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Teacher pedagogical knowledge on technology-enhanced mathematical creativity

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Abstract: This study aims to examine the extent to which junior high school teachers' pedagogical and technological knowledge, as well as their ability to integrate technology, influence the development of students' mathematical creativity. Technology integration is positioned as an intervening variable connecting teachers' knowledge with students' creative thinking. A quantitative research design was employed, utilizing Structural Equation Modeling–Partial Least Squares (SEM-PLS) to analyze the relationships among five latent variables. Data were collected through a 54-item questionnaire administered to 128 junior high school mathematics teachers, selected purposively from three school districts in East Java, Indonesia. The results show that teachers' pedagogical skills are positively influenced by technology integration ($\beta = 0.198$), suggesting that integrating technology can enhance pedagogical practices and promote students' mathematical creativity. The study concludes that teachers who are competent in integrating technology are more capable of designing meaningful learning activities that foster creative thinking. The practical implication is that professional development programs should not only strengthen teachers' pedagogical competence but also provide training on how to effectively integrate technology into classroom practices to support mathematical creativity.

Keywords: *Knowledge of technology integration, Mathematical creativity, Teacher conception, Teacher pedagogical skills, Teacher technological knowledge.*

1. Introduction

In this industrial era 4.0, integrating technology into classroom practice is a new way to change pedagogy [1, 2]. Several factors can influence the integration of technology into the teaching and learning process, including the teachers' use of technology, the availability of technology, the students' use of technology, the student's attitude toward technology, and the overall effectiveness of the instructional process implemented by the teachers [3-5]. Regarding teacher competence in the use of technology, many findings show many mathematics teachers are still not mastered to convey of mathematical principles so they still not confident when integrating technology in learning process [6, 7]. The claim supports this finding that while sufficient technology is available in schools, many teachers lack the requisite knowledge to integrate it effectively into their learning process [8, 9]. It shows that many mathematics teachers are still have limited proficiency on utilizing technology for teaching mathematics [10].

Teacher pedagogical knowledge determines teacher quality and influences student achievement [11]. In classroom learning, teachers, with their knowledge and actions, are required to manage learning, explore the subject matter, and utilize the assessment of learning outcomes obtained from their

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pedagogic competencies Siswono, et al. [12]. Hollebrands and Okumuş [13] stated that if the teacher has good pedagogical competence, then the teacher can understanding what is required of students during the learning process, as well as the type of material and resources that will be conveyed to them by their cognitive development, knows how to convey material to their students as well as having many teaching models and good communication with students. With these pedagogic abilities, it is hoped that it will affect the learning output carried out.

Creativity is one of the essential skills that must be developed in education, especially in an era that is increasingly influenced by technology [14]. The education curriculum in Indonesia, including the Merdeka Curriculum, has emphasized the importance of developing creativity to prepare students to face future challenges [15-17]. The curriculum that is implemented, such as the Merdeka Curriculum, has emphasized the importance of creativity, but its implementation is often not in accordance with expectations so in practice, students' creative thinking skills, especially in mathematics, are still relatively low [18]. However, the success of technology integration in learning is highly dependent on various factors, including the teacher's ability to use technology, the teacher's knowledge of creative thinking, the teacher's pedagogical skills, and the teacher's ability to integrate technology with learning strategies that enhance students' creative thinking [19, 20]. Although technology has great potential to support creative learning, the teacher's ability to manage and integrate technology effectively is the main key. Therefore, the research aims to identify which factors of junior high school teacher knowledge about technology have the significant influence on the development of students' creative thinking skills in mathematics is very important. This research question can help determine the most effective interventions and training for teachers, so that the use of technology can be maximized to enhance students' creativity in mathematics learning.

1.1. Technological Knowledge

Technological knowledge is knowledge about technology used for processing any information, communication and application in a more productive and effective daily life. According to Raveh, et al. [21] this technological knowledge discusses how to use various types of technology effectively. Technology knowledge covers a broad spectrum of understanding in the ever-evolving landscape of hardware, software, networks and new technologies. This includes familiarity with computer components, programming languages, internet technologies, artificial intelligence, augmented reality, robotics, etc [22].This knowledge empowers individuals and professionals to navigate, leverage, and contribute to the advances shaping the digital era, driving innovation, efficiency, and transformative solutions across industries. Technological knowledge is related to understanding and applying edutech, understanding how to apply technology in various lessons, understanding whether it will enhance or obstruct learning process, and continuing to learn with new technology [23, 24].

1.2. Teacher Conception of Mathematical Creativity

The teacher's view of the concept of mathematical creative thinking in class is still not following its actual concept, which can affect the teacher's performance in carrying out learning that supports students' creative thinking [25]. Creativity is the ability of the mind and spirit that enables us to create, as if from nothing, something useful, orderly, beautiful or meaningful. Creativity is defined as putting something in a new way, building something new, unusual or conventional, using images that still work to create interesting things [26]. Furthermore, mathematical creative thinking refers to the general definition of creative thinking, namely creative thinking is defined as mental activities carried out by someone to generate new ideas or ideas by meeting the indicators of fluency, flexibility and novelty [27]. Mathematical creative thinking includes skills for solving mathematical problems and evaluating students' conceptual ideas [28]. Mathematical creative thinking is related to problem solving and understanding new relationships through divergent and convergent thinking to generate new ideas in problem solving [29].

Teachers' conceptions of students' mathematical creativity have a significant influence on the learning process and enhancement of students' creative thinking skills [30, 31]. Teachers who have a positive view and high appreciation of creativity in mathematics tend to be more open to implementing innovative and challenging learning methods [32, 33]. In this context, the role of teachers becomes very crucial, especially in planning, implementing, and assessing learning that not only focuses on logical and analytical thinking skills but also encourages students to think outside the box. Teachers need to design learning experiences that create opportunities for students to generate new ideas, explore various approaches to solving problems, and take risks in their thinking processes. In addition, assessments of students' reasoning skills must include aspects of creativity, such as originality, mistakes, and the ability to produce unconventional solutions. Thus, teachers' views on mathematical creativity not only influence the way they teach but also how they support and assess the development of students' creative thinking skills [34]. Teachers who recognize the importance of creativity will make more of an effort to create a learning environment that encourage the exploration of ideas, thereby enabling students to develop the creative thinking skills that are essential in mathematics and everyday life [35-37].

