

مشارکت والدین در محیط‌های یادگیری دیجیتال
ارتباطات مدرسه
خودکارآمدی والدین
کنشگری مثبت دیجیتال دانش‌آموزان

* نویسنده مسئول

m.namdari@cfu.ac.ir

۰۲۱-۸۷۷۵۱۰۰۰ (۱)

روش‌ها: این پژوهش از طرح توصیفی - همبستگی با رویکرد کمی و با استفاده از مدل‌سازی معادلات ساختاری مبتنی بر کوواریانس استفاده کرد. جامعه آماری، والدین دانش‌آموزان ابتدایی شهر قزوین در سال تحصیلی ۱۴۰۴-۱۴۰۵ بودند که حداقل یک سال تجربه یادگیری دیجیتال فرزندشان را داشتند. از روش نمونه‌گیری خوشه‌ای چندمرحله‌ای استفاده شد و پس از حذف پاسخ‌های ناقص یا نامناسب، حجم نمونه نهایی ۳۶۲ نفر بود. داده‌ها با استفاده از چهار پرسش‌نامه استاندارد فارسی جمع‌آوری شد: مقیاس خودکارآمدی والدینی، مقیاس ارتباطات مدرسه - والدین، مقیاس مشارکت دیجیتال والدین و مقیاس کنشگری مثبت دیجیتال دانش‌آموزان. تحلیل داده‌ها شامل بررسی پیش‌فرض‌های اولیه (مانند نرمال بودن)، انجام تحلیل عاملی تأییدی برای اعتبارسنجی مدل اندازه‌گیری و آزمون مدل ساختاری بود. معناداری اثرات مستقیم و غیرمستقیم (میانجی) با استفاده از روش بوت‌استرپ با ۵۰۰۰ نمونه بازتولید، ارزیابی شد.

یافته‌ها: مدل مفهومی برازش قابل‌قبولی داشت ($CFI = 0.96$, $RMSEA = 0.07$). مسیرهای مستقیم ارتباطات مدرسه به مشارکت دیجیتال ($\beta = 0.60$)، خودکارآمدی والدین به مشارکت دیجیتال ($\beta = 0.26$) و مشارکت دیجیتال به کنشگری مثبت ($\beta = 0.53$) معنادار بودند. تحلیل اثرات غیرمستقیم، نقش میانجی‌گری مشارکت دیجیتال والدین را تأیید کرد و نشان داد که این متغیر به‌عنوان یک میانجی کامل در رابطه بین دو متغیر پیش‌بین (ارتباط مدرسه و خودکارآمدی والدین) و متغیر پیامد (کنشگری مثبت دیجیتال دانش‌آموزان) عمل می‌کند. در مجموع، مدل توانست ۶۵ درصد از واریانس مشارکت دیجیتال والدین و ۲۸ درصد از واریانس کنشگری مثبت دیجیتال دانش‌آموزان را تبیین کند.

نتیجه‌گیری: نتایج بر ضرورت هماهنگی عوامل محیطی (ارتباط مؤثر مدرسه) و فردی (خودکارآمدی والدین) از طریق مشارکت عملی دیجیتال والدین برای پرورش کنشگری مثبت دیجیتال دانش‌آموزان تأکید دارد. برای پرورش دانش‌آموزان به‌عنوان شهروندانی مسئول و خلاق در فضای دیجیتال، مدارس باید کانال‌های ارتباطی دوسویه را تقویت کرده و والدین را به طور فعال توانمند سازند. کاربردهای عملی این یافته‌ها شامل طراحی کارگاه‌های آموزشی هدفمند برای والدین با محوریت مهارت‌های دیجیتال و راهبردهای حمایتی، و همچنین ادغام آموزش شهروندی دیجیتال در برنامه درسی اصلی مدرسه است. محدودیت‌های این مطالعه شامل تمرکز جغرافیایی خاص (قزوین) و اتکا به داده‌های خودگزارشی است. برای تحقیقات آینده، توصیه می‌شود نقش متغیرهای تعدیل‌گر بالقوه، مانند وضعیت اقتصادی - اجتماعی، بررسی شده و برنامه‌های مداخله‌ای عملی در مقیاسی وسیع‌تر برای اعتباربخشی و تعمیم بیشتر مدل پیشنهادی آزمون شوند.

Introduction

Rapid advancements in technology have positioned digital technologies as increasingly central to transformations in education. The prioritization of integrating digital technologies into teaching and learning processes has become a key strategy in national and international educational policies [1]. The COVID-19 pandemic and the emergency responses in education during this period have highlighted its implications for educational processes, while post-COVID policies [2] signal the emergence of a new paradigm that has even engaged parents in online learning [3].

The rise of e-learning as an alternative to traditional education—which has dominated for several decades—has generated considerable excitement [4]. E-learning constitutes a form of distance education that employs digital infrastructures and resources to

deliver educational content to learners. This mode of education, also referred to as 'electronic learning,' 'distance learning,' or 'virtual learning,' enables learners to acquire information at their own preferred pace, according to Lown and colleagues [5]. In response to the rapid pace of technological innovation and the evolving educational environment, a comprehensive examination of e-learning methods, their effectiveness, and the factors influencing their successful implementation is essential [4][6].

Various factors contribute to the success of this learning mode, among which parental involvement plays a prominent role [3][7][8]. When parents actively participate in their children's activities, students perceive them as supportive figures, which can be expected to correlate with improved academic achievement and performance [9]. To assist children at home, parents must provide guidance,

instruction, understanding, collaboration, and supervision. At the same time, they need to monitor and control the activities and information children receive through digital media, offering appropriate explanations. Effective parental modeling is required to leverage technology for knowledge construction and to support children's learning [10]. Parental involvement shapes students' attitudes and behaviors in response to digital learning and is crucial because it influences communication patterns and interactions. In this digital model, parental involvement exerts a strong impact on children's development. One notable negative consequence for students who use technology without parental supervision is moral degradation, as the use of information technology is often not balanced with high ethical values from the real world [11]. Children are particularly vulnerable to the long-term effects of exposure to inappropriate content. Parents therefore have a responsibility to guide and accompany them in managing the negative impacts of technology use.

Another key factor in this domain is school-home communication. Effective communication between teachers and parents is vital for enhancing children's learning both at school and at home. However, implementing such communication faces numerous challenges. Teacher-parent communication depends on coordinated and collaborative efforts from all key stakeholders (teachers, parents, students, and school administration) in the child's learning process. It is therefore recommended that each group actively contributes to improving and expanding these communications [12]. Effective interaction between home and school can lay the foundation for improving educational quality and students' academic progress. Such interaction also helps reduce educational and upbringing inconsistencies, thereby better

achieving the objectives of the education system [13]. Recent studies indicate that while digital tools and remote education have created new opportunities for school-family communication, they have also introduced new barriers. For instance, parents with limited digital skills or a lack of access to technology often find it difficult to engage in their children's education [14]. Moreover, many schools lack structured programs or policies to support diverse forms of parental involvement, particularly in multicultural or multilingual communities [15].

