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UNDERSTANDING THE ROLE OF TECHNOLOGICAL SELF-EFFICACY IN FOSTERING CREATIVE PROBLEM-SOLVING AND CURIOSITY IN TEACHER EDUCATION: A STRUCTURAL EQUATION MODELING APPROACH

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Abstract

The integration of digital technologies in education has transformed teacher education, emphasizing creativity, problem-solving, and inquiry-based learning. Despite extensive research on technological self-efficacy, creativity, and curiosity, gaps remain in understanding their interrelationships, particularly in teacher education contexts. This study employs a cross-sectional design and PLS-SEM to examine the relationships among technological attitudes, self-efficacy, problem-solving engagement, intrinsic motivation, learning engagement, pedagogical knowledge, content knowledge, creative reasoning, and curiosity. Data from 875 pre-service teachers at a state university in Cebu City, Philippines, reveal that positive technological attitudes significantly enhance technological self-efficacy, which influences problem-solving engagement but does not directly impact creative reasoning or curiosity. However, technological problem-solving engagement and intrinsic motivation are key drivers of creativity and curiosity. Additionally, pedagogical and content knowledge play crucial roles in fostering these attributes. These findings highlight the importance of incorporating holistic strategies in teacher education programs, integrating both technological and pedagogical frameworks to equip pre-service teachers with the skills necessary to foster creativity and curiosity in their classrooms, ultimately enhancing educational outcomes.

Keywords – Technological self-efficacy, Technological problem-solving, Creativity, Teacher education, Structural equation modeling.

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1. Introduction

The rapid advancement of digital technologies in the 21st century has dramatically reshaped the educational landscape, creating new avenues for teaching and learning (Mhlongo, Mbatha, Ramatsetse & Dlamini, 2023; Timotheou, Miliou, Dimitriadis, Sobrino, Giannoutsou, Cachia et al., 2022). With the increasing use of digital tools, teacher education has undergone significant transformations, integrating technology into curricula to promote creativity, problem-solving, and inquiry-driven learning (Abedi, 2023). These shifts highlight the growing need for pre-service teachers to acquire not only strong pedagogical content knowledge but also the confidence to effectively navigate and utilize various technological tools (Backfisch, Sibley, Lachner, Kirchner, Hische & Scheiter, 2024; Garcia, Rosak-Szyrocka, Yılmaz, Metwally, Acut, Ofosu-Ampong et al., 2025). This capability is essential for preparing future educators to foster engaging and interactive learning environments. Equipping themselves with these skills enables teachers to create dynamic educational experiences that inspire student curiosity and drive creative problem-solving (Scott-Barrett, Johnston, Denton-Calabrese, McGrane & Hopfenbeck, 2023).

Technological self-efficacy refers to an individual's belief in their ability to successfully use technology for tasks, and it plays a crucial role in determining whether educators embrace or resist digital tools in the classroom (Gomez, Trespalacios, Hsu & Yang, 2021). Teachers with high levels of self-efficacy are more likely to explore innovative teaching methods and integrate new technologies into their instruction, enriching the learning experience with creative and problem-solving opportunities (Backfisch, Lachner, Stürmer & Scheiter, 2021). On the other hand, educators with low self-efficacy may hesitate to incorporate technology, potentially limiting their teaching strategies to conventional methods (Mlambo, Rambe & Schlebusch, 2020). This hesitance can prevent students from engaging in exploratory learning, reducing the chances of fostering creative inquiry in classrooms (Henriksen, Henderson, Creely, Carvalho, Cernochova, Dash et al., 2020). Therefore, promoting technological self-efficacy is essential in teacher education.

In today's educational climate, fostering creativity and curiosity has gained increasing significance, as students need interdisciplinary thinking, critical problem-solving, and innovation skills to succeed (Tang, 2019; Mangubat, Mangubat, Uy, Acut & Garcia, 2025). Creative problem-solving enables individuals to approach challenges with unique and innovative solutions, while curiosity encourages a desire for continuous learning and exploration (Bishara, 2016; Cavicchi, 2024). These attributes are especially important in teacher education, where pre-service teachers must be trained to guide learners through complex, real-world issues. Teachers who can nurture these skills in their students prepare them not only for academic success but also for life beyond the classroom, where adaptability and creativity are vital (Scott-Barrett et al., 2023).

While the importance of technological self-efficacy and its role in fostering creativity and curiosity has been recognized, a gap exists in research that explicitly links these factors within the context of teacher education. Most existing studies focus on technological competency or attitudes toward technology but overlook the complex relationship between self-efficacy, creativity, and curiosity-driven learning in educational settings. To the best of our knowledge, few studies have explored how pre-service teachers' technological self-efficacy influences their ability to promote creative problem-solving and curiosity in the classroom. This gap in research underscores the need for a deeper understanding of how technological self-efficacy directly impacts the development of creativity and curiosity in pre-service teachers and, by extension, in their students. This study uniquely addresses this gap by examining these relationships in the context of teacher education programs, offering new insights into how curricula can be designed to enhance both technological self-efficacy and creative inquiry.

2. Literature Review

2.1. Technology Integration in Educational Settings

The integration of technology into educational settings has been an area of extensive research, with previous studies emphasizing the need for both access to and effective use of digital tools in classrooms.

Successful technology integration has long been associated with not only the availability of digital tools but also the professional development of educators to maximize the pedagogical value of these tools (Haleem, Javaid, Qadri & Suman, 2022). The active engagement of educators in experimenting with various digital platforms is critical for fostering confidence in using technology and understanding its pedagogical potential (Garcia, 2023; Acut, Gamusa, Pernaa, Yuenyong, Pantaleon, Espina et al., 2025). However, a growing body of literature underscores the need for technology to be integrated in a manner that moves beyond just usage; it should be embedded within the broader context of student-centered learning environments that promote creativity, problem-solving, and inquiry (Kerimbayev, Umirzakova, Shadiev & Jotsov, 2023; Gantalao, Dela-Calzada, Capuyan, Lumantas, Acut & Garcia, 2025).

This study builds on existing research by emphasizing not only the significance of technology in teaching and learning but also the intersection of this integration with pre-service teachers' technological self-efficacy. While much has been written about technology's role in enhancing student outcomes, less attention has been given to the dynamic relationship between teachers' confidence in using technology and their ability to foster creative problem-solving and curiosity in students. This research uniquely contributes by addressing this gap through the lens of pre-service teacher preparation, offering fresh insights into how technological competence can directly influence teacher creativity and instructional innovation.

2.2. Technological Self-Efficacy in Teacher Education

Technological self-efficacy, defined as an individual's belief in their ability to effectively use technology, is increasingly recognized as a determinant of how teachers integrate technology into their instructional practices (Bandura, 1997; Gomez et al., 2021). Within teacher education, this construct has gained prominence as pre-service teachers are expected to be equipped not only with pedagogical knowledge but also the confidence to effectively use technology in a rapidly evolving digital landscape. Previous studies have demonstrated that pre-service teachers with high technological self-efficacy are more likely to adopt and innovate with digital tools in their teaching practices (Backfisch et al., 2021).

However, while much of the literature has focused on general technological competencies, this study provides a novel contribution by examining the specific role of technological self-efficacy in fostering both creative problem-solving and curiosity among pre-service teachers. Unlike prior research, which has often treated technological self-efficacy in isolation, our approach recognizes that this construct is a catalyst for fostering deeper educational outcomes, such as creativity and inquiry-based learning. This dual focus on technological self-efficacy and its relationship to creative competencies represents a unique contribution to the field.

2.3. Role of Technology in Fostering Creative Problem-Solving

The use of technology in education has been increasingly recognized as an essential tool for fostering creative problem-solving (Garcia, 2024). Creative problem-solving refers to the ability to approach challenges from novel perspectives, using critical thinking and innovative strategies to find solutions (Bishara, 2016). Technology facilitates this process by offering diverse platforms for students to collaborate, explore ideas, and engage in hands-on, problem-based learning (Haleem et al., 2022).