Teachers can assess students' creative thinking abilities through a combination of strategies that emphasize originality, critical thinking, and problem solving. This approach includes asking open-ended questions to encourage unique perspectives, providing project-based assessments that require in-depth exploration and innovation [38]. In addition, teachers can utilize technology to assess students' creative thinking abilities by integrating digital tools [39] and platforms into the assessment process [40]. Online collaboration tools, such as Google Workspace, geogebra, worksheets, and augmented reality (AR) applications can facilitate collaborative projects where students can brainstorm collectively, share ideas, and co-create solutions innovative. Adaptive learning platforms can provide personalized challenges to students, encouraging creative thinking by tailoring content to individual needs [41]. However, the obstacles experienced by teachers can be caused by obstacles in accessing the internet or limited experience and ability to use technology effectively and flexibly. Furthermore, prospective teachers' concept of creativity is still limited to student activities in solving contextual problems, and teaching experience using various models can affect characteristics of creative prospective teachers [42, 43]. Barriers experienced by teachers could be due to obstacles to accessing the internet or limited experience and ability to use technology effectively and flexibly.

2. Literature Review

2.1. Integration technological Knowledge

Technology integration is the collaboration of technology and the use of technology in daily life. The utilization of technology in the educational process is known as technology integration, and how teachers utilize technology for more effective and productive activities and how the use of technology integration can change those activities [44]. There are also those who define the integration of technology in a way that a teacher uses it to enhance student thinking skills [45]. Furthermore, teaching all material using technology does not mean being able to integrate technology effectively [46] but utilizing technology provides students the chance to work collaboratively and enhance their knowledge as well as foster innovative learning styles. In addition, for integration to be successful, integration must be carried out routinely, smoothly, and efficiently and effectively in supporting integration. Integration is related to the appropriate use of the technology used [47].

Integrating technology into education means using technology to achieve learning goals [48]. The integration of technology in education can work if teachers have an understanding of technology and are trained in the appropriate application of technology and routinely use technology in learning. When given access to the appropriate tools and applications, technology may revolutionize education and provide learners for success in the global era [49]. So that implementation integration technology in early education will also aim to enhance knowledge and competence [7].

So that, Technological knowledge integration refers to the process of effectively combining diverse technological elements, such as hardware, software, networks, and practices, into a cohesive and integrated system that aims to improve functionality, efficiency, and collaboration in various contexts, such as education, and how to utilize technology for more effective and productive activities.

2.2. Integration technological Knowledge to Enhance Mathematical Creativity

Integration of Technological Knowledge to Increase Mathematical Creativity is basically a learning model that aims to provide concrete learning experiences using technology to find various kinds of solutions to mathematical problems with fluency, flexibility, and originality [50]. Research shows that the use of technology in education process can enhance students' thinking skills and reasoning skills which has implications for enhancing students' creative thinking skills [51]. This knowledge also has particular relevance to mathematics teaching and learning, according to Attard, et al. [52] the more and more precise technology that is integrated into mathematics learning can change the complexity of mathematics [53]. This learning experience can enhance the ability of student creative thinking skills in mathematical problem-solving. Technology allows students to generate new ideas that can help them produce creative solutions [54, 55].

Mathematical creativity is enhanced and developed when students use technology to (a) understand mathematical principal and mathematization; (b) engage with mathematics in social life; (c) employ a variety of connections and representations to enhance of mathematical concepts; (d) solve mathematical problems in various ways [56]. Various technologies such as virtual applications or augmented reality [57] mean content can be presented in a variety of ways so that students have many opportunities to learn mathematics and produce new ways of solving mathematical problems using technology.

2.3. Teachers' Pedagogical Skills in Utilizing Technology

Teachers' pedagogical skills in utilizing technology are the ability to integrate technology in teaching creative content (mathematics) to develop students' creative thinking abilities [1]. The use of digital technology by teachers for certain pedagogical activities not only shows slides but also the teacher's ability to invite students to solve mathematical problems using technology [58]. Modern teachers need to have knowledge about integrating technology into classroom practices to enhance the teaching and learning process [59]. Furthermore, modern teachers are required to have knowledge of appropriate integration technology to enhance the teaching and learning process in the classroom [60, 61]. Technological knowledge represents teachers' technological skills. According to Salas-Rueda [62] the successful use of integrated technological devices in effective and productive learning requires teachers to improve pedagogical and technological skills. The performance of students is affect by the role teachers. Teacher knowledge has a crusial role in technology integration. Teachers' experience with integration technology is critical to successful integration of technology in mathematics teaching and learning [63]. They must be aware of the appropriateness of technology applications to carry out tasks within affordances and limitations Raveh, et al. [21]. Raveh, et al. [21] proposed the theoretical framework of Technological, Pedagogical, and Content Knowledge (TPACK), which in the context of mathematics education, consist of mathematical, technological, and pedagogical knowledge. This concept is closely related to teachers' knowledge of integrating technology in mathematics learning. Mathematics learning and teaching that integrates technology produces a way of thinking with technology designed by teachers trough instructional media, so that the technology put forward influences the exploration of problems visually, numerically and experimentally [64]. Teachers can make tactical and strategic decisions in developing plans to reach solutions, which demonstrates how crucial metacognitive control are while using technology to solve mathematical problems [65]. Teachers who have beliefs and apply technology to enhance creativity show that teachers can utilize the role of technology in increasing creativity.

Furthermore, Teachers' perspectives on technology integration are not only about the use of technology, but also their knowledge about how and why the technology is used [66]. Knowledge to guide the use of technological tools in mathematics learning to be able to determine problem solving approaches and conceptual modes that are appropriate to the integration of the technology used [67].