Furthermore, research demonstrates a bidirectional relationship between parental self-efficacy and positive parenting [16-17]. Parental self-efficacy can be defined as parents' belief in their capacity to support their child's development, learning, and attainment of desirable educational outcomes [18]. This concept reflects the degree of confidence parents have in their ability to perform effectively in the teaching-learning process and can be a critical factor influencing the quality and nature of their participation in students' educational activities [19]. With the expansion of digital education, parents play a significant role in supporting their children's learning. Studies have shown that parents who believe in their abilities within online environments can perform more effectively by reducing the stress associated with technology use [20-21]. Thus, parental self-efficacy not only enhances the quality of their support but can also positively influence students' engagement and success.

Several international studies have indicated that the use of digital technologies results in only modest improvements in academic performance [22-24]. In contrast, other studies [3][7][8] suggest that when parents are aware of digital learning environments and perceive themselves as efficacious [16-17], improvements in students' academic

performance are more likely. The present study aims to examine the role of efficacious parental involvement in students' learning through active engagement in digital learning environments, aligned with the school's academic objectives.

Review of the Related Literature

Parental Involvement in Digital Learning Environments

The transformations induced by the COVID-19 pandemic and the widespread adoption of educational technologies have significantly amplified the role of parents in their children's digital learning. Research consistently demonstrates that active parental involvement in online education contributes to enhanced student academic performance, as well as improved motivation and self-efficacy.

For instance, one study [25] found that parental involvement in online education at the primary school level is shaped by parents' competencies, emotional support, and educational infrastructure, ultimately leading to improved student learning outcomes. Another investigation [26] examined the relationships among digital literacy, parental mediation, and online education risks, with student self-control serving as a mediating factor. The findings revealed significant negative associations between digital literacy and parental mediation on the one hand, and online risks on the other. The mediating role of self-control in the relationships between parental mediation/digital literacy and educational risks was confirmed. Other researchers have emphasized that parents, through modeling responsible online behavior and engaging in discussions with their children, play a crucial role in fostering digital literacy and cyber responsibility [27].

At the international level, evidence indicates that parents served as facilitators of digital learning before, during, and after the COVID-19 pandemic, with their role evolving from assisting with homework to managing digital learning environments [28]. In another study, parental involvement in online English language learning was shown to increase students' intrinsic and extrinsic motivation, thereby promoting greater academic engagement [29]. Additional studies have underscored the importance of school–parent communication in digital learning contexts. A qualitative study conducted in Iran demonstrated that effective parental interaction with schools during virtual education supports children's emotional well-being and educational care [30]. In a similar vein, scholars have stressed the need to redefine parental roles in digital learning to strengthen students' moral development and resilience [31]. As explained, the literature suggests that parental involvement in digital learning not only contributes to improved academic performance among students but is also positively associated with enhanced digital literacy, academic motivation, and the quality of school–family communication.

School Communication and Students' Positive Digital Agency

In the current digital era, schools play a role far beyond the mere transmission of knowledge, evolving into central hubs for shaping students' behaviors and agency in virtual spaces. Positive digital agency refers to a set of responsible, ethical, and constructive behaviors and attitudes that students exhibit in their interactions with digital technologies and online environments. This concept encompasses components such as sharing beneficial content, engaging in respectful interactions, constructive criticism, participating in online communities for positive purposes, and

adhering to cybersecurity practices and privacy norms [32]. The development of this form of agency is strongly influenced by the quality and nature of school communication. Here, school communication encompasses all formal and informal interactions, channels, and strategies that occur between the school (including administration, teachers, and staff) and students, as well as among students themselves within the educational context [33].

Recent research indicates that school communication serves as a key factor in fostering positive digital agency. This influence operates through two primary pathways: first, through explicit and structured education, and second, through the creation of a supportive communicative culture and environment. In the explicit education pathway, schools develop and implement programs on digital literacy and digital citizenship education, teaching students not only to be passive consumers but also active, effective creators and agents in digital spaces. The content of these programs extends beyond basic technical skills to emphasize critical thinking, online ethics, awareness of the social impacts of online activities, and positive communication skills [34]. For example, findings from one study revealed that students participating in integrated curricula focused on responsible digital agency demonstrated greater involvement in online campaigns with social objectives (such as environmental protection or peer support) and higher proficiency in detecting misinformation compared to a control group [35]. The quality of teacher–student relationships is critical in delivering these educational efforts. Teachers who foster open, dialogue-oriented environments and position themselves as supportive guides (rather than mere transmitters of absolute knowledge) are more successful in modeling positive digital behaviors.

The profound impact of school communication, however, arises indirectly through the establishment of school culture. In schools where communication is grounded in mutual respect, trust, transparency, and collective participation, a safe and inspiring foundation is created for practicing and internalizing positive behaviors. Communication theories in educational settings support the notion that when students experience a sense of belonging and responsibility toward their school community, they extend this sense to the broader digital realm [36]. In other words, students who learn in school to express opinions respectfully, listen to diverse viewpoints, and collaborate on group projects are more likely to replicate these behavioral patterns on social media platforms and other online environments.

The role of digital communication channels within the school (such as learning management systems, school-specific social networks, and online forums) is also significant in this process. These channels provide a semi-protected, guided space where students can experiment with their initial digital agency experiences. A study in smart schools in Punjab, Pakistan, revealed that in institutions utilizing internal platforms for group discussions on social issues and collaborative projects, students not only acquired stronger technical skills but also exhibited more responsible attitudes toward information sharing and peer support in online spaces. These platforms, under indirect teacher supervision, enable practice, feedback, and behavioral refinement. In contrast, schools characterized by one-way, directive, or overly controlling communication—or those failing to leverage digital tools for meaningful interaction—miss opportunities to cultivate positive agency [37]. In such environments, students may perceive the digital space as disconnected from school

values or resort to minimal or risk-prone behaviors. Therefore, school communication acts as a driving force and model in shaping students' positive digital agency. This is achieved through a combination of direct digital citizenship education and, more importantly, the creation of a participatory and respectful communicative culture within the school. Investing in the enhancement of intra-school interactions and the purposeful use of digital tools to facilitate these interactions not only enriches the educational environment but also prepares the next generation for active, ethical, and constructive participation in the complex digital society.

Parental Self-Efficacy and Students' Positive Digital Agency

Parental involvement in the teaching–learning process enhances students' motivation, leading to greater engagement and academic participation. As a result, students exhibit more active presence in class, greater interest in completing assignments, heightened responsibility toward learning, and more positive responses to teachers and peers. Ultimately, these factors contribute to increased satisfaction and improved academic performance [38]. In today's complex digital environment, parental self-efficacy—defined as parents' belief in their ability to effectively guide their children's learning and online experiences—has emerged as a strong predictor of students' positive digital agency. Parents with higher feelings of competence and control in the digital realm experience less anxiety and are more likely to actively participate in their child's educational activities while creating a richer digital home environment [36]. This supportive environment, in turn, substantially increases the likelihood of responsible and constructive online behaviors among students.

