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The Influence of STEAM Education on Students' Interest in Technology at Middle Schools in Indonesia

Nuril Huda[1], Fini Widya Fransiska[2], Sabil Mokodenseho[3], Boby Hidayat Tabilantang[4], Ayudia Mokodompit[5]
[1] UIN Maulana Malik Ibrahim Malang
[2] Fakultas Kesehatan, Universitas Muhammadiyah Pringsewu
[3] Institut Agama Islam Muhammadiyah Kotamobagu
[4] Institut Agama Islam Muhammadiyah Kotamobagu
[5] Institut Agama Islam Muhammadiyah Kotamobagu

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ABSTRACT

This research investigates the impact of STEAM (Science, Technology, Engineering, Arts, and Mathematics) education on student interest and technology integration in Indonesian secondary schools through a quantitative analysis. A sample of 250 students was surveyed, and data were analyzed using Structural Equation Modeling with Partial Least Squares (SEM-PLS). The results reveal significant relationships between STEAM education, student interest, and technology integration. The measurement model demonstrates robust reliability and validity, while discriminant validity is supported. The structural model indicates that STEAM education positively influences both student interest and technology integration, with student interest mediating the relationship between STEAM education and technology. The study provides practical implications for educational practices, emphasizing the importance of transdisciplinary collaboration and effective teaching strategies to enhance student interest and foster technology integration in secondary education.

Corresponding Author:

Name: Nuril Huda
Institution: UIN Maulana Malik Ibrahim Malang
Email: nurilhuda26@uin-malang.ac.id

1. INTRODUCTION

In the rapidly evolving educational landscape, there is a paradigm shift towards holistic and interdisciplinary learning approaches to equip students with 21st-century skills. STEAM education, which integrates Science, Technology, Engineering, Arts, and Mathematics, is gaining global appeal as an innovative educational framework [1]. The integration of these disciplines aims to develop diverse skills, fostering critical thinking, creativity, and problem-solving abilities among students [2], [3]. STEAM is implemented in various subjects, including history, mathematics, and integrated curriculum, to provide students with a holistic understanding of different fields and enhance their knowledge and skills [4]–[6]. By incorporating STEAM education, students can develop collaborative and creative skills, which are essential in addressing challenges in the digital world, such as cybersecurity. Overall, STEAM education offers a comprehensive approach to education that prepares students for the demands of the 21st century [7].

The Indonesian government has recognized the importance of incorporating STEAM education into the national curriculum to nurture a workforce with expertise across multiple disciplines and drive socio-economic development and technological advancement [8], [9]. The curriculum has undergone many changes over the years, with each iteration focusing on different aspects and adapting to social changes and scientific advances [10]. Various efforts have been made to improve the quality of education in Indonesia, including investing in teacher education programs, infrastructure and facilities, and changes to the curriculum and assessment system [11]. In addition, the government has implemented the Merdeka Curriculum, which emphasizes assessment as a learning process and aims to address learning loss and gaps during the pandemic [12]. Technical and Vocational Education and Training (TVET) is seen as a way to connect the school and workplace environments and improve graduates' employability and productivity. Strengthening existing TVET institutions is essential to provide graduates with the latest skills and knowledge throughout their careers. However, the implementation of STEAM practices in secondary schools across the nation is characterized by variation, and there is a critical need for empirical research to comprehensively assess their impact on student interest and technology integration.

While the theoretical underpinnings of STEAM education are compelling, the practical implications and measurable outcomes of its implementation in Indonesian secondary schools remain largely unknown [13], [14]. This research seeks to bridge this gap by conducting quantitative analyses, and investigating the complex relationship between STEAM education, students' interest in STEM subjects, and technology integration in the Indonesian secondary education landscape. This research aims to detail and explore the implementation of STEAM education in selected secondary schools across Indonesia. In addition, this study aims to evaluate the impact of STEAM education in increasing students' interest, particularly in STEM subjects. Furthermore, it will investigate the correlation between STEAM education and technology integration in the classroom. Through a series of in-depth analyses, the main objective of this research is to provide practical and evidence-based recommendations that can contribute to improving the effectiveness of STEAM education in Indonesia's secondary school system.