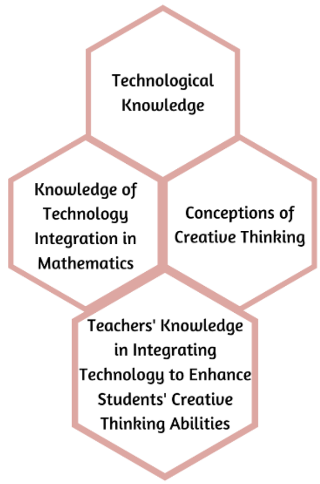

Figure 1.
The Conceptual Framework.

The key intention behind the conception of this model is the articulation of research regarding technological knowledge, knowledge of the integration of technology in mathematics, and conceptions of creative thinking according to teachers which can influence teachers' knowledge in integrating technology to enhance students' creative thinking abilities. Technological knowledge in an educational context becomes the basis for teachers to build innovative and effective learning strategies. A teacher's proficiency in a variety of technologies with the tools to integrate technological knowledge into their teaching and learning process. This integration involves strategically combining technology to enhance learning experiences that engage students.

The effectiveness of the integration of technological knowledge depends on the teacher's ability to utilize pedagogical skills to create meaningful learning experiences. Technological knowledge and teachers' conceptions of mathematical creativity are very important in shaping the learning landscape. Teachers' beliefs and perceptions about mathematical creativity influence how they utilize technology to improve their students' mathematical creative thinking abilities. Integration of technological knowledge to enhance mathematical creativity involves the judicious use of digital tools and resources to encourage problem solving, critical thinking, and exploration of mathematical concepts. Teachers who are equipped with an understanding of technology and a conception of mathematical creativity can design activities that inspire students to think creatively, collaborate, and face mathematical challenges with innovative and new solutions.

This includes designing technology-enhanced learning, managing classroom dynamics, and implementing assessment strategies that align with the goal of enhancing mathematical creativity. The synergy between technological knowledge, pedagogical skills, and teachers' conceptions of mathematical creativity is essential in cultivating a dynamic and responsive educational environment where technology becomes a catalyst to inspire and foster students' creative thinking in mathematics.

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3. Research Method

3.1. Research Design

This study utilizes a quantitative survey design to explore the relationships between variables that influence teachers' skills. Data was collected through a survey completed by junior high school mathematics teachers.

3.2. Sample

This study involved 128 junior high school mathematics teachers from three cities in East Java, Indonesia: Mojokerto, Gresik, and Sidoarjo. The sample was selected to provide a representative understanding of teachers' knowledge and professional skills in integrating technology into their teaching.

3.3. Instument and Data Collection

The data collection technique in this study was in the form of an online questionnaire using Google Forms. The questionnaire was constructed by a sub-questionnaire of technological knowledge, knowledge of creative thinking abilities, technology integration, technology integration to improve students' creative thinking, and teacher pedagogical skill. The questionnaire was arranged in the form of positive statements followed by five responses indicating the level of answers for each statement item using a Likert scale. Technology knowledge instrument (A) was measured by 6 (six) items, technology integration (B) by 12 (twelve) items, knowledge of creative thinking skills (C) by 12 (twelve) items, technology integration for improving students' creative thinking (D) by 16 (sixteen) items, and the teacher's pedagogical skill (E) by 8 (eight) items. The instrument had gone through the process of validity and reliability tests, resulting in a valid and reliable one with a coefficient value of 0.60.

3.4. Data Analysis

This research uses the SEM – PLS (Structural Equation Modeling – Partial Least Square) model. When the sample size is minimal, PLS, a non-parametric approach, is utilized for theory confirmation [68]. The justification for using SEM-PLS is based on its ability to handle small sample sizes and its flexibility in testing complex relationships between variables [69], which is highly relevant to the objectives of this study. The sample size for this study is 128, this is a sufficient size for PLS-SEM (structural equation modeling), which consists both of a measurement and structural model. This is the rationale behind employing PLS-SEM [70]. We evaluated internal reliability, indicator reliability, discriminant validity, and convergent validity with the aim to determine the measurement model's outcomes. Endogenous variables and exogenous latent variables are the two categories of measurement models.

Table 1.
Variables Studied, Types of Variables, and Items Compiled.

No.	Variable	Variable Type	Code	Items
1	Knowledge of technology	exogenous variable	A	6
2	Knowledge of technology integration in learning	exogenous variable	B	12
3	Knowledge of creative thinking	exogenous variable	C	12
4	Knowledge of technology integration in learning to improve students' creative thinking	endogenous variable	D	16
5	Knowledge of pedagogical skill	endogenous variable	E	8

This research examines five variables, namely 3 exogenous variables and 2 endogenous variables. Exogenous variables are technological knowledge, knowledge of technology integration in learning, knowledge of creative thinking. Meanwhile, the exogenous variable is knowledge of technology integration in learning to improve students' creative thinking and teachers' pedagogical skills. Researchers developed an instrument in the form of a questionnaire to measure the construct of each

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variable based on theoretical studies. Details of the number of items for each variable are presented in Table 1.