This influence operates through several mechanisms. First, parents with high self-efficacy are more inclined and able to establish clear structures and rules for technology use. These rules are not merely restrictive; they are often accompanied by constructive dialogue, explanations of rationales, and instruction in self-regulation skills. This interactive approach helps students develop a deeper understanding of the 'why' behind appropriate digital behaviors and internalize them. Second, such parents serve as effective role models. When children observe their parents using technology for learning, meaningful communication, or problem-solving (rather than passive entertainment), they are likely to adopt similar positive attitudes [32]. Third, efficacious parents shift from mere supervision and control to acting as digital guides or coaches. They identify learning opportunities, collaborate on digital projects, and build their child's resilience in facing online challenges (such as misinformation or cyber conflicts).

Despite the importance of this role, many parents face challenges in achieving adequate self-efficacy due to generational digital divides, limited specialized knowledge, or feelings of helplessness in the face of rapidly evolving technologies [18]. This underscores the critical role of schools and educational institutions. Schools can systematically empower parents through targeted intervention programs. The most effective programs go beyond basic technical training to focus on enhancing parents' parenting, communication, and critical media literacy skills [39]. Practical, evidence-based strategies include interactive workshops, parent support networks, and accessible resources delivered through diverse communication channels (e.g., messaging apps or school portals). The outcome of such collaborative investment between home and school is the cultivation of a generation of

students who are not passive consumers but informed, creative, and responsible agents in the digital era.

Parental involvement in digital learning environments, particularly following the COVID-19 pandemic, plays a pivotal role in improving students' academic performance, motivation, and digital literacy. Domestic studies emphasize that factors such as parental competence, emotional support, digital literacy, and mediation reduce online education risks and facilitate learning. Internationally, research highlights the shift in parental roles toward facilitating digital learning and enhancing academic engagement through active participation. This involvement is positively associated not only with effective school–home communication but also with the promotion of digital ethics and student resilience. School communication, as a key environmental factor, supports academic progress by fostering belonging, motivation, and timely feedback. Studies stress the quality of teacher–parent interactions and the purposeful use of digital tools to support home-based learning. Furthermore, parental self-efficacy—as belief in one's capacity to support children's learning—is linked to positive parenting and better academic outcomes. Research indicates that parents with high self-efficacy perform more

effectively in monitoring, guiding, and transferring educational responsibilities, ultimately leading to greater student satisfaction and positive agency. Collectively, these factors exert synergistic effects on success in digital environments. Figure 1 illustrates the expected relationships in this study as a conceptual model.

Method

The present study employed a descriptive-correlational design with a quantitative approach. The primary objective was to test a conceptual model and examine the structural relationships, based on the theoretical framework, among school–parent communication in digital learning environments, parental self-efficacy, parental involvement in digital learning, and students' positive digital agency. To test this theoretical model, covariance-based structural equation modeling (CB-SEM) was utilized. This approach is considered a standard and valid method in behavioral and educational research due to its ability to simultaneously test the measurement and structural models, provide overall model fit indices, and accommodate theoretical model testing.

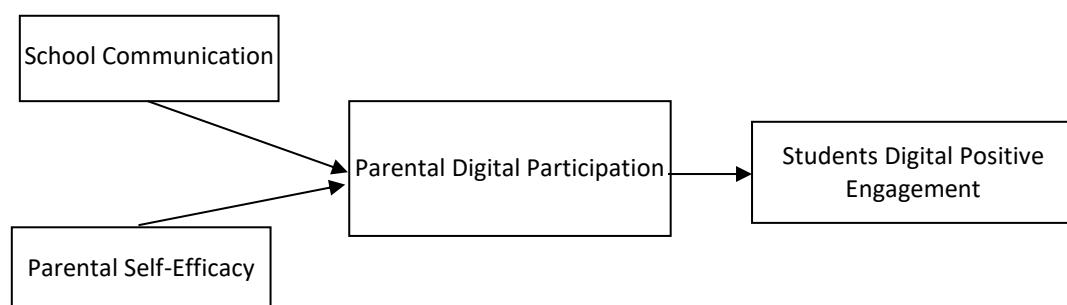


Fig. 1: Research model

Participants

The statistical population consisted of parents of primary school students in Qazvin city during the 2025–2026 academic year (1404–1405 in the Persian calendar), whose children had at least one year of experience with digital learning (fully online or blended). Multi-stage cluster sampling was employed: first, 10 public and private schools were randomly selected; subsequently, eligible classes within each school were identified, and parents of the students were invited to participate. Sample size was determined based on the requirements of covariance-based structural equation modeling, the complexity of the conceptual model, and the need to achieve adequate statistical power. Accordingly, a minimum sample size of over 200 participants was estimated. To enhance parameter estimation precision, a total of 385 questionnaires were collected. After excluding incomplete responses and multivariate outliers, 362 valid questionnaires (response rate: 94%) were retained for final analysis. Demographic characteristics of the sample indicated that 68% of respondents were mothers. The mean age of parents was 42.3 years ($SD = 5.7$), and the distribution of parental educational levels was relatively balanced.

Instruments

Data were collected using four standardized questionnaires. All instruments were translated into Persian, localized, and their validity and reliability were examined in the present sample.

Parental Self-Efficacy: The Parental Self-Efficacy Scale developed by Eslam Panah Amleshi and colleagues [40] was used. This scale comprises 41 items across 8 subscales: emotion-affect (5 items), play-enjoyment (5 items), empathy-understanding (5 items), inhibitory control (6 items), discipline-

boundaries (5 items), pressure (5 items), self-acceptance (5 items), and learning-knowledge (5 items). Items are rated on a 5-point Likert scale (1 = never to 5 = always). The Cronbach's alpha for the total scale was 0.94. Given the structural equation modeling approach, construct reliability and validity were assessed in the measurement model through composite reliability, average variance extracted (AVE), and factor loadings.

School–Parent Communication (School Bonding): To measure this construct, the Parental Involvement and Engagement Questionnaire by Fan and Williams [41] was employed. This instrument includes 42 items across 8 subscales: parental enthusiasm (6 items, $\alpha = 0.82$), parental participation in extracurricular activities (5 items, $\alpha = 0.74$), parental recommendations (6 items, $\alpha = 0.85$), parent–school communication related to student school issues (6 items, $\alpha = 0.83$), school contact with parents (5 items, $\alpha = 0.79$), parental attendance at school gatherings (5 items, $\alpha = 0.82$), family regulations (5 items, $\alpha = 0.81$), and socioeconomic base (4 items, $\alpha = 0.81$). Responses are recorded on a 5-point Likert scale. (Note: The reported Cronbach's alpha values are for the subscales; overall internal consistency reliability was assessed accordingly.)

