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ORIGINAL

Influence of collaborative problem-solving based STEAM, academic ability, and support on engagement and creative thinking skills: a SEM study from Indonesia

Influencia de la resolución de problemas colaborativa basada en STEAM, habilidad académica y apoyo sobre el compromiso y las habilidades de pensamiento creativo: un estudio SEM desde Indonesia

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ABSTRACT

Introduction: this study examined the impact of Collaborative Problem-Solving Based STEAM (Science, Technology, Engineering, Arts, and Mathematics), academic ability, and support on student engagement and creative thinking skills among university students in Indonesia.
Objective: the objective of this study was to explore how Collaborative Problem-Solving Based STEAM, academic ability, and support influenced students' engagement and creative thinking, with a focus on understanding the relationships between these factors.
Method: a quantitative research design was employed, utilizing Structural Equation Modeling (SEM) to analyze data. The sample consisted of 290 students from Universitas PGRI Mpu Sindok, STKIP PGRI Situbondo, UIN Sunan Gunung Djati Bandung and Universitas Negeri Gorontalo, selected using purposive sampling. Data were collected through a structured questionnaire that measured five latent variables: STEAM, academic ability, support, engagement, and creative thinking skills.
Results: the analysis revealed that STEAM-based learning significantly enhanced both engagement (β=0,463, p<0,001) and creative thinking skills (β=1,042, p<0,001), with engagement serving as a mediator between the two. Support was found to positively influence engagement (β=0,405, p<0,001) but negatively impacted creative thinking skills (β=−0,360, p<0,001), suggesting that excessive support may have hindered independent creativity. Academic ability had no significant direct effect on either engagement (β=0,0163, p=0,732) or creative thinking (β=0,0483, p=0,217).
Conclusion: the study concluded that STEAM education significantly enhanced engagement and creativity, with a balanced level of support being crucial for fostering student autonomy. These findings provided valuable insights for developing educational strategies, particularly in countries like Indonesia, where resources were limited. Future research should focus on integrating STEAM learning while ensuring a balance between support and independence to further enhance student creativity and engagement.

Keywords: Collaborative Problem-Solving; Creative Thinking; Indonesia; STEAM; Structural Equation Modelling.

RESUMEN

Introducción: este estudio examinó el impacto de la resolución de problemas colaborativa basada en STEAM (Ciencia, Tecnología, Ingeniería, Artes y Matemáticas), la capacidad académica y el apoyo en el compromiso de los estudiantes y las habilidades de pensamiento creativo entre los estudiantes universitarios en Indonesia.
Objetivo: el objetivo de este estudio fue explorar cómo la resolución de problemas colaborativa basada en STEAM, la capacidad académica y el apoyo influyeron en el compromiso y el pensamiento creativo de los estudiantes, con un enfoque en comprender las relaciones entre estos factores.
Método: se empleó un diseño de investigación cuantitativa, utilizando el Modelado de Ecuaciones Estructurales (SEM) para analizar los datos. La muestra consistió en 290 estudiantes de Universitas PGRI Mpu Sindok, STKIP PGRI Situbondo, UIN Sunan Gunung Djati Bandung and Universitas Negeri Gorontalo, seleccionados mediante muestreo por conveniencia. Los datos fueron recolectados a través de un cuestionario estructurado que midió cinco variables latentes: STEAM, capacidad académica, apoyo, compromiso y habilidades de pensamiento creativo.
Resultados: el análisis reveló que el aprendizaje basado en STEAM mejoró significativamente tanto el compromiso (β=0,463, p<0,001) como las habilidades de pensamiento creativo (β=1,042, p<0,001), con el compromiso sirviendo como mediador entre ambos. Se encontró que el apoyo influyó positivamente en el compromiso (β=0,405, p<0,001), pero impactó negativamente en las habilidades de pensamiento creativo (β=−0,360, p<0,001), lo que sugiere que el apoyo excesivo puede haber obstaculizado la creatividad independiente. La capacidad académica no tuvo un efecto directo significativo ni en el compromiso (β=0,0163, p=0,732) ni en el pensamiento creativo (β=0,0483, p=0,217).
Conclusión: el estudio concluyó que la educación basada en STEAM mejoró significativamente el compromiso y la creatividad, siendo un nivel equilibrado de apoyo crucial para fomentar la autonomía de los estudiantes. Estos hallazgos proporcionaron información valiosa para desarrollar estrategias educativas, particularmente en países como Indonesia, donde los recursos eran limitados. La investigación futura debería centrarse en integrar el aprendizaje STEAM mientras se asegura un equilibrio entre el apoyo y la independencia para mejorar aún más la creatividad y el compromiso de los estudiantes.