3.5. Hypotheses

The alternative hypotheses of this study are:

H_1: Knowledge of technology (A) affects Knowledge of technology integration to improve students' creative thinking (D)

H_2: Knowledge of technology (A) affects teacher pedagogical skills (E)

H_3: Knowledge of technology integration (B) affects Knowledge of technology integration to improve students' creative thinking (D)

H_4: Knowledge of technology integration (B) affects teacher pedagogical skills (E)

H_5: Knowledge of creative thinking (C) affects Knowledge of technology integration to improve students' creative thinking (D)

H_6: Knowledge of creative thinking (C) affects teacher pedagogical skills (E)

H_7: Knowledge of technology integration to improve students' creative thinking (D) affects Teacher pedagogical skills (E)

H_8: Knowledge of technology (A), Knowledge of technology integration (B), Knowledge of creative thinking (C) affects teacher pedagogical skills (E) through Knowledge of technology integration to improve students' creative thinking (D)

4. Analysis and Discussion

4.1. Measurement Model

The preliminary stage of SEM-PLS is a reflective measurement model using confirmatory factor analysis. This analysis aims to assess the quality of the instruments used in data collection. Assessment is carried out through data collected in the field to confirm whether the statement items in an instrument are related to a variable construct being measured. This research involved five variables, so tests were carried out on these variables. The test results on the measurement model are presented in Figure 3. Figure 3 shows the statement items that have been confirmed as suitable for measuring the construct of the related variable. In the technological knowledge variable, 1 item was deleted and 5 items remained, the technology integration variable in learning was deleted 7 items and 5 items remained, the creative thinking variable was deleted 8 items and 4 items remained, the technology variable in learning to improve students' creative thinking was deleted and 9 items remained 7 items, as well as the variable teacher pedagogical knowledge, 3 items were deleted and 5 items remained. The deletion criteria are seen from the outer loading which is below 0.6, so that construct validity and reliability are met (Table 2) as well as discriminant validity (Tables 3, 4, and 5). The validity and reliability of the construct are seen from the Cronbach's alpha, Composite reliability (rho_a), Composite reliability (rho_c), and Average variance extracted (AVE) values. Meanwhile, discriminant validity is seen from the Heterotrait-Monotrait (HTMT) Ratio, Fornell-Larcker Criterion, and Cross Loading values.

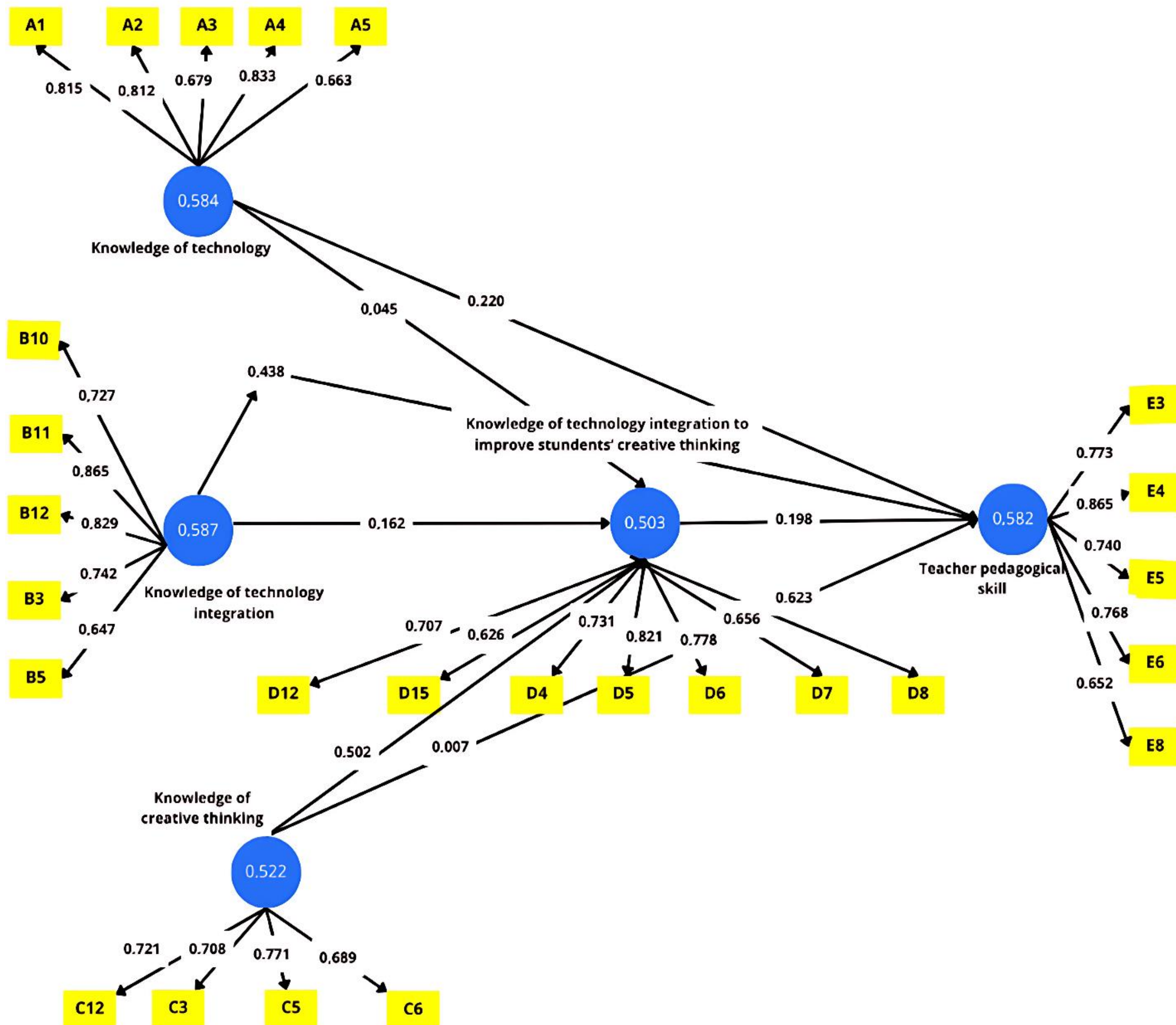

Figure 2.
Measurement Model.

Table 2.
Construct Reliability and Validity.

Variable	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Knowledge of creative thinking	0.696	0.700	0.814	0.522
Knowledge of technology	0.825	0.860	0.874	0.584
Knowledge of technology integration	0.820	0.819	0.875	0.587
Teacher pedagogical skill	0.818	0.827	0.873	0.582
Knowledge of technology integration to improve students' creative thinking	0.835	0.847	0.875	0.503

The composite reliability and Cronbach's alpha scores show how reliable the indicator is. An indicator is considered consistent in measuring a variable if either the composite reliability and Cronbach's alpha values are higher than 0.6. Table 2 results indicate that all variables are consistent or

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reliable in their measurements because either the composite reliability and Cronbach's alpha values are higher than 0.6.

