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A Novel Approach to Enhancing the Effectiveness of Chemistry Teaching by Preservice Teachers

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Abstract

The objective of this article is to develop a new approach for improving the effectiveness of chemistry teaching, which involves transforming the teaching process via the use of interactive digital technologies. The research methodology is based on the Self-Determination Theory (SDT) and the Stimulus-Organism-Response (SOR) model. The study explores key constructs such as Perceived Usability (PU), Perceived Autonomy (PAU), Perceived Teaching Support (PTS), Perceived Competency (PCM), Perceived Relatedness (PRT), Perceived Ease of Use (PEOU), Cognitive Teaching Involvement (CTI), and Affective Teaching Involvement (ATI), examining their influence on teaching performance. Data were collected from 254 preservice chemistry teachers trained at Akhmet Yassawi International Kazakh-Turkish University, Kazakhstan. Structural equation modeling (SEM) was applied to test the scientific hypotheses. The findings showed that PU, PEOU, PAU, and PTS have a significant effect on CTI and ATI, which in turn have a positive effect on teaching effectiveness. In other words, the study confirms the importance of user-friendly and effective digital tools in developing positive attitudes towards technology adoption. The novelty of this paper comprises the author's concept of the educational process transformation through the usage of interactive digital technologies, which increases the chemistry education effectiveness.

Keywords:

Novel Educational Approach;
Educational Interactive Digital Technologies;
Chemistry Teaching Quality;
Stimulus-Organism-Response (SOR);
SDT Theory; Preservice Teachers;
Kazakhstan.

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1- Introduction

Kazakhstan universities have been adopting digital technologies not only for pure teaching and learning purposes but also for education management goals, including supervision, control, and monitoring [1, 2]. Overall, digital technology integration is specifically significant for Kazakhstan as a country with a transitional economy, where the effective use of digital tools is essential for both educational development and general economic growth [3, 4]. Some research mentioned that digital technologies, including online learning platforms, blended learning models, or other modes of learning, have a positive impact on student learning outcomes [3, 4]. Furthermore, some studies have found that students in online learning environments can perform better than their peers in traditional settings [5-7]. Moreover, digital tools have made it possible to deliver quality education in remote areas, addressing issues related to accessibility and inclusivity [8, 9]. Flexible learning models, enabled by digital technologies, are increasingly being adapted to meet the needs of various student populations in Kazakhstan [3, 10, 11].

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Successful integration of digital technologies for educational purposes depends significantly on teachers' competence in selecting the right tools and methodologies. The adoption and use of various digital platforms such as Google Classroom, Moodle, Microsoft Teams, and Zoom have become more familiar in higher education, allowing for both synchronous and asynchronous teaching and learning [12, 13]. These platforms are also increasingly used for administrative tasks to make the educational process more efficient and effective [4, 14].

Chemistry education often involves abstract concepts that need to be understood at both macroscopic and molecular levels, which makes interactive digital tools especially useful [1, 15], such as simulations, virtual laboratories, or interactive platforms [16-18]. The shift from traditional teaching (i.e., lecture-based instruction) to interactive and technology-enhanced pedagogies is particularly important in Kazakhstan, where the education system aims to meet global standards and improve teaching quality in the STEM (Science, Technology, Engineering, and Mathematics) field [19-21].

The adoption of digital technologies in education reflects a significant move towards more interactive and student-centered learning environments [19, 22]. Meanwhile, the cognitive technologies that have enhanced the students' cognitive development are becoming integral to modern educational practices [23, 24]. The many digital technologies are designed specifically for chemistry education, which offers significant benefits, allowing preservice chemistry teachers to enhance content delivery and teaching methods, making the learning process more engaging and effective [23, 25, 26]. The interactive simulations and animations helped students visualize and interact with chemical processes to overcome the conventional teaching challenges [25, 27, 28].

Kazakhstan is currently aimed at enhancing teaching quality, mainly in STEM disciplines [29-31], with a focus on integrating digital technologies into university curricula [31, 32]. A key issue here is ensuring that digital tools are not merely used for information transfer but are integrated in ways that engage students in creative and critical thinking processes [29, 30, 33].

To explore the role of interactive digital technologies in improving teaching performance, this study applies two theoretical frameworks: the Stimulus-Organism-Response (SOR) model and Self-Determination Theory (SDT). The SOR framework suggests that stimuli from external environments, such as digital technologies, influence individuals' internal states—both cognitive and affective—which, in turn, lead to specific behavioral outcomes [34, 35]. In this study, the stimuli refer to interactive digital tools, while the internal states are teachers' cognitive and affective involvement in teaching, and the behavioral response is teaching performance. The SOR framework has been widely applied in various disciplines to understand decision-making processes and user engagement with technology [34]. In parallel, SDT allows understanding how teachers become self-motivated and perform effectively in technology-enhanced learning environments [36]. SDT posits that individuals are driven by three inherent psychological needs: autonomy, competence, and relatedness [37, 38]. Autonomy reflects teachers' ability to select and control their teaching methods and tools freely. Competence refers to their capacity to effectively use digital technologies to achieve teaching objectives, while relatedness refers to the sense of connection and support teachers feel within their professional environment [36, 38]. Teachers who perceive digital tools as enhancing their autonomy, competence, and relatedness are more likely to be cognitively and affectively engaged in their teaching, which is likely to improve their overall teaching performance [39, 40].

Although the impact of digital technologies on student outcomes is well-researched, the effect of these tools on teaching performance remains underexplored, at least in Kazakhstan. Our research aims to address this gap by examining how preservice chemistry teachers' perceptions of usability, autonomy, teaching support, and ease of use of interactive digital technologies affect their cognitive and affective involvement in teaching. Moreover, this study investigates how these cognitive and affective factors influence teaching performance.

1-1- Research Questions

The following questions guide the research:

- How do factors such as perceived usability, autonomy, teaching support, competence, relatedness, and ease of use influence preservice chemistry teachers' cognitive and affective teaching involvement?
- What are the most significant factors that influence preservice chemistry teachers' adoption and effective use of interactive digital tools to improve teaching performance?

By addressing these questions, the study aims to bridge the gap between the theoretical understanding of interactive digital technologies and their practical implementation in improving future chemistry teachers' performance.

2- Theoretical Model and Hypothesis Development

In this study, we integrate the Stimulus-Organism-Response (S-O-R) model and Self-Determination Theory (SDT) to explore the impact of interactive digital technologies on teaching performance [41]. Both frameworks provide balancing perspectives for understanding how digital technologies influence teachers' cognitive and affective engagement, which in turn affects their teaching outcomes.

2-1- Stimulus-Organism-Response Framework

The Stimulus-Organism-Response (S-O-R) model is a widely used theoretical framework for analyzing the behavior of digital technologies' users. The model posits that external stimuli (S) affect an individual's internal cognitive and affective states (O), which then lead to a behavioral response (R). In the context of interactive digital technologies for teaching, stimuli include features of the digital tools, such as perceived usability, ease of use, and perceived support, which influence teachers' cognitive and affective teaching involvement, eventually impacting teaching performance [42, 43].

Stimulus (S): Features of Interactive Digital Technologies: In this model, the stimulus refers to the external features of interactive digital technologies that trigger cognitive and affective reactions in teachers [44]. The stimuli examined in this study include perceived usability, perceived ease of use, perceived autonomy, perceived teaching support, perceived competency, and perceived relatedness. These features represent the functional and psychological aspects of digital technologies that influence teachers' experiences with them. Perceived Usability and Perceived Ease of Use refer to how intuitive and user-friendly teachers perceive these digital tools to be: if future teachers find the technologies easy to navigate and useful, they are more likely to engage with them cognitively and emotionally. Perceived autonomy refers to the degree of teachers feeling free to use digital tools in a way that suits their teaching styles [45, 46]. Greater autonomy fosters a sense of ownership and motivation. Perceived teaching support reflects the extent to which teachers feel supported by the institution or platform when using digital technologies. Perceived competency relates to how confident teachers feel in their ability to use these technologies effectively, while perceived relatedness highlights the sense of connection with the colleagues and pupils when using the tools. These stimuli influence the organism, which includes cognitive and affective teaching involvement [35].

Organism (O): Cognitive and Affective Teaching Involvement: The organism in the S-O-R framework refers to the internal states triggered by external stimuli. In this study, it is represented by teachers' cognitive and affective teaching involvement. Cognitive teaching involvement refers to the intellectual engagement teachers experience when using digital technologies [35]. This involves their belief in the effectiveness of these tools in facilitating teaching and learning processes. Affective teaching involvement is the emotional reaction teachers have toward using digital technologies, including feelings of satisfaction or frustration [47]. Teachers who perceive digital tools as intuitive and beneficial are more likely to develop positive emotional responses [47, 48].

Response (R): Teaching Performance: The response in this model refers to the behavioral outcome [49], which is teaching performance in our case. According to the S-O-R model, cognitive and affective involvement drive teachers' decisions to adopt and integrate digital technologies into their practice [47, 48]. Teachers who experience higher levels of cognitive and affective involvement are more likely to see improvements as they feel more competent and motivated to use the tools effectively [49]. The S-O-R framework has been applied across various sectors, including online shopping [50, 51], tourism [35], and online education [52].

In the context of this study, the S-O-R framework helps to analyze how digital technologies influence preservice teachers' cognitive and emotional processes, affecting their teaching effectiveness. For example, in online education, the perceived usability of digital tools is a significant stimulus that can either facilitate or hinder the learning process [53-55]. When digital tools are easy to use and provide high interactivity, they can stimulate a positive cognitive attitude, encouraging teachers to adopt these technologies more readily [56-58].

2-2- SDT Framework

Self-Determination Theory (SDT) explains how individuals become self-motivated and perform optimally when their basic psychological needs are satisfied [36]. These needs include autonomy, competence, and relatedness. According to SDT, when teachers perceive that digital technologies enhance their autonomy (freedom to use the tools as desired), competence (ability to use the tools effectively), and relatedness (sense of connection with peers and students), they are more likely to experience higher engagement and perform better in teaching.

2-3- Research Model based on S-O-R Approach

By integrating S-O-R and SDT, we create a model that utilizes both the external stimuli provided by digital technologies and the internal psychological needs that must be satisfied for effective teaching performance (Figure 1). SDT complements this by identifying the psychological needs (autonomy, competence, and relatedness) that influence preservice chemistry teachers' motivation to engage with these technologies. In the context of Kazakhstan's educational sector, where the adoption of digital technologies is increasingly emphasized, this model can provide new perceptions on designing and implementing digital tools that meet functional requirements and satisfy preservice chemistry teachers' psychological needs, ultimately leading to improved teaching performance.

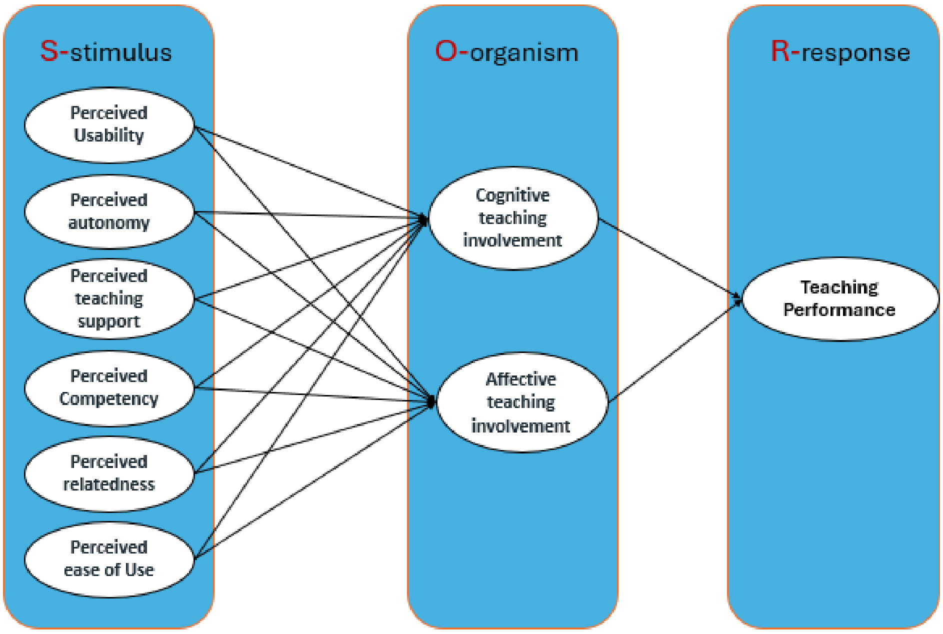

Figure 1. **Theoretical Framework**

2-4- Perceived Usability and Cognitive and Affective Teaching Involvement

Perceived usability plays a pivotal role in shaping preservice chemistry teachers' cognitive and affective involvement with interactive digital technologies. It refers to the extent to which users find a digital tool easy to use and effective in achieving teaching objectives [59]. When preservice chemistry teachers perceive a system as highly usable, this external stimulus (S) triggers internal cognitive and affective reactions (O), which ultimately influence their teaching performance (R). In our context, perceived usability acts as a stimulus that impacts cognitive and emotional processes in preservice chemistry teachers [60]. Cognitive teaching involvement refers to an educator’s belief in the effectiveness and utility of digital tools, while affective involvement encompasses the emotional satisfaction or frustration experienced when using those tools [47]. When technologies are perceived as user-friendly, teachers are more likely to believe in their effectiveness (cognitive involvement) and feel positive emotions (affective involvement), facilitating greater adoption and engagement. From an SDT perspective, perceived usability also satisfies the basic psychological needs of competence and autonomy [61, 62]. When teachers find digital tools easy to use, they experience a sense of mastery over the technology, which boosts their competence and ability to improve teaching outcomes [61, 63]. Moreover, ease of use enhances the sense of autonomy by giving teachers greater control over their teaching methods, leading to positive emotional responses, thus influencing affective involvement [64]. Therefore, we propose the following hypotheses:

- H1: Perceived Usability positively influences Cognitive Teaching Involvement.
- H2: Perceived Usability positively influences Affective Teaching Involvement.

2-5- Perceived Autonomy and Cognitive and Affective Teaching Involvement

Perceived autonomy, a key concept in Self-Determination Theory (SDT), refers to the degree to which individuals feel they have control and choice in their actions [65-67]. It plays a significant role in shaping teachers’ cognitive and affective teaching involvement [47]. Cognitive involvement refers to the belief in the effectiveness and utility of these technologies, while affective involvement encompasses the emotional reactions, such as satisfaction or frustration, experienced during their use [68, 69]. According to SDT, autonomy is a fundamental psychological need that, when fulfilled, promotes intrinsic motivation [70]. When teachers feel autonomous in their use of digital tools, they are more likely to experience cognitive involvement [6, 71, 72]. Additionally, autonomy allows teachers to align digital technologies with their teaching styles, increasing their affective involvement [73]. From the perspective of the S-O-R model, perceived autonomy triggers positive cognitive and emotional responses, ultimately influencing teaching behavior [74]. Therefore, we propose the following hypotheses:

- H3: Perceived Autonomy positively influences Cognitive Teaching Involvement.
- H4: Perceived Autonomy positively influences Affective Teaching Involvement.