Parental Involvement in Digital Learning Environments: This construct was measured using the 19-item instrument developed by Amelia and colleagues [42]. The questionnaire consists of four subscales: use of technology for educational games (4 items), use of technology for studying (3 items), fostering children's critical thinking skills based on images and words (6 items), and describing websites accessible to children (6 items). The tool possesses content, construct, and empirical validity, with responses recorded on a 5-point Likert scale [42].

Students' Positive Digital Agency: To assess this construct, the scale developed by Yasa and Rahaya [43] was utilized. The instrument uses a 5-point Likert scale and comprises 10 items across three subscales: digital literacy and cognitive-learning competence (5 items), social and ethical digital agency (3 items), and creative digital agency (2 items). Parental agreement is evaluated based on their observations of their child's behaviors and skills in using digital tools and engaging in virtual spaces. The internal consistency in the original study was reported as 0.89.

Data Analysis

Data analysis was conducted at both descriptive and inferential statistical levels using covariance-based structural equation modeling. In the first phase, data were screened for completeness, multivariate outliers (identified via Mahalanobis distance), and statistical assumptions. Multivariate outliers were removed where appropriate. Normality of variable distributions was evaluated through skewness and kurtosis indices and multivariate tests. Given the adequate sample size, analyses were considered robust to minor deviations from normality. Next, the measurement model was tested via confirmatory factor analysis (CFA) to evaluate construct validity and reliability. Standardized factor loadings, composite reliability (CR), and average variance extracted (AVE) were computed. Factor loadings above 0.50, CR values greater than 0.70, and AVE values exceeding 0.50 were regarded as evidence of internal reliability and convergent validity.

Discriminant validity was confirmed by comparing the square root of AVE for each construct with inter-construct correlations. Following confirmation of the measurement model, the structural model was estimated to test the hypothesized relationships among

constructs. Standardized path coefficients, standard errors, and statistical significance of paths were examined. Path significance was assessed using Z-statistics at the 0.05 level. Additionally, the explanatory power of the model was evaluated by reporting coefficients of determination (R^2) for endogenous constructs.

Results and Findings

Table 1 presents the descriptive statistics, internal reliability, and convergent validity indices for the constructs. This table includes means (M), standard deviations (SD), Cronbach's alpha (α), composite reliability (CR), average variance extracted (AVE), and factor loadings for each construct and its indicators.

The measurement model demonstrated satisfactory validity and reliability. Internal consistency reliability for all constructs was excellent, with Cronbach's alpha coefficients exceeding 0.89 across the board. To evaluate convergent validity, three key indices were examined. First, all standardized factor loadings were statistically significant ($p < 0.01$) and generally above 0.50, indicating that each indicator adequately contributed to defining its respective construct. Second, composite reliability (CR) values for all constructs ranged from 0.77 to 0.93, surpassing the recommended threshold of 0.70 and reflecting excellent internal consistency among the indicators of each construct. Third, average variance extracted (AVE) values exceeded 0.50 for three constructs (positive digital agency, parental self-efficacy, and parental involvement), while the AVE for parental involvement in digital learning was close to 0.50 (0.47). This suggests that, for most constructs, the shared variance among indicators was greater than the variance due to measurement error, thereby establishing convergent validity.

Table 1: Descriptive Statistics, Reliability, and Convergent Validity of the Constructs

Construct/Indicator	Mean	SD	SD λ	α	CR	AVE
Parental Self-Efficacy				0.94	0.93	0.58
Empathy-Understanding	21.81	2.81	0.81	-	-	-
Discipline- Setting Boundaries	21.06	3.05	0.81	-	-	-
Learning-Knowledge	21.20	2.67	0.79	-	-	-
Emotion Regulation	22.44	3.85	0.76	-	-	-
Play-Enjoyment	22.58	2.64	0.68	-	-	-
Self-Acceptance	25.01	3.01	0.66	-	-	-
Emotion-Affection	20.75	3.08	0.44	-	-	-
Pressure	24.35	3.71	0.38	-	-	-
School Communication				0.91	0.92	0.56
Family Rules	20.93	3.06	0.69			
Parent-School Communication	25.74	3.78	0.66			
Parental Advice	26.67	2.95	0.66			
School Meetings	18.54	4.12	0.60			
Extracurricular Activities	19.98	3.33	0.59			
School Contact	18.62	4.03	0.50			
Parental Aspiration	26.16	3.49	0.53			
Socioeconomic Status	14.81	3.53	0.44			
Digital Participation				0.90	0.78	0.47
Educational Play	15.48	3.06	0.71			
Studying	11.60	2.19	0.53			
Critical Thinking	10.02	2.17	0.34			
Website Description	14.42	4.33	0.26			
Positive Engagement				0.89	0.77	0.53
Learning Literacy	11.68	2.45	0.70			
Creative Engagement	16.71	7.10	0.31			
Social-Ethical	7.34	1.96	0.43			

Although the AVE for parental involvement in digital learning falls slightly below the conventional 0.50 threshold, it remains acceptable given the high composite reliability (0.78) and the overall strength of the other indices, consistent with guidelines that allow flexibility when CR is adequate and AVE is near the cutoff. Table 2 presents the inter-construct correlations (values above the main diagonal) and the square root of the AVE for each construct (bolded values on the main diagonal) to assess discriminant validity.

Discriminant validity (distinctiveness of the constructs from one another) was assessed using the Fornell-Larcker criterion. This criterion compares the correlations between each pair of constructs with the square root of the average variance extracted (VAVE; bolded

values on the diagonal) for the same construct. Discriminant validity is established if the VAVE for a construct exceeds its correlation with every other construct in the model. As shown, this condition holds for all construct pairs. For example, the VAVE for parental self-efficacy (0.76) is greater than its correlation with positive digital agency (0.35) and with other constructs. This indicates that each construct captures a unique portion of variance in the model and does not substantially overlap with others. Furthermore, the correlation matrix provides the necessary prerequisites for testing the structural model. Table 3 reports the standardized path coefficients, standard errors, t-statistics, significance levels, and explained variance.

Table 2: Correlation Matrix and Extracted Average Variance

Construct	(1)	(2)	(3)	(4)
(1) Parental Self-Efficacy	0.76			
(2) School Communication	0.65	0.75		
(3) Parental Digital Participation	0.67	0.78	0.69	
(4) Student Positive Engagement	0.35	0.41	0.53	0.73

Table 3: Results of Structural Model Analysis (Direct and Indirect Path Coefficients)

Direct Paths	β	SD	t	p	Result
School Communication → Parental Digital Engagement	0.60	0.09	6.06	<0.001	Supported
Parental Self-Efficacy → Parental Digital Engagement	0.26	0.08	3.39	<0.001	Supported
Parental Digital Engagement → Student Positive Digital Activism	0.53	0.08	6.02	<0.001	Supported
Indirect Effects					
School Communication → Parental Digital Engagement → Student Positive Digital Activism	0.32	0.06	4.89	<0.001	Supported
Parental Self-Efficacy → Parental Digital Engagement → Student Positive Digital Activism	0.14	0.05	3.03	<0.001	Supported
R^2					
Parental Digital Engagement	0.65				
Student Positive Digital Activism	0.28				

The structural model was evaluated using bootstrapping with 5000 resamples and 95% confidence intervals. All direct paths were statistically significant ($|t| > 2.58$, $p < 0.01$). School–parent communication emerged as the strongest predictor of parental involvement in digital learning ($\beta = 0.60$), followed by parental self-efficacy ($\beta = 0.26$). Parental involvement in digital learning, in turn, was a significant and strong predictor of students' positive digital agency ($\beta = 0.53$).