Research by Li, Kim and Palkar (2022) and Lee and Choi (2017) have demonstrated that technology-enriched environments significantly improve students' ability to think creatively and solve problems in innovative ways. However, the integration of these tools for fostering creativity is often dependent on teachers' own technological competencies and self-efficacy. While existing studies have focused on the impact of technology on student creativity, this research contributes by examining how pre-service teachers' self-efficacy in using technology influences their ability to foster creativity in students. By linking self-efficacy with creative problem-solving, this study highlights the need for teacher education programs to prioritize technological training that fosters not only basic competence but also creativity-enhancing strategies.

2.4. Curiosity as A Key Driver in Educational Contexts

Curiosity is a critical factor in driving intellectual growth and engagement in educational settings. Defined as the desire to acquire new knowledge and explore unfamiliar concepts, curiosity motivates both teachers and students to seek out novel information and solutions (Cavicchi, 2024). In teacher education, curiosity is essential for fostering inquiry-based learning and motivating students to actively participate in their own learning journeys (Levanon, 2021).

In the context of teacher education, fostering curiosity in pre-service teachers not only prepares them to adopt innovative teaching practices but also enables them to instill the same curiosity in their students. While much research has focused on the role of curiosity in enhancing teacher development and student engagement (Evans, Burke, Vitiello, Zumbrunn & Jirout, 2023), fewer studies have explored how curiosity can be linked to technological self-efficacy. This study fills this gap by exploring how curiosity, as a motivating factor, can drive pre-service teachers to engage with new technological tools, thereby enhancing their instructional practices. The interplay between curiosity and self-efficacy is underexplored in the literature, and this research provides unique insights into how these constructs interact to shape teacher behavior in the digital classroom.

2.5. Research Gaps and the Necessity for SEM Analysis

Despite the growing body of literature on technological self-efficacy, creativity, and curiosity in teacher education, significant gaps remain in understanding the interrelationships between these constructs. Most existing research has examined these variables in isolation, focusing either on the impact of technology on creativity or the role of self-efficacy in technology adoption, but few studies have attempted to explore how these factors interact and influence one another in a holistic way.

Structural Equation Modeling (SEM) is a powerful tool that allows researchers to simultaneously analyze complex relationships between multiple variables (Hair, Hult, Ringle, Sarstedt, Danks & Ray, 2021). SEM is particularly useful for studying latent constructs, such as self-efficacy, creativity, and curiosity, as it accounts for measurement errors and enables a comprehensive understanding of how these factors relate to one another (Dash & Paul, 2021). This study employs SEM to model the interactions between technological self-efficacy, creative problem-solving, and curiosity, offering novel insights into how these constructs influence each other in the context of pre-service teacher education. This methodological approach represents a distinctive contribution by providing a deeper, more detailed understanding of the dynamics that shape teacher preparedness in the digital age.

3. Hypothesis Development

This study investigates the interrelationships among technological attitudes (TA), technological self-efficacy (TSE), technological problem-solving engagement (TPSE), intrinsic motivation (IM), learning engagement (LE), pedagogical knowledge (PK), content knowledge (CK), creativity (CR), and curiosity (CU) within the context of teacher education. These constructs are examined to understand how pre-service teachers effectively integrate technology to foster creativity and curiosity, drawing on foundational theories such as Bandura's Self-Efficacy Theory (Bandura, 1997), the Technology Acceptance Model (TAM) (Davis, 1989), and the Technological Pedagogical Content Knowledge (TPACK) framework (Mishra & Koehler, 2006).

3.1. Technological Attitudes, Technological Self-Efficacy, and Technological Problem-Solving Engagement

Technological attitudes (TA) encompass the beliefs, perceptions, and predispositions that pre-service teachers hold regarding the integration of technology in educational settings. Positive attitudes reflect an openness to adopting digital tools and innovative teaching practices, aligning with the TAM's assertion that perceived usefulness and ease of use directly shape users' attitudes toward technology (Teo & van Schaik, 2012).

According to the TAM, users are more likely to develop favorable attitudes toward technology when they perceive it as useful and easy to use, leading to greater confidence in their technological capabilities (Davis, 1989).

Bandura's (1997) Self-Efficacy Theory underscores that self-efficacy arises from mastery experiences, social modeling, and verbal persuasion. Thus, pre-service teachers with positive technological attitudes are more confident in their abilities to utilize technology effectively, enhancing their willingness to engage in technological problem-solving.

This confidence not only supports effective teaching but also encourages experimentation with digital tools to address instructional challenges, fostering innovative teaching practices (Levanon, 2021).

Further, technological self-efficacy (TSE) directly influences teachers' willingness to experiment with digital resources. Teachers with high TSE are more inclined to engage in problem-solving tasks using technology, reflecting creative uses of educational software, digital simulations, or collaborative platforms (Kerschner & Ehlers, 2016).

H1: Positive technological attitudes positively influence technological self-efficacy.

H2: Technological self-efficacy positively influences technological problem-solving engagement.

3.2. Technological Self-Efficacy, Technological Problem-Solving Engagement, and Creative-Curiosity Capacities

Technological self-efficacy significantly impacts creative and curiosity-driven capacities among pre-service teachers. Individuals who believe in their technological competence are more likely to innovate and approach challenges creatively, consistent with Bandura's (1997) theory that self-efficacy facilitates adaptive problem-solving and creative thinking (Compeau & Higgins, 1995).

Teachers with high TSE are more willing to take instructional risks and adopt innovative approaches, promoting both creative teaching and problem-solving (Mishra & Koehler, 2006).

Moreover, curiosity as an intrinsic driver of professional growth is amplified when teachers feel confident using technology. TSE nurtures an exploratory mindset, encouraging teachers to seek out and utilize digital tools that enhance creative teaching (Alieto, Abequibel-Encarnacion, Estigoy, Balasa, Eijansantos & Torres-Toukoumidis, 2024).

This dynamic interplay between TSE and curiosity supports continuous learning and pedagogical innovation, fostering a culture of curiosity among both teachers and their students.

Technological problem-solving engagement (TPSE) further reinforces this relationship by facilitating the practical application of creative ideas. Teachers actively engaged in problem-solving with technology continuously adapt their methods, demonstrating both creativity and curiosity (Johnson, Jacovina, Russell & Soto, 2016).

H3: Technological self-efficacy positively influences creativity.

H4: Technological self-efficacy positively influences curiosity.

H5: Technological problem-solving engagement positively influences creativity.

H6: Technological problem-solving engagement positively influences curiosity.

3.3. Intrinsic Motivation, Creativity, and Curiosity

Intrinsic motivation (IM) reflects the internal drive to pursue tasks for personal fulfillment rather than external rewards (Deci & Ryan, 2000). In educational contexts, intrinsic motivation is a critical factor that fosters both creativity and curiosity, as teachers driven by personal satisfaction tend to innovate and adopt creative teaching practices (Sternberg & Lubart, 1996).

This motivational state aligns with self-determination theory, where autonomy and competence stimulate deeper engagement and innovative problem-solving (Mononen, Havu-Nuutinen & Haring, 2023).

Intrinsic motivation also nurtures curiosity by promoting inquiry-based teaching methods that encourage exploration and critical thinking. Teachers motivated intrinsically are more likely to foster a classroom environment where questioning, experimentation, and creative thinking are normalized (Kashdan & Steger, 2007).

H7: Intrinsic motivation positively influences creativity.

H8: Intrinsic motivation positively influences curiosity.

3.4. Pedagogical Knowledge, Content Knowledge, Learning Engagement, and Creative-Curiosity Capacities

Pedagogical knowledge (PK) and content knowledge (CK) are essential components of effective teaching. According to Shulman (1987), integrating pedagogical and content knowledge enables teachers to deliver instruction creatively, fostering critical thinking and curiosity.

Teachers with strong foundations in these areas are better positioned to design lessons that challenge students to think critically and creatively, promoting higher levels of student engagement (Grossman, 1990).

Learning engagement (LE) also plays a crucial role, as students who are actively involved in the learning process are more likely to experience increased curiosity and creativity (Fredricks, Blumenfeld & Paris, 2004). Teachers who integrate technology into their pedagogical approaches can enhance this engagement, resulting in more dynamic and interactive learning environments.

H9: Pedagogical knowledge positively influences creativity.

H10: Learning engagement positively influences creativity.

H11: Learning engagement positively influences curiosity.

H12: Content knowledge positively influences curiosity.