2-6- Perceived Teaching Support and Cognitive and Affective Teaching Involvement

Perceived teaching support refers to the assistance and resources teachers receive from their institutions, colleagues, and educational technologies in implementing instructional strategies [75, 76]. In the context of Self-Determination

Theory (SDT), perceived teaching support is crucial for fostering teachers' cognitive and affective teaching involvement [77, 78]. Cognitive involvement includes the beliefs and understanding teachers hold regarding the effectiveness of teaching tools, while affective involvement encompasses their emotional responses [79, 80]. This aligns with SDT, which posits that support from the environment enhances motivation and engagement [77, 78]. For instance, when institutions provide training, resources, and encouragement for the use of digital tools, teachers feel more confident in their capabilities, which improves cognitive involvement [73]. Teachers who receive adequate support are likely to experience reduced anxiety and frustration, fostering a more enjoyable teaching experience [77, 78]. Therefore, we propose the following hypotheses:

- H5: Perceived Teaching Support positively influences Cognitive Teaching Involvement.
- H6: Perceived Teaching Support positively influences Affective Teaching Involvement.

In summary, perceived teaching support is vital for enhancing both cognitive and affective teaching involvement, ultimately leading to improved educational outcomes when utilizing interactive digital technologies.

2-7- Perceived Competency and Cognitive and Affective Teaching Involvement

Perceived competency refers to an individual's belief in their ability to perform tasks effectively [81, 82]. In the context of Self-Determination Theory (SDT), perceived competency plays a critical role in shaping both cognitive and affective teaching involvement [48]. Cognitive involvement reflects teachers' understanding and evaluation of their ability to integrate digital technologies into their teaching, while affective involvement relates to their emotional reactions to using these tools. When teachers perceive themselves as competent, they are more likely to develop positive cognitive attitudes toward digital technologies, believing they can use them effectively [82, 83]. This emotional involvement, driven by a sense of mastery, leads to a more enjoyable and engaging teaching experience. Thus, we propose:

- H7: Perceived Competency positively influences Cognitive Teaching Involvement.
- H8: Perceived Competency positively influences Affective Teaching Involvement.

2-8- Perceived Relatedness and Cognitive and Affective Teaching Involvement

Perceived relatedness, a core component of Self-Determination Theory (SDT), refers to the sense of connection and belonging an individual feels with others in their environment [84]. In the context of teaching, perceived relatedness influences both cognitive and affective teaching involvement [85]. When teachers experience a strong sense of relatedness, they are more likely to develop positive cognitive attitudes toward adopting digital technologies [86-88]. This connection fosters a collaborative environment, increasing teachers' willingness to engage with new tools and methods. Perceived relatedness also enhances affective teaching involvement by fostering positive emotional experiences [86, 88]. This emotional engagement can improve their teaching performance and encourage further use of interactive technologies. Thus, we hypothesize:

- H9: Perceived Relatedness positively influences Cognitive Teaching Involvement.
- H10: Perceived Relatedness positively influences Affective Teaching Involvement.

2-9- Perceived Ease of Use (PEOU) and Cognitive and Affective Teaching Involvement

Perceived ease of use (PEOU) refers to the degree to which individuals believe that using a particular technology will be free of effort [89]. In educational contexts, perceived ease of use plays a critical role in shaping both cognitive and affective teaching involvement [89]. When teachers perceive digital tools as easy to use, they are more likely to engage cognitively [90-92]. This ease reduces the cognitive load and increases their confidence in effectively employing technology to enhance learning outcomes [93, 94]. Teachers who find technology easy to navigate are more likely to experience positive emotions, which further encourages their adoption of digital tools [89, 95]. Thus, we hypothesize:

- H11: Perceived Ease of Use positively influences Cognitive Teaching Involvement.
- H12: Perceived Ease of Use positively influences Affective Teaching Involvement.

2-10- Cognitive and Affective Teaching Involvement and Teacher Performance

Cognitive and affective teaching involvement plays a significant role in shaping teaching performance [96]. Cognitive involvement refers to the intellectual engagement of teachers with teaching materials and strategies, focusing on how they integrate knowledge and tools to enhance student learning outcomes. Affective involvement, on the other hand, relates to the emotional connection teachers develop toward their teaching, including their passion, enthusiasm, and emotional investment [97, 98]. When teachers are cognitively engaged, they are more likely to apply effective teaching practices, reflect critically on their teaching methods, and seek innovative solutions, leading to improved teaching performance [8, 99, 100]. Similarly, affective involvement drives motivation and satisfaction, which contribute to a more dynamic and interactive learning environment. Positive emotional investment leads to greater effort in lesson preparation and delivery, thereby enhancing the overall effectiveness of teaching [101]. Therefore, both cognitive and affective teaching involvement are essential for improving teaching performance, as they influence how teachers plan, implement, and refine their instructional strategies [102, 103], leading to better teaching outcomes [104]. Thus, we hypothesize:

- H13: Cognitive Teaching Involvement positively affects Teaching Performance.
- H14: Affective Teaching Involvement positively affects Teaching Performance.

Figure 2 shows the relation of established hypotheses to estimation of preservice chemistry teachers' performance efficiency.

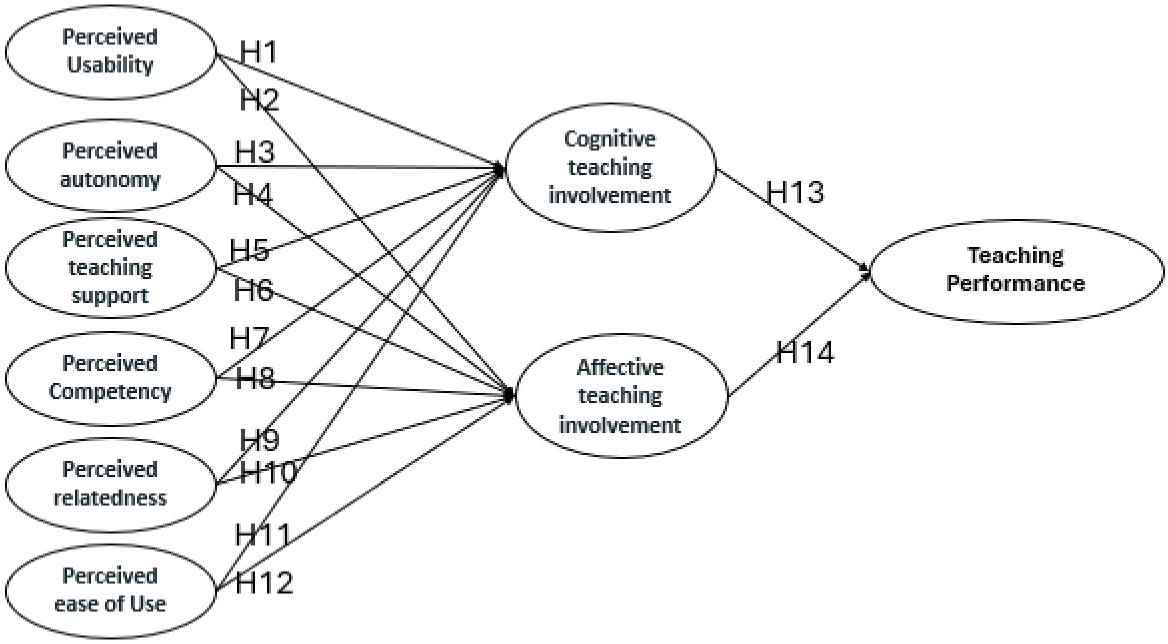

Figure 2. Proposed Hypotheses

Every hypothesis above utilizes one of the concepts that are commonly used for estimation of teachers' performance and digital technologies accessibility. Verifying these hypotheses in specific reality of Kazakhstan and chemistry teaching will allow creating a comprehensive estimation system and therefore make a valid conclusion about the role of digital technologies in improving efficiency of future chemistry teachers in Kazakhstan.

3- Research Methodology

3-1- Research Approach

In this study, we used a quantitative research approach, which is well-suited for examining relationships between variables and testing hypotheses [13, 105, 106]. Quantitative research is chosen for its ability to provide objective and measurable results, making it ideal for analyzing more complex relationships and presenting more accurate results. This approach facilitates a structured analysis of the study main factors and their impact on teaching performance in Kazakhstan.

3-2- Data Collection

Data for this study was collected through a survey-based approach, which is being used in quantitative research to gather information [107]. In this study, the survey specifically targeted preservice chemistry teachers in Kazakhstan to assess their perceptions of interactive digital technologies and their attitudes toward these tools. Participants were selected at Akhmet Yassawi International Kazakh-Turkish University. They attended pedagogical experiments training conducted at Akhmet Yassawi International Kazakh-Turkish University. Based on their participation in workshops focused on digital learning tools for chemistry teaching purposes. These workshops provided participants with hands-on experience using various digital learning tools, offering practical usage of these technologies in chemistry education. This ensured participants had a relevant context for providing informed responses on the effectiveness of digital learning tools.

A total of 275 surveys were distributed via WhatsApp groups using online survey links, and 10 incomplete responses were removed. An additional 11 cases with missing data or outliers were excluded following a manual data-cleaning process. The final sample size of 254 participants aligns with recommendations for SEM analysis [108].

In this study, the demographic information of the survey sample, which consisted of a total of 254 preservice chemistry teachers' information, is summarized in Table 1. The data shows the distribution of participants by age, gender, and usage of digital tools. The participants comprised 45 (17.7%) first-year chemistry education, 119(46.9%) second-year chemistry education, 48(18.9%) third-year chemistry education, and 42(16.5%) fourth-year chemistry education. Gender distribution was notably skewed, with a majority of female participants, 229(90.2%), compared to male participants 25 (9.8%). Of all respondents, 254 (100%) reported using digital tools for teaching and learning.

Table 1. Demographic Information of Participants

Items	Count	%
Study Year & Age (years)		
1st year (18 years)	45	17.7
2nd year (18-19 years)	119	46.9
3rd year (19-20 years)	48	18.9
4th year (20-21 years)	42	16.5
Gender		
Male	25	9.8
Female	229	90.2
Have you used Digital tools for teaching and learning?		
Yes	254	100%

The survey tool contains two main sections: one for demographic information and the other for model constructs related to interactive digital technologies (Appendix I). The constructs were carefully adopted from the literature, as details are presented in Table 2. Each item was rated using a five-point Likert scale, with responses ranging from "strongly disagree" to "strongly agree." A pilot study was conducted with 50 students who had prior experience with the use of digital technologies for chemistry teaching. The purpose was to assess the reliability of the survey tool and to make necessary adjustments before the main data collection. The pilot study findings showed strong reliability for all constructs, with Cronbach's Alpha values above 0.80 [108], demonstrating internal consistency, as mentioned in Table 2. Minor changes were made based on pilot feedback, like refining item phrasing for clarity.

Table 2. Pilot Study Reliability Results

Construct	No of Items	Reliability (Pilot Study Results)	Sources of Adoption
Perceived usability	9	0.87	Chen et al. [109]
Perceived autonomy	4	0.85	Arghashi & Yuksel [110]
Perceived teaching support	5	0.88	Almulla [111]
Perceived competency	5	0.86	Pillai & Sivathanu [112]
Perceived relatedness	4	0.84	Martín-García et al. [113]
Perceived ease of use	5	0.83	Almulla [111]
Cognitive teaching involvement	4	0.82	Rafiq et al. [114]
Affective teaching involvement	5	0.87	Rafiq et al. [114]
Teaching performance	4	0.85	Berdi et al. [6]

Through the pilot study, we ensured that the constructs used in the survey instrument were reliable and valid. The strong reliability coefficients and satisfactory validity indicators ensured that the survey effectively captured the relevant data for the main study.

3-3- Structural Equation Modeling (SEM) Analysis

To analyze the data, we employed Structural Equation Modeling (SEM), and various SEM statistical analysis techniques were used to evaluate and validate our theoretical model involving multiple variables and their relationships [115]. SEM is effectively used for analyzing relationships between various variables and also helps in testing hypotheses by applying measurement and structural models' analysis procedures. In the first phase of SEM analysis, the measurement model is used to ensure the reliability and validity of the constructs by evaluating factor loadings, which determine how well each item represents its respective construct [115, 116]. Convergent validity is assessed using Composite Reliability (CR) and Average Variance Extracted (AVE), with CR values above 0.7 and AVE values exceeding 0.5 indicating adequate validity [115]. Additionally, Cronbach's Alpha is used to measure internal consistency, with values above 0.7 deemed acceptable [117]. Discriminant validity is evaluated using the Heterotrait-Monotrait Ratio (HTMT) and Fornell-Larcker criteria, ensuring that each construct is distinct from others [118, 119]. After validating the measurement model, the study progresses to the second phase of SEM analysis. This phase includes assessing R-square values to measure the explanatory power of the model, indicating how much variance in dependent variables is explained by independent variables [115]. F-square values are used to evaluate the effect sizes of predictor variables on outcomes [120]. The final phase involves path analysis to test the proposed hypotheses and examine the direct and indirect relationships between constructs. Bootstrapping methods are employed to ensure robust and reliable results for path coefficients [115]. This analysis gives an understanding of the impacts of interactive digital technologies on teaching quality and validates our proposed theoretical model of the study.

4- Findings

4-1- Construct Reliability and Validity

Table 3 demonstrates that all factor loadings exceed the recommended threshold of 0.60, confirming the reliability and validity of the constructs [121]. For Affective Teaching Involvement (ATI), factor loadings range from 0.77 to 0.86, indicating a strong representation of emotional engagement. Cognitive Teaching Involvement (CTI) also shows robust factor loadings between 0.71 and 0.85, highlighting its solid contribution to teaching involvement. Perceived Ease of Use (PEOU) has factor loadings between 0.79 and 0.82, confirming the significance of usability in engaging teachers. Similarly, Perceived Autonomy (PAU) exhibits high loadings from 0.79 to 0.88, emphasizing the role of autonomy in teaching. Perceived Relatedness (PRT) shows loadings from 0.81 to 0.87, and Perceived Teaching Support (PTS) ranges from 0.76 to 0.86, both indicating the importance of connection and institutional support in improving teaching engagement [121].

