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

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ABSTRACT

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 (β = 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.

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
39	1	3

مقاله پژوهشی

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

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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 معلم 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.

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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 قابل‌قبول است. داده‌ها با استفاده از آمار توصیفی و مدل‌یابی معادلات ساختاری در نرم‌افزار PLS4 تجزیه‌وتحلیل شد.

یافته‌ها: نتایج نشان داد که باورهای فناورانه قوی‌ترین پیش‌بین مثبت و معنادار یکپارچه‌سازی فناوری در کلاس درس هستند (β =۰/۳۸۸ ، p <۰/۰۱) که با چارچوب‌های نظری تأکیدکننده بر نقش فیلترهای ادراکی معلمان در پذیرش نوآوری‌های آموزشی همسوست. ساختارهای دانش به‌عنوان دومین عامل تأثیرگذار شناسایی شدند (β = ۰/۲۸۷، p < ۰/۰۱) که اهمیت چارچوب (TPACK) را در یکپارچه‌سازی معنادار فناوری برجسته می‌سازد. در میان ویژگی‌های فردی، تنها سطح تحصیلات دارای رابطه مثبت و معنادار بود (β = ۰/۰۹۴، p <۰/۰۵) ، 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 (NFI= /۹۳، CFI= ۰/۹۶ ، RMSEA= ۰/۰۵۶ و ۶۸ درصد از واریانس یکپارچه‌سازی فناوری را تبیین کرد R^2= ۰/۶۸ که بیانگر آن است که متغیرهای مستقل به طور جمعی سهم قابل‌توجهی 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 باتکیه‌بر 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 α = 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 (β = 0.388) emerged as the strongest predictor of technology integration;
- Knowledge structures (β = 0.287) ranked second in importance;
- Among individual characteristics, only educational attainment showed a positive, significant relationship (β = 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 → Technology Integration	0.388	8.92	$p < 0.01$	Significant
Knowledge Structures → Technology Integration	0.287	6.45	$p < 0.01$	Significant
Educational Attainment → Technology Integration	0.094	2.12	$p < 0.05$	Significant
Gender → Technology Integration	0.021	0.89	$p > 0.05$	Not Significant
Age → Technology Integration	0.032	1.12	$p > 0.05$	Not Significant
Teaching Experience → 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 (β = 0.388) as the most influential factor, followed by knowledge structures (β = 0.287) and educational attainment (β = 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.

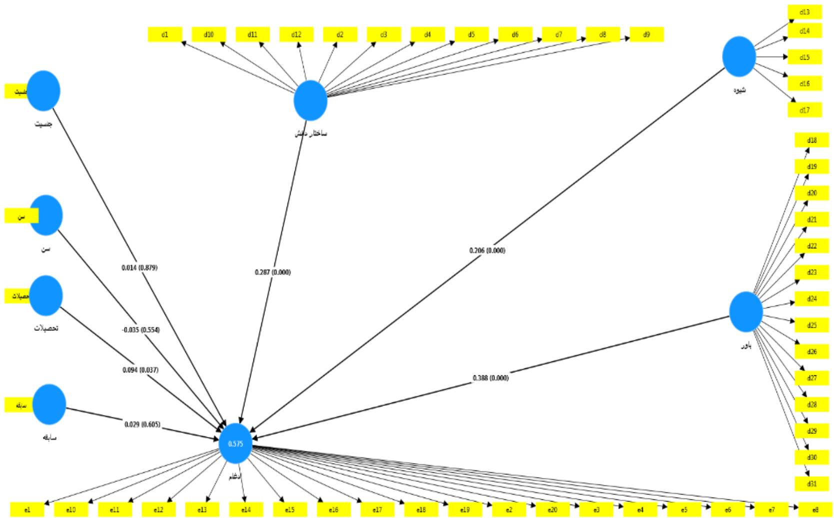

Fig. 1: Structural model with standardized path coefficients

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 Robatjazy 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.

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Conflicts of Interest

The authors declare no conflict of interest.

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