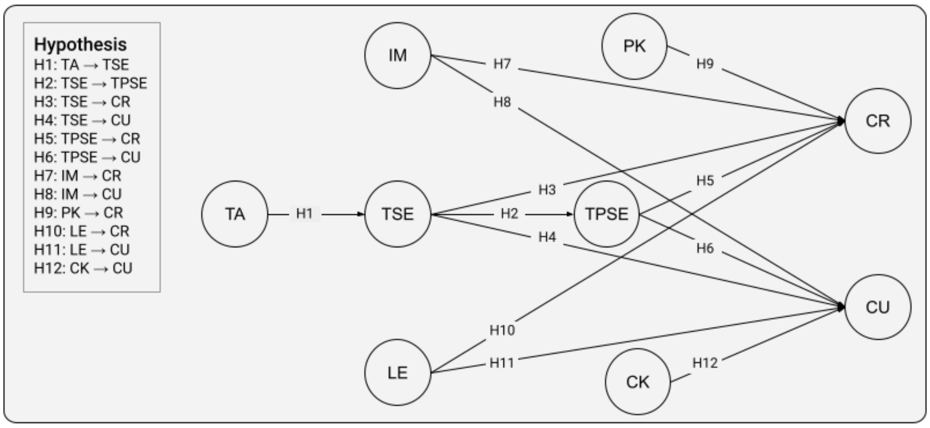

Figure 1. Hypothesized research model illustrating proposed paths

4. Methodology

4.1. Research Design

This research employed a cross-sectional design and utilized Partial Least Squares Structural Equation Modeling (PLS-SEM) to explore the connections between key factors influencing creativity and curiosity in teacher education through technology integration. PLS-SEM was chosen due to its flexibility in handling complex models with multiple constructs, making it particularly suitable for examining both reflective and formative constructs within an exploratory framework. Given the study's aim to understand relationships between constructs such as TA, TSE, TPSE, IM, LE, PK, CK, CR, and CU, PLS-SEM was appropriate for predicting latent variable relationships and handling smaller to large sample sizes efficiently (Hair, Ringle & Sarstedt, 2011).

PLS-SEM is particularly advantageous in this context because the study explores relatively new relationships between constructs, such as the role of technological attitudes (TA) and technological problem-solving in fostering creativity and curiosity, which may not yet have established theoretical models. By employing PLS-SEM, this research provides an in-depth look at how various dimensions of technology integration impact the development of creativity and curiosity in future teachers. The model evaluation included assessments of the reliability and validity of the constructs through composite reliability (CR) and average variance extracted (AVE), ensuring robust findings. To assess the validity and reliability of the measurement model, Confirmatory Factor Analysis (CFA) was employed, focusing on factor loadings, composite reliability (CR), and average variance extracted (AVE) to ensure the robustness of the constructs (Mustafa, Alkawsi, Ofosu-Ampong, Vanduhe, Garcia & Baashar, 2022).

4.2. Instrument Development and Evaluation

The constructs listed in Appendix A were adapted from established research but were carefully refined and contextualized to align with the specific focus of this study, which explores the relationships among technological self-efficacy, pedagogical knowledge, and creativity in teacher education. To ensure content validity, the initial instrument underwent a rigorous review by a panel of four experts, including specialists in educational technology, pedagogy, and psychometrics. This process included a Content Validity Index (CVI) assessment, yielding a CVI score of 0.88, indicating excellent content validity and alignment with the study's objectives. Feedback from this panel led to significant revisions, including the addition of items to better capture the multifaceted nature of technological problem-solving, intrinsic motivation, and creative reasoning, as well as refinements to item phrasing to improve clarity and reduce potential bias.

The revised instrument was then subjected to a pilot test with a convenience sample of 50 pre-service teachers to assess both reliability and construct validity. Confirmatory Factor Analysis (CFA) and Confirmatory Composite Analysis (CCA) were performed to ensure that the items effectively measured the intended latent variables, achieving strong internal consistency with Cronbach's alpha values ranging from 0.87 to 0.95, and high composite reliability (CR) scores above 0.7, indicating robust internal reliability. The Average Variance Extracted (AVE) values for each construct exceeded the 0.5 threshold, confirming convergent validity.

The final version of the questionnaire included two main sections: (1) Demographic Data, collecting information such as age, gender, academic program, and technology use experience, and (2) Construct Measurement, comprising 45 items across the key constructs of Technological Self-Efficacy (TSE), Technological Problem-Solving Efficacy (TPSE), Intrinsic Motivation (IM), Learning Engagement (LE), Pedagogical Knowledge (PK), Content Knowledge (CK), Creative Reasoning (CR), and Curiosity (CU). Items were rated on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), ensuring comprehensive measurement of each construct's impact on teacher readiness.

4.3. Participants and Data Collection

The participants in this study were pre-service teachers enrolled in the teacher education programs at a public, non-sectarian, state-funded higher education institution located in Cebu, Philippines. Students from first to fourth year were selected to provide a broad range of perspectives on the integration of technology into teacher education. These students were considered ideal for the study due to their varying levels of exposure to educational technology, as well as their engagement with courses such as Educational Technology, Pedagogy, and Field Study. Their experiences with digital tools and platforms, both within academic settings and in practical teaching environments, made them well-suited for examining the relationship between technological self-efficacy, creative problem-solving, and curiosity in teacher education. To recruit participants, purposive-convenience and chain referral sampling methods were used, targeting students with relevant experiences in integrating technology in education. Class representatives facilitated the distribution of an online self-administered questionnaire through Google Forms. Data collection occurred from September to October 2024, ensuring a comprehensive understanding of how technological engagement influences creativity and curiosity across varying stages of teacher preparation.

The study adhered to stringent ethical guidelines in compliance with the Data Privacy Act of 2012 (Republic Act No. 10173) of the Philippines. Informed consent was obtained from all adult pre-service teacher participants, ensuring they understood the study's purpose, procedures, and their rights, including the option to withdraw at any time without consequence. Data were collected anonymously, without personally identifiable information, and securely stored, accessible only to the research team. This ensured that participant privacy was fully protected, with findings reported in aggregate form solely for academic purposes.

A total of 886 responses were initially gathered, but only 875 complete and valid responses were included in the final analysis. During the data processing, a sincerity test was employed to ensure the reliability and accuracy of the responses. This test helped to identify any inconsistencies or patterns indicating inattentive or insincere answers, further enhancing the data's integrity. Participants were given ample time to complete the survey, encouraging thoughtful responses that reflect their genuine experiences with educational technology. The participants were predominantly female (n = 826, 94%), with a smaller number of male respondents (n = 49, 6%). The largest age group consisted of 19-year-olds (n = 237, 27%), followed by 20-year-olds (n = 203, 23%), 21-year-olds (n = 170, 19%), and 18-year-olds (n = 76, 9%). There were fewer respondents aged 22 (n = 113, 13%), 23 (n = 59, 7%), and only 1% were aged 24 or older. Regarding their year level, the largest group was second-year students (n = 276, 32%), followed by third-year students (n = 208, 24%), first-year students (n = 199, 23%), and fourth-year students (n = 192, 22%). In terms of degree programs, Technology and Livelihood Education students were the largest group (n = 106, 12%), followed by those enrolled in Elementary Education (n = 132, 15%), Secondary Education – Mathematics (n = 104, 12%), and Technical and Vocational Teacher Education (n = 96, 11%). Other participants were from Secondary Education – Science (n = 80, 9%), Special Needs Education (n = 92, 11%), and Early Childhood Education (n = 62, 7%). Smaller groups pursued Secondary Education specializations in Filipino (n = 74, 8%), Social Studies (n = 66, 8%), and English (n = 63, 7%).

The majority of participants reported frequent use of various educational technologies, emphasizing not just their years of experience but the range and frequency of interactions with these tools. Classroom tools such as interactive whiteboards, tablets, and projectors were used daily by 86% of respondents, with 14% using them weekly. Additionally, learning platforms like Google Classroom were used daily by 72%, while 25% used them weekly. Educational software such as simulation programs, virtual labs, and instructional games were incorporated daily by 41% and weekly by 37% of participants. The integration of online and blended learning tools (e.g., Zoom, Google Meet) was highly prevalent, with 36% using them daily and 64% weekly. Moreover, online collaboration and communication tools, such as shared documents and discussion forums, were used daily by 61% and weekly by 37% of participants.