Table 3. Factor Loadings

Constructs	Items	Factor Loadings	Constructs	Items	Factor Loadings
Affective teaching involvement	ATI01	0.77	**Perceived ease of Use**	PEOU01	0.80
	ATI02	0.86		PEOU02	0.79
	ATI03	0.84		PEOU03	0.82
	ATI04	0.83		PEOU04	0.81
	ATI05	0.83		PEOU05	0.79
Perceived relatedness	**PRT**01	0.86	**Perceived Competency**	PCM01	0.78
	PRT02	0.87		PCM02	0.79
	PRT03	0.86		PCM03	0.83
	PRT04	0.81		PCM04	0.84
Cognitive teaching involvement	CTI01	0.81		PCM05	0.81
	CTI02	0.84	**Perceived Usability**	PU01	0.72
	CTI03	0.85		PU03	0.74
	CTI04	0.71		PU04	0.70
Perceived autonomy	PAU01	0.79		PU05	0.78
	PAU02	0.88		PU06	0.75
	PAU03	0.85		PU07	0.74
	PAU04	0.80		PU08	0.79
Perceived teaching support	PTS01	0.86		PU09	0.76
	PTS02	0.83	**Teaching Performance**	TPR01	0.85
	PTS03	0.85		TPR02	0.88
	PTS04	0.76		TPR03	0.81
	PTS05	0.76		TPR04	0.85

Perceived Competency (PCM) has factor loadings from 0.78 to 0.84, reflecting teachers' confidence in using technology. Perceived Usability (PU), with loadings between 0.70 and 0.79, and Teaching Performance (TPR), with values from 0.81 to 0.88, show acceptable loadings, suggesting these constructs are well-represented by their items and significantly contribute to the overall model.

Table 4 presents the results of the reliability analysis, including Cronbach's alpha, Composite Reliability (CR), and Average Variance Extracted (AVE) values for the constructs. All Cronbach's alpha values exceed the recommended threshold of 0.70, confirming strong internal consistency across the constructs [117, 122]. Specifically, Affective Teaching Involvement (ATI) has a high alpha value of 0.88, and Perceived Relatedness (PRT) also shows a strong alpha value of 0.87, demonstrating the robustness and reliability of these constructs [117, 122].

Table 4. Reliability Analysis (Cronbach's alpha, CR, and AVE)

Constructs	Cronbach's alpha	Composite reliability	Average variance extracted (AVE)
ATI	0.88	0.91	0.68
PRT	0.87	0.91	0.72
CTI	0.81	0.88	0.65
PAU	0.85	0.90	0.69
PTS	0.87	0.91	0.66
PEOU	0.86	0.90	0.64
PCM	0.87	0.91	0.66
PU	0.86	0.89	0.51
TPR	0.87	0.91	0.72

The Composite Reliability (CR) values also exceed 0.70 for all constructs, indicating good overall reliability. For instance, Perceived Teaching Support (PTS) and Perceived Competency (PCM) both have CR values of 0.91, affirming their consistency [117, 122].

Most constructs meet the recommended threshold of 0.50 for Average Variance Extracted (AVE), ensuring good construct validity [123, 124]. Perceived Relatedness (PRT) and Teaching Performance (TPR) both exhibit AVE values of 0.72, indicating that these constructs capture sufficient variance from their indicators [123, 124]. However, Perceived Usability (PU) has a lower AVE of 0.51, which, while acceptable, suggests room for improvement. To enhance validity, items PU02, PU04, and PU05 were excluded from further analysis [123, 124]. The constructs demonstrate strong reliability and validity, as evidenced by their Cronbach's alpha, CR, and AVE values, supporting the robustness of the measurement model in this study. Figure 3 visualizes the results of performed reliability analysis.

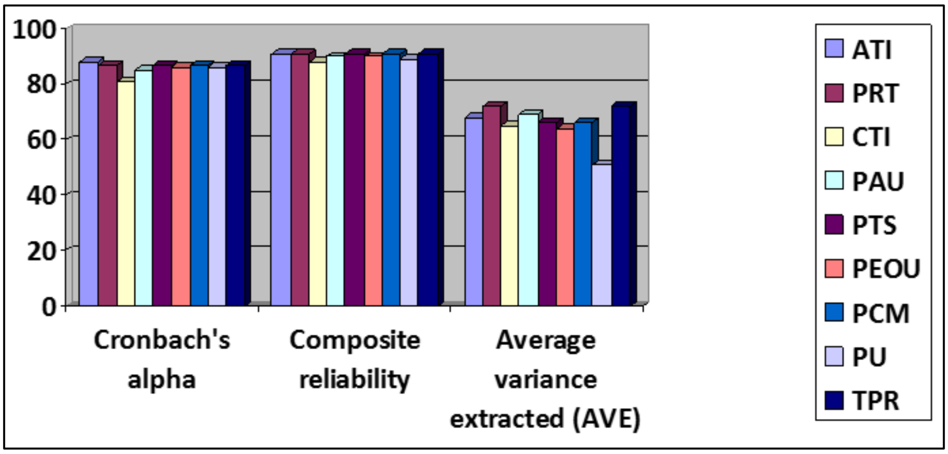

Figure 3. Visual chart of reliability analysis (Cronbach's alpha, CR, and AVE)

In this study, discriminant validity was evaluated using the Heterotrait-Monotrait Ratio of Correlations (HTMT) and the Fornell-Larcker criterion. Table 5 presents the HTMT results, which indicate the degree to which constructs are distinct from each other. Following Henseler et al. [119], recommendation that HTMT values should be below 0.90, all the constructs in this study meet this threshold. This confirms that the constructs exhibit adequate discriminant validity and are distinct from one another. Figure 4 visualizes the results of discriminant validity HTMT evaluation.

Table 5. Discriminant Validity (HTMT Results)

	AAT	PRT	CTI	PAU	PTS	PEOU	PCM	PU	TPR
ATI									
PRT	0.840								
CTI	0.850	0.860							
PAU	0.810	0.720	0.870						
PTS	0.680	0.850	0.660	0.560					
PEOU	0.880	0.630	0.750	0.620	0.810				
PCM	0.810	0.730	0.820	0.760	0.570	0.620			
PU	0.810	0.800	0.850	0.850	0.620	0.620	0.800		
TPR	0.850	0.840	0.850	0.820	0.710	0.700	0.790	0.820	

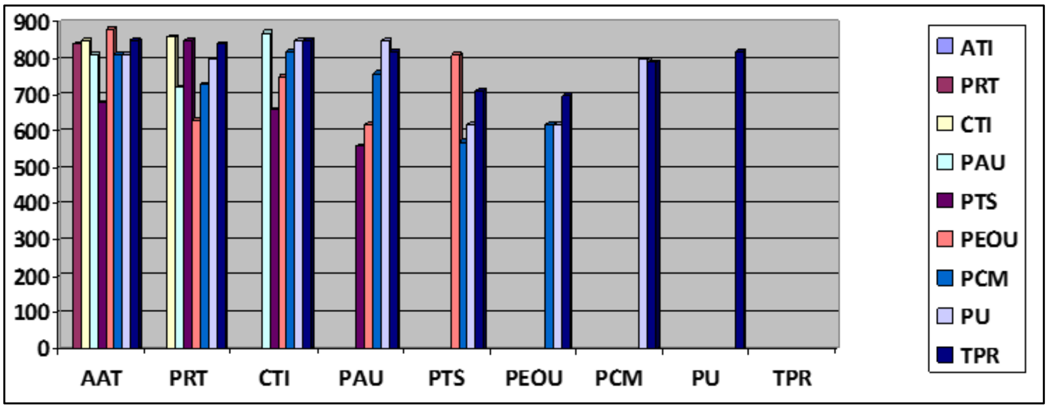

Figure 4. Visual chart of discriminant Validity (HTMT Results)

Table 6 shows the results of the Fornell-Larcker criterion, which further supports the discriminant validity of the constructs. The square root of the Average Variance Extracted (AVE) for each construct (diagonal values) is greater than the correlations between the constructs (off-diagonal values) [118]. Together, these results from both HTMT and Fornell-Larcker criteria confirm that the constructs in the study are distinct and adequately discriminant, ensuring the robustness of the model's measurement properties. This alignment with recommended thresholds further strengthens the construct validity and reliability of the study [118]. Figure 5 provides visual chart of discriminant validity evaluation with Fornell-Larcker criterion.

Table 6. Discriminant Validity (Fornell-Larcker criterion Results)

	AAT	PRT	CTI	PAU	PTS	PEOU	PCM	PU	TPR
ATI	0.830								
PRT	0.740	0.850							
CTI	0.760	0.730	0.800						
PAU	0.710	0.620	0.730	0.830					
PTS	0.590	0.790	0.560	0.490	0.810				
PEOU	0.770	0.550	0.630	0.530	0.700	0.800			
PCM	0.710	0.640	0.700	0.650	0.500	0.540	0.810		
PU	0.720	0.700	0.770	0.830	0.550	0.540	0.700	0.710	
TPR	0.790	0.740	0.800	0.710	0.620	0.610	0.680	0.720	0.850

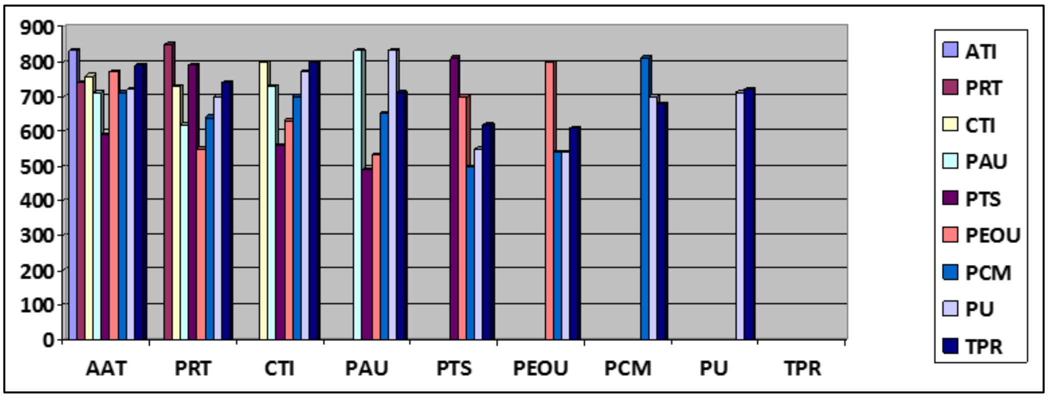

Figure 5. Visual chart of discriminant Validity (Fornell-Larcker criterion Results

4-2- Structural Model Analysis

The structural model analysis focuses on evaluating the model's fitness through R-squared and f-squared values. Table 7 displays the R-squared and adjusted R-squared values for the constructs within the model. According to Hair et al. (2017) [125], R-squared values are categorized as follows: 0.75 (substantial), 0.50 (moderate), and 0.25 (weak). The findings reveal that Affective Teaching Involvement (ATI) has an R-squared value of 0.82 with an adjusted R-squared of 0.82, indicating a substantial level of explanation regarding the variance in this construct. Similarly, Cognitive Teaching Involvement (CTI) demonstrates an R-squared of 0.74 and an adjusted R-squared of 0.73, reflecting a moderate level of explanation. Furthermore, the Teaching Performance (TPR) construct shows an R-squared of 0.72 and an adjusted R-squared of 0.72, also representing a moderate level of explanation. These results suggest that the model effectively explains a significant portion of the variance across the evaluated constructs, highlighting the model's robustness and validity. The substantial and moderate R-squared values reinforce the importance of the proposed relationships in the model and support its relevance in explaining the factors influencing teaching involvement and performance.

Table 7. R Square Values (Model fitness Score)

	R-square	R-square adjusted	Criteria
ATI	0.82	0.82	0.75 ⇒ Substantial 0.50 ⇒ Moderate
CTI	0.74	0.73	0.25 ⇒ Weak
TPR	0.72	0.72	*Hair et al.* [125]

Table 8 summarizes the f-squared values, which indicate the effect size of various predictors on the dependent variables, interpreted based on Cohen's criteria: 0.35 (large), 0.15 (medium), and 0.02 (small). The analysis reveals that the relationship between Affective Teaching involvement (ATI) and Teaching Performance (TPR) has an f-squared value of 0.260, indicating a medium effect size. Notably, Perceived Relatedness (PRT) shows a large effect on both ATI (0.350) and Cognitive Teaching involvement (CTI) (0.160). Additionally, the f-squared value for the relationship between CTI and TPR is 0.340, which also reflects a large effect size. Perceived Ease of Use (PEOU) has a significant impact on ATI, with a high f-squared value of 0.790, suggesting a large effect size, while its effect on CTI is medium (0.150). On the other hand, relationships involving Perceived Autonomy (PAU) and Perceived competency (PCM) yield small effect sizes, with f-squared values of 0.030 and 0.040 for ATI, respectively, and similar trends for CTI. Furthermore, the Perceived usability (PU) shows no effect on ATI and a small effect size on CTI (0.060). Overall, the structural model effectively explains the variance in the dependent constructs, with PEOU and PRT identified as significant predictors influencing both Affective Teaching Intention and Teaching Practice Readiness.

Table 8. F Square Values (Model fitness Score)

Paths	F-square	Criteria
ATI → TPR	0.260	
PRT → ATI	0.350	
PRT → CTI	0.160	
CTI →TPR	0.340	
PAU → ATI	0.030	
PAU → CTI	0.020	The following threshold values for effect sizes are based on Cohen [120]
PTS →ATI	0.200	Small (S): f2 ⇒ 0.02
PTS → CTI	0.060	Medium (M): f2 ⇒ 0.15
PEOU → ATI	0.790	Large (L): f2 ⇒ 0.35
PEOU → CTI	0.150	
PCM → ATI	0.040	
PCM → CTI	0.020	
PU → ATI	0.000	
PU → CTI	0.060	

The structural model analysis results provide valuable insights into the relationships among various constructs, as detailed in Table 9 and illustrated in Figure 6. Hypothesis 1 (H1) examined the effect of Perceived Usability (PU) on Affective Teaching Involvement (ATI), which was found to be non-significant ($\beta = 0.040$, $T = 0.760$, $p = 0.440$), leading to the conclusion that H1 is unsupported. In contrast, Hypothesis 2 (H2) indicated that PU significantly influences

Cognitive Teaching Involvement (CTI) (β = 0.260, T = 3.560, p = 0.000), thereby supporting the hypothesis. Hypothesis 3 (H3) showed that Perceived Relatedness (PRT) has a significant positive effect on ATI (β = 0.510, T = 5.000, p = 0.000), which is also supported. Similarly, Hypothesis 4 (H4) demonstrated that PRT significantly impacts CTI (β = 0.410, T = 5.160, p = 0.000), providing further support. Hypothesis 5 (H5) confirmed that CTI has a significant positive effect on Teaching Performance (TPR) (β = 0.480, T = 7.170, p = 0.000), indicating support for this hypothesis. Additionally, Hypotheses 6 (H6) and 7 (H7) revealed that Perceived Autonomy (PAU) positively affects both Affective Teaching Involvement (ATI) (β = 0.140, T = 2.230, p = 0.030) and CTI (β = 0.130, T = 1.960, p = 0.050), supporting both hypotheses. Hypotheses 8 (H8) and 9 (H9) highlighted that Perceived Teaching Support (PTS) negatively influences ATI (β = -0.360, T = 4.160, p = 0.000) and CTI (β = -0.250, T = 3.540, p = 0.000), resulting in support for both hypotheses. Furthermore, Hypotheses 10 (H10) and 11 (H11) indicated that Perceived Ease of Use (PEOU) significantly enhances both Affective Teaching Involvement (ATI) (β = 0.580, T = 7.440, p = 0.000) and Cognitive Teaching Involvement (CTI) (β = 0.310, T = 4.750, p = 0.000), thus supporting both hypotheses. Finally, Hypotheses 12 (H12) and 13 (H13) showed that the Perceived Competency Model (PCM) positively influences both ATI (β = 0.130, T = 2.930, p = 0.000) and CTI (β = 0.120, T = 2.220, p = 0.030), providing support for both hypotheses. In conclusion, out of the 13 hypotheses tested, 12 were supported, indicating that factors such as PEOU, PRT, and PCM significantly contribute to enhancing technology integration in teaching practices. The findings underscore the critical roles of perceived usability, autonomy, and support in shaping teachers' attitudes and practices, ultimately leading to improved teaching performance.