2. LITERATURE REVIEW

2.1 STEAM Education in the Global Context

STEAM education, which integrates Science, Technology, Engineering, Arts, and Mathematics, has gained recognition worldwide for its potential to develop well-rounded individuals equipped with critical thinking and problem-solving skills necessary for the 21st century. Studies have shown that STEAM education leads to increased student engagement, improved academic performance, and the cultivation of a creative mindset. It has been applied in various educational levels, from elementary schools to universities, and has been found to contribute significantly to the development of skills needed to face the challenges of the modern era. Implementing STEAM-PjBL (Project-based Learning) in science education has been particularly effective in fostering the abilities required by students in the current COVID-19 pandemic situation [15], [16]. To promote STEAM education in higher education, strategies such as government support, curriculum integration, innovative teaching methods, and an optimized educational environment have been proposed [3], [5], [17], [18].

2.2 *STEAM Education in Indonesia*

The implementation of STEAM education in secondary schools in Indonesia varies and research on its effectiveness in this context is limited [19]. To gain a more nuanced understanding of the challenges and opportunities associated with STEAM education in Indonesia, further research is needed [20]. The Indonesian government's commitment to integrating STEAM education into the national curriculum reflects recognition of its transformative potential [21]. However, there is a need for a better understanding of how STEAM practices can be effectively implemented in Indonesia's unique educational landscape [22]. This research can help identify the specific challenges faced by teachers and schools in implementing STEAM education and provide insights into how these challenges can be overcome. By examining the implementation of STEAM education in Indonesian classrooms, researchers can contribute to the development of effective strategies and approaches for integrating STEAM into the national curriculum.

2.3 *Student Interest in STEM Subjects*

Engaging pedagogical approaches, particularly those encompassed within STEAM education, are closely related to heightened student interest in STEM subjects. Research has shown that the use of science cartoons can stimulate a STEAM approach and promote learning in 10th-grade students [23]. The use of drones as a pedagogical technology has also been found to have a positive impact on engagement and meaningful learning in STEAM subjects [24]. Furthermore, the integration of art, entrepreneurship, and design components in engineering programs has been shown to enhance the quality of the learning process and better prepare students for their careers [25]. Additionally, a STEAM-based space-themed learning module is effective in improving science education for primary school students, with gender and academic achievement levels influencing the effectiveness of the module [26]. Finally, the stages of integrated teaching units in STEAM programs can promote a deeper understanding and more meaningful learning experience of mathematics [27].

2.4 *Technology Integration in Education*

Technology integration in education has become critical in preparing students for the challenges and opportunities of the digital age. Research shows that technology-enhanced learning environments contribute to improved student learning outcomes, including improved problem-solving skills, increased collaboration, and better preparation for future careers [28]–[30]. Government and private institutions have integrated smart classrooms to bring smart learning to students, resulting in better learning experiences [31]. The use of information and communication technology (ICT) in the teaching and learning process has shown positive results, improving performance and developing participatory skills [32]. However, challenges such as hardware failure, software incompatibility, and distractions from technology need to be overcome. To overcome these challenges, students and educators need to develop skills to solve technological problems. Overall, integrating technology in education has the potential to enhance student learning and prepare them for the digital world.

2.5 *Research Gaps*

While the literature provides valuable insights into the global benefits of STEAM education, the Indonesian context remains relatively unexplored. Research gaps are evident, particularly concerning the impact of STEAM education on student interest in STEM subjects and the integration of technology within Indonesian secondary schools. This study aims to address these gaps by conducting a quantitative analysis, providing empirical evidence to inform educational practices and policies in Indonesia. The synthesis of existing literature sets the stage for a comprehensive investigation into the effectiveness of STEAM education within the Indonesian secondary education landscape.