Palabras clave: Resolución de Problemas Colaborativa; Pensamiento Creativo; Indonesia; STEAM; Modelado de Ecuaciones Estructurales.

INTRODUCTION

The development of creative thinking skills has been increasingly recognized as a critical competency in the 21st century.[1] Education systems worldwide have shifted towards approaches that emphasize higher-order thinking, collaboration, and problem-solving to prepare students for complex and dynamic challenges[2] One such approach is Collaborative Problem-Solving Based STEAM (Science, Technology, Engineering, Arts, and Mathematics), which integrates interdisciplinary learning and encourages creativity through real-world problem-solving.[3] This innovative pedagogical strategy not only fosters students' engagement but also enhances their ability to generate innovative solutions.

However, the success of such strategies also depends on key individual and contextual factors, such as academic ability and support.[4] Academic ability reflects students' readiness to process complex information and tackle challenges, while support from peers, instructors, and families creates an enabling environment that fosters motivation and active participation in learning activities. Together, these factors contribute to the development of engagement and readiness, which are essential for nurturing creative thinking skills.[5]

Despite the growing recognition of STEAM education and its potential benefits, the mechanisms linking STEAM-based learning, academic ability, and support to creative thinking skills remain underexplored.[6] In particular, the roles of engagement and readiness as mediating factors in this relationship are not well understood. This issue is particularly relevant in the Indonesian context, where the integration of STEAM approaches is still in its early stages, and educators face challenges in fostering creativity among students. Existing studies have predominantly focused on Western contexts, leaving a gap in understanding how these dynamics operate within different cultural and systemic environments, such as in Indonesia.

This study aims to fill this gap by examining the direct and indirect effects of Collaborative Problem-Solving Based STEAM, academic ability, and support on students' engagement and creative thinking skills.[7] Furthermore, it explores the mediating roles of engagement and readiness in shaping these relationships. By adopting a Structural Equation Modeling (SEM) approach, the study offers a comprehensive framework to analyze these interactions.

The findings of this study will contribute to the literature on STEAM education by providing insights into its

effectiveness in fostering creativity among university students.[8]

Additionally, it highlights the critical roles of engagement and readiness as mediators and offers practical recommendations for educators to design strategies that enhance creative thinking skills in Indonesian educational contexts.[9] This research not only advances theoretical understanding but also provides actionable insights for improving educational practices in developing nations.

Literature review and hypothesis framework

Collaborative Problem-Solving Based STEAM

Collaborative Problem-Solving Based STEAM (Science, Technology, Engineering, Arts, and Mathematics) was an interdisciplinary learning approach that integrated multiple disciplines and encouraged collaboration to solve real-world problems.[9,10] Previous research highlighted the effectiveness of STEAM in enhancing creative thinking skills and student engagement through exploration and innovation.[11] In the context of higher education, STEAM provided opportunities for students to develop cross-disciplinary thinking skills that were relevant to real-world challenges.[12]

Academic Ability

Academic ability was a crucial element reflecting students' readiness to process complex information, comprehend difficult concepts, and achieve academic success.[13] Studies showed that students with higher academic ability were more engaged in the learning process, as they felt more confident in completing academic tasks and actively contributing to group activities.[14] Furthermore, academic ability was suggested to influence students' readiness to develop creative solutions in various learning contexts.[15]

Support

Support from peers, instructors, and families played a significant role in creating a conducive learning environment. Strong support increased motivation, confidence, and engagement in the learning process.[16] Research demonstrated that social and academic support helped students remain actively involved in learning activities and prepared them to apply the skills they had learned in practical situations.[17]

Engagement

Engagement was an essential factor that described the extent to which students were actively involved in the learning process, both emotionally, behaviorally, and cognitively.[18] According to literature, engagement was influenced not only by internal factors such as attitudes and motivation but also by external factors like teaching approaches and the support provided. Higher levels of engagement were positively associated with students' readiness to think creatively and produce innovative solutions.[19]

Creative Thinking Skills

Creative Thinking Skills referred to the ability to think flexibly, generate innovative ideas, and create unique solutions. The development of creative thinking skills was crucial for preparing students to face the challenges of the 21st century. The implementation of STEAM-based learning had been proven effective in enhancing students' creative thinking skills.[20,21] STEAM provided a holistic approach that integrated various disciplines, creating an interactive learning environment that encouraged students to actively explore ideas, design innovative solutions, and connect scientific concepts to real-life situations.[22]

Hypothesis Framework

The hypothesis framework of this study was designed to explore the relationships between Collaborative Problem-Solving Based STEAM, academic ability, support, engagement, and creative thinking skills. Figure 1 illustrates the theoretical pathways were identified for each relationship, including both direct and indirect effects.