Table 9. Structural Model analysis (Direct effects)

Path	Original sample	T statistics	P values	Result
PU → ATI	0.040	0.760	0.440	Unsupported
PU → CTI	0.260	3.560	0.000	Supported
PRT → ATI	0.510	5.000	0.000	Supported
PRT → CTI	0.410	5.160	0.000	Supported
CTI → TPR	0.480	7.170	0.000	Supported
PAU → AAT	0.140	2.230	0.030	Supported
PAU → CTI	0.130	1.960	0.050	Supported
PTS → ATI	-0.360	4.160	0.000	Supported
PTS → CTI	-0.250	3.540	0.000	Supported
PEOU → ATI	0.580	7.440	0.000	Supported
PEOU → CTI	0.310	4.750	0.000	Supported
PCM → ATI	0.130	2.930	0.000	Supported
PCM → CTI	0.120	2.220	0.030	Supported

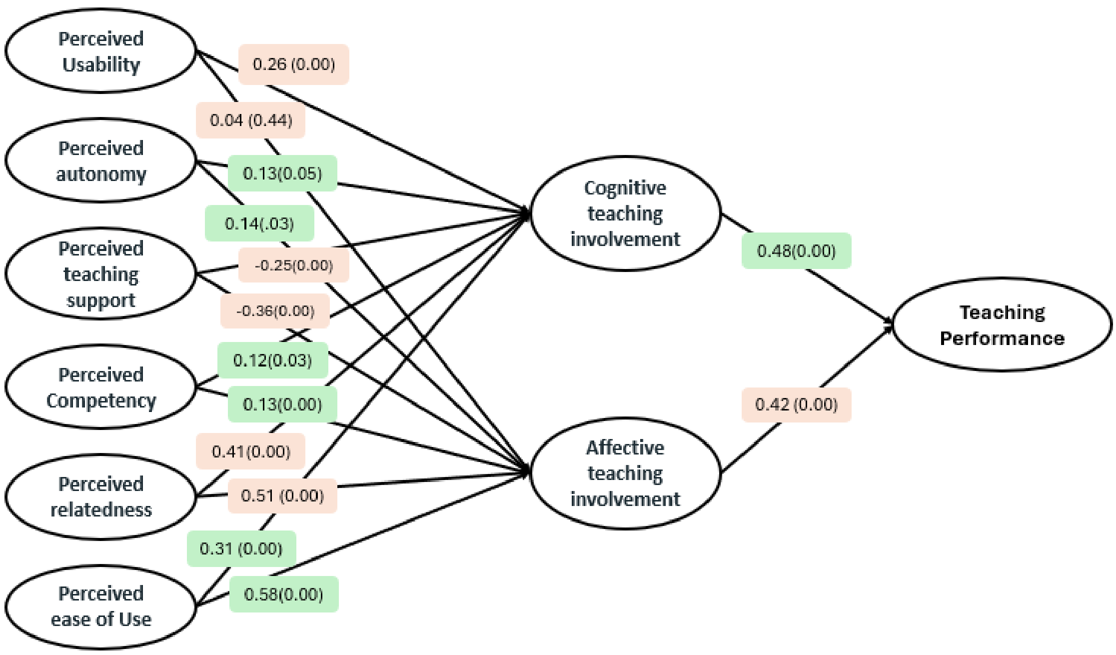

Figure 6. Hypothesis Validating Results

The analysis of indirect effects on Teaching Performance (TPR) reveals significant relationships among various constructs, as outlined in Table 10.

Table 10. Structural Model analysis Indirect effects

	Original sample	T statistics	P values	Results
PRT → TPR	0.410	5.670	0.000	Supported
PAU → TPR	0.120	2.670	0.010	Supported
PTS → TPR	-0.270	4.590	0.000	Supported
PEOU → PR	0.390	7.380	0.000	Supported
PCM → TPR	0.110	3.370	0.000	Supported
PU → TPR	0.140	3.040	0.000	Supported

Perceived Relatedness of Technology (PRT) has a strong positive indirect effect on TPR ($\beta = 0.410$, $p = 0.000$), indicating that a sense of connection with technology enhances teaching performance. Similarly, Perceived Autonomy (PAU) positively impacts TPR ($\beta = 0.120$, $p = 0.010$), emphasizing the importance of allowing teachers to exercise autonomy in their teaching. In contrast, Perceived Teaching Support (PTS) shows a negative indirect effect on TPR ($\beta = -0.270$, $p = 0.000$), suggesting that low perceived support can hinder performance. Additionally, Perceived Ease of Use (PEOU) significantly boosts TPR ($\beta = 0.390$, $p = 0.000$), reinforcing the importance of usability in educational technology. Perceived Competency Model (PCM) ($\beta = 0.110$, $p = 0.000$) and Perceived Usability (PU) ($\beta = 0.140$, $p = 0.000$) also positively influence TPR, highlighting the critical role of teachers' skills and usability perceptions. Overall, these findings underscore that relatedness, autonomy, ease of use, competency, and usability are essential for enhancing teaching performance.

5- Discussion

The findings of this study contribute to a deeper understanding of how interactive digital technologies influence the quality of preservice chemistry teachers' performance.

PU→CTI

Hypothesis 1 (H1) examined the relationship between perceived usability (PU) and cognitive teaching involvement (CTI), and the results indicate a significant positive effect ($\beta = 0.260$, $T = 3.560$, $p = 0.000$). This suggests that when chemistry teachers perceive digital tools as easy to use, it enhances their cognitive engagement in teaching. This finding is consistent with previous literature, where usability is often linked to better cognitive processing and task performance [63]. In the context of education, a user-friendly interface can reduce the cognitive load, allowing teachers to focus more on content delivery rather than grappling with technical issues. Son and Foshay [126] noted that technologies with higher perceived usability tend to promote deeper cognitive involvement in educational tasks. Thus, ensuring that interactive digital tools used in chemistry teaching are intuitive and easy to navigate can foster better cognitive engagement among teachers, leading to improved teaching outcomes.

PU→ ATI

For Hypothesis 2 (H2), which explored the effect of perceived usability (PU) on affective teaching involvement (ATI), the results show no significant impact ($\beta = 0.040$, $T = 0.760$, $p = 0.440$). This suggests that usability does not strongly influence the emotional engagement of teachers with digital tools in this context. While prior studies [127-129] argue that perceived usability can enhance users' emotional satisfaction and engagement with technology, our results suggest that in the specific context of chemistry education, other factors may play a more prominent role in shaping affective attitudes. Elements such as content quality, interactivity, or relevance to pedagogical goals may be more critical in driving affective involvement. This result supports the findings by Abdelmawgoud [130], who emphasized that usability alone may not be sufficient to foster positive emotional experiences unless paired with other motivators like the perceived value or effectiveness of the tool in teaching.

PAU→ CTI

Hypothesis 3 (H3) examined the relationship between Perceived Autonomy (PAU) and Cognitive Teaching Involvement (CTI). The results show a significant positive effect ($\beta = 0.130$, $T = 1.960$, $p = 0.050$), suggesting that autonomy—teachers' perception of control and self-direction over how they use interactive digital tools—positively influences their cognitive engagement. According to Self-Determination Theory (SDT), autonomy is a fundamental psychological need that enhances intrinsic motivation [65, 66]. The findings of Reeve [131] also revealed that environments promoting autonomy led to greater cognitive involvement and learning engagement. In the context of preservice chemistry teachers using interactive digital technologies, the ability to have control over how they implement these tools in teaching enhances their intellectual involvement, encouraging deeper cognitive processing and reflection during instructional design and delivery.

PAU → ATI

Hypothesis 4 (H4) explored the relationship between Perceived Autonomy (PAU) and Affective Teaching Involvement (ATI), and the results revealed a significant positive impact ($\beta = 0.140$, $T = 2.230$, $p = 0.030$). This finding is consistent with the SOR framework [87, 132], which posits that stimuli (in this case, the perception of autonomy) can trigger emotional responses (affective involvement). When teachers feel they have autonomy over how they engage with digital tools, it not only enhances their cognitive performance but also their emotional connection to the technology [75, 133]. Affective engagement, such as enthusiasm and positive attitudes toward technology, is essential for fostering creativity and innovation in teaching, ultimately leading to improved teaching outcomes [133]. In the context of interactive digital technology for preservice chemistry teachers, perceived autonomy plays a dual role. It enhances both cognitive involvements, enabling teachers to think critically about their pedagogical approaches, and affective involvement, creating a more emotionally engaging and satisfying teaching experience. These results are in line with the principles of SDT, where autonomy acts as a driving force for both intellectual engagement and emotional well-being in educational environments [134, 135]. By allowing preservice teachers to have flexibility and control over the use of digital tools, educational institutions can foster more motivated, engaged, and effective teachers, particularly in subjects like chemistry, where technology plays an increasingly important role in enhancing teaching quality.

PTS→CTI

Hypothesis 5 (H5) examined the relationship between Perceived Teaching Support (PTS) and Cognitive Teaching Involvement (CTI), revealing a significant negative effect ($\beta = -0.250$, $T = 3.540$, $p = 0.000$). This indicates that higher levels of perceived teaching support, surprisingly, may reduce cognitive involvement in teaching activities [136]. While it is generally believed that adequate support enhances engagement, this result suggests that excessive or overly prescriptive teaching support may hinder teachers' intellectual autonomy and creativity, leading to lower cognitive involvement [137, 138]. This finding aligns with research that highlights the potential drawbacks of overly structured or controlling support systems, which can stifle innovation and critical thinking [137]. In the context of interactive digital technology for preservice chemistry teachers, excessive guidance or rigid instructional frameworks may restrict teachers' ability to explore and adapt technology to their unique teaching styles, thereby reducing their cognitive engagement.

PTS→ ATI

Hypothesis 6 (H6) explored the relationship between Perceived Teaching Support (PTS) and Affective Teaching Involvement (ATI), revealing a significant negative effect ($\beta = -0.360$, $T = 4.160$, $p = 0.000$). This suggests that higher levels of perceived teaching support can lead to lower emotional engagement in teaching. The Self-Determination Theory (SDT) provides insight into this finding, as it emphasizes the importance of autonomy in fostering intrinsic motivation and positive emotional experiences [136, 137]. Excessive external support may undermine the autonomy and competence of teachers, leading to a reduction in positive affective responses such as enthusiasm and emotional connection to their teaching. Teachers who feel over-reliant on external support might experience a lack of ownership or control over their teaching methods, reducing their emotional investment in the use of interactive digital technologies. This outcome aligns with prior studies that suggest an inverse relationship between over-dependence on support and affective engagement [137, 139]. In the context of preservice chemistry teachers, these findings underscore the importance of a balanced approach to teaching support. While some guidance is necessary for the effective integration of digital technologies, excessive support may inadvertently suppress both cognitive and emotional engagement. Stimulus-Organism-Response (SOR) theory also supports this view, as overly structured stimuli (such as rigid teaching support) may negatively impact both cognitive and affective responses in the organism (teachers), ultimately leading to suboptimal teaching performance [136, 137, 139]. To optimize both cognitive and affective teaching involvement, institutions should focus on providing flexible, empowering support systems that encourage autonomy, innovation, and emotional connection to the teaching process.

PCM → CTI

Hypothesis 7 (H7) investigated the relationship between Perceived Competency (PCM) and Cognitive Teaching Involvement (CTI), with results showing a significant positive effect ($\beta = 0.120$, $T = 2.220$, $p = 0.030$). This suggests that teachers who perceive themselves as competent are more cognitively engaged in their teaching activities, especially when using interactive digital technologies [140, 141]. Self-Determination Theory (SDT) highlights the importance of perceived competency in fostering intrinsic motivation, which can drive deeper cognitive engagement [142]. This finding is consistent with previous research, which has demonstrated that individuals who feel capable and skilled in their tasks are more likely to engage in problem-solving, critical thinking, and innovation in their teaching practices [139-141]. In the context of interactive digital technologies for chemistry preservice teachers, higher perceived competency enables teachers to confidently explore, adapt, and integrate digital tools, thus enhancing their cognitive involvement in lesson planning and classroom activities.

PCM → ATI

Hypothesis 8 (H8) examined the impact of Perceived Competency (PCM) on Affective Teaching Involvement (ATI), also revealing a significant positive relationship (β = 0.130, T = 2.930, p = 0.000). This indicates that teachers who perceive themselves as competent experience greater emotional engagement in their teaching. A positive emotional connection to teaching is vital for motivating teachers to adopt new technologies and pedagogical approaches. SDT highlights that competence, when fulfilled, leads to positive emotional outcomes such as increased satisfaction and enthusiasm [143, 144]. This aligns with the broader literature that connects perceived competence to affective outcomes, showing that teachers who feel skilled in their use of digital tools are more likely to display passion, excitement, and emotional investment in their teaching [84]. In the context of chemistry education, preservice teachers who feel confident in their abilities are not only more cognitively engaged but also emotionally involved, creating a more dynamic and effective teaching environment. This positive emotional connection can foster a willingness to experiment with and integrate interactive digital technologies into the curriculum, potentially improving teaching effectiveness and student learning outcomes. These findings reflect the Stimulus-Organism-Response (SOR) theory, where perceived competency (stimulus) positively influences the emotional and cognitive responses (organism) of teachers, leading to more effective teaching performance (response).