To test indirect effects, the bootstrapping method was employed. Since the 95% confidence intervals for both indirect effects did not include zero—school–parent communication via parental involvement in digital learning [0.20, 0.45]; parental self-

efficacy via parental involvement in digital learning [0.05, 0.24]—these mediated effects were statistically significant at the 95% confidence level. These findings support complete mediation (full mediation) by parental involvement in digital learning, as the direct effects of school–parent communication and parental self-efficacy on students' positive digital agency became non-significant in the presence of the mediator.

The model explained 65% of the variance in parental involvement in digital learning and 28% of the variance in students' positive digital agency, indicating moderate to good explanatory power overall. Table 4 presents the absolute, incremental, and parsimony fit indices for the overall evaluation of the model.

Table 4: Goodness-of-Fit Indices for the Measurement and Structural Models

Fit Category	Index Acronym	Model Value	Desired Value	Judgment
Absolute Fit Indices	χ^2	990.83 (df=226)	-	-
	χ^2/df	4.38	< 5.0	Acceptable
	RMSEA	0.07	< 0.08	Acceptable
	SRMR	0.05	< 0.08	Acceptable
	GFI	0.98	> 0.90	Acceptable
	CFI	0.96	> 0.90	Acceptable
Incremental Fit Indices	NFI	0.94	> 0.90	Acceptable
	TLI (NNFI)	0.72	> 0.90	Acceptable
Parsimonious Fit Indices	PNFI	0.92	> 0.50	Acceptable
	PGFI	0.91	> 0.50	Acceptable

Overall evaluation of the model using a range of fit indices indicates that the model exhibits relative or acceptable fit with the data. Absolute fit indices show: the χ^2/df ratio of 4.38, which falls within the acceptable range (typically < 5.0, though preferably < 3.0–4.0 in many guidelines). The RMSEA value of 0.07, while higher than the excellent threshold (≤ 0.05 – 0.06), remains within the commonly accepted range (0.05–0.10), suggesting a reasonable approximation error. The SRMR of 0.07 is at the border of acceptability (≤ 0.08). On the positive side, the GFI value of 0.98 exceeds the desirable threshold (> 0.90 – 0.95). Incremental fit indices all surpassed the standard threshold of 0.90, indicating ideal incremental fit relative to the baseline (null) model. Parsimony-adjusted indices (PNFI = 0.92, PGFI = 0.91) demonstrate that the model, despite a moderate number of parameters, accounts for a substantial portion of fit without excessive complexity.

This pattern—strong parsimony and incremental indices alongside somewhat elevated χ^2/df and RMSEA—is frequently observed in complex models with relatively limited sample sizes or in applied educational/behavioral research. It may reflect minor unmodeled cross-loadings, correlated

measurement errors, or the sensitivity of χ^2 -based statistics (including RMSEA) to sample size and model degrees of freedom, rather than severe misspecification. In covariance-based SEM, researchers commonly prioritize a combination of indices (e.g., Hu & Bentler, 1999 guidelines: CFI/TLI ≥ 0.95 combined with SRMR ≤ 0.09 or RMSEA ≤ 0.06 with SRMR ≤ 0.09) over any single index. Here, the overall profile supports proceeding with interpretation of the structural parameters, while acknowledging that minor local misspecifications (e.g., omitted error covariances) could contribute to the elevated χ^2/df .

Discussion

Consistent with the paradigmatic shifts in the post-COVID era [2] and the prioritization of educational policies on technology integration [1], this study tested a causal model to examine the predictive roles of school–parent communication and parental self-efficacy on students' positive digital agency, mediated by parental involvement in digital learning. The empirical findings from structural equation modeling provided strong support for the conceptual model. The results not only

demonstrated acceptable model fit but also confirmed all direct and indirect paths at high levels of statistical significance.

A central finding of this study is the strong positive effect of school–parent communication on parental involvement in digital learning, which is theoretically and empirically well-grounded. This result directly aligns with Bronfenbrenner's ecological systems theory [44], which posits that individual development (here, student agency) occurs within a nested system of interconnected environments, beginning with microsystems (family and school) and extending to meso-, exo-, and macrosystems. The quality of linkages between microsystems—termed the mesosystem by Bronfenbrenner—is critical for optimal development. The present findings indicate that a robust mesosystem, characterized by effective, multi-channel, and purposeful school–parent communication [12], directly enhances parental engagement within the home microsystem in digital contexts. This is consistent with recent domestic and international research emphasizing that effective home–school interactions reduce educational inconsistencies and elevate instructional quality. In digital settings, such interactions require redefining communication channels and content [13]. Other scholars have highlighted the need to redefine parental and school roles in the digital age to foster students' ethics and resilience [31]. Our results suggest that schools leveraging digital tools not merely for one-way information dissemination but for bidirectional dialogue, consultation, and genuine parental involvement in learning processes [15] are more successful in transforming parents into active facilitators of digital learning. Conversely, barriers such as parents' limited digital skills can be substantially mitigated through supportive, education-oriented school communication [14]. Thus, this

finding underscores both the importance of communication quality and positions the school as the primary catalyst and facilitator of family involvement in the digital domain.

The positive and significant influence of parental self-efficacy on digital involvement provides compelling evidence for the application of Bandura's social cognitive theory to digital parenting. According to this theory, self-efficacy refers to individuals' beliefs in their capacity to organize and execute courses of action required to manage prospective situations. Parents with high digital self-efficacy believe they can navigate challenges in digital learning environments, benefit their children, and influence learning outcomes [18]. This belief enhances their motivation and persistence in activities such as assisting with online assignments, managing screen time, or discussing web content with their child [20]. This aligns with studies demonstrating bidirectional relationships between parental self-efficacy and positive parenting [16–17], particularly those showing that self-efficacy reduces technology-related anxiety and empowers parents in supportive roles [19]. Notably, the path coefficient for self-efficacy was lower than that for school communication, potentially indicating that, in the cultural context of this study, exogenous environmental factors (school role) exert a stronger influence on motivating parental digital involvement than endogenous individual factors (self-efficacy beliefs). This interpretation warrants further exploration in cross-cultural comparative studies. Nonetheless, it does not diminish the importance of self-efficacy but highlights the need for psychological empowerment of parents alongside environmental facilitation through communication.