Table 3.
Discriminant Validity – Heterotrait-Monotrait (HTMT) Ratio.

	Knowledge of creative thinking	**Knowledge of technology**	**Knowledge of technology integration**	**Teacher pedagogical skill**	**Knowledge of technology integration to improve students' creative thinking**
Knowledge of creative thinking					
Knowledge of technology	0.196				
Knowledge of technology integration	0.243	0.560			
Teacher pedagogical skill	0.283	0.508	0.703		
Knowledge of technology integration to improve students' creative thinking	0.674	0.186	0.319	0.408	

Discriminant validity between the two reflecting constructs has been established if the HTMT value is less than 0.90, indicating that discriminant validity has been satisfied and is acceptable.

Table 4.
Discriminant Validity – Fornell-Larcker Criterion.

	Knowledge of creative thinking	**Knowledge of technology**	**Knowledge of technology integration**	**Teacher pedagogical skill**	**knowledge of technology integration to improve students' creative thinking**
Knowledge of creative thinking	0.723				
Knowledge of technology	0.096	0.764			
Knowledge of technology integration	0.181	0.454	0.766		
Teacher pedagogical skill	0.213	0.453	0.593	0.763	
knowledge of technology integration to improve students' creative thinking	0.536	0.166	0.273	0.358	0.709

Based on the Fornell-Larcker Criterion measurement results, the square root Average Variance Extracted (AVE) on teacher pedagogical skills (0.763) is greater than the correlation value of teacher pedagogical skills with knowledge of technology integration to improve students' creative thinking (0.358), then the square root value The AVE for each indicator is greater than the square root correlation value with the others. Based on this data, it shows that the discriminant validity value requirements have been met and are acceptable

Table 5.
Discriminant Validity – Cross Loading.

Item	Knowledge of technology (A)	Knowledge of technology integration (B)	Knowledge of creative thinking (C)	knowledge of technology integration to improve students' creative thinking (D)	Teacher pedagogical skill (E)
A1	0.815	0.35	0.004	0.12	0.43
A2	0.812	0.375	0.101	0.15	0.409
A3	0.679	0.306	-0.054	0.101	0.244
A4	0.833	0.344	0.179	0.16	0.369
A5	0.663	0.417	0.144	0.082	0.16
B10	0.339	0.727	0.166	0.182	0.447
B11	0.316	0.865	0.086	0.169	0.499
B12	0.245	0.829	0.127	0.121	0.443
B3	0.292	0.742	0.188	0.296	0.394
B5	0.514	0.647	0.128	0.263	0.467
C12	0.133	0.144	0.721	0.397	0.244
C3	-0.019	0.14	0.708	0.409	0.078
C5	0.107	0.11	0.771	0.409	0.165
C6	0.041	0.129	0.689	0.324	0.112
D12	0.111	0.107	0.447	0.707	0.316
D15	0.243	0.294	0.358	0.626	0.236
D4	0.073	0.147	0.414	0.731	0.246
D5	0.124	0.215	0.436	0.821	0.295
D6	0.158	0.269	0.412	0.778	0.303
D7	0.047	0.114	0.274	0.656	0.192
D8	-0.026	0.175	0.226	0.623	0.103
E3	0.324	0.321	0.19	0.35	0.773
E4	0.332	0.509	0.202	0.394	0.865
E5	0.299	0.33	0.037	0.206	0.74
E6	0.349	0.546	0.2	0.212	0.768
E8	0.407	0.497	0.146	0.184	0.652

All of the outer loading values of the indicators on the correlated constructs are greater than the cross-loading values on the other constructs, according to the cross-loading test results. All of the constructs have strong discriminant validity, it may be determined.

4.2. Structural Model

The second stage of SEM – PLS (Structural Equation Modeling – Partial Least Square) is the structural model used to test the significance of the paths in the modeling. Before testing the structural model, there are assumptions that must be met, namely that there are no multicollinearity problems. A phenomenon known as multicollinearity occurs when two or more independent variables or exogenous constructs have a high correlation with one another, which impairs the predictive power of the model [71].