PRT→ CTI

Hypothesis 9 (H9) examined the relationship between Perceived Relatedness (PRT) and Cognitive Teaching Involvement (CTI), with the results showing a strong positive effect (β = 0.410, T = 5.160, p = 0.000). This suggests that when teachers feel a sense of connection and belonging—whether with their students, peers, or the educational community—they are more likely to engage cognitively with their teaching tasks [145, 146]. According to Self-Determination Theory (SDT), relatedness is a fundamental psychological need that influences motivation and engagement [84]. When teachers feel related to their social environment, they are more likely to invest cognitive resources into their teaching activities. This finding aligns with previous research, which highlights that relatedness enhances collaborative learning and promotes deeper intellectual engagement [48]. In the context of interactive digital technologies for chemistry preservice teachers, fostering a sense of relatedness through digital tools, such as collaborative platforms, may significantly enhance cognitive teaching involvement, allowing teachers to explore new teaching methods and technologies more thoroughly.

PRT → ATI

Hypothesis 10 (H10) investigated the impact of Perceived Relatedness (PRT) on Affective Teaching Involvement (ATI), showing an even stronger positive effect (β = 0.510, T = 5.000, p = 0.000). This indicates that teachers who feel socially connected are more emotionally invested in their teaching practices [47]. SDT emphasizes that when the need for relatedness is satisfied, individuals experience greater emotional well-being, leading to higher emotional engagement in tasks [48]. This finding aligns with the literature that emphasizes the importance of relatedness in promoting positive emotional responses, such as enthusiasm and passion for teaching. In the case of chemistry preservice teachers, feeling connected to the learning community or their students can foster greater affective involvement, driving them to engage more deeply and emotionally with the use of digital technologies in teaching [47]. These results are consistent with the Stimulus-Organism-Response (SOR) model, where Perceived Relatedness (stimulus) positively influences both the cognitive and emotional responses (organism) of teachers, enhancing their teaching involvement. When teachers feel part of a supportive community, they are more likely to use interactive digital technologies with greater cognitive engagement and emotional investment, which can improve teaching effectiveness and student outcomes Perceived Relatedness was found to have a significant positive impact on both cognitive and affective teaching involvement. Teachers who feel connected to their educational community not only engage more intellectually in their teaching but also develop stronger emotional ties to their work. This highlights the importance of fostering a sense of relatedness in education, particularly in the context of using interactive digital technologies for chemistry preservice teachers, as it enhances both cognitive and affective involvement, leading to more effective teaching practices.

PEOU→ CTI

Hypothesis 11 (H11) examined the relationship between Perceived Ease of Use (PEOU) and Cognitive Teaching Involvement (CTI), showing a significant positive effect (β = 0.310, T = 4.750, p = 0.000). This finding suggests that when interactive digital tools are easy to use, teachers are more likely to engage cognitively with their teaching tasks. Technology Acceptance Model (TAM) underscores that the perceived ease of using technology influences individuals' attitudes toward using it, often leading to greater cognitive investment in its utilization [147]. In this study, the ease with which teachers can use digital technologies for chemistry education promotes their intellectual engagement and allows them to focus more on instructional design and content delivery rather than on navigating technical complexities [148]. This aligns with previous research, which shows that the easier a technology is to use, the more likely it is to foster cognitive engagement and effective usage in educational settings [148, 149]. Therefore, simplifying the interfaces and functionalities of digital tools for preservice teachers can significantly enhance their cognitive involvement in the teaching process.

PEOU → ATI

Hypothesis 12 (H12) explored the effect of Perceived Ease of Use (PEOU) on Affective Teaching Involvement (ATI), revealing an even stronger positive impact ($\beta = 0.580$, $T = 7.440$, $p = 0.000$). This suggests that the easier teachers perceive digital tools to use, the more emotionally engaged they become with their teaching activities. The Stimulus-Organism-Response (SOR) framework also supports this finding, where PEOU acts as a stimulus that positively influences teachers' emotional responses (organism), leading to greater affective involvement in teaching [148, 149]. When teachers find interactive digital tools easy to operate, they are more likely to develop positive emotional responses such as satisfaction, enthusiasm, and motivation. This aligns with existing literature that emphasizes how ease of use fosters emotional engagement and enjoyment in using technology [150]. In the context of preservice chemistry teachers, enhancing the usability of digital technologies can thus promote positive emotional connections, encouraging teachers to integrate these tools more deeply into their educational practices. The significant role of Perceived Ease of Use in both cognitive and affective teaching involvement aligns with the Self-Determination Theory (SDT), which posits that perceived competence promotes both cognitive and emotional engagement in tasks [150, 151].

CTI→ TPR

Hypothesis 13 (H13) examined the relationship between Cognitive Teaching Involvement (CTI) and Teaching Performance (TPR), and the results revealed a significant positive effect ($\beta = 0.480$, $T = 7.170$, $p = 0.000$). This finding suggests that higher cognitive engagement by teachers in their instructional tasks leads to better teaching performance. According to the Self-Determination Theory (SDT), cognitive involvement reflects the autonomy and competence teachers feel when engaging in educational activities, which directly impacts their effectiveness in the classroom [152, 153]. When teachers actively invest intellectual effort in planning, delivering, and assessing their lessons — particularly with the use of interactive digital tools—their overall performance improves. This aligns with prior studies highlighting that deeper cognitive engagement is crucial for improving instructional quality and learning outcomes [152]. In the context of preservice chemistry teachers, greater cognitive involvement facilitated by user-friendly technologies can enhance their ability to convey complex scientific concepts more effectively, leading to improved teaching performance.

ATI → TPR

Hypothesis 14 (H14) explored the relationship between Affective Teaching Involvement (ATI) and Teaching Performance (TPR), and it also demonstrated a significant positive effect ($\beta = 0.420$, $T = 6.210$, $p = 0.000$). This indicates that teachers who are emotionally engaged with their teaching tasks tend to perform better. According to the Stimulus-Organism-Response (SOR) framework, emotional involvement acts as an organismic response to positive stimuli (such as perceived ease of use or autonomy), which leads to enhanced behavioral outcomes, such as improved performance [47]. Affective involvement manifests as enthusiasm, passion, and emotional investment in teaching activities, which not only enhances teaching practices but also fosters a positive learning environment. This finding is consistent with the literature that shows how emotionally engaged teachers are more motivated to perform well, leading to better educational outcomes [154, 155]. In the case of chemistry education, emotionally engaged teachers are more likely to use digital tools effectively, improving student engagement and overall learning experiences. These findings further emphasize that both cognitive and affective involvement play significant roles in enhancing teaching performance. When teachers are intellectually stimulated and emotionally invested in their teaching activities, particularly with the support of interactive digital technologies, their performance improves significantly. This reflects the importance of promoting both cognitive and emotional engagement in teacher training programs, particularly in the integration of digital tools for science education.

Cognitive teaching involvement (CTI) and affective teaching involvement (ATI) are key factors of teaching performance (TPR). By encouraging greater intellectual and emotional engagement in teaching, particularly through user-friendly and engaging digital technologies, preservice chemistry teachers can significantly improve their teaching quality and student outcomes. These findings highlight the need for integrating cognitive and affective aspects into professional development programs for preservice chemistry teachers, ensuring that they are well-equipped to deliver high-quality education.

Our study results are aligning with findings of Zimmermann et al. [156] who identified that enhancing digital literacy for preservice chemistry teachers helped them to improve lessons planning quality. Also, our findings agree with the outcomes of Paiwithayasiritham et al. [157] who confirmed that new digital competences are critically important for modern and future teachers. Study of Norhagen et al. [158] indicates that while different institutions across the world are working on developing digital competences for future teachers, there are still gaps in this field, depending on the subject area or regional features. Our research is specifically aimed for preservice chemistry teachers in Kazakhstan, while other studies may obtain partially different results with other regions or teaching subjects' area in their focus. Carpenter et al. [159] had added that personnel digital competence is not the only determining factor of digital technology application by teachers. According to Carpenter et al. [159], external factors are going to make teachers to adopt digital technologies anyway – either naturally, via general accessibility of digital technologies in modern world, or forcefully, in case if curricular demands of digital competence emerge. Our study also assumes that digital competences are developing in future chemistry teachers in accordance with global trend of educational digitalization.

5-1- Theoretical Implications

This study significantly advances the theoretical understanding of interactive digital technologies in education by integrating Self-Determination Theory (SDT) and Stimulus-Organism-Response (SOR) frameworks. It illustrates how constructs such as Perceived Usability (PU), Perceived Autonomy (PAU), Perceived Competence (PCM), and Perceived Teaching Support (PTS) shape both Cognitive Teaching Involvement (CTI) and Affective Teaching Involvement (ATI) among pre-service chemistry teachers. Additionally, this study refines the SOR framework by demonstrating how external stimuli, such as digital tools, influence internal states (cognitive and affective attitudes) that lead to improved teaching performance. By incorporating SDT, the research highlights the importance of promoting autonomy, competence, and relatedness to enhance preservice chemistry teachers' emotional and cognitive responses toward technology. This theoretical integration highlighted that both cognitive and emotional factors are important in technology adoption, ultimately leading to better educational outcomes and teaching quality.

5-2- Practical Implications

The practical implications of this study highlight the necessity of integrating digital technologies — such as simulations, virtual reality (VR), and interactive games — into chemistry education to enhance both teaching quality and student learning outcomes. Preservice chemistry teachers and policymakers should prioritize training future chemistry teachers in essential online teaching skills and the effective use of these digital tools. By focusing on resources that promote Perceived Usability, Interactivity, and Perceived Intelligence, educational institutions can better equip teachers to incorporate these technologies into their classroom practices. This proactive approach will not only enhance teaching effectiveness but also ensure that educational strategies align with the evolving demands of the digital learning landscape. Furthermore, as preservice chemistry teachers become more adept at utilizing these tools, students are likely to experience improved educational outcomes in chemistry. Ultimately, investing in the integration of interactive digital technologies in teacher training programs will foster a richer, more engaging learning environment that meets the needs of today's learners, preparing them for the complexities of the modern educational landscape.

6- Conclusion

This study aimed to investigate the impact of interactive digital technologies on enhancing chemistry teaching quality in Kazakhstan. The research focused on understanding how various factors influence preservice chemistry teachers' attitudes and, ultimately, the quality of instruction they provide. The primary objectives were to identify key constructs that mostly contribute to the effectiveness of interactive digital technologies and to evaluate their relationships within a theoretical framework. The results of this study provide important insights into how interactive digital technologies impact the quality of chemistry teaching among preservice teachers in Kazakhstan. First, Perceived Usability (PU) and Perceived Ease of Use (PEOU) were found to significantly influence both Cognitive Teaching Involvement (CTI) and Affective Teaching Involvement (ATI). This emphasizes the critical role of user-friendly technologies in fostering both cognitive engagement and positive emotional responses toward digital tools. Additionally, Perceived Autonomy (PAU) and Perceived Teaching Support (PTS) showed a substantial impact on both CTI and ATI, highlighting the importance of autonomy and external support in shaping teachers' attitudes toward technology adoption. Perceived Competency (PCM) and Perceived Relatedness (PRT) were also positively linked to CTI and ATI, demonstrating that feelings of competence and connectedness enhance both cognitive and emotional involvement in teaching practices. Furthermore, CTI and ATI were found to directly and positively affect teaching performance, underlining that both cognitive and emotional attitudes are essential for improving overall teaching quality. These findings reinforce the relevance of Self-Determination Theory (SDT) and the Stimulus-Organism-Response (SOR) model in understanding technology adoption in educational contexts. This study successfully achieved its objectives by demonstrating that interactive digital technologies significantly enhance the quality of chemistry teaching. The research highlights the critical role of usability and emotional engagement in shaping preservice chemistry teachers' attitudes towards technology, reinforcing the need for well-designed digital tools in educational settings. These findings contribute to the broader understanding of technology adoption in education and provide valuable insights for educational institutions aiming to improve teaching practices through innovative technological solutions.

6-1- Limitations

This study, while illuminating the impact of interactive digital technologies on chemistry teaching quality, is subject to several limitations. First, the data collection was confined to a specific sample from universities in Kazakhstan, which may restrict the generalizability of the findings to other cultural and educational contexts. The unique sociocultural factors in Kazakhstan could influence how preservice chemistry teachers perceive and utilize digital tools, suggesting that outcomes might differ in other regions. Additionally, the study employed a cross-sectional methodology, capturing attitudes and perceptions at a single point in time. This limits the ability to assess the long-term impacts of digital technology adoption on teaching practices. The focus on key constructs such as Perceived Usability, Perceived Autonomy, Perceived Teaching Support (PTS), Cognitive Teaching Involvement (CTI), and Affective Teaching Involvement (ATI), while insightful, does not account for other potential moderating factors, such as institutional support and technological infrastructure, which may significantly influence teaching quality. Future research should extend these findings by exploring additional contextual and institutional factors and examining the longitudinal impact of digital technology adoption on learning outcomes in different educational settings.

6-2- Future Research

Future research should aim to address the limitations of this study by expanding its scope and methodology. To enhance the robustness and applicability of findings, it would be beneficial to replicate the study in diverse geographical and cultural contexts, thus assessing the generalizability of the results across various educational systems. Comparative studies could explore how different factors, including Perceived Usability, Perceived Autonomy, and Perceived Teaching Support, influence technology adoption in different regions. Furthermore, incorporating additional constructs—such as teacher resilience, institutional support, and professional development opportunities—could provide a more comprehensive understanding of the factors affecting technology integration. Longitudinal studies are recommended to examine the long-term impacts of interactive digital technologies on preservice chemistry teachers' attitudes and teaching quality. Finally, employing mixed methods approaches, combining quantitative and qualitative data, could yield richer insights into preservice chemistry teachers' experiences and inform actionable strategies for enhancing technology adoption in educational settings

7- Declarations

7-1- Author Contributions

Conceptualization, A.M. and D.B.; methodology, D.B.; software, A.M.; validation, A.M., D.B., and Z.B.; formal analysis, A.M.; investigation, A.M.; resources, I.I.; data curation, M.S.; writing—original draft preparation, all authors; writing—review and editing, all authors; visualization, A.M.; supervision, D.B.; project administration, D.B.; funding acquisition, D.B. All authors have read and agreed to the published version of the manuscript.

7-2- Data Availability Statement

The data presented in this study are available in the present article.

7-3- Funding

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7-4- Institutional Review Board Statement

Not applicable.

7-5- Informed Consent Statement

Participation in the study was entirely voluntary, with informed consent obtained from all participants prior to their involvement.