The strongest outcome-level finding was the profound positive effect of parental digital involvement on students' positive digital

agency, forming the core of the conceptual model and affirming the study's central premise: engaged and informed parents cultivate responsible, creative, and ethical digital citizens among their children. This relationship can be interpreted through multiple theoretical lenses. From Bandura's social learning theory perspective, parents serve as primary behavioral models. When parents actively and critically engage with digital content, participate in creative digital projects, or discuss online ethics, they directly model positive agency [42]. From Self-Determination Theory, high-quality parental involvement can satisfy students' basic psychological needs for competence, autonomy, and relatedness in digital environments. Parental support fosters feelings of competence in technology use, autonomy within clear boundaries, and positive emotional bonds through shared digital activities—thereby enhancing intrinsic motivation for positive, self-regulated behaviors. From activity theory (rooted in Vygotsky's framework), learning occurs within meaningful social activities. Parental involvement transforms students' digital learning from solitary individual activity into collaborative social practice. Parents act as 'more knowledgeable others', providing scaffolding to guide the child from current to potential developmental levels. This finding directly supports prior research emphasizing appropriate parental modeling for constructive technology use [7-9], the role of dialogue and modeling in developing digital literacy and cyber responsibility [27], and the link between parental involvement and increased academic engagement (a component of positive agency) [29]. Our results add comprehensiveness by demonstrating that parental involvement extends beyond academic performance improvements [9] to influence students' digital literacy, ethics, and

creativity—the very dimensions underpinning positive digital agency [32].

A key contribution of this study is the identification of complete mediation by parental digital involvement. This implies that the effects of school–parent communication and parental self-efficacy on students' positive digital agency are fully transmitted through increased parental participation, with no significant direct paths remaining. This finding holds theoretical importance in two respects:

(a) Clarification of mechanisms: It elucidates how distal factors operate to produce outcomes, rejecting a "black box" approach. Schools foster opportunities through improved communication; self-efficacy provides the motivation and confidence to seize them, but it is parents' observable behavioral involvement that directly permeates the child's learning environment and shapes agency. This underscores the complexity and sequential nature of influence processes in educational ecosystems.

(b) Validation of an integrated model: The results strongly endorse a unified model in which parental involvement serves as the essential connective link between external/environmental factors (school) and internal/individual factors (parental beliefs) on the one hand, and student outcomes on the other. This integrated approach offers clear advantages over single-factor models focused solely on school or parental elements. It aligns with dynamic systems perspectives, wherein changes in one subsystem (e.g., enhanced school communication) transfer to another (student agency) only when the intermediary subsystem (parental involvement) functions effectively.

Employing rigorous quantitative methodology (covariance-based structural equation modeling), this study successfully tested and validated an integrated causal model

explaining how school-level (communication) and parent-level (self-efficacy) factors, through a key behavioral mechanism at the family level (digital involvement), influence advanced student outcomes in the digital era (positive agency). The findings clearly demonstrate that cultivating students who are active, creative, and ethical digital citizens—rather than passive consumers—requires coordinated strengthening of the school–parent–student triad: schools invite and empower parents through effective supportive channels; parents, believing in their capabilities, become models and guides through active engagement; and students, in this enriched context, internalize positive digital agency as part of their identity. This study also emphasizes the need to move beyond single-factor or mechanistic views of complex educational phenomena. Success in digital learning environments emerges from dynamic, nonlinear interactions among multilevel factors. Accordingly, any educational intervention or policy must adopt this systemic, ecological perspective.

Conclusions

In summary, this study successfully tested and validated an integrated causal model demonstrating that school–parent communication and parental self-efficacy positively influence students' positive digital agency, but only through the full mediation of parental involvement in digital learning. The findings confirm that cultivating active, creative, and ethical digital citizens requires coordinated action across the school–parent–student triad: schools must initiate bidirectional, supportive communication; parents, empowered by their self-efficacy beliefs, must translate that into behavioral engagement; and students, in turn, internalize

positive digital agency as part of their developmental identity.

Several limitations should be acknowledged. First, the cross-sectional design precludes causal inferences despite the theoretical causal ordering. Second, data were collected via self-report measures, which may be subject to social desirability and common method bias. Third, the sample was drawn from a specific cultural and educational context, which may limit the generalizability of the findings to other regions or school systems. Fourth, the study focused on parental involvement as the sole mediator; other potential mediators (e.g., student–teacher interaction, peer influence) were not examined.

Future studies should employ longitudinal or experimental designs to establish temporal precedence and causal relationships. Cross-cultural comparative research is particularly needed to examine whether the relative weights of school communication versus parental self-efficacy vary across different educational systems. Additionally, incorporating qualitative methods (e.g., interviews with parents and students) could enrich understanding of the processes underlying parental digital involvement. Exploring moderators such as parental digital literacy, child's age, or socioeconomic status would also extend the current model.

Practically, the findings offer clear guidelines for educational policy and practice. Schools should invest in digital communication platforms that enable genuine two-way dialogue, not just information broadcasting, and provide training for teachers on how to engage parents constructively in digital learning. Parental empowerment programs should include both skill-building (digital literacy) and psychological components (self-efficacy enhancement) to reduce technology-related anxiety and increase active

participation. Policymakers are advised to adopt an ecological, systemic perspective when designing interventions, recognizing that student outcomes in the digital era emerge from dynamic interactions among family, school, and individual factors—not from isolated efforts. This study provides empirical support for moving beyond single-factor approaches toward integrated, multi-level strategies for fostering positive digital citizenship among youth.

Authors' Contribution

The first author (corresponding author) was responsible for overall supervision, conceptualization, guidance of the research process, data analysis, interpretation of results, drafting the discussion section, and writing the conclusion. The second author contributed to the formulation of the problem statement, literature review, development of the theoretical framework, data collection, questionnaire administration, and data entry and writing the methodology section.

Acknowledgments

The authors express their sincere gratitude to all teachers, school administrators, and colleagues who assisted in the distribution and completion of the questionnaires and supported the data collection process.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work.

References

[1] Qualter D. From digital exclusion to digital inclusion: shaping the role of parental involvement in home-based digital learning—a narrative literature review. *Comput Sch.* 2024;41(2):120–44. doi:10.1080/07380569.2024.2322167.

[2] NamdariPejman M. Practicum analysis in the conditions of Corona pandemic: inference of post-corona policies. *Theory Pract Teach Educ.* 2024;10(17):1–17. [In Persian]. <https://doi.org/10.48310/itt.2024.3564>

[3] Liu X, Liu J, Demmans Epp C, Cui Y. Exploring the effect of parental involvement on student engagement and academic performance using process data from a learning management system. *Educ Technol Res Dev.* 2025;73(2):1071–92. doi:10.1007/s11423-024-10440-3.

[4] Bashir S, Lapshun AL. E-learning future trends in higher education in the 2020s and beyond. *Cogent Educ.* 2025;12(1):2445331. doi:10.1080/2331186X.2024.2445331.

[5] Lone SA, Paju JA, Mir MT. Invigoration of e-learning in education: challenges and opportunities. *Int J Indian Psychol.* 2023;11(2):1285–92. doi:10.25215/1102.138.