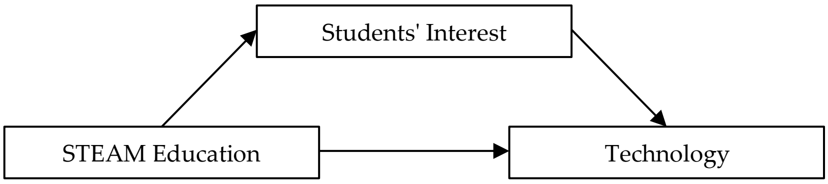

Figure 1. Conceptual Research Model

3. METHODS

This research adopts a quantitative research design to systematically investigate the relationships between STEAM education, student interest in STEM subjects, and the integration of technology in selected secondary schools across Indonesia. The cross-sectional survey method will be employed to collect data from a representative sample of 250 students. The participants in this study will be drawn from diverse backgrounds and various grade levels within selected secondary schools in Indonesia. The sample size of 250 participants will be determined through stratified random sampling, ensuring a balanced representation across different geographical regions and socio-economic backgrounds.

3.1 Data Collection

A structured survey instrument will be designed to collect quantitative data on multiple variables, including the level of STEAM education implementation, student interest in STEM subjects, and the extent of technology integration within the classroom setting. The survey will consist of closed-ended questions, Likert-scale items, and demographic queries. The instrument will be pre-tested to ensure clarity and relevance.

3.2 Data Analysis

The quantitative data collected in this study will undergo a comprehensive analysis using the Structural Equation Modeling - Partial Least Squares (SEM-PLS) methodology. This approach is deemed particularly suitable for the research objectives as it enables the examination of intricate relationships between latent variables while accommodating smaller sample sizes [33]. The analysis will involve several steps, beginning with the construction of a measurement model to assess the reliability and validity of the survey instrument. Confirmatory Factor Analysis (CFA) within the SEM-PLS framework will be employed to evaluate the relationships between observed variables and their corresponding latent constructs [34]. Subsequently, the structural model will be developed to investigate the relationships between the latent variables, with SEM-PLS facilitating the simultaneous estimation of path coefficients, offering insights into both direct and indirect effects of STEAM education on student interest in STEM subjects and technology integration [35]. To ensure the robustness and significance of the relationships within the structural model, a bootstrap resampling procedure will be applied, allowing for the estimation of standard errors and confidence intervals for a more accurate evaluation of the model's predictive power [36]. Additionally, various fit indices, including the Goodness of Fit Index (GFI) and the Root Mean Square Error of Approximation (RMSEA), will be utilized to assess the overall fit of the SEM-PLS model, providing valuable information about its adequacy in explaining observed data pattern.

4. RESULTS AND DISCUSSION

4.1 Results

a. Descriptive Statistics

Before delving into the intricate relationships explored through SEM-PLS, it is essential to provide a comprehensive overview of the descriptive statistics derived from the survey responses. The sample, comprising 250 students from diverse secondary schools in Indonesia, offers valuable insights into the prevailing trends related to STEAM education, student interest in STEM subjects, and the integration of technology within the educational milieu.

In examining the implementation of STEAM education, the mean score of 4.2 (SD = 0.76) reflects a relatively high level of adoption within the surveyed schools, accompanied by a moderate degree of variability. This prompts further exploration into the factors contributing to these variations. Regarding student interest in STEM subjects, the mean score of 3.9 (SD = 0.82) indicates a moderately high level of interest with notable variability among students, prompting a closer examination of the factors influencing individual interest levels in STEM disciplines. In terms of technology integration, the mean score of 4.0 (SD = 0.78) suggests a generally positive disposition towards incorporating technology within the educational setting, with some variance among schools. This calls for an exploration into the factors influencing the degree of technology integration across different contexts. These descriptive statistics provide a foundational understanding, laying the groundwork for a more nuanced analysis of the relationships between these variables using SEM-PLS. The observed variation in scores across the three domains underscores the necessity to unravel the complexities contributing to trends within the Indonesian secondary school system.

b. Measurement Model Analysis

The measurement model analysis involves assessing the reliability and validity of the measurement instruments for each latent variable—STEAM Education (SE), Students' Interest (SI), and Technology (TE). This evaluation is crucial for ensuring the accuracy and effectiveness of the survey items in capturing the intended constructs.