7-6- Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

8- References

[1] Zarubina, V., Zarubin, M., Yessenkulova, Z., Salimbayeva, R., & Satbaeva, G. (2024). Digital transformation of the promotion of educational services of Kazakhstani universities. Journal of Innovation and Entrepreneurship, 13(1), 3. doi:10.1186/s13731-023-00355-3.

[2] Zhashkenova, R., Pritvorova, T., Talimova, L., Mazhitova, S., Dauletova, A., & Kernebaev, A. (2021). Analysis of the transformation of higher educational institutions through entrepreneurship in the conditions of digitalization. International Journal of Entrepreneurship, 25(4), 1-10.

[3] Berdykulova, G. M., Daineko, Y. A., Kamysbayev, M. K., & Abdinova, M. K. (2022). What Experience and Survey Say About University Digitalization in Kazakhstan? Proceedings of the 7th International Conference on Digital Technologies in Education, Science and Industry (DTESI 2022), 20-21 October, 2022, Almaty, Kazakhstan.

[4] Nurtayeva, D., Kredina, A., Kireyeva, A., Satybaldin, A., & Ainakul, N. (2024). The role of digital technologies in higher education institutions: The case of Kazakhstan. Problems and Perspectives in Management, 22(1), 562–577. doi:10.21511/ppm.22(1).2024.45.

[5] Ngo, T. T. A. (2023). The Perception by University Students of the Use of ChatGPT in Education. International Journal of Emerging Technologies in Learning, 18(17), 4–19. doi:10.3991/ijet.v18i17.39019.

[6] Berdi, D., Niyazova, G., Bayterekova, N., Koshanova, G., & Usembayeva, I. (2024). Digital hygiene skills and cyberbullying reduction: a study among teenagers in Kazakhstan. International Journal of Evaluation and Research in Education, 13(6), 4170–4188. doi:10.11591/ijere.v13i6.28418.

[7] Dahri, N. A., Vighio, M. S., Al-Rahmi, W. M., & Alismaiel, O. A. (2022). Usability Evaluation of Mobile App for the Sustainable Professional Development of Teachers. International Journal of Interactive Mobile Technologies, 16(16), 4–30. doi:10.3991/ijim.v16i16.32015.

[8] Meirbekov, A., Nyshanova, S., Meiirbekov, A., Kazykhankyzy, L., Burayeva, Z., & Abzhekenova, B. (2024). Digitisation of English language education: Instagram and TikTok online educational blogs and courses vs. traditional academic education. How to increase student motivation? Education and Information Technologies, 29(11), 13635–13662. doi:10.1007/s10639-023-12396-y.

[9] Turysbayeva, A., Zhumabayeva, A., Yessenova, K., Bainazarova, T., & Maigeldiyeva, S. (2023). The impact of formative assessment techniques on students' self-assessment skills. Journal of Education and E-Learning Research, 10(4), 657–665. doi:10.20448/jeelr.v10i4.5045.

[10] Hetrick, A. R. (2019). Using the Technology Acceptance Model to Determine Student Perception of E-learning Readiness in Kazakhstan. PhD Thesis, Boise State University, Boise, United States. doi:10.18122/td/1524/boisestate.

[11] Huang, F., Sánchez-Prieto, J. C., Teo, T., García-Peñalvo, F. J., Olmos-Migueláñez, S., & Zhao, C. (2021). A cross-cultural study on the influence of cultural values and teacher beliefs on university teachers' information and communications technology acceptance. Educational Technology Research and Development, 69(2), 1271–1297. doi:10.1007/s11423-021-09941-2.

[12] Yedilbayev, Y., Sarybayeva, A., Zharylgapova, D., Shektibayev, N., Usembayeva, I., & Kurbanbekov, B. (2023). Factors influencing future physics teachers' acceptance of information and communicative competence technologies: A survey study. Cogent Education, 10(1), 2212119. doi:10.1080/2331186X.2023.2212119.

[13] Mukataeva, Z., Dinmukhamedova, A., Kabieva, S., Baidalinova, B., Khamzina, S., Zekenova, L., & Aizman, R. (2023). Comparative characteristics of developing morphofunctional features of schoolchildren from different climatic and geographical regions. Journal of Pediatric Endocrinology and Metabolism, 36(2), 158–166. doi:10.1515/jpem-2022-0474.

[14] Hussaini, I., Ibrahim, S., Wali, B., Libata, I., & Musa, U. (2020). Effectiveness of Google classroom as a digital tool in teaching and learning: Students' perceptions. International Journal of Research and Innovation in Social Science (IJRISS), 4(4), 51-54.

[15] Faresta, R. A., Nicholas, T. Z. S. B., Chi, Y., Sinambela, I. A. N., & Mopoliu, A. Z. (2024). Utilization of Technology in Physics Education: A Literature Review and Implications for the Future Physics Learning. Lensa: Jurnal Kependidikan Fisika, 12(1), 1. doi:10.33394/j-lkf.v12i1.11676.

[16] Krajcik, J. S., & Mun, K. (2014). Promises and challenges of using learning technologies to promote student learning of science. In Handbook of research on science education, volume II, Routledge, Milton Park, United States. doi:10.4324/9780203097267-28.

[17] Lewis, D. I. (2014). The pedagogical benefits and pitfalls of virtual tools for teaching and learning laboratory practices in the biological sciences. The Higher Education Academy: STEM, 1-30.

[18] Scalise, K., Timms, M., Moorjani, A., Clark, L., Holtermann, K., & Irvin, P. S. (2011). Student learning in science simulations: Design features that promote learning gains. Journal of Research in Science Teaching, 48(9), 1050–1078. doi:10.1002/tea.20437.

[19] Abdullahi, A. M., & Chimbo, B. (2023). Co-designing a framework for a persuasive educational technology tool for motivating female students for enrolment into Science, Technology, Engineering and Mathematics disciplines. The Journal for Transdisciplinary Research in Southern Africa, 19(1), 1349. doi:10.4102/td.v19i1.1349.

[20] Savchuk, G., Iakimova, O., & Yufereva, A. (2019). Students from central Asia in Russian universities: Social media as a tool for adjustment. Proceedings of the 18th European Conference on E-Learning, 87. doi:10.34190/eel.19.045.

[21] Kazantseva, L., Nicolini, P., & Cirilli, E. (2019). E-Learning, Professional Training, and Digital Tools: New Opportunities for Students of All Ages. EDULEARN19 Proceedings, 1, 6701–6707. doi:10.21125/edulearn.2019.1609.

[22] Wong, K. M. (2021). "A design framework for enhancing engagement in student-centered learning: own it, learn it, and share it" by Lee and Hannafin (2016): an international perspective. Educational Technology Research and Development, 69(1), 93–96. doi:10.1007/s11423-020-09842-w.

[23] Aguti, B., Walters, R. J., & Wills, G. B. (2014). Effective Use of E-Learning Technologies to Promote Student Centered Learning Paradigms within Higher Education Institutions. International Journal for E-Learning Security, 4(2), 391–398. doi:10.20533/ijels.2046.4568.2014.0051.

[24] Otto, S., Bertel, L. B., Lyngdorf, N. E. R., Markman, A. O., Andersen, T., & Ryberg, T. (2024). Emerging Digital Practices Supporting Student-Centered Learning Environments in Higher Education: A Review of Literature and Lessons Learned from the Covid-19 Pandemic. Education and Information Technologies, 29(2), 1673–1696. doi:10.1007/s10639-023-11789-3.

[25] Kolil, V. K., & Achuthan, K. (2024). Virtual labs in chemistry education: A novel approach for increasing student's laboratory educational consciousness and skills. Education and Information Technologies, 29(18), 25307–25331. doi:10.1007/s10639-024-12858-x.

[26] Skliarova, I., Meireles, I., Martins, N., Tchemisova, T., & Cação, I. (2022). Enriching Traditional Higher STEM Education with Online Teaching and Learning Practices: Students' Perspective. Education Sciences, 12(11), 806. doi:10.3390/educsci12110806.

[27] Alberto, M. C. L., Viviana, B. V. C., Vladimir, B. E. C., & Fernanda, P. A. P. (2024). Innovative strategies to strengthen teaching-researching skills in chemistry and biology education: a systematic literature review. Frontiers in Education, 9, 1363132. doi:10.3389/feduc.2024.1363132.

[28] Alzahrani, N. M. (2020). Augmented reality: A systematic review of its benefits and challenges in e-learning contexts. Applied Sciences (Switzerland), 10(16), 5660. doi:10.3390/app10165660.

[29] Dosymov, Y., Usembayeva, I., Polatuly, S., Ramankulov, S., Kurbanbekov, B., Mintassova, A., & Mussakhan, N. (2023). Effectiveness of Computer Modeling in the Study of Electrical Circuits: Application and Evaluation. International Journal of Engineering Pedagogy, 13(4), 93–112. doi:10.3991/ijep.v13i4.34921.

[30] Almukhambetova, A. (2023). Exploring STEM Teacher Educators' Gender Awareness and Understanding of Gender-responsive Pedagogies in Kazakhstan. The Political Economy of Education in Central Asia. The Steppe and Beyond: Studies on Central Asia, Palgrave Macmillan, Singapore. doi:10.1007/978-981-99-8517-3_6.

[31] Azhmukhambetov, A. (2020). Teachers' experiences of the updated pedagogy within the scope of the curriculum reform: A case study of two mainstream schools in Kazakhstan. Master Thesis, Nazarbayev University Graduate School of Education, Nur-Sultan city, Kazakhstan.

[32] Zharylkassyn, M. B. (2023). Integrating Continuing professional development with Education system reform in Kazakhstan. Materials of International Practical Internet Conference "Challenges of Science," 6, 22–28. doi:10.31643/2023.03.

[33] Sarmurzin, Y., Amanzhol, N., Toleubayeva, K., Zhunusova, M., & Amanova, A. (2021). The impact of OECD research on the education system of Kazakhstan. Asia Pacific Education Review, 22(4), 757–766. doi:10.1007/s12564-021-09715-8.

[34] Islam, J., & Rahman, Z. (2017). The impact of online brand community characteristics on customer engagement: An application of Stimulus-Organism-Response paradigm. Telematics and Informatics, 34(4), 96–109. doi:10.1016/j.tele.2017.01.004.

[35] Kim, M. J., Lee, C. K., & Jung, T. (2020). Exploring Consumer Behavior in Virtual Reality Tourism Using an Extended Stimulus-Organism-Response Model. Journal of Travel Research, 59(1), 69–89. doi:10.1177/0047287518818915.

[36] ay, D. K. (2023). A Transcendental Phenomenological Study of the Lived Experiences of Middle Managers: Self-Determined Lifelong Learning in the Banking Industry, PhD Thesis, Liberty University, Lynchburg, United States.

[37] Lincoln, A. (2019). Can a blended learning environment enhance teaching and learning in large heterogeneous first-year classes?: a study in a private higher education institution. PhD Thesis, Queen's University Belfast, Belfast, United Kingdom.

[38] Corey, A. (2019). Teacher as facilitator: a case study of enhanced student agency. Master Thesis, Memorial University of Newfoundland, St. John's, Canada.

[39] Schneider, S., Nebel, S., Beege, M., & Rey, G. D. (2018). The autonomy-enhancing effects of choice on cognitive load, motivation and learning with digital media. Learning and Instruction, 58, 161–172. doi:10.1016/j.learninstruc.2018.06.006.

[40] Zainuddin, Z. (2018). Students' learning performance and perceived motivation in gamified flipped-class instruction. Computers and Education, 126, 75–88. doi:10.1016/j.compedu.2018.07.003.

[41] Jacoby, J. (2002). Stimulus- Organism- Response Reconsidered: An Evolutionary Step in Modeling (Consumer) Behavior. Journal of Consumer Psychology, 12(1), 51–57. doi:10.1207/s15327663jcp1201_05.

[42] Floh, A., & Madlberger, M. (2013). The role of atmospheric cues in online impulse-buying behavior. Electronic Commerce Research and Applications, 12(6), 425–439. doi:10.1016/j.elerap.2013.06.001.

[43] Liu, H., Chu, H., Huang, Q., & Chen, X. (2016). Enhancing the flow experience of consumers in China through interpersonal interaction in social commerce. Computers in Human Behavior, 58, 306–314. doi:10.1016/j.chb.2016.01.012.

[44] Yao-Ping Peng, M., Xu, Y., & Xu, C. (2023). Enhancing students' English language learning via M-learning: Integrating technology acceptance model and S-O-R model. Heliyon, 9(2), 13302. doi:10.1016/j.heliyon.2023.e13302.

[45] Gomez, F. C., Trespalacios, J., Hsu, Y. C., & Yang, D. (2022). Exploring Teachers' Technology Integration Self-Efficacy through the 2017 ISTE Standards. TechTrends, 66(2), 159–171. doi:10.1007/s11528-021-00639-z.

[46] Tandon, A., Jabeen, F., Talwar, S., Sakashita, M., & Dhir, A. (2021). Facilitators and inhibitors of organic food buying behavior. Food Quality and Preference, 88, 104077. doi:10.1016/j.foodqual.2020.104077.

[47] Yang, S., Zhou, S., & Cheng, X. (2019). Why do college students continue to use mobile learning? Learning involvement and self-determination theory. British Journal of Educational Technology, 50(2), 626–637. doi:10.1111/bjet.12634.

[48] Shen, Y., & Cui, W. (2024). Perceived support and AI literacy: the mediating role of psychological needs satisfaction. Frontiers in Psychology, 15. doi:10.3389/fpsyg.2024.1415248.

[49] Tsai, H.-T., & Bagozzi, R. P. (2014). Contribution Behavior in Virtual Communities: Cognitive, Emotional, and Social Influences. MIS Quarterly, 38(1), 143–163. doi:10.25300/misq/2014/38.1.07.

[50] Kühn, S. W., & Petzer, D. J. (2018). Fostering Purchase Intentions Toward Online Retailer Websites in an Emerging Market: An S-O-R Perspective. Journal of Internet Commerce, 17(3), 255–282. doi:10.1080/15332861.2018.1463799.

[51] Kühne, R., & Peter, J. (2023). Anthropomorphism in human–robot interactions: a multidimensional conceptualization. Communication Theory, 33(1), 42–52. doi:10.1093/ct/qtac020.

[52] Xia, Y., Deng, Y., Tao, X., Zhang, S., & Wang, C. (2024). Digital art exhibitions and psychological well-being in Chinese Generation Z: An analysis based on the S-O-R framework. Humanities and Social Sciences Communications, 11(1), 1-15. doi:10.1057/s41599-024-02718-x.