The approach of focusing on specific types and frequencies of educational technology use provides a contextual view of the participants' experiences, enabling this study to capture the full scope of their interactions with technology in educational settings. Instead of solely measuring the duration of use, this method examines the frequency and variety of digital tools and platforms employed, offering a richer understanding of how technology is integrated into teaching and learning environments. This detailed perspective enables a deeper exploration of how these varied experiences shape teacher readiness and enhance their ability to foster creative problem-solving and curiosity through technology integration. The demographic information presented in Figure 2 further contextualizes these findings, shedding light on the diversity of participants and highlighting how different background factors may influence their engagement with educational technologies.

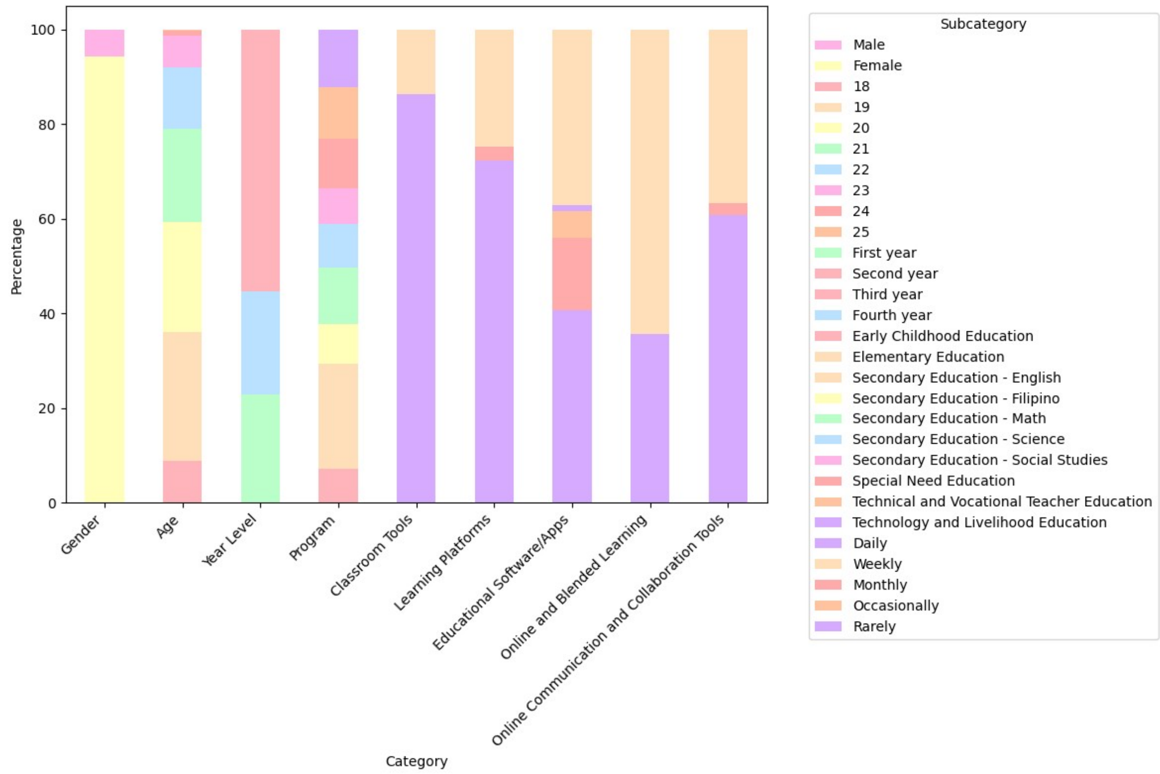

Figure 2. Demographic information of the participants included in the study

4.4. Data Analysis

Data analysis for this study utilized SmartPLS 4.0 for Partial Least Squares Structural Equation Modeling (PLS-SEM). Although PLS-SEM is often associated with small-to-moderate sample sizes (Hair et al., 2021), it is highly flexible and can accommodate both smaller and larger samples, making it suitable for the current study with 875 respondents. This method is particularly well-suited for complex, exploratory models, especially when the focus is on latent constructs. PLS-SEM was chosen to assess both measurement and structural models, leveraging its ability to handle non-normal data distributions effectively.

To ensure sufficient statistical power for the analysis, a power analysis was conducted using G*Power 3.1 (Faul, Erdfelder, Buchner & Lang, 2009). The following parameters were set: effect size f^2 at 0.15, α error probability at 0.05, and Power (1 - β error prob) at 0.95, with 7 predictors. Based on a sample size of 153, the power analysis revealed a non-centrality parameter λ of 22.95, a critical F value of 2.0733, and an actual power of 0.9503. These results confirm that the study's actual sample size of 875 respondents is more than adequate for detecting meaningful effects, ensuring the reliability of the findings. Figure 3 shows the G*Power 3.1 plot, illustrating the power analysis for the study.

The analysis then followed a three-step approach:

1. Measurement Model Assessment: The initial stage involved Confirmatory Factor Analysis (CFA) and Confirmatory Composite Analysis (CCA) to verify the reliability and validity of the measurement model. This included examining factor loadings, Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE) to confirm convergent and discriminant validity. All constructs demonstrated high internal consistency, with factor loadings exceeding 0.7 and AVE values above the recommended 0.5 threshold, indicating that the items reliably represented the intended latent variables.

2. Structural Model Evaluation: Path coefficients were computed to assess the relationships among latent variables, with t-values and p-values calculated via bootstrapping to test the statistical significance of the hypothesized paths. This step also included assessing the model's predictive power using R^2 values, which indicated the proportion of variance explained by each dependent variable, and Q^2 values for predictive relevance, both of which confirmed the model's robustness.

3. Model Fit and Predictive Relevance: The overall model fit was evaluated using the Standardized Root Mean Square Residual (SRMR) and Goodness of Fit (GoF) indices, supported by advanced metrics like Predictive Relevance (Q^2), ensuring a comprehensive assessment of the model's explanatory power. This approach confirmed that the structural model provided a reliable representation of the relationships among the studied constructs, aligning well with the study's theoretical framework (Hair & Alamer, 2022; Sarstedt, Hair, Cheah, Becker & Ringle, 2019).

These methodological refinements and statistical validations collectively enhance the study's analytical depth, ensuring a robust alignment between the research instrument and the study context, as recommended.

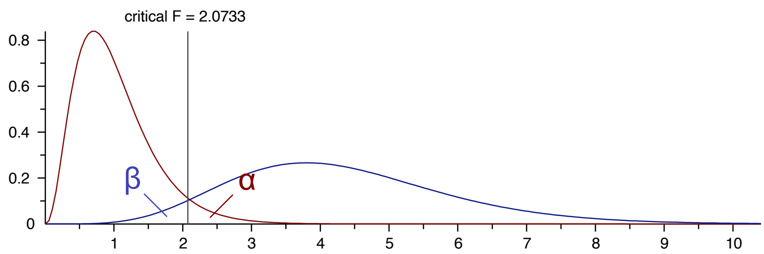

Figure 3. Power analysis for PLS-SEM using G*Power 3.1

5. Results and Findings

This study utilized PLS-SEM to investigate the relationships among the constructs of TA, TSE, TPSE, IM, LE, PK, CK, CR, and CU. PLS-SEM was chosen for its ability to manage complex models involving multiple constructs and indicators, offering valuable insights into variable relationships by maximizing the shared variance among latent constructs (Dash & Paul, 2021). Notably, the majority of participants reported frequent interactions with various educational technologies, indicating a high level of engagement in their teaching practices. Classroom tools like interactive whiteboards, tablets, and projectors were used daily by 86% of respondents, while 72% engaged with learning platforms such as Google Classroom on a daily basis. This frequent and varied use of technology not only reflects their experience but also emphasizes its significance in fostering creativity and curiosity in educational contexts. The following subsections will detail the descriptive statistics and evaluation of the measurement model, as well as the analysis of the structural model.