Hypotheses:

- H1: Collaborative Problem-Solving Based STEAM positively influences engagement.
- H2: Academic ability positively influences engagement.
- H3: Support positively influences engagement.
- H4: Collaborative Problem-Solving Based STEAM positively influences creative thinking skills.
- H5: Engagement positively influences creative thinking skills.
- H6: Support positively influences creative thinking skills.
- H7: Engagement mediates the relationship between Collaborative Problem-Solving Based STEAM, academic ability, and support with creative thinking skills.

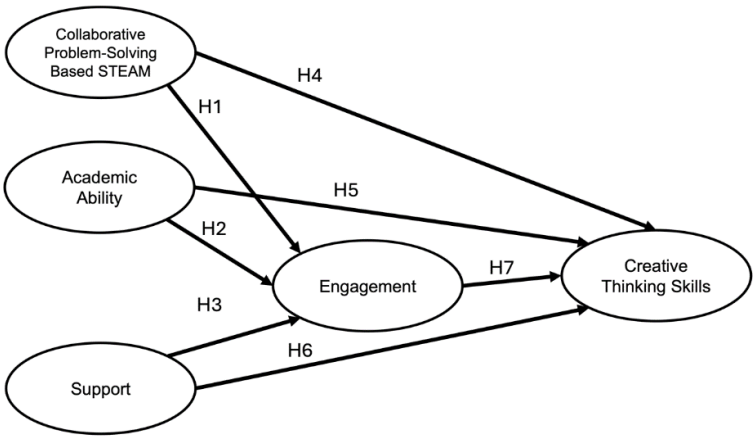

Figure 1. Hypothesis Framework

In summary, this hypothesis framework provides a theoretical structure for examining the causal relationships among the key variables, as visualized in figure 1. This analysis aims to offer both theoretical insights and practical recommendations for enhancing student engagement and creativity through STEAM-based learning, academic strengthening, and supportive environments. Additionally, the framework is grounded in the current educational context, especially in countries with limited resources like Indonesia, where STEAM education is still in its early stages. Therefore, the study justifies its relevance by focusing on the gap in understanding how STEAM can specifically improve student outcomes in such contexts, providing evidence to inform future educational strategies.

Moreover, the study addresses the need for a balanced approach between academic support and fostering student autonomy, as over-reliance on support could potentially hinder independent creative thinking. This research provides a comprehensive approach by integrating various educational aspects, such as the influence of academic ability, support systems, and engagement, and it aims to contribute to the development of effective educational practices.

METHOD

Type of Study

This study employed a quantitative research design using Structural Equation Modeling (SEM) to examine the relationships among Collaborative Problem-Solving Based STEAM, academic ability, support, engagement, and creative thinking skills. This approach allowed for the exploration of both direct and indirect effects between the variables.

Universe and Sample

The population of this study consisted of university students from UIN Ternate, Indonesia. A purposive sampling method was used to select 290 participants who were actively involved in STEAM-based learning programs. The participants represented various academic disciplines, including Science and Technology, Social Sciences, and Education, ensuring a balanced representation.

Variables

The study focused on three exogenous variables:

- Collaborative Problem-Solving Based STEAM (STEAM)
- Academic Ability (AB)
- Support (SU)

And two endogenous variables:

- Engagement (EN)
- Creative Thinking Skills (CT)

Each of these variables was measured using a structured questionnaire with five-point Likert scale items, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The items covered different dimensions of each variable, including student perceptions of STEAM learning, their academic self-assessment, support from peers and instructors, levels of engagement in learning activities, and the development of creative thinking.

Data Collection and Processing

Data were collected using a structured questionnaire that was distributed through Google Forms.[23] The questionnaire consisted of sections that measured the participants' demographic information, perceptions of STEAM-based learning, academic ability, support, engagement, and creative thinking skills.