[53] Eom, S. B., & Ashill, N. (2016). The Determinants of Students' Perceived Learning Outcomes and Satisfaction in University Online Education: An Update*. Decision Sciences Journal of Innovative Education, 14(2), 185–215. doi:10.1111/dsji.12097.

[54] Nokelainen, P. (2006). An empirical assessment of pedagogical usability criteria for digital learning material with elementary school students. Educational Technology and Society, 9(2), 178–197.

[55] Zhao, Y., Wang, A., & Sun, Y. (2020). Technological environment, virtual experience, and MOOC continuance: A stimulus–organism–response perspective. Computers & Education, 144, 103721. doi:10.1016/j.compedu.2019.103721.

[56] Huang, H. M., Rauch, U., & Liaw, S. S. (2010). Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach. Computers and Education, 55(3), 1171–1182. doi:10.1016/j.compedu.2010.05.014.

[57] Sprenger, D. A., & Schwaninger, A. (2021). Technology acceptance of four digital learning technologies (classroom response system, classroom chat, e-lectures, and mobile virtual reality) after three months' usage. International Journal of Educational Technology in Higher Education, 18(1), 8. doi:10.1186/s41239-021-00243-4.

[58] Gunesekera, A. I., Bao, Y., & Kibelloh, M. (2019). The role of usability on e-learning user interactions and satisfaction: a literature review. Journal of Systems and Information Technology, 21(3), 368–394. doi:10.1108/JSIT-02-2019-0024.

[59] Hoehle, H., Aljafari, R., & Venkatesh, V. (2016). Leveraging Microsoft's mobile usability guidelines: Conceptualizing and developing scales for mobile application usability. International Journal of Human Computer Studies, 89, 35–53. doi:10.1016/j.ijhcs.2016.02.001.

[60] Duong, C. D. (2023). Applying the stimulus-organism-response theory to investigate determinants of students' social entrepreneurship: moderation role of perceived university support. Social Enterprise Journal, 19(2), 167–192. doi:10.1108/SEJ-10-2022-0091.

[61] Kasilingam, D. L. (2020). Understanding the attitude and intention to use smartphone chatbots for shopping. Technology in Society, 62, 101280. doi:10.1016/j.techsoc.2020.101280.

[62] Barari, M., Ross, M., & Surachartkumtonkun, J. (2020). Negative and positive customer shopping experience in an online context. Journal of Retailing and Consumer Services, 53, 101985. doi:10.1016/j.jretconser.2019.101985.

[63] Pal, D., & Vanijja, V. (2020). Perceived usability evaluation of Microsoft Teams as an online learning platform during COVID-19 using system usability scale and technology acceptance model in India. Children and Youth Services Review, 119, 105535. doi:10.1016/j.childyouth.2020.105535.

[64] De Cicco, R., e Silva, S. C., & Alparone, F. R. (2020). Millennials' attitude toward chatbots: an experimental study in a social relationship perspective. International Journal of Retail and Distribution Management, 48(11), 1213–1233. doi:10.1108/IJRDM-12-2019-0406.

[65] Mih, V., & Mih, C. (2013). Perceived autonomy-supportive teaching, academic self-perceptions and engagement in learning: Toward a process model of academic achievement. Brain & Behavior. An Interdisciplinary Journal, 4, 289-313.

[66] Leisterer, S., & Paschold, E. (2022). Increased perceived autonomy-supportive teaching in physical education classes changes students' positive emotional perception compared to controlling teaching. Frontiers in Psychology, 13. doi:10.3389/fpsyg.2022.1015362.

[67] Gutiérrez, M., & Tomás, J. M. (2019). The role of perceived autonomy support in predicting university students' academic success mediated by academic self-efficacy and school engagement. Educational Psychology, 39(6), 729–748. doi:10.1080/01443410.2019.1566519.

[68] Perse, E. M. (1998). Implications of cognitive and affective involvement for channel changing. Journal of Communication, 48(3), 49–68. doi:10.1111/j.1460-2466.1998.tb02759.x.

[69] Wang, M., & Kang, M. (2006). Cybergogy for Engaged Learning: A Framework for Creating Learner Engagement through Information and Communication Technology. Engaged Learning with Emerging Technologies, Springer, Dordrecht, Netherlands. doi:10.1007/1-4020-3669-8_11.

[70] Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. Psychological Inquiry, 11(4), 227–268. doi:10.1207/S15327965PLI1104_01.

[71] Reeve, J. (2013). How students create motivationally supportive learning environments for themselves: The concept of agentic engagement. Journal of Educational Psychology, 105(3), 579–595. doi:10.1037/a0032690.

[72] Achuthan, K., Nair, V. K., Kowalski, R., Ramanathan, S., & Raman, R. (2023). Cyberbullying research—Alignment to sustainable development and impact of COVID-19: Bibliometrics and science mapping analysis. Computers in Human Behavior, 140, 107566. doi:10.1016/j.chb.2022.107566.

[73] Howard, J. L., Gagné, M., & Bureau, J. S. (2017). Testing a continuum structure of self-determined motivation: A meta-analysis. Psychological Bulletin, 143(12), 1346–1377. doi:10.1037/bul0000125.

[74] Mehrabian, A. (1974). An approach to environmental psychology. MIT Press, Cambridge, United States.

[75] Sakiz, G. (2012). Perceived instructor affective support in relation to academic emotions and motivation in college. Educational Psychology, 32(1), 63–79. doi:10.1080/01443410.2011.625611.

[76] Yerdelen, S. (2013). Multilevel investigations of students' cognitive and affective learning outcomes and their relationships with perceived classroom learning environment and teacher effectiveness PhD Thesis, Ankara, Turkey.

[77] Sadoughi, M., & Hejazi, S. Y. (2021). Teacher support and academic engagement among EFL learners: The role of positive academic emotions. Studies in Educational Evaluation, 70, 101060. doi:10.1016/j.stueduc.2021.101060.

[78] Liu, R. De, Zhen, R., Ding, Y., Liu, Y., Wang, J., Jiang, R., & Xu, L. (2018). Teacher support and math engagement: roles of academic self-efficacy and positive emotions. Educational Psychology, 38(1), 3–16. doi:10.1080/01443410.2017.1359238.

[79] Russo, T. C., & Benson, S. (2005, January). Learning with invisible others: Perceptions of online presence and their relationship to cognitive and affective learning. International Forum of Educational Technology and Society.

[80] Collie, R. J., & Martin, A. J. (2024). Students' perceived competence across academic and social-emotional domains: Unique roles in relation to autonomy-supportive teaching, academic engagement, and well-being. Learning and Individual Differences, 116, 102563. doi:10.1016/j.lindif.2024.102563.

[81] Bakx, A. W. E. A., Van Der Sanden, J. M. M., Sijtsma, K., Croon, M. A., & Vermetten, Y. J. M. (2006). The role of students' personality characteristics, self-perceived competence and learning conceptions in the acquisition and development of social communicative competence: A longitudinal study. Higher Education, 51(1), 71–104. doi:10.1007/s10734-004-6377-6.

[82] Merino-Soto, C., Fernández-Arata, M., Fuentes-Balderrama, J., Chans, G. M., & Toledano-Toledano, F. (2022). Research Perceived Competency Scale: A New Psychometric Adaptation for University Students' Research Learning. Sustainability, 14(19), 12036. doi:10.3390/su141912036.

[83] Li, W., Lee, A. M., & Solmon, M. A. (2005). Relationships among dispositional ability conceptions, intrinsic motivation, perceived competence, experience, persistence, and performance. Journal of Teaching in Physical Education, 24(1), 51–65. doi:10.1123/jtpe.24.1.51.

[84] Wood, D. R. (2016). The impact of students' perceived relatedness and competence upon their motivated engagement with learning activities: a self-determination theory perspective. PhD Thesis, University of Birmingham, Birmingham, United Kingdom.

[85] Furrer, C., & Skinner, E. (2003). Sense of relatedness as a factor in children's academic engagement and performance. Journal of Educational Psychology, 95(1), 148–162. doi:10.1037/0022-0663.95.1.148.

[86] Hartnett, M. (2015). Influences that undermine learners' perceptions of autonomy, competence and relatedness in an online context. Australasian Journal of Educational Technology, 31(1), 86–99. doi:10.14742/ajet.1526.

[87] Ryan, R. M., & Powelson, C. L. (1991). Autonomy and relatedness as fundamental to motivation and education. Journal of Experimental Education, 60(1), 49–66. doi:10.1080/00220973.1991.10806579.

[88] Sakiz, G., Pape, S. J., & Hoy, A. W. (2012). Does perceived teacher affective support matter for middle school students in mathematics classrooms? Journal of School Psychology, 50(2), 235–255. doi:10.1016/j.jsp.2011.10.005.

[89] Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. MIS Quarterly, 13(3), 319. doi:10.2307/249008.

[90] Na, S., Heo, S., Han, S., Shin, Y., & Roh, Y. (2022). Acceptance Model of Artificial Intelligence (AI)-Based Technologies in Construction Firms: Applying the Technology Acceptance Model (TAM) in Combination with the Technology–Organisation–Environment (TOE) Framework. Buildings, 12(2), 90. doi:10.3390/buildings12020090.

[91] Sánchez-Prieto, J. C., Cruz-Benito, J., Therón, R., & García-Peñalvo, F. (2020). Assessed by Machines: Development of a TAM-Based Tool to Measure AI-based Assessment Acceptance Among Students. International Journal of Interactive Multimedia and Artificial Intelligence, 6(4), 80. doi:10.9781/ijimai.2020.11.009.

[92] Grover, P., Kar, A. K., Janssen, M., & Ilavarasan, P. V. (2019). Perceived usefulness, ease of use and user acceptance of blockchain technology for digital transactions–insights from user-generated content on Twitter. Enterprise Information Systems, 13(6), 771–800. doi:10.1080/17517575.2019.1599446.

[93] Kizilcec, R. F., Pérez-Sanagustín, M., & Maldonado, J. J. (2017). Self-regulated learning strategies predict learner behavior and goal attainment in Massive Open Online Courses. Computers and Education, 104, 18–33. doi:10.1016/j.compedu.2016.10.001.

[94] Venkatesh, Morris, Davis, & Davis. (2003). User Acceptance of Information Technology: Toward a Unified View. MIS Quarterly, 27(3), 425. doi:10.2307/30036540.

[95] Venkatesh, V., & Bala, H. (2008). Technology acceptance model 3 and a research agenda on interventions. Decision Sciences, 39(2), 273–315. doi:10.1111/j.1540-5915.2008.00192.x.

[96] Madichie, N. O. (2009). Consumer Behavior: Buying, Having, and Being (8th ed.). Management Decision, 47(5), 845–848. doi:10.1108/00251740910960169.

[97] Ajzen, I. (2011). The theory of planned behaviour: Reactions and reflections. Psychology and Health, 26(9), 1113–1127. doi:10.1080/08870446.2011.613995.

[98] Eagly, A. H. (1993). The psychology of attitudes. Thomson Wadsworth, Stamford, United States.

[99] Eroglu, S. A., Machleit, K. A., & Davis, L. M. (2001). Atmospheric qualities of online retailing. Journal of Business Research, 54(2), 177–184. doi:10.1016/s0148-2963(99)00087-9.

[100] Hanifah, U., Binti Adam, Z., Faizin, M., Miftakhul Jannah, I., & Hanafi, Y. (2024). Accelerating the digitalisation of learning post-COVID-19 era to improve the pedagogical competence of pre-service Arabic teachers. Cogent Education, 11(1), 2413241. doi:10.1080/2331186X.2024.2413241

[101] Wang, J., Tigelaar, D. E. H., Zhou, T., & Admiraal, W. (2023). The effects of mobile technology usage on cognitive, affective, and behavioural learning outcomes in primary and secondary education: A systematic review with meta-analysis. Journal of Computer Assisted Learning, 39(2), 301–328. doi:10.1111/jcal.12759.

[102] Desmet, P. (2018). Measuring Emotion: Development and Application of an Instrument to Measure Emotional Responses to Products. Funology 2. Human–Computer Interaction Series, Springer, Cham, Switzerland. doi:10.1007/978-3-319-68213-6_25.

[103] Korol, T. (2021). Digital Teacher Feedback as a Translation Assessment Tool. Journal of Teaching English for Specific and Academic Purposes, 9(4), 575–586. doi:10.22190/JTESAP2104575K.

[104] Hill, R. J., Fishbein, M., & Ajzen, I. (1977). Belief, Attitude, Intention and Behavior: An Introduction to Theory and Research. Contemporary Sociology, 6(2), 244. doi:10.2307/2065853.

[105] Bell, E., Bryman, A., & Harley, B. (2022). Business Research Methods. Oxford University Press, Oxford, United Kingdom. doi:10.1093/hebz/9780198869443.001.0001.

[106] Krasil'nikova, V. A., Buduk-Ool, L. K., & Aizman, R. I. (2008). Morphofunctional development of Tyvan and Russian schoolchildren. Human physiology, 34(1), 66-72. doi:10.1134/S0362119708010106.

[107] Dlodlo, N., & Dhurup, M. (2013). Drivers of e-marketing adoption among small and medium enterprises (SMEs) and variations with age of business owners. Mediterranean Journal of Social Sciences, 4(14), 53–66. doi:10.5901/mjss.2013.v4n14p53.

[108] Hair, J. F., Black, W. C., Babin, B. J. & Anderson, R. E. (2010) Multivariate Data Analysis. 7th Edition, Pearson, New York, United States.

[109] Chen, Y., Jensen, S., Albert, L. J., Gupta, S., & Lee, T. (2023). Artificial Intelligence (AI) Student Assistants in the Classroom: Designing Chatbots to Support Student Success. Information Systems Frontiers, 25(1), 161–182. doi:10.1007/s10796-022-10291-4.

[110] Arghashi, V., & Yuksel, C. A. (2022). Interactivity, Inspiration, and Perceived Usefulness! How retailers' AR-apps improve consumer engagement through flow. Journal of Retailing and Consumer Services, 64, 102756. doi:10.1016/j.jretconser.2021.102756.

[111] Almulla, M. A. (2022). Using Digital Technologies for Testing Online Teaching Skills and Competencies during the COVID-19 Pandemic. Sustainability (Switzerland), 14(9), 5455. doi:10.3390/su14095455.

[112] Pillai, R., & Sivathanu, B. (2020). Adoption of AI-based chatbots for hospitality and tourism. International Journal of Contemporary Hospitality Management, 32(10), 3199–3226. doi:10.1108/IJCHM-04-2020-0259.

[113] Martín-García, A. V., Martínez-Abad, F., & Reyes-González, D. (2019). TAM and stages of adoption of blended learning in higher education by application of data mining techniques. British Journal of Educational Technology, 50(5), 2484–2500. doi:10.1111/bjet.12831.