5.1. Descriptive Statistics and Measurement Model Evaluation

The descriptive statistics for each construct indicate generally positive perceptions among participants (Table 1). Mean values ranged from 4.04 to 4.54, suggesting favorable attitudes towards TA, TSE, TPSE, IM, LE, PK, CK, CR, and CU. Standard deviations varied from 0.70 to 0.93, reflecting moderate variability in responses. To evaluate the reliability and validity of the measurement model, Cronbach's alpha, CR, and AVE values were calculated for each construct. All constructs demonstrated satisfactory internal consistency, with Cronbach's alpha values exceeding the recommended threshold of 0.70, ranging from 0.878 to 0.951 (Hair et al., 2021). Similarly, CR values ranged from 0.912 to 0.962, significantly surpassing the cutoff of 0.70, thereby confirming the model's reliability. Furthermore, the AVE for all constructs exceeded the recommended value of 0.50, indicating that each construct captured a substantial amount of variance from its indicators. The AVE values ranged from 0.677 to 0.837, supporting the convergent validity of the constructs (Hair, Hult, Ringle & Sarstedt, 2017).

Constructs	Item	Mean	SD	Factor Loading	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Technological Attitudes (TA)	TA1	4.54	0.85	0.877	0.909	0.932	0.733
	TA2	4.08	0.80	0.822			
	TA3	4.23	0.83	0.881			
	TA4	4.36	0.78	0.848			
	TA5	4.29	0.90	0.851			
Technological Self-Efficacy (TSE)	TSE1	4.26	0.83	0.867	0.878	0.912	0.677
	TSE2	3.55	0.86	0.651			
	TSE3	4.24	0.87	0.880			
	TSE4	4.15	0.83	0.855			
	TSE5	4.26	0.79	0.840			
Technological Problem-Solving Engagement (TPSE)	TPSE1	4.10	0.81	0.890	0.901	0.927	0.716
	TPSE2	4.08	0.83	0.841			
	TPSE3	4.10	0.79	0.810			
	TPSE4	4.16	0.81	0.852			
	TPSE5	4.25	0.70	0.837			
Intrinsic Motivation (IM)	IM1	4.24	0.85	0.897	0.932	0.948	0.786
	IM2	4.15	0.78	0.863			
	IM3	4.43	0.83	0.928			
	IM4	4.34	0.90	0.863			
	IM5	4.30	0.88	0.881			
Learning Engagement (LE)	LE1	4.23	0.92	0.900	0.951	0.962	0.837
	LE2	4.30	0.88	0.927			
	LE3	4.08	0.93	0.915			
	LE4	4.28	0.90	0.939			
	LE5	4.27	0.88	0.892			
Pedagogical Knowledge (PK)	PK1	4.33	0.85	0.803	0.902	0.928	0.721
	PK2	4.33	0.75	0.878			
	PK3	4.27	0.76	0.914			
	PK4	4.09	0.85	0.760			
	PK5	4.26	0.77	0.881			
Content Knowledge (CK)	CK1	4.14	0.80	0.848	0.921	0.941	0.761
	CK2	4.12	0.93	0.852			
	CK3	4.12	0.85	0.926			
	CK4	4.09	0.93	0.878			
	CK5	4.13	0.81	0.854			
Creativity (CR)	CR1	4.04	0.91	0.851	0.922	0.941	0.763
	CR2	4.24	0.91	0.876			
	CR3	4.14	0.94	0.907			
	CR4	4.47	0.84	0.863			
	CR5	4.27	0.81	0.868			
Curiosity (CU)	CU1	4.38	0.92	0.905	0.933	0.949	0.789
	CU2	4.20	0.95	0.888			
	CU3	4.42	0.86	0.893			
	CU4	4.23	0.83	0.913			
	CU5	4.49	0.85	0.838			

Table 1. Descriptive statistics, factor loadings, and reliability measures for the model constructs

Specifically, TA had factor loadings ranging from 0.822 to 0.877, with a mean score of 4.54, demonstrating strong internal consistency as indicated by a Cronbach's alpha of 0.909, CR of 0.932, and an AVE of 0.733. TSE exhibited loadings from 0.651 to 0.880, with a mean of 4.26, and displayed reliable metrics (Cronbach's alpha = 0.878, CR = 0.912, AVE = 0.677). The TPSE construct showed loadings between 0.810 and 0.890, with a mean score of 4.10 and strong reliability (Cronbach's alpha = 0.901, CR = 0.927, AVE = 0.716). IM had factor loadings ranging from 0.863 to 0.928, with a mean of 4.24, supported by excellent reliability metrics (Cronbach's alpha = 0.932, CR = 0.948, AVE = 0.786). LE yielded loadings from 0.892 to 0.900 and a mean score of 4.23, along with a high Cronbach's alpha of 0.951, CR of 0.962, and an AVE of 0.837. PK demonstrated factor loadings ranging from 0.760 to 0.914, a mean score of 4.27, and satisfactory reliability measures (Cronbach's alpha = 0.902, CR = 0.928, AVE = 0.721).

CK exhibited loadings from 0.848 to 0.926, with a mean score of 4.12 and reliable metrics (Cronbach's alpha = 0.921, CR = 0.941, AVE = 0.761). CR had factor loadings ranging from 0.851 to 0.907, with a mean of 4.14, supported by a Cronbach's alpha of 0.922, CR of 0.941, and an AVE of 0.763. Finally, CU showed factor loadings between 0.838 and 0.905, with a mean score of 4.38, and strong reliability measures (Cronbach's alpha = 0.933, CR = 0.949, AVE = 0.789). Overall, the constructs in this study demonstrated robust reliability and validity, establishing a solid foundation for further analysis of the relationships between technological engagement and pedagogical knowledge within the educational context.

Furthermore, the data presented in Table 2 provides evidence of discriminant validity among the constructs by employing the Fornell-Larcker criterion, as evidenced by the diagonal values representing the square roots of the AVE, which surpass the off-diagonal correlation coefficients. This finding affirms the uniqueness of each construct. The AVE values for TA (0.856), TSE (0.823), TPSE (0.846), IM (0.887), LE (0.915), PK (0.849), CK (0.872), CR (0.873), and CU (0.888) all exceed the acceptable threshold of 0.50, signifying that each construct effectively captures a considerable amount of variance from its respective items (Fornell & Larcker, 1981; Henseler, Ringle & Sarstedt, 2014).

In addition, the correlation matrix reveals several strong positive relationships among constructs, most notably between LE and PK (r = 0.811) and CK and CR (r = 0.886). Significant correlations are also evident between TSE and TPSE (r = 0.851) and IM and LE (r = 0.760). While these correlations indicate interrelatedness, the distinctiveness of each construct is upheld, reinforcing the importance of understanding the contributions of TA, TSE, TPSE, IM, LE, PK, CK, CR, and CU within the framework of educational technology and its role in enhancing pre-service teachers' creativity and curiosity.

Constructs	TA	TSE	TPSE	IM	LE	PK	CK	CR	CU
Technological Attitudes	0.856								
Technological Self-Efficacy	0.855	0.823							
Technological Problem-Solving Engagement	0.801	0.851	0.846						
Intrinsic Motivation	0.760	0.734	0.688	0.887					
Learning Engagement	0.595	0.618	0.525	0.760	0.915				
Pedagogical Knowledge	0.715	0.725	0.701	0.794	0.811	0.849			
Content Knowledge	0.724	0.723	0.701	0.774	0.809	0.875	0.872		
Creativity	0.728	0.731	0.704	0.792	0.845	0.874	0.886	0.873	
Curiosity	0.683	0.730	0.702	0.824	0.795	0.834	0.864	0.910	0.888

Note: Diagonal values represent the square root of average variance extract (AVE), and off-diagonal values are correlations between constructs.

Table 2. Discriminant validity and correlation matrix of constructs

5.2. Structural Model Analysis

The following results illustrate the relationships among the study constructs, as assessed through structural equation modeling. The dataset in Table 3 reveals the structural relationships among key study constructs, highlighting significant pathways and effect sizes that contribute to understanding creativity and curiosity within teacher education, particularly through technological integration. Path coefficients, effect sizes, and hypothesis testing outcomes demonstrate that most proposed relationships were supported.

TA significantly influences TSE (H1), with a strong positive impact ($\beta = 0.855$, $t = 75.638$, $f^2 = 2.716$, $p < 0.001$), emphasizing the critical role of attitudes toward technology in shaping self-efficacy. Similarly, TSE strongly affects TPSE (H2), with high path significance ($\beta = 0.851$, $t = 71.741$, $f^2 = 2.617$, $p < 0.001$). However, TSE does not significantly impact CR (H3) or CU (H4), as indicated by low path coefficients and non-significant p-values.