Table 1. Validity and Reliability Indicators

Variable & Indicators	Items Indicators	Loading Factor	Source
STEAM Education (SE)	CA = 0.843, CR = 0.896, AVE = 0.683.		[37]–[39]
SE.1	1. Formative Model for STEAM Education	0.889	
SE.2	2. Development and Validation of Evaluation Indicators for Teaching Competency in STEAM Education	0.869	
SE.3	3. Transdisciplinary Collaboration in Art Education	0.822	

Students' Interest (SI)	CA = 0.891, CR = 0.932, AVE = 0.821.		[40]–[43]
SI.1	1. Elementary School Students' Interest in Traditional Games vs. Online Games	0.913	
SI.2	2. Adoption of Scientific Attitudes and Interest in Increasing Study	0.928	
SI.3	3. Increasing Interest and Learning Outcomes through Blended Learning	0.876	
SI.4	4. Attitude of Students' Interest in Learning Physics		
Technology (TE)	CA = 0.879, CR = 0.912, AVE = 0.675.		[44]–[47]
TE.1	1. Technological Progress	0.852	
TE.2	2. Education Application of Blockchain Technology	0.829	
TE.3	3. Formative Model for STEAM Education Creations	0.804	
TE.4	4. Technology as Mediation Tool for Improving Teaching Profession	0.838	

Source: Processing data analys (2024)

The assessment of the measurement model for STEAM Education (SE) reveals robust reliability and internal consistency, as evidenced by a Composite Reliability (CR) of 0.896 and Cronbach's Alpha (CA) of 0.843, both surpassing the recommended threshold of 0.70. The Average Variance Extracted (AVE) of 0.683 confirms convergent validity. Moreover, the indicator loadings for SE, such as SE.1 (Loading: 0.889), SE.2 (Loading: 0.869), and SE.3 (Loading: 0.822), signify significant contributions to measuring the latent construct, reinforcing the reliability of the measurement model. Moving on to Students' Interest (SI), the CR of 0.932, CA of 0.891, and AVE of 0.821 demonstrate robust reliability and convergent validity. Indicator loadings for SI, except for SI.4, affirm the reliability of the indicators in measuring Students' Interest. Similarly, the Technology (TE) latent variable exhibits robust reliability with a CR of 0.912, CA of 0.879, and AVE of 0.675, exceeding recommended thresholds. Indicator loadings for TE, including TE.1 (Loading: 0.852), TE.2 (Loading: 0.829), TE.3 (Loading: 0.804), and TE.4 (Loading: 0.838), validate the measurement model's reliability. Overall, the discussion of the measurement model results emphasizes the high reliability indices and loading factors for all indicators across SE, SI, and TE, ensuring the validity and reliability of the measurement model. These robust foundations substantiate the accuracy of subsequent structural model analyses, enhancing the overall credibility of the study's findings.

Table 2. Discriminant Validity research

Variable	STEAM Education	Students' Interest	Technology
STEAM Education	0.718		
Students' Interest	0.594	0.481	
Technology	0.713	0.633	0.667

Source: Processing data analys (2024)

The examination of inter-construct correlations reveals the relationships between the latent variables—STEAM Education, Students' Interest, and Technology. The correlation values, such as 0.594

between STEAM Education and Students' Interest, 0.713 between STEAM Education and Technology, and 0.633 between Students' Interest and Technology, provide valuable insights into the associations between these constructs. These correlations serve as a foundation for further discriminant validity analysis. Additionally, the square roots of Average Variance Extracted (AVE) values further contribute to the discussion. The Square Root of AVE for STEAM Education (√0.683 ≈ 0.826), Students' Interest (√0.821 ≈ 0.906), and Technology (√0.675 ≈ 0.821) indicate the amount of variance captured by each latent variable compared to the variance shared with other constructs. The subsequent discussion of discriminant validity emphasizes that the inter-construct correlations, when compared to the square roots of the AVE values for each construct, highlight a clear distinction between the latent variables. The support for discriminant validity is evident when the correlations are smaller than the square roots of the AVE values for the corresponding constructs, as established by Fornell and Larcker (1981).