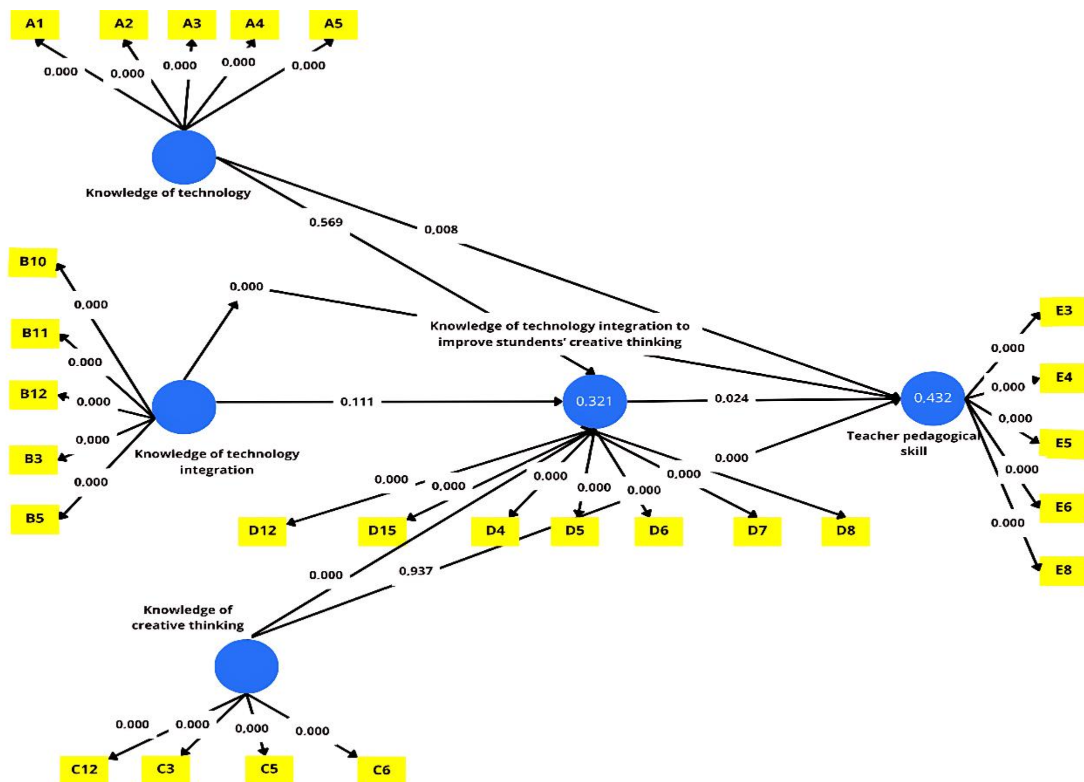

Figure 4.
Structural Model.

Table 6.
Collinearity Statistics Inner Model – Variance Inflation Factor (VIF).

Relationship Between Variables	VIF
Knowledge of creative thinking -> Knowledge of technology integration to improve students' creative thinking	1.034
Knowledge of creative thinking -> Teacher pedagogical skill	1.405
Knowledge of technology -> Knowledge of technology integration to improve students' creative thinking	1.26
Knowledge of technology -> Teacher pedagogical skill	1.263
Knowledge of technology integration to improve students' creative thinking -> Teacher pedagogical skill	1.472
Knowledge of technology integration -> Knowledge of technology integration to improve students' creative thinking	1.291
Knowledge of technology_integration -> Teacher pedagogical_abilities	1.329

To assess collinearity, the Variance Inflation Factor (VIF) was utilized. Less than five is the required VIF score, as five or more suggests that there may be collinearity problems between the constructs [72]. The statistics test used a significance level of 5%, so the t-table value is 1.76. H0 is rejected if the statistic > t-table or if p-value < $\alpha = 5\%$. The results of hypothesis testing were obtained in Table 3.

Table 7.
Path Coefficient (Direct Effect) and Significance Test.

No	Track	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
1	Knowledge of creative thinking (C) -> Knowledge of technology integration to improve students' creative thinking (D)	0.502	0.516	0.084	6.001	0.000
2	Knowledge of creative thinking (C) -> Teacher pedagogical skill (E)	0.007	0.017	0.086	0.079	0.937
3	Knowledge of technology (A) -> Knowledge of technology integration to improve students' creative thinking (D)	0.045	0.046	0.078	0.57	0.569
4	Knowledge of technology (A) -> Teacher pedagogical skill (E)	0.22	0.225	0.083	2.643	0.008
5	Knowledge of technology integration to improve students' creative thinking (D) -> Teacher pedagogical skill (E)	0.198	0.197	0.088	2.26	0.024
6	Knowledge of technology integration (B) -> Knowledge of technology integration to improve students' creative thinking (D)	0.162	0.169	0.102	1.594	0.111
7	Knowledge of technology integration (B) -> Teacher pedagogical skill (E)	0.438	0.442	0.101	4.337	0.000

The values of the path coefficients range from -1 to +1. The higher the correlation between the two constructs, the closer the value is to +1. A connection is regarded as negative when its value is closer to -1 [72]. The variable D has a positive influence on E, as indicated by the parameter coefficient of 0.198 for D on E. Alternatively, it might mean that E will increase according to the value of D. Based on the data, the p value is 0.024<0.05 so accept H1 or which means the direct effects of knowledge of technology integration to improve students' creative thinking (D) on teacher pedagogical skill (E) is meaningful or statistically significant. This also applies to other variables, if the p value <0.05 then accept H1 which means the direct effect is meaningful or statistically significant. If the p value is > 0.05 then accept H0 which means the direct effect is not meaningful or not statistically significant.

Table 8.
Indirect Effects and Significance Test.

No	Track	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
1	Knowledge of creative thinking (C) -> Knowledge of technology integration to improve students' creative thinking (D) -> Teacher pedagogical skill (E)	0.099	0.101	0.047	2.114	0.035
2	Knowledge of technology integration (B) -> Knowledge of technology integration to improve students' creative thinking (D) -> Teacher pedagogical skill (E)	0.032	0.035	0.028	1.15	0.25
3	Knowledge of technology (A) -> Knowledge of technology integration to improve students' creative thinking (D) -> Teacher pedagogical skill (E)	0.009	0.009	0.018	0.503	0.615

The parameter coefficient for the variable C on E through D is 0.099, which means there is a positive indirect influence of C on E through D. Based on the data, the p value is 0.035 <0.05 so that accepting H1 or which means the indirect influence of knowledge of creative thinking (C) on teacher pedagogical skill (E) through knowledge of technology integration to improve students' creative thinking (D) is meaningful or statistically significant. The assertion that Knowledge of creative thinking (C) affects Teacher pedagogical skill (E) through Knowledge of technology integration to improve students' creative thinking (D) implies a hypothetical pathway in which a teacher's understanding of creative thinking influences their pedagogical skills indirectly, mediated by their knowledge of technology integration and its impact on students' creative thinking.

This is also applicable to the other variables, if the p value < 0.05 then accept H1 which means the indirect effect is meaningful or statistically significant. If the p value is > 0.05 then accept H0 which means the indirect effect is not meaningful or not statistically significant. The lack of a significant effect from knowledge of technology integration (B) to Teacher pedagogical skill (E) through Knowledge of technology integration to improve students' creative thinking (D) may be influenced by several factors. One possible explanation is that the knowledge of technology integration held by teachers (B) might not be directly linked to the development of teacher pedagogical skills (E). It's conceivable that teachers possess technological knowledge but do not necessarily apply it in ways that directly improve their overall pedagogical skills. Additionally, the connection between Knowledge of technology integration (B) and Teacher pedagogical skill (E) may be more complex and indirect, involving other mediating factors not considered in the current model. This also applies to lack of a significant effect from knowledge of technology (A) to teacher pedagogical skill (E) through Knowledge of technology integration to improve students' creative thinking (D).