[6] Zine M, Harrou F, Terbeche M, Sun Y. Evaluating e-learning readiness using explainable machine learning and key organizational change factors in higher education. *Educ Inf Technol.* 2025;30:12905–37. doi:10.1007/s10639-025-13335-9.

[7] Lasut EMM, Maramis JG. Parents' involvement during science online learning of junior high school students and their learning outcome. *J Penelit Pendidik IPA.* 2024;10(Special Issue):514–20. doi:10.29303/jppipa.v10iSpecialIssue.8317.

[8] Li Y, Rahman MN. Parental involvement in digital learning during elementary school education: a systematic literature review. *Eur J Educ.* 2025;60(3):e70186. doi:10.1111/ejed.70186.

[9] Abraha KW. Effects of parental involvement on students' learning at public primary schools in Tigray, Ethiopia. *Am J Qual Res.* 2025;9(3):26–46. doi:10.29333/ajqr/16528.

[10] Herwin H, Dahalan SC. Technological integration factors in parental involvement during distance learning. *Int J Inf Educ Technol.* 2022;12(7):637–42. doi:10.18178/ijiet.2022.12.7.1664.

[11] Shahzad MF, Xu S, Zahid H. Exploring the impact of generative AI-based technologies on learning performance through self-efficacy, fairness and ethics, creativity, and trust in higher education. *Educ Inf Technol.* 2025;30(3):3691–716. doi:10.1007/s10639-024-12949-9.

[12] Mutangira DT, Tandika P, Edward G. Effective teacher-parent communication strategies for enhancing children's learning in early-grade classes: a cross-contextual study. *Educ Dimens.* 2026;15:108–27. doi:10.55056/ed.900.

[13] Mosayebi Ardakani M, Rezapour Mirsaleh Y, Behjati Ardakani F. Examining the participation of primary school students' families in virtual education during the COVID-19 pandemic: a qualitative study. *Q J Fam Res.* 2025;21(4):65–84. [In Persian]

- [14] Owens M, Ravi V, Hunter E. Digital inclusion as a lens for equitable parent engagement. *TechTrends*. 2023;1–11. doi:10.1007/s11528-023-00859-5.
- [15] Zou Y, Kuek F, Feng W, Cheng X. Digital learning in the 21st century: trends, challenges, and innovations in technology integration. *Front Educ*. 2025;10:1562391. doi:10.3389/feduc.2025.1562391.
- [16] Glatz T, Lippold M, Chung G, Jensen TM. A systematic review of parental self-efficacy among parents of school-age children and adolescents. *Adolesc Res Rev*. 2024;9(1):75–91. doi:10.1007/s40894-023-00216-w.
- [17] Waid J, Abusaleh K, Marsalis S. Approaches to strengthen parental self-efficacy: an umbrella review of systematic reviews. *Child Youth Serv Rev*. 2025;177:108483. doi:10.1016/j.chilcyouth.2025.108483.
- [18] Holzer J, Korlat S, Pelikan E, Schober B, Spiel C, Lüftenegger M. The role of parental self-efficacy regarding parental support for early adolescents' coping, self-regulated learning, learning self-efficacy and positive emotions. *J Early Adolesc*. 2024;44(2):171–97. doi:10.1177/02724316231162306.
- [19] Liu X, Zhao L, Su YS. Impact of parents' attitudes on learning ineffectiveness: the mediating role of parental self-efficacy. *Int J Environ Res Public Health*. 2022;19(1):615. doi:10.3390/ijerph19010615.
- [20] Banić L, Orehovački T. A comparison of parenting strategies in a digital environment: a systematic literature review. *Multimodal Technol Interact*. 2024;8(4):32. doi:10.3390/mti8040032.
- [21] Bayar ME, Kulaksiz T, Toran M. How does parental media mediation regulate the association between digital parental awareness and the parent-child relationship? *Early Child Educ J*. 2026;54:773–87. doi:10.1007/s10643-025-01879-x.
- [22] Valverde-Berrocoso J, Acevedo-Borrega J, Cerezo-Pizarro M. Educational technology and student performance: a systematic review. *Front Educ*. 2022;7:916502. doi:10.3389/feduc.2022.916502.
- [23] Al-Abdullatif AM, Gameil AA. The effect of digital technology integration on students' academic performance through project-based learning in an e-learning environment. *Int J Emerg Technol Learn*. 2021;16(11):189–210. doi:10.3991/ijet.v16i11.19421.
- [24] Milkova E, Moldoveanu M, Krcil T. Sustainable education through information and communication technology: a case study on enhancing digital competence and academic performance of social science higher education students. *Sustainability*. 2025;17(10):4422. doi:10.3390/su17104422.
- [25] Jafarzadeh A, Taheri M, Taheri M. Antecedents, contextual factors and consequences of parents' participation in the online education process of primary schools. *Teach Learn Res*. 2023;20(2):1–17. [In Persian] doi:10.22070/tlr.2024.18168.1483.
- [26] Mehrparsa S. The effect of digital literacy and parental mediation on the risks of online education: the mediating role of students' self-control. *Technol Scholarsh Educ*. 2022;1(2):35–45. [In Persian]. doi:10.30473/t-edu.2021.8718.
- [27] Vali-Moradi S, Abbasi F. Investigating the role of parental involvement in developing students' digital literacy and cyber responsibility. In: *Proceedings of the First International Conference on Recent Developments in Educational Systems*; 2025 May 12–24; Bushehr, Iran. [In Persian]
- [28] Panduwiyasa H, Rifqi F, Alexandra E, Putri M, Mannan I. Digital learning: indispensable impact of parental involvement toward children's learning beyond the pandemic era. In: *Proceedings of the 3rd International Conference on Psychology and Health Issues (ICoPHI 2024)*; 2024 Nov 2; Padang, West Sumatra, Indonesia. EAI; 2025. doi:10.4108/eai.2-11-2024.2354566.
- [29] Shebani Z, Aldhafri S, Alsaidi F. The effect of parental involvement on academic passion: the mediating role of student motivation in learning English online. *Int J Adolesc Youth*. 2025;30(1):2467109. doi:10.1080/02673843.2025.2467109.
- [30] Jafarzadeh A, Taheri M, Abolghasemi M, Abbaspour A. Parents' participation model in the virtual education process of primary schools: a qualitative study during the COVID-19 pandemic. *Res Teach*. 2022;10(2):277–305. [In Persian] doi:10.34785/J012.2022.035.
- [31] Istenič A, Rosanda V, Volk M, Gačnik M. Parental perceptions of children's play in the post-digital era: parents' dilemma with digital formats informing the kindergarten curriculum. *Children (Basel)*. 2023;10(1):101. doi:10.3390/children10010101.
- [32] Choi M, Glassman M, Cristol D. What it means to be a citizen in the internet age: development of a reliable and valid digital citizenship scale. *Comput Educ*. 2017;107:100–12. doi:10.1016/j.compedu.2017.01.002.
- [33] Kraft MA, Dougherty SM. The effect of teacher-family communication on student engagement: evidence from a randomized field experiment. *J Res Educ Eff*. 2013;6(3):199–222. doi:10.1080/19345747.2012.743636.
- [34] Hollandsworth R, Donovan J, Welch M. Digital citizenship: you can't go home again. *TechTrends*. 2017;61(6):524–30. doi:10.1007/s11528-017-0190-4.
- [35] Magis-Weinberg L, Muñoz López DE, Gys CL, Berger EL, Dahl RE. Promoting digital citizenship through a school-based

intervention in early adolescence in Perú: a pilot quasi-experimental study. *Child Adolesc Ment Health*. 2023;28(1):83–9. doi:10.1111/camh.12625.