The analysis further shows that TPSE positively impacts both CR (H5; $\beta = 0.177$, $t = 5.740$, $f^2 = 0.049$, $p < 0.001$) and CU (H6; $\beta = 0.104$, $t = 3.711$, $f^2 = 0.015$, $p < 0.001$), although with moderate effect sizes. IM emerges as a crucial factor, significantly enhancing both CR (H7; $\beta = 0.063$, $t = 2.396$, $f^2 = 0.007$, $p = 0.017$) and CU (H8; $\beta = 0.273$, $t = 7.399$, $f^2 = 0.119$, $p < 0.001$). PK and LE demonstrate robust contributions to CR (H9; $\beta = 0.357$, $t = 9.699$, $f^2 = 0.181$, $p < 0.001$; H10; $\beta = 0.396$, $t = 12.030$, $f^2 = 0.287$, $p < 0.001$) and CU (H11; $\beta = 0.184$, $t = 7.324$, $f^2 = 0.053$, $p < 0.001$), with CK similarly contributing strongly to Curiosity (H12; $\beta = 0.406$, $t = 12.470$, $f^2 = 0.211$, $p < 0.001$).

Hypothesis	β	t-value	f²	p-value	Supported
H1: Technological Attitudes → Technological Self-Efficacy	0.855	75.638	2.716	0.000*	Yes
H2: Technological Self-Efficacy → Technological Problem-Solving Engagement	0.851	71.741	2.617	0.000*	Yes
H3: Technological Self-Efficacy → Creativity	0.030	1.155	0.001	0.248	No
H4: Technological Self-Efficacy → Curiosity	0.033	0.967	0.001	0.334	No
H5: Technological Problem-Solving Engagement → Creativity	0.177	5.740	0.049	0.000*	Yes
H6: Technological Problem-Solving Engagement → Curiosity	0.104	3.711	0.015	0.000*	Yes
H7: Intrinsic Motivation → Creativity	0.063	2.396	0.007	0.017*	Yes
H8: Intrinsic Motivation → Curiosity	0.273	7.399	0.119	0.000*	Yes
H9: Pedagogical Knowledge → Creativity	0.357	9.699	0.181	0.000*	Yes
H10: Learning Engagement → Creativity	0.396	12.030	0.287	0.000*	Yes
H11: Learning Engagement → Curiosity	0.184	7.324	0.053	0.000*	Yes
H12: Content Knowledge → Curiosity	0.406	12.470	0.211	0.000*	Yes

Legend: Significance level set at $\alpha = 0.05$. Values marked with * indicate statistical significance at the 0.05 level.

Table 3. Structural model path coefficients, effect size, and hypothesis testing

Endogenous Construct	R²	Q²	Interpretation
Technological Self-Efficacy	0.731	0.730	Strong R²; Strong Predictive Relevance
Technological Problem-Solving Engagement	0.723	0.635	Moderate R²; Moderate Predictive Relevance
Creativity	0.843	0.836	Strong R²; Strong Predictive Relevance
Curiosity	0.819	0.805	Strong R²; Strong Predictive Relevance

Table 4. Coefficient of determination and predictive relevance

Notably, Table 4 provides an overview of the coefficient of determination (R^2) and predictive relevance (Q^2) values for each endogenous construct in the model, underscoring their explanatory power and predictive accuracy. TSE shows a strong R^2 value of 0.731 and a Q^2 of 0.730, indicating high explanatory power and predictive relevance. Similarly, CR and CU exhibit robust R^2 values of 0.843 and 0.819, respectively, alongside strong predictive relevance with Q^2 values of 0.836 and 0.805, highlighting their substantial variance explained by the model. TPSE has a moderate R^2 of 0.723 and a Q^2 of 0.635, reflecting a solid degree of variance explained, though at a more moderate level compared to TSE, CR, and CU. The model fit indices also support the adequacy of this structural model, with a SRMR of 0.082, indicating an acceptable fit, and a Normed Fit Index (NFI) of 0.670, which suggests reasonable model fit given the study context.

The SEM results, depicted in Figure 4, illustrate the relationships between the latent constructs and their respective observed indicators. The model demonstrates key path coefficients (β), R^2 values, and significant loadings, providing evidence of both the structural and measurement validity of the model. Each indicator showed strong factor loadings on their corresponding constructs, with values ranging from 0.794 to 0.929, supporting strong convergent validity across the model. In particular, TA showed strong relationships with TSE (β = 0.855), explaining 73.1% of its variance (R^2 = 0.731). This suggests that attitudes toward technology significantly influence self-efficacy levels among teachers. Furthermore, TSE demonstrated a high impact on TPSE (β = 0.851), which had a moderate explanatory power (R^2 = 0.723), emphasizing the critical link between self-efficacy and engagement in technological problem-solving tasks.

On the outcome side, both CR and CU displayed strong explained variance values of R^2 = 0.843 and R^2 = 0.819, respectively. This indicates that a significant portion of their variance is explained by the predictors within the model. TPSE was shown to influence both CR (β = 0.177) and CU (β = 0.104), although with moderate effect sizes. Additionally, IM and PK emerged as significant predictors, contributing to both CR and CU in various capacities, further reinforcing the importance of these variables in fostering creative and curious mindsets in teacher education.

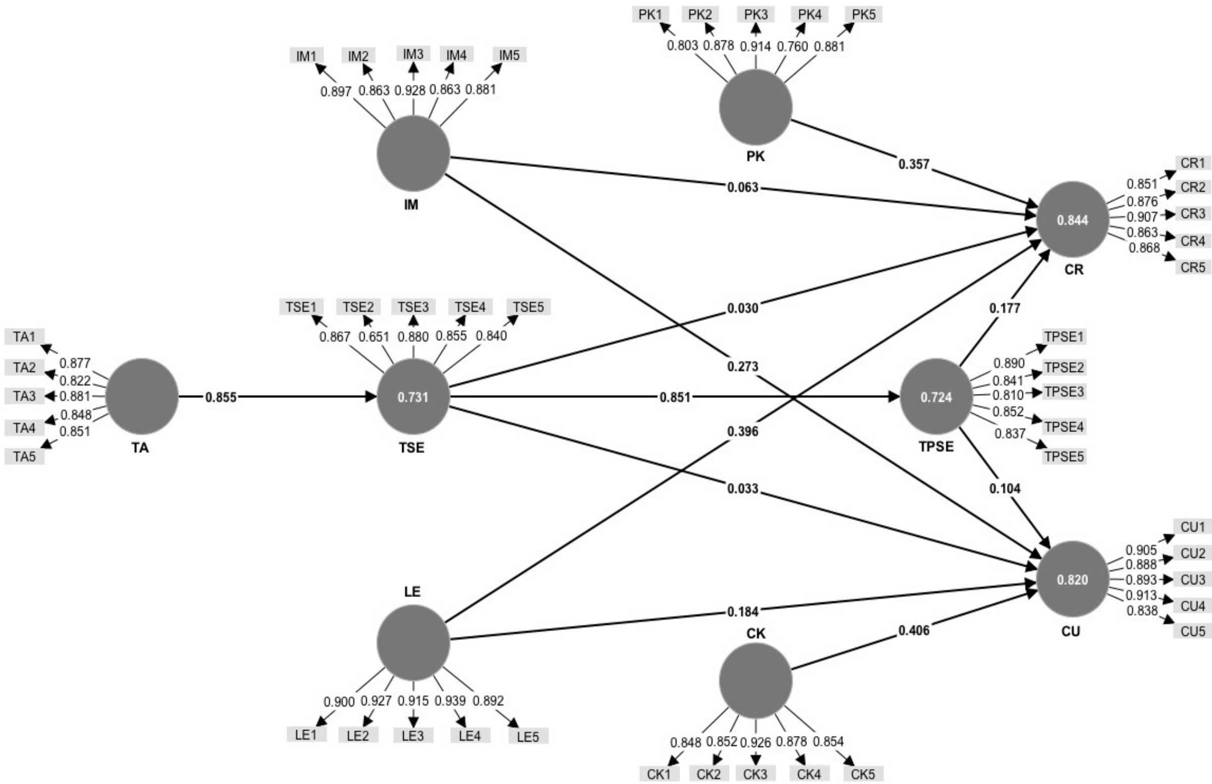

Figure 4. Path coefficients structural model

6. Discussion

This study explored the relationships between TA, TSE, TPSE, IM, LE, PK, CK, CR, and CU using PLS-SEM. The results yielded several significant insights into the complex dynamics of how educational technology, self-efficacy, and pedagogical knowledge contribute to fostering creativity and curiosity among pre-service teachers. A key finding was the strong positive effect of TA on TSE, as indicated by the high path coefficient and large effect size. This result underscores the importance of positive attitudes toward technology in enhancing pre-service teachers' confidence in their ability to use educational technologies effectively. Previous studies have similarly shown that favorable technological attitudes are pivotal in shaping educators' technological self-efficacy (Pan, 2020; Seufert, Guggemos & Sailer, 2020). For instance, Seufert et al. (2020) highlighted that educators who perceive technology positively are more likely to integrate it into their teaching practices confidently, which is consistent with the present findings.