[114] Rafiq, F., Dogra, N., Adil, M., & Wu, J. Z. (2022). Examining Consumer's Intention to Adopt AI-Chatbots in Tourism Using Partial Least Squares Structural Equation Modeling Method. Mathematics, 10(13), 2190. doi:10.3390/math10132190.

[115] Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. European Business Review, 31(1), 2–24. doi:10.1108/EBR-11-2018-0203.

[116] air, J. F., Hult, G. T. M., Ringle, C. M., Sarstedt, M., Danks, N. P., & Ray, S. (2021). Partial Least Squares Structural Equation Modeling (PLS-SEM) Using R. In Classroom Companion: Business. Springer International Publishing, Cham, Switzerland. doi:10.1007/978-3-030-80519-7.

[117] Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. Psychometrika, 16(3), 297–334. doi:10.1007/BF02310555.

[118] Fornell, C., & Larcker, D. F. (1981). Structural Equation Models with Unobservable Variables and Measurement Error: Algebra and Statistics. Journal of Marketing Research, 18(3), 382–388. doi:10.1177/002224378101800313.

[119] Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. Journal of the Academy of Marketing Science, 43(1), 115–135. doi:10.1007/s11747-014-0403-8.

[120] Cohen, J. (1990). Statistical power analysis for the behavioral sciences. Computers, Environment and Urban Systems, 14(1), 71. doi:10.1016/0198-9715(90)90050-4.

[121] Henseler, J., Ringle, C. M., & Sinkovics, R. R. (2009). The use of partial least squares path modeling in international marketing. New Challenges to International Marketing, 277–319, Emerald Group Publishing Limited, Leeds, United Kingdom. doi:10.1108/S1474-7979(2009)0000020014.

[122] Hayes, A. F., & Coutts, J. J. (2020). Use Omega Rather than Cronbach's Alpha for Estimating Reliability. But…. Communication Methods and Measures, 14(1), 1–24. doi:10.1080/19312458.2020.1718629.

[123] Stensen, K., & Lydersen, S. (2022). Internal consistency: from alpha to omega? Tidsskrift for Den Norske Legeforening. doi:10.4045/tidsskr.22.0112.

[124] Nasir, M., Adil, M., & Kumar, M. (2022). Phobic COVID-19 Disorder Scale: Development, Dimensionality, and Item-Structure Test. International Journal of Mental Health and Addiction, 20(5), 2718–2730. doi:10.1007/s11469-021-00544-9.

[125] Hair Jr, J. F., Matthews, L. M., Matthews, R. L., & Sarstedt, M. (2017). PLS-SEM or CB-SEM: updated guidelines on which method to use. International Journal of Multivariate Data Analysis, 1(2), 107. doi:10.1504/ijmda.2017.087624.

[126] Son, C., Foshay, W. R. (2012). What does the Korean experience tell us about issues in the integration of advanced technologies into mathematics classrooms in developed countries? 12th International Congress on Mathematical Education, 8-15 July, 2012, COEX, Seoul, Korea.

[127] Kim, Y. H., Kim, D. J., & Wachter, K. (2013). A study of mobile user engagement (MoEN): Engagement motivations, perceived value, satisfaction, and continued engagement intention. Decision Support Systems, 56(1), 361–370. doi:10.1016/j.dss.2013.07.002.

[128] Dirin, A., Laine, T. H., & Nieminen, M. (2017). Sustainable usage through emotional engagement: a user experience analysis of an adaptive driving school application. Cognition, Technology and Work, 19(2–3), 303–313. doi:10.1007/s10111-017-0406-6.

[129] Vlachogianni, P., & Tselios, N. (2023). Perceived Usability Evaluation of Educational Technology Using the Post-Study System Usability Questionnaire (PSSUQ): A Systematic Review. Sustainability (Switzerland), 15(17), 12954. doi:10.3390/su151712954.

[130] Abdelmawgoud, S. (2022). Using Gamification to Design and Develop an E learning Environment to Prepare Students for Reflective Writing. PhD Thesis, UNSW Sydney, Sydney, Australia. doi:10.26190/unsworks/24257

[131] Reeve, J. (2012). A Self-determination Theory Perspective on Student Engagement. Handbook of Research on Student Engagement, Springer, Boston, United States. doi:10.1007/978-1-4614-2018-7_7.

[132] Bandura, A. (1993). Perceived Self-Efficacy in Cognitive Development and Functioning. Educational Psychologist, 28(2), 117–148. doi:10.1207/s15326985ep2802_3.

[133] van Loon, A. M., Ros, A., & Martens, R. (2012). Motivated learning with digital learning tasks: What about autonomy and structure? Educational Technology Research and Development, 60(6), 1015–1032. doi:10.1007/s11423-012-9267-0.

[134] Shen, H., Ye, X., Zhang, J., & Huang, D. (2024). Investigating the role of perceived emotional support in predicting learners' well-being and engagement mediated by motivation from a self-determination theory framework. Learning and Motivation, 86, 101968. doi:10.1016/j.lmot.2024.101968.

[135] Ryan, R. M., & Deci, E. L. (2016). Facilitating and hindering motivation, learning, and well-being in schools: Research and observations from self-determination theory. Handbook of motivation at school. Routledge, Milton Park, United States.

[136] Liu, X. xian, Gong, S. Y., Zhang, H. po, Yu, Q. lei, & Zhou, Z. Jin. (2021). Perceived teacher support and creative self-efficacy: The mediating roles of autonomous motivation and achievement emotions in Chinese junior high school students. Thinking Skills and Creativity, 39, 100752. doi:10.1016/j.tsc.2020.100752.

[137] Xu, X., Wu, Z., & Wei, D. (2023). The relationship between perceived teacher support and student engagement among higher vocational students: A moderated mediation model. Frontiers in Psychology, 14. doi:10.3389/fpsyg.2023.1116932.

[138] Guo, Q., Samsudin, S., Yang, X., Gao, J., Ramlan, M. A., Abdullah, B., & Farizan, N. H. (2023). Relationship between Perceived Teacher Support and Student Engagement in Physical Education: A Systematic Review. Sustainability (Switzerland), 15(7), 6039. doi:10.3390/su15076039.

[139] Mercer, S. H., Nellis, L. M., Martínez, R. S., & Kirk, M. (2011). Supporting the students most in need: Academic self-efficacy and perceived teacher support in relation to within-year academic growth. Journal of School Psychology, 49(3), 323–338. doi:10.1016/j.jsp.2011.03.006.

[140] Kilipamwambu, S. T. (2021). Teachers' Perceived Difference Between Content and Competence Based Curricula in Secondary School: A Case of Dar es Salaam Region. Master Thesis, The Open University of Tanzania, Dar es Salaam, Tanzania.

[141] Wiese, S. (2023). The perceived roles and competencies for distance educators employed by a private higher education institution. Master Thesis, Stellenbosch University, Stellenbosch, South Africa.

[142] Ryan, R. M., & Deci, E. L. (2017). Self-Determination Theory: Basic Psychological Needs in Motivation, Development, and Wellness. Guilford Press, London, United Kingdom. doi:10.1521/978.14625/28806.

[143] Brandon-Lai, S. A., Funk, D. C., & Jordan, J. S. (2015). The stage-based development of behavioral regulation within the context of physically active leisure. Journal of Leisure Research, 47(4), 401–424. doi:10.1080/00222216.2015.11950368.

[144] Manrai, R., Goel, U., & Yadav, P. D. (2021). Factors affecting adoption of digital payments by semi-rural Indian women: extension of UTAUT-2 with self-determination theory and perceived credibility. Aslib Journal of Information Management, 73(6), 814–838. doi:10.1108/AJIM-12-2020-0396.

[145] Saadé, R., & Bahli, B. (2005). The impact of cognitive absorption on perceived usefulness and perceived ease of use in on-line learning: An extension of the technology acceptance model. Information & Management, 42(2), 317–327. doi:10.1016/j.im.2003.12.013.

[146] Bereczki, E. O., & Kárpáti, A. (2021). Technology-enhanced creativity: A multiple case study of digital technology-integration expert teachers' beliefs and practices. Thinking Skills and Creativity, 39, 100791. doi:10.1016/j.tsc.2021.100791.

[147] Baki, R., Birgoren, B., & Aktepe, A. (2018). A meta-analysis of factors affecting perceived usefulness and perceived ease of use in the adoption of E-Learning systems. Turkish Online Journal of Distance Education, 19(4), 4–42. doi:10.17718/tojde.471649.

[148] Arpaci, I., & Basol, G. (2020). The impact of preservice teachers' cognitive and technological perceptions on their continuous intention to use flipped classroom. Education and Information Technologies, 25(5), 3503–3514. doi:10.1007/s10639-020-10104-8.

[149] Tao, D., Shao, F., Wang, H., Yan, M., & Qu, X. (2020). Integrating usability and social cognitive theories with the technology acceptance model to understand young users' acceptance of a health information portal. Health Informatics Journal, 26(2), 1347–1362. doi:10.1177/1460458219879337.

[150] Aggarwal, A., & Rahul, M. (2017). Impact of perceived usability and perceived information quality on Indian consumer purchase intentions in online shopping: implication of TAM and S-O-R theory. International Journal of Technology Transfer and Commercialisation, 15(2), 160. doi:10.1504/ijttc.2017.087683.

[151] Jeong, S. H., & Chung, J. Y. (2022). Integrated technology acceptance model (TAM) of sports team smartphone application (STSA) in the stimulus organism response (SOR) framework. Journal of Physical Education and Sport, 22(9), 2152–2161. doi:10.7752/jpes.2022.09275.

[152] Willsey, P. J. (1989). A study of the effectiveness of the direct instruction of thinking skills on science and social studies achievement and on cognitive skills application. PhD Thesis, University of Colorado at Denver, Denver, United States.

[153] Block, J. H. (1970). The effects of various levels of performance on selected cognitive, affective, and time variables. PhD Thesis, The University of Chicago, Chicago, United States.

[154] Van Beek, J. A., de Jong, F. P. C. M., Wubbels, T., & Minnaert, A. E. M. G. (2014). Measuring teacher regulating activities concerning student learning in secondary education classrooms: Reliability and validity of student perceptions. Studies in Educational Evaluation, 43, 206–213. doi:10.1016/j.stueduc.2014.07.001.

[155] Ibrahim, A., Clark, K., Reese, M. J., & Shingles, R. (2020). The effects of a teaching development institute for early career researchers on their intended teaching strategies, course design, beliefs about instructors' and students' knowledge, and instructional self-efficacy: The case of the Teaching Institute at Johns Hopkins University. Studies in Educational Evaluation, 64, 100836. doi:10.1016/j.stueduc.2020.100836.

[156] Zimmermann, F., Melle, I., & Huwer, J. (2021). Developing Prospective Chemistry Teachers' TPACK-A Comparison between Students of Two Different Universities and Expertise Levels Regarding Their TPACK Self-Efficacy, Attitude, and Lesson Planning Competence. Journal of Chemical Education, 98(6), 1863–1874. doi:10.1021/acs.jchemed.0c01296.

[157] Paiwithayasiritham, C., Mingsiritham, K., Chanyawudhiwan, G., Amatmontree, S., & Iamsa-ard, A. (2024). Self-Perception About Digital Skills of Pre-Service Teachers in a Thailand University Context. Journal of Education and Learning, 14(1), 177. doi:10.5539/jel.v14n1p177.

[158] Norhagen, S. L., Krumsvik, R. J., & Røkenes, F. M. (2024). Developing professional digital competence in Norwegian teacher education: a scoping review. Frontiers in Education, 9. doi:10.3389/feduc.2024.1363529.

[159] Carpenter, J. P., Rosenberg, J. M., Kessler, A., Romero-Hall, E., & Fischer, C. (2024). The importance of context in teacher educators' professional digital competence. Teachers and Teaching, 30(4), 400–416. doi:10.1080/13540602.2024.2320155.

Appendix I: Research Questionnaire

Table A-I. Interactive Digital Technology Effect on Teaching Performance (Preservice Chemistry Teachers)

Construct	Item Statements	SD	D	N	A	SA
Perceived Usability	1. The digital tools used in teaching are easy to use.					
	2. The system enables me to accomplish tasks more quickly.					
	3. I find the tools flexible to interact with.					
	4. The tools are designed to match my needs.					
	5. Using these tools improves my teaching productivity.					
	6. The digital tools are clear and understandable.					
	7. I feel confident using digital tools for teaching.					
	8. I can easily learn how to use new features of the tools.					
	9. Overall, the usability of digital tools is satisfactory.					
Perceived Autonomy	1. I feel in control when using digital tools in teaching.					
	2. I can make decisions about how to use the tools in my teaching.					
	3. I feel independent when using technology in the classroom.					
	4. Using digital tools allows me to teach in my own style.					
Perceived Teaching Support	1. I receive adequate support to use digital tools effectively in teaching.					
	2. The institution provides resources to enhance my digital teaching skills.					
	3. There is enough guidance available for integrating digital tools in teaching.					
	4. I feel encouraged to use digital tools by my peers and mentors.					
	5. The technical support for using digital tools is readily accessible.					
Perceived Competency	1. I feel competent using digital tools for teaching.					
	2. I am confident in my ability to teach using digital tools.					
	3. I have the necessary skills to use technology effectively in teaching.					
	4. I feel capable of troubleshooting basic issues with digital tools.					
	5. I am proficient in adapting to new teaching technologies.					
Perceived Relatedness	1. I feel connected to my students when using digital tools in teaching.					
	2. The use of technology enhances my interaction with students.					
	3. I feel that digital tools help me build strong relationships with students.					
	4. Digital tools enable effective communication between me and my students.					
Perceived Ease of Use	1. I find the digital tools easy to learn.					
	2. The interface of the tools is user-friendly.					
	3. I feel that the tools are simple to navigate.					
	4. It takes little effort to use digital tools for teaching.					
	5. I find the system intuitive and easy to manage.					
Cognitive Teaching Involvement	1. I actively think about how to improve my use of digital tools in teaching.					
	2. I reflect on my experiences using technology in teaching.					
	3. I try to improve my technology-enhanced teaching practices continuously.					
	4. I am mentally engaged when using digital tools in my teaching activities.					
Affective Teaching Involvement	1. I enjoy using digital tools in my teaching.					
	2. I feel satisfied with the role of technology in my teaching.					
	3. The use of technology makes teaching more enjoyable for me.					
	4. I feel positive about incorporating new digital tools into my teaching.					
	5. I am enthusiastic about using interactive digital tools in my classes.					
Teaching Performance	1. Digital tools have improved my overall teaching performance.					
	2. My students' learning outcomes have improved due to the use of technology.					
	3. I feel that digital tools have increased my teaching effectiveness.					
	4. My teaching methods have become more innovative through the use of digital tools.					