[36] Capuno R, Suson R, Suladay D, Arnaiz V, Villarin I, Jungoy E. Digital citizenship in education and its implication. *World J Educ Technol Curr Issues*. 2022;14(2):426–37. doi:10.18844/wjet.v14i2.6952.

[37] Zafeer HM, Maqbool S, Rong Y, Maqbool S. Impact of digital learning tools on students' engagement and achievement in middle school science classes. *Int J Technol Educ Sci*. 2025;9(2):177–96. doi:10.46328/ijtes.622.

[38] Abdi L, Rezaei E, Chaharbashloo H. Investigating the effectiveness of parental involvement training on learning and motivation of primary school students in a blended learning environment. *Q J Fam Res*. 2025;21(4):159–74. [In Persian]

[39] Suprobo NR, Hasanah WK, Puriastuti AC, Novembriani RP, Widya Y, Alim MS, et al. Empowering parents through e-learning: assessing digital readiness for online parenting education. *BIO Web Conf*. 2025;193:00074. doi:10.1051/bioconf/202519300074.

[40] Esmaeelpanah Amlashi Z, Hosseinkhanzadeh AA, Akbari B, Moghtader L. Psychometric properties of the parenting self-efficacy questionnaire (TOPSE). *J Psychol Sci*. 2021;20(102):939–51. [In Persian]

[41] Barghi I, Garyi Garavand P. Investigating the effect of parent participation on quality of life and adjustment in students. *J Sch Psychol*. 2021;9(4):96–105. [In Persian] doi:10.32598/JSPI.9.4.8.

[42] Amelia R, Mustadi A, Ghufon A, Suriansyah A. Parental involvement in digital learning: mothers' experiences of elementary school students. *Int J Interact Mob Technol*. 2023;17(10):118–35. doi:10.3991/ijim.v17i10.38253.

[43] Yasa AD, Rahayu S, Handayanto SK, Ekawati R. Investigation effects digital literacy on primary student attitude in Indonesia. *Int J Elem Educ*. 2024;8(1):11–19. doi:10.23887/ijee.v8i1.70413.

[44] Onwuegbuzie AJ, Collins KMT, Frels RK. Foreword: using Bronfenbrenner's ecological systems theory to frame quantitative, qualitative, and mixed research. *Int J Mult Res Approaches*. 2013;7(1):2–8. doi:10.5172/mra.2013.7.1.2.

AUTHOR(S) BIOSKETCHES

Mahdi Namdari Pejman is an assistant professor at Farhangian University, Faculty of Educational Sciences, Department of Educational Management. His expertise includes educational administration, quality assurance in teacher education, lesson study, and quantitative/qualitative data analysis. He has published over 40 articles and 6 books.

Namdari-Pejman, M., Assistant Professor, Educational Administration, Farhangian University, Tehran, Iran

✉ m.namdari@cfu.ac.ir

Mohsen Zandian holds a master's degree in Educational Administration from the University of Tehran. His research interests encompass educational technology in school management, teacher empowerment, home-school communication, qualitative research methodologies in school leadership, and organizational culture.

Zandian, M., MA, Educational Administration, Department of Educational Management, Faculty of Psychology and Education, University of Tehran, Tehran, Iran

✉ zandian.mohsen@ut.ac.ir

Citation (Vancouver): Namdari-Pejman M, Zandian M. [Parental Involvement in Digital Learning Environments: Examining School-Parent Communication, Parental Self-Efficacy, and Students' Positive Digital Agency] *Tech. Edu. J*. 2026; 20(1): 179-197

 <https://doi.org/10.22061/tej.2026.12938.3360>



فرصت‌های آینده آموزش کتب «کار و فناوری» دوره متوسطه اول ایران مبتنی بر روندهای ۱۳۳-۱۵۶
فناورانه: رویکردی آینده‌پژوهانه

مصطفی کشاورز ترک

ارزیابی عملکرد دانشجو معلمان در تکالیف مدل‌سازی ریاضی: مقایسه با پاسخ‌های هوش مصنوعی ۱۵۷-۱۷۸

نفیسه آزادی، ابراهیم ریحانی، مجتبی قربانی، رضا ابراهیم‌پور، سعید حق جو

مشارکت والدین در محیط‌های یادگیری دیجیتال: مطالعه‌ای در مورد ارتباطات مدرسه، ۱۷۹-۱۹۷
خودکارآمدی والدین و کنشگری مثبت دیجیتال دانش‌آموزان

مهدی نامداری پژمان، محسن زندیان

نشریه علمی فناوری آموزش

دوره ۲۰، شماره ۱، زمستان ۱۴۰۴

بکارگیری توره‌های واقعیت مجازی ۳۶۰ درجه معلم ساخت در یادگیری زبان خارجی: وا کاوی ۱-۲۲
درماندگی آموخته شده در یک بافت اقتصادی-اجتماعی پایین

ملیکا افتخاری، مهرک رحیمی

فرا تحلیل پژوهش‌های مرتبط با بازی گونه سازی با تاکید بر اثرات دراز مدت آنها بر عملکرد ۲۳-۴۲
تحصیلی دانش آموزان ابتدایی

جواد کیهان، گلستان شیخ لو

قدرت زمان: چگونه فنون فاصله گذاری یادگیری واژگان ESP را در محیط آنلاین متحول ۴۳-۶۴
می کنند

زهرا چراغی، هنگامه عمرانپور، عطیه مطهری نژاد

باورهای فناورانه، ساختار دانش و ویژگی‌های فردی: عوامل شکل دهنده ادغام فناوری در ۶۵-۷۸
کلاس درس

سعید بی باک، سیروس اسدیان

نقش میانجی مشغولیت تحصیلی در رابطه میان حمایت اجتماعی و رضایت مندی دانشجویان ۷۹-۹۶
در محیط‌های یادگیری آنلاین

عباس تقی زاده، افضل اکبری بلوط بنگان

خودکارآمدی فناوری، درگیری با فناوری و لذت تدریس در میان معلمان زبان انگلیسی ایران: ۹۷-۱۱۴
مدلی با نقش تعدیل گری سن

رضا نجاتی

آیا یادگیرندگان خود راهبر عامل یادگیری خود هستند؟ بررسی نقش هوش مصنوعی در تغییر ۱۱۵-۱۳۲
عاملیت شناختی دانشجویان

عباس رمضانی