Interestingly, while TSE had a significant impact on TPSE, it did not significantly influence CR or CU. This suggests that while self-efficacy is a crucial driver of engagement in problem-solving tasks, it does not automatically translate into enhanced creativity or curiosity among pre-service teachers. This finding indicates that developing creativity and curiosity may require more than just confidence in using technology; these traits could depend on deeper pedagogical strategies or intrinsic motivational factors that inspire exploration and innovation. This distinction highlights the necessity for teacher education programs to emphasize a holistic approach that combines TSE with robust pedagogical frameworks. By integrating structured learning experiences that foster creative thinking and curiosity, educators can create an environment where pre-service teachers feel empowered to apply their technological skills in inventive ways (Crompton & Sykora, 2021). This aligns with the insights from Yan, Lee, Hui and Lao (2022), who argued that creativity in educational contexts is often nurtured through intentional pedagogical practices rather than relying solely on technological self-efficacy, reinforcing the need for a comprehensive strategy in teacher development.

Moreover, the findings indicate that TPSE significantly influences both CR and CU, albeit with moderate effect sizes. This suggests that engaging in technological problem-solving tasks effectively fosters creative and curious dispositions among pre-service teachers. These results align with the insights of Essel, Vlachopoulos, Essuman and Amankwa (2023), who highlighted that leveraging technology for problem-solving stimulates learners to think creatively and explore innovative solutions. However, the moderate effect sizes imply that while TPSE plays a vital role in enhancing creativity and curiosity, it is likely part of a broader framework of factors that collectively contribute to these dispositions. This highlights the importance of considering additional elements such as pedagogical strategies, classroom environments, and intrinsic motivation when aiming to cultivate creativity and curiosity in future educators (Scott-Barrett et al., 2023). Therefore, teacher education programs should adopt a multifaceted approach that integrates technological engagement with diverse teaching methodologies, collaborative learning opportunities, and real-world problem-solving experiences. Such an approach can create a richer learning environment that not only enhances technological competencies but also nurtures the essential qualities of creativity and curiosity, ultimately preparing pre-service teachers for the complexities of modern educational settings (Bereczki & Kárpáti, 2021).

IM emerged as a significant predictor of both CR and CU, reinforcing its role in fostering engagement in learning activities that promote higher-order thinking skills. These findings are consistent with Deci and Ryan's (1985) self-determination theory, which posits that intrinsic motivation enhances cognitive engagement and curiosity in educational contexts. Pre-service teachers who are intrinsically motivated may be more likely to explore creative solutions and remain curious about the content they teach (Abós, Haerens, Sevil, Aelterman & García-González, 2018). PK and LE also significantly influenced both CR and CU, with high path coefficients and large effect sizes. For instance, PK had a substantial impact on CR and CU, while LE strongly affected both CR and CU. These findings align with Shulman's (1986) concept of pedagogical content knowledge, which suggests that teachers with strong pedagogical knowledge are better able to engage students and foster their creativity and curiosity. LE, in particular, seems to play a critical role in shaping creative and curious mindsets, as engaged learners are more likely to explore new ideas and think critically about the content they encounter (Acut, 2022; Li & Xue, 2023).

Notably, CK significantly influences CU, indicating that pre-service teachers with a robust understanding of their subject matter are more likely to demonstrate curious behaviors (Levanon, 2021). This finding aligns with Sternberg and Lubart's (1999) investment theory of creativity, which asserts that individuals possessing deep domain knowledge are better equipped to engage in creative thinking and innovative problem-solving. The strong correlation between CK and CU observed in this study underscores that pre-service teachers who are well-versed in their content are not only more likely to grasp complex concepts but also more inclined to explore new ideas and teaching approaches, thereby enhancing their overall effectiveness as educators (Keiler, 2018). This relationship suggests that fostering CK should be a central focus in teacher education programs, as it lays a foundation for cultivating curiosity and creativity (Fernandez, Madelo, Lu Suico, Cane, Magsayo, Capuyan et al., 2024). By integrating content mastery with opportunities for exploration and experimentation, educators can encourage pre-service teachers to adopt a mindset of lifelong learning (Matsumoto-Royo, Conget & Ramírez-Montoya, 2023). Additionally, the implications extend beyond individual development; a curious and knowledgeable teaching workforce can significantly impact student engagement and learning outcomes, ultimately contributing to a more dynamic and innovative educational environment (Singh & Manjaly, 2022).

The model's overall explanatory power was robust, with high R^2 values for key constructs such as CR ($R^2 = 0.843$) and CU ($R^2 = 0.819$). These values indicate that the model explains a substantial portion of the variance in creativity and curiosity, aligning with studies that emphasize the importance of multifaceted approaches to teacher development (Mishra & Koehler, 2006; Shulman, 1986). The significant R^2 values underscore the influence of technological engagement, pedagogical knowledge, and intrinsic motivation in shaping these outcomes, which supports findings from Fredricks et al. (2004) on the role of engagement in promoting higher-order thinking skills. Furthermore, the strong predictive relevance, highlighted by Q^2 values for CR (0.836) and CU (0.805), reinforces the model's effectiveness in forecasting creative and curious dispositions among pre-service teachers. This outcome echoes Deci and Ryan's (2000) self-determination theory, which posits that intrinsic motivation enhances cognitive engagement and curiosity. The combined impact of technological engagement and robust pedagogical strategies on these traits reflects insights from Sternberg and Lubart's (1999) investment theory, which emphasizes deep domain knowledge as essential for creative exploration. These findings stress the importance of teacher education programs adopting integrated approaches that blend technology, pedagogy, and motivation to cultivate a more dynamic and innovative learning environment. By doing so, teacher education can prepare future educators who are well-equipped to adapt and inspire creativity in diverse educational contexts (Darling-Hammond, Schachner, Wojcikiewicz & Flook, 2023).

6.1. Implications of the Study

The findings have important implications for teacher education programs. The significant relationships between TA, TSE, TPSE, IM, LE, PK, CK, CR, and CU suggest that fostering positive attitudes toward technology and building self-efficacy should be central components of teacher training curricula. By intentionally integrating modules that focus on the development of TSE and positive attitudes towards technology, teacher education programs can empower future educators to approach technological tools with confidence, thereby enhancing their ability to effectively engage students in learning (Wilson, Ritzhaupt & Cheng, 2020). Additionally, the strong role of IM, PK, and LE in driving creativity and curiosity indicates that teacher education programs should emphasize intrinsic motivation and pedagogical strategies that engage learners deeply. This can be achieved by incorporating active learning experiences, project-based assessments, and collaborative teaching methods that inspire pre-service teachers to harness their creativity and curiosity in innovative ways (Scott-Barrett et al., 2023). As creativity and curiosity are critical for 21st-century teaching and learning, integrating these factors into teacher education programs can better prepare pre-service teachers to cultivate these dispositions in their future classrooms (Fernandez et al., 2024). Furthermore, programs should provide opportunities for pre-service teachers to reflect on their teaching practices and explore how to create classroom environments that foster a culture of inquiry and exploration (Matsumoto-Royo et al., 2023; Soh, 2024). By doing so, they can help future educators not only to develop their own creative and curious mindsets but also to inspire their students to embrace these essential qualities. Ultimately, this holistic approach to teacher training can lead to a more dynamic and responsive educational landscape, where teachers are equipped to adapt to the diverse needs of their students and the challenges of an ever-evolving world.