Table 9.
Total Effect and Test of Significance.

No	Jalur	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
1	Knowledge of creative thinking (C) -> Knowledge of technology integration to improve students' creative thinking (D)	0.502	0.516	0.084	6.001	0
2	Knowledge of creative thinking (C) -> Teacher pedagogical skill (E)	0.106	0.117	0.078	1.365	0.172
3	Knowledge of technology (A) -> Knowledge of technology integration to improve students' creative thinking (D)	0.045	0.046	0.078	0.57	0.569
4	Knowledge of technology (A) -> Teacher pedagogical skill (E)	0.229	0.234	0.086	2.673	0.008
5	Knowledge of technology integration to improve students' creative thinking (D) -> Teacher pedagogical skill (E)	0.198	0.197	0.088	2.26	0.024
6	Knowledge of technology integration (B) -> Knowledge of technology integration to improve students' creative thinking (D)	0.162	0.169	0.102	1.594	0.111
7	Knowledge of technology integration (B) -> Teacher pedagogical skill (E)	0.47	0.477	0.087	5.402	0

Based on the data, if the p value is <0.05 then accept H1 or which means the total influence between constructs is meaningful or statistically significant. So, the effect of C and D, A and E, D and E, B and E is meaningful or statistically significant

Table 10.
Contribution of exogenous variables to endogenous variables.

No	Variabel Endogen	R-square	R-square adjusted
1	Teacher pedagogical skill (D)	0.432	0.413
2	knowledge of technology integration to improve students' creative thinking (E)	0.321	0.304

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The P value of R Square's and R-square adjusted simultaneous influence on D and E is moderate. According to Chin [68], If the R-Square value is greater than 0.67, it is considered strong; if it is greater than 0.33 but less than 0.67, it is considered moderate; and if it is greater than 0.19 but less than 0.33, it is considered weak. So it can be concluded that the simultaneous influence of constructs A, B, C on D based on the probability that R Square have an influence of 43.2% and the simultaneous influence of constructs A, B, C, D on E based on the probability that R Square have an influence of 32.1%.

Based on the p value in the F Square table image above, we can see that the p value of F Square is <0.05. So it means that all F Square values are significant or accept H1. These results provide the conclusion that there is a relationship between constructs. Based on the data, constructs C and D have a value of 0.359 so it can be concluded that C has a strong influence on D.

Table 11.
f-square.

No	Variable	Knowledge of creative thinking (C)	Knowledge of technology (A)	Knowledge of technology integration to improve students' creative thinking (D)	Knowledge of technology integration (B)	Teacher pedagogical skill (E)
1	Knowledge of creative thinking (C)			0.359		0.000
2	Knowledge of technology (A)			0.002		0.068
3	Knowledge of technology integration to improve students' creative thinking (D)					0.047
4	Knowledge of technology integration (B)			0.030		0.254
5	Teacher pedagogical skill (E)					

Based on Table 9 above, the structural equation model obtained is D = 0.045 A + 0.502 C + 0.162 B, the technology integration variable to increase students' creative thinking is influenced by the technology knowledge variable by 0.045, influenced by the knowledge variable creative thinking skills by 0.502, and influenced by the technology integration variable of 0.162. If the technological knowledge variable increases by one unit, then technology integration to improve students' creative thinking will increase by 0.045, assuming the knowledge of creative thinking skills and technology integration remains constant. If the variable knowledge of creative thinking skills increases by one unit, then the integration of technology to improve students' creative thinking will increase by 0.502 if knowledge of technology and technology integration remains constant. If the technology integration variable increases by one unit, then the integration of technology to improve students' creative thinking will increase by 0.162, assuming that knowledge of technology and knowledge of creative thinking skills remains the same. Then, D = 0.198E, the teacher's pedagogic skill variable is influenced by the technology integration variable to increase students' creative thinking by 0.198. If the technology integration variable to improve students' creative thinking increases by one unit, then the teacher's pedagogic skill will increase by 0.198.

From the results of table 7, the t-statistics between knowledge of creative thinking and knowledge of technology integration to improve students' creative thinking is 6.001, knowledge of technology to teacher pedagogical skill is 2.643, knowledge of technology integration to improve students' creative thinking to teacher pedagogical skill is 2.26, and knowledge of technology integration t teacher pedagogical skills is 4.337. From these results, because the value of the t-statistic is more than the t-table, namely 1.76, the relationship between these variables is significant. Thus, it can be concluded that technological knowledge influences technology integration to improve students' creative thinking, knowledge of creative thinking skills affects technology integration to increase students' creative thinking, technology integration affects technology integration to increase students' creative thinking and influences technology integration to increase students' creative thinking influences teacher pedagogical knowledge.

4.3. Model Fit

Table 12.
Model Fit Test.

	Saturated model	Estimated model
SRMR	0.091	0.091
d_ULS	2.883	2.883
d_G	1.039	1.039
Chi-square	667.324	667.324
NFI	0.619	0.619

If the Standardized Root Mean Square Residual (SRMR) value is less than 0.10 or 0.08, the model will fit according to the criteria for model fit Beribisky and Cribbie [73]. Hensler, et al. [74] introduced For PLS-SEM, SRMR is a goodness-of-fit metric that can be used to prevent model error. The difference between the correlation matrix implied by the model and the observed correlation is known as the SRMR. As a result, it provides to assess of the goodness-of-fit criterion (model) as an absolute measure based on the mean value of the difference between actual and expected correlations. So that the data conclusions describe the overall model or the model fits the data.