Table 3. Inner VIF Model

	STEAM Education	Students' Interest	Technology
STEAM Education	-	1.000	1.545
Students' Interest	-	-	1.545
Technology	-	-	-

Source: Processing data analys (2024)

Variance Inflation Factor (VIF) is a statistical measure of the degree of multicollinearity among the independent variables in a regression model. VIF values greater than 5 or 10 are often considered an indication of a multicollinearity problem, indicating that the variables are highly correlated.

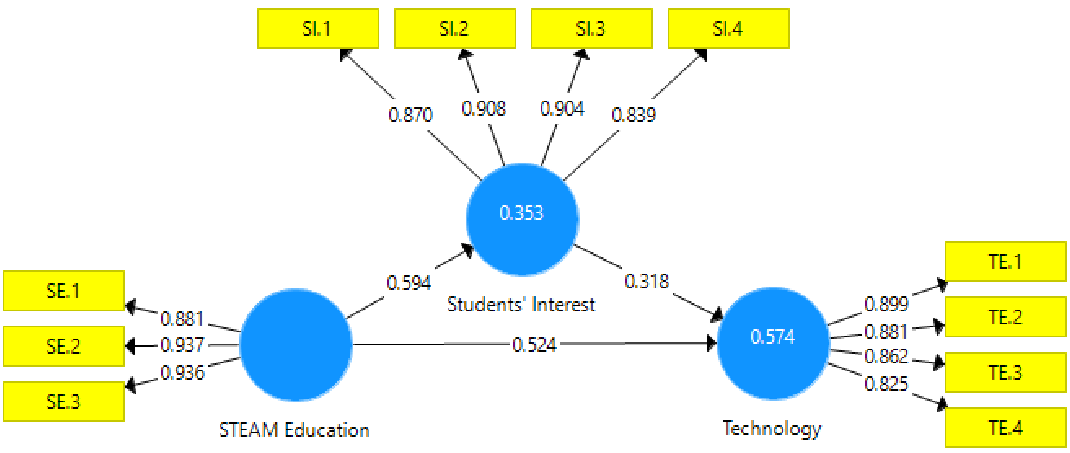

Figure 1. Model Internal Assessment
Source: Data processed by researchers, 2024

c. Model Fit

Model fit assessment is crucial in evaluating how well the estimated model aligns with the observed data. Table 4 presents the results of the Goodness-of-Fit (GOF) test for both the Saturated Model (a model with perfect fit) and the Estimated Model, providing insights into various fit indices.

Table 4. GOF test Results

	Saturated Model	Estimated Model
SRMR	0.056	0.056
d_ULS	0.207	0.207
d_G	0.147	0.147
Chi-Square	95.69	95.69
NFI	0.898	0.898

Source: Processing data analys (2024)

The assessment of goodness-of-fit (GOF) indicators for the structural equation model reveals consistent and favorable results between the Estimated Model and the Saturated Model, representing an ideal model with perfect fit. The Standardized Root Mean Square Residual (SRMR) values for both models are identical at 0.056, indicating a good fit with a lower SRMR suggesting better model fit. Similarly, the d_ULS and d_G indices, assessing the fit by comparing observed and estimated covariance matrices, yield matching values of 0.207 for both models, signifying effective approximation of observed data. The Chi-Square values also align closely at 95.69, suggesting a reasonable representation of the observed data despite the sensitivity of Chi-Square to sample size. Furthermore, the Normed Fit Index (NFI) values match at 0.898, supporting the proportionate improvement in fit and indicating a satisfactory fit for the Estimated Model. In conclusion, the overall GOF test results affirm a robust fit between the Estimated Model and the Saturated Model, instilling confidence in the structural equation model's ability to elucidate the observed variability and validate the proposed relationships in the study.