6.2. Limitations and Future Research Works

Although this study offers valuable insights, several limitations must be considered. First, the research primarily relied on self-reported measures, which may introduce bias and affect the accuracy of the findings regarding TA, TSE, TPSE, IM, LE, PK, CK, CR, and CU. Second, the sample size was limited to a specific geographic region, which may restrict the generalizability of the results to broader populations of pre-service teachers. Additionally, while the study integrates creativity and curiosity to examine technological self-efficacy's function in teacher education, the novelty of this work is moderate due to the existing body of research on similar interactions. Previous studies have explored the individual factors of technological self-efficacy, pedagogical knowledge, and intrinsic motivation, but fewer studies have combined these factors in a way that directly links them to creativity and curiosity in the context of teacher education, particularly in the Philippine educational context. Future research could address this limitation by expanding the focus to include more diverse cultural and educational contexts, helping to test the robustness and novelty of these findings in varied settings.

Furthermore, future studies could employ a mixed-methods approach, incorporating qualitative interviews, to gain deeper insights into the factors influencing creativity and curiosity in educational contexts. Longitudinal studies could provide valuable information on how these constructs develop over time and their long-term impact on teaching practices. Expanding the research to diverse educational settings and various cultural contexts could further enhance the understanding of how TA, TSE, and pedagogical strategies intersect to foster creativity and curiosity among educators. Lastly, exploring the role of specific interventions designed to enhance intrinsic motivation and engagement could provide a clearer picture of effective strategies for cultivating these essential dispositions in teacher education programs.

7. Conclusion

In conclusion, this study contributes to the growing body of research by providing insights into the interplay between technological self-efficacy, pedagogical knowledge, and intrinsic motivation in fostering creativity and curiosity among pre-service teachers. While prior studies have explored these factors individually, this research highlights how their combined influence shapes the development of creative and curious dispositions in future educators. Although technological self-efficacy is a crucial factor, our findings suggest that its impact on creativity and curiosity is maximized when supported by pedagogical strategies and intrinsic motivation. This challenges the notion that technological self-efficacy alone can enhance creative problem-solving and emphasizes the role of comprehensive teaching practices in amplifying its effects.

Furthermore, the study underscores the importance of pedagogical and content knowledge as key drivers of creativity and curiosity, offering a fresh perspective on the essential elements that should be integrated into teacher education programs. While the study's regional focus and the use of self-reported data may limit its generalizability, it provides valuable insights into the need for a holistic, integrated approach to teacher training. This approach prepares educators to foster innovation and exploration in their future classrooms. Through Structural Equation Modeling, the research demonstrates the high explanatory power and predictive relevance of the model, highlighting the need for teacher education programs to adopt balanced strategies that integrate technological engagement, pedagogical knowledge, and intrinsic motivation to cultivate creativity and curiosity in the next generation of educators.

Declaration of Conflicting Interests

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Appendix A

Constructs of survey items and definitions of latent variables.

Construct, Definition, and Source	Code	Statement
Technological Attitudes (TA). Refers to an individual's beliefs and predispositions toward the use of technology in educational contexts. It encompasses the perceived value, usefulness, and overall acceptance of digital tools and resources in teaching (Teo, 2011).	TA1	I believe technology is an essential tool for modern teaching.
	TA2	I feel confident in my ability to integrate technology into my teaching practices.
	TA3	Technology improves my students' engagement and learning outcomes.
	TA4	I am open to experimenting with new digital tools in the classroom.
	TA5	I see technology as a valuable asset for instructional innovation.
Technological Self-Efficacy (TSE). Describes an individual's confidence in their ability to effectively use technology for teaching, learning, and problem-solving. It reflects the perceived capability to integrate and manage digital tools in educational practices (Compeau & Higgins, 1995).	TSE1	I can effectively use technology to enhance student learning.
	TSE2	I feel confident troubleshooting technological problems that arise during lessons.
	TSE3	I am comfortable learning new educational software or digital tools.
	TSE4	I can adapt my lesson plans to include new technologies as needed.
	TSE5	I am capable of using technology to create interactive and engaging lessons.
Technological Problem-Solving Engagement (TPSE). Refers to the active involvement of educators in using technology to address and solve instructional challenges. It highlights the creative and innovative application of technological tools to enhance teaching strategies (Mishra & Koehler, 2006).	TPSE1	I actively seek out technological solutions to address instructional challenges.
	TPSE2	I enjoy experimenting with technology to solve teaching problems.
	TPSE3	I often use digital tools to develop creative solutions in my lessons.
	TPSE4	I feel motivated to explore new technologies when faced with teaching difficulties.
	TPSE5	I use technology to improve my instructional methods and problem-solving abilities.
Intrinsic Motivation (IM). The internal drive to engage in activities for personal satisfaction and enjoyment rather than external rewards. In an educational context, it motivates teachers to innovate and create meaningful learning experiences (Deci & Ryan, 2000).	IM1	I enjoy teaching because I find it personally rewarding.
	IM2	I feel motivated to create new teaching methods without the need for external rewards.
	IM3	I teach because I find the process of helping students learn inherently satisfying.
	IM4	I am driven to improve my teaching skills for personal fulfillment, not for recognition.
	IM5	I engage in teaching activities because I truly enjoy the process.

Construct, Definition, and Source	Code	Statement
Learning Engagement (LE). Refers to the strategies and practices that a pre-service teacher implements to foster active participation, curiosity, and commitment among students during learning activities (Fredricks et al., 2004).	LE1	I actively involve my students in the learning process during my lessons.
	LE2	I design activities that encourage my students to engage deeply with the material.
	LE3	I observe high levels of participation and curiosity during my classroom discussions.
	LE4	I create a learning environment where my students are willing to explore new ideas and concepts.
	LE5	My teaching practices foster a sense of commitment and motivation among my students.
Pedagogical Knowledge (PK). Refers to the understanding and mastery of teaching methods and instructional strategies. It includes knowledge of how students learn, classroom management, assessment practices, and curriculum development (Shulman, 1987).	PK1	I can adapt my teaching strategies to meet the diverse needs of my students.
	PK2	I feel confident in using a variety of instructional methods to enhance student learning.
	PK3	I understand how to structure lessons to promote student understanding and engagement.
	PK4	I am skilled in developing assessments that accurately measure student progress.
	PK5	I can manage classroom behavior in a way that supports student learning.
Content Knowledge (CK). Denotes a teacher's mastery of the subject matter they teach. It involves a deep understanding of the key concepts, theories, and practices within a specific academic discipline (Grossman, 1990).	CK1	I have a deep understanding of the subjects I teach.
	CK2	I feel confident answering student questions about my subject matter.
	CK3	I can explain complex concepts in my content area in a way that students understand.
	CK4	I regularly update my content knowledge to stay informed about new developments in my field.
	CK5	I feel equipped to teach the content that is required in my subject area.
Creativity (CR). Involves the ability to generate novel and valuable ideas or solutions in the classroom. Creative teachers use innovative approaches to foster student learning, encouraging original thinking and problem-solving (Sternberg & Lubart, 1996).	CR1	I frequently develop new and original ideas for my lesson plans.
	CR2	I encourage my students to think outside the box when solving problems.
	CR3	I often use creative approaches to make learning more engaging for students.
	CR4	I believe creativity is a key component of successful teaching.
	CR5	I regularly find innovative ways to deliver educational content.
Curiosity (CU). Reflects the desire to explore, investigate, and learn new things. In education, it drives both teachers and students to seek out knowledge, ask questions, and maintain a mindset of continuous learning and discovery (Kashdan & Steger, 2007).	CU1	I enjoy exploring new ideas and concepts in my teaching practice.
	CU2	I encourage my students to ask questions and investigate unfamiliar topics.
	CU3	I am constantly seeking new knowledge to improve my teaching.
	CU4	I create a classroom environment that fosters inquiry and exploration.
	CU5	I am curious about how new technologies can enhance my teaching methods.

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