4.4. Knowledge of Technology (A), Knowledge of Technology Integration (B), Knowledge of Creative Thinking (C) affects Teacher Pedagogical skills (E) Through Knowledge of technology integration to improve students' Creative Thinking (D)

The result show that teacher's pedagogic skill variable is influenced by the technology integration variable to increase students' creative thinking by 0.198. The justification of these results can be understood by referring to the literature that emphasizes the importance of technology integration in the learning process. Technology integration not only provides adequate tools to support more interactive teaching methods, but also allows teachers to adopt more innovative pedagogical strategies. According to Hattie [75] in his meta-analysis, effective use of technology can improve teachers' pedagogical skills and facilitate a more dynamic learning environment, which in turn supports the development of students' creative thinking. Thus, the variable of teachers' pedagogical skills that increases due to technology integration can explain the positive impact on students' creative thinking. In addition, technology provides opportunities for students to collaborate, explore new ideas, and participate in activities that stimulate their creativity [76-78]. Therefore, improving teachers' pedagogical skills through technology integration is an important factor that encourages students' creative thinking, supporting the finding that the variable of teachers' pedagogical skills is influenced by technology integration to improve students' creative thinking.

The findings of this study are in alignment with McCulloch, et al. [79] where the integration of the technology can improve students' creative thinking and students' achievement [77]. According to McCulloch, et al. [79] ICT incorporated into curriculum activities can inspire creativity. Students will improve their divergent thinking abilities through increasingly complex creative writing activities and the use of multimedia systems. Furthermore, Yılmaz [80] and Hidayat, et al. [77] also explains that the integration of technology into education has a positive influence on enhancing multi-dimensional 21st century skills and academic achievement. The developing of early mathematical abilities and understanding is the foundation for many creative ideas and discoveries in science, technology, and engineering, which makes the development of mathematical creativity is crucial [81]. This is also relate to Suherman and Vidákovich [82] who state that creative thinking skills can improve the quality of education so they must be introduced at the school stage. The application of integrated technology in an educational approach can be effective in solving global challenges in the modern world

As part of investigative methods, researchers have proposed components of an analytical framework aimed at exploring teachers' knowledge and beliefs regarding the integration of technology-supported education for creative thinking. The teacher's conception, which was considered a construct that integrates teachers' skills and beliefs [83] has become one of the crusial issues in education. A method of integrating technology in mathematics learning, namely recognizing, accepting, adapting, exploring, and advancing, which shows the hierarchical levels of integrated learning [13].

Many multidisciplinary researchers to study the use of technology integration at the teacher level [14]. The use of technology is only used initially (e.g. motivation, recognition). Teachers who previously used technology returned to traditional teaching methods. In other words, technology is limited to replacing conventional methods for performing calculations and generating graphs. Additionally, technology is incorporated into the learning process to increase productivity and efficiency, while the fundamental learning flow remains unchanged. until it reaches the full use of technology to encourage new learning arrangements (teaching), student learning processes (learning), or new curricular goals (learning objectives) that effective.

There have been several published studies about teacher perceptions of creativity and creative thinking in mathematics as well as the use of technology to foster students' creative thinking. For example, according to Bolden, et al. [84] analysis, pre-service teachers' ideas about creativity are limited, mostly related to the use of tools and technology and related to focusing on teaching creatively rather than teaching for creativity. This has implications for those who are still unable to determine strategies for enhancing and evaluating creativity in the classroom. The result show that teacher's pedagogic skill variable is influenced by the knowledge of creative thinking. Lev-Zamir & Leikin [83] believe that teachers require to possess a deeper understanding of their own definition of creativity in mathematics in order to improve their ability to teach with and for creativity.. Moreover, Bereczki and Kárpáti [14] analysis shows that their epistemic notions influence expert teachers' use of technology to stimulate creativity. In the end, the learning based on technology model is a method of teaching that aims to provide students real-world experience through situations that are similar to those in the classroom. These results indicate that students' thinking styles must be considered in the acquisition and development of technology use [85]. To ensure that these skills are acquired by students, it is very important for teachers to establish the necessary learning environment in advance [86]. Activities to develop abilities in technology integration will have a positive impact on creative thinking abilities. This learning experience can improve students' learning outcomes, in this case increasing students' creative thinking abilities in solving mathematical problems.

5. Conclusion

Based on the data above, the results of the SEM test show that the technology integration variable to increase students' creative thinking is influenced by the technology knowledge variable by 0.045, influenced by the knowledge variable creative thinking skills by 0.502, and influenced by the technology integration variable of 0.162. Then, the teacher's pedagogical skill is influenced by the integration of technology to increase students' creative thinking by 0.198. It means that the pedagogical skill of junior high school teachers can be improved by integrating technology to increase students' creative thinking.

The results of this study accept H_4 dan H_5, H_4 = Knowledge of technology integration (B) affects teacher pedagogical skills (E) and H_5 = Knowledge of creative thinking (C) affects Knowledge of technology integration to improve students' creative thinking (D) which has implications for acceptance H_8. This observation provides evidence supporting hypothesis H8. It is observed that knowledge of technology (A), knowledge of technology integration (B), and knowledge of creative thinking (C) collectively contribute to the enhancement of teacher pedagogical skills (E). This affects is found by the impact of knowledge of technology integration to improve students' creative thinking (D). The interconnected of these variables highlights the importance of considering a holistic approach to teacher development, incorporating technological knowledge, integration skills, and fostering creative thinking for enhances pedagogical skills in knowledge of technology integration to improve students' creative thinking.

Recommendations for further research include greater emphasis on teacher training related to enhance knowledge of creative thinking (C) and knowledge of technology integration (B) in order to improve students' creative thinking abilities. In this context, research can focus on developing and structured training programs, enable educators to creatively integrate technology in the learning process. In addition, it is recommended to consider implementation innovative learning methods that encourage students' creative exploration through technology. Further research can also explore effective assessment strategies to measure increases in students' creative thinking abilities which can be attributed to increases in teachers' Knowledge of Creative and Technology Integration. It is hoped that an in-depth understanding of these factors can enrich educational practice, making a significant contribution to improving the quality of classroom learning.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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