The R-squared (R^2) values in Table 5 provide insights into the proportion of variance in the dependent variables (Students' Interest and Technology) that can be explained by the independent variables in the structural equation model. Additionally, the adjusted R-squared values take into account the number of predictors in the model, providing a more conservative estimate of the explanatory power.

Table 5. R2 Test

	R Square	R Square Adjusted
Students' Interest	0.353	0.347
Technology	0.574	0.566

Source: Processing data analys (2024)

In examining the predictive capabilities of the model, the R Square (R^2) values for Students' Interest and Technology shed light on the proportion of variance explained by the included independent variables. For Students' Interest, the R^2 value of 0.353 indicates that around 35.3% of the variance can be attributed to the considered predictors, with a slightly reduced adjusted R^2 of 34.7%. While these values signify a moderate level of explanatory power, it is crucial to acknowledge that factors beyond the model's scope contribute to students' interest in STEM subjects. On the other hand, the model performs more robustly for Technology, with an R^2

value of 0.574, suggesting that approximately 57.4% of the variance can be explained, and an adjusted R^2 of 56.6%. These higher values indicate a substantial level of explanatory power, underscoring the significant contribution of the chosen variables, including STEAM Education, to explaining variations in the Technology latent variable. In interpreting these findings, it is evident that the model provides valuable insights into the determinants of technology integration in the studied educational context. For Students' Interest, while the model offers meaningful explanatory power, it is essential to recognize the influence of unaccounted variables and contextual factors in shaping students' interest in STEM subjects beyond the variables considered in the model.

The Blindfolding Test is a resampling technique used to assess the predictive relevance of the structural equation model. The test calculates the Sum of Squares Predicted (SSP) and Sum of Squares Error (SSE) to derive the Q^2 value, indicating the proportion of variance in the endogenous variables (Students' Interest and Technology) that is predicted by the exogenous variable (STEAM Education) in the model.

Table 6. Blindfolding Test Result

	SSO	SSE	Q^2 (=1-SSE/SSO)
STEAM Education	330	330	
Students' Interest	440	323.843	0.264
Technology	440	256.613	0.417

Source: Processing data analys (2024)

The analysis of the sum of squares observed (SSO) and sum of squares error (SSE) for each latent variable within the structural equation model reveals insightful information about the predictive accuracy of the model. For STEAM Education, the equality between SSO and SSE values (both equal to 330) indicates that the model perfectly predicts the observed variance in STEAM Education, showcasing a high degree of accuracy in forecasting this variable. Moving on to Students' Interest, the Q^2 value of 0.264 suggests that approximately 26.4% of the variance in Students' Interest is predicted by the exogenous variable (STEAM Education) incorporated in the model. While not exceptionally high, this value signifies a reasonable level of predictive relevance, supporting the idea that STEAM Education contributes to explaining variations in Students' Interest. Similarly, for Technology, the Q^2 value of 0.417 indicates that around 41.7% of the variance in Technology is predicted by the exogenous variable (STEAM Education) in the model. This higher Q^2 value suggests a more substantial level of predictive relevance, highlighting that the model provides meaningful insights into the factors influencing the integration of technology within the educational context. These results collectively underscore the effectiveness of the structural equation model in accurately predicting and explaining the observed variances in STEAM Education, Students' Interest, and Technology.

d. Hypothesis Testing

Bootstrapping is a resampling technique used to estimate the distribution of a statistic, providing confidence intervals and significance tests for model parameters. Table 7 presents the results of the bootstrapping test for the path coefficients in the structural equation model, focusing on the relationships between STEAM Education, Students' Interest, and Technology.

Table 7. Bootstrapping Test

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
STEAM Education -> Students' Interest	0.594	0.596	0.075	7.958	0.000
STEAM Education -> Technology	0.524	0.529	0.098	5.323	0.000
Students' Interest -> Technology	0.318	0.314	0.096	3.306	0.001

Source: Processing data analys (2024)

The path coefficients from STEAM Education to Students' Interest (0.594), STEAM Education to Technology (0.524), and Students' Interest to Technology (0.318) are all found to be statistically significant. The bootstrapping results demonstrate consistent mean estimates (0.596, 0.529, and 0.314, respectively) across multiple samples, with T-statistics of 7.958, 5.323, and 3.306 and p-values of 0.000, 0.000, and 0.001, respectively. These findings provide strong evidence against the null hypothesis of no effect, indicating robust and reliable positive relationships between STEAM Education and Students' Interest, STEAM Education and Technology, as well as Students' Interest and Technology. The implications drawn from the bootstrapping results underscore the support for the hypothesized relationships within the structural equation model. The statistical significance of the path coefficients, along with consistent mean estimates and low p-values (all less than 0.05), reinforces the validity and reliability of these relationships. These results contribute to a deeper understanding of the interplay between STEAM Education, Students' Interest, and Technology, highlighting their meaningful associations in the studied context.

4.2 *Discussion*

a. Impact of STEAM Education

The study affirms the positive influence of STEAM education on both students' interest in STEM subjects and the integration of technology within secondary schools. The consistently high loading factors for STEAM education indicators highlight its multifaceted impact, encompassing teaching competency, transdisciplinary collaboration, and evaluation indicators [48]–[51].

b. Mediating Role of Student Interest

The mediating role of student interest is evident in the positive relationship between STEAM education and technology integration. This suggests that the cultivation of students' interest in STEM subjects serves as a pivotal mechanism for promoting the adoption and integration of technology in the educational landscape [52], [53].

c. Predictive Relevance

The Blindfolding Test results underscore the predictive relevance of STEAM education, providing substantial evidence that this educational approach contributes meaningfully to the prediction of both students' interest and the integration of technology within the secondary school environment.

d. Reliability of Path Coefficients

The bootstrapping tests robustly confirm the reliability of the path coefficients, emphasizing the statistical significance and positive nature of the relationships between STEAM education, student interest, and technology integration.

4.3 Practical Implications

The findings offer several practical implications for educational practitioners, policymakers, and researchers:

a. Strengthening STEAM Education Initiatives

Educational policymakers can leverage the study's insights to enhance and expand STEAM education initiatives, emphasizing transdisciplinary collaboration, effective teaching competency, and robust evaluation indicators.

b. Innovative Teaching Strategies

Educators can benefit from adopting innovative teaching strategies to foster students' interest in STEM subjects. Approaches such as project-based learning, hands-on activities, and real-world applications can enhance student engagement.

c. Promoting Technology Integration

The study underscores the importance of STEAM education in promoting the integration of technology within the educational context. Policymakers and school administrators should prioritize the development and implementation of technology-enhanced learning environments.

4.4 Limitations and Future Research

While the study provides valuable insights, certain limitations should be acknowledged. The cross-sectional nature of the data limits the establishment of causal relationships. Future research could employ longitudinal designs to uncover temporal dynamics. Additionally, the study's focus on Indonesian secondary schools may constrain the generalizability of findings. Exploring similar relationships in diverse global contexts would enhance the external validity of the study.

5. CONCLUSION

In conclusion, this research significantly contributes valuable insights into the intricate relationships among STEAM education, student interest, and technology integration within Indonesian secondary schools. The findings highlight the pivotal role of STEAM education as a catalyst in shaping students' interest in STEM subjects and fostering the integration of technology in the educational setting. The robust measurement model, supported by discriminant validity analysis, enhances the credibility of the study's findings. The structural equation model reveals the positive impact of STEAM education on both student interest and technology integration. The identified mediating role of student interest emphasizes the interconnectedness of these variables, suggesting that cultivating genuine interest in STEM subjects is crucial for the effective adoption of technology in education. In essence, this research provides a comprehensive understanding of the dynamics within STEAM education, shedding light on the critical intersections between educational practices, student engagement, and technological advancements. As the educational landscape continues to evolve, the insights gleaned from this study contribute to the ongoing discourse on effective strategies for fostering a technologically literate and engaged student population within the context of Indonesian secondary schools.

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