This table 1 lists the variables and their respective questionnaire items, which were used in the study to measure the constructs. The questionnaire consisted of sections covering demographic information, perceptions of STEAM-based learning, academic ability, support, engagement, and creative thinking skills.[24]

Table 1. Research Instrument

Construct	Measuring Instruments
Collaborative Problem-Solving Based STEAM (ST)	I feel that STEAM-based learning helps me better understand the material.
	I am often involved in group discussions while solving STEAM-based problems.
	STEAM-based learning encourages me to think creatively.
	STEAM activities help me explore various ways to solve problems.
Academic Ability (AB)	I feel capable of completing academic tasks well.
	I am confident in my ability to understand difficult concepts in learning.
	I often achieve satisfactory academic results.
	I can manage my time well to complete academic tasks.
Support Environment (SU)	I feel that support from my peers helps to boost my learning motivation.
	Lecturers or instructors provide sufficient assistance to understand the material.
	I feel my family supports me in the learning process.
	The support I receive makes me more confident in learning.
Engagement (EN)	I often feel interested in actively engaging in the learning process.
	I pay full attention during the learning process.
	I often actively participate in group activities.
	I feel engaged in every learning process conducted.
Creative Thinking Skills (CT)	I can find innovative solutions to solve problems.
	I can think flexibly when facing various challenges.
	I often generate unique and different ideas from others.
	I can develop simple ideas into more complex solutions.

Once the data were collected, it was analyzed using SEM, which allowed for the examination of the hypothesized relationships between the variables. The SEM analysis was performed using the Robust Weighted Least Square (WLSMV) method, which is suitable for data with non-normal distributions. Although potential biases, such as self-selection and accessibility issues from using Google Forms, were not formally analyzed, the researcher made efforts to adhere to research best practices and ensure that the study followed appropriate research protocols.

RESULT

Demographic Data

The demographic profile of the respondents revealed a diverse group of students from UIN Ternate. A total of 290 students participated in the study, with 58,6 % of the participants being female and 41,4 % being male. The age distribution of the respondents showed that the majority (48,3 %) were between 18 and 20 years old, followed by 41,4 % in the 21–23 years age group. Only 10,3 % were aged 24 years or older, indicating that the sample predominantly consisted of younger university students. These demographic characteristics, as presented in table 2. The respondents were distributed across three academic programs: Science and Technology (34,5 %), Social Sciences (34,5 %) and Education (31,0 %). This balanced representation across fields of study ensured that the findings reflected the perspectives of students from various academic disciplines, providing a broad understanding of the relationships between STEAM-based learning, academic ability, support, engagement, and creative thinking skills.

Table 2. Demographic data

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	120	41,4 %
	Female	170	58,6 %
Age	18–20 years	140	48,3 %
	21–23 years	120	41,4 %
	24 years and above	30	10,3 %
Program of Study	Science and Technology	100	34,5 %
	Education	90	31,0 %
	Social Sciences	100	34,5 %

Reliability and Validity

The reliability and validity of the constructs were assessed using Cronbach's alpha, Composite Reliability (CR), and Average Variance Extracted (AVE)[25], as shown in table 3. The results indicate high reliability across all constructs, with Cronbach's alpha values exceeding the recommended threshold of 0,7. Specifically, Collaborative Problem-Solving Based STEAM (α = 0,898), Academic Ability (α = 0,913), Support (α = 0,899), Engagement (α = 0,901), and Creative Thinking Skills (α = 0,898) demonstrate excellent internal consistency among the items.

Table 3. Reliability and Validity test

Construct	Measuring Instruments	Cronbach's	SD	CR	AVE
Collaborative Problem-Solving Based STEAM (ST)	ST1	0,898	1,273	0,847	0,582
	ST2	0,898	0,955		
	ST3	0,899	1,005		
	ST4	0,899	1,006		
Academic Ability (AB)	AB1	0,913	1,183	0,856	0,592
	AB2	0,912	1,241		
	AB3	0,912	0,996		
	AB4	0,911	0,994		
Support Environment (SU)	SU1	0,899	1,246	0,882	0,658
	SU2	0,899	1,248		
	SU3	0,896	1,215		
	SU4	0,898	1,185		
Engagement (EN)	EN1	0,901	1,118	0,765	0,473
	EN2	0,900	1,253		
	EN3	0,898	1,187		
	EN4	0,904	1,179		
Creative Thinking Skills (CT)	CT1	0,898	0,992	0,890	0,666
	CT2	0,898	1,024		
	CT3	0,897	1,003		
	CT4	0,898	1,042		

The Composite Reliability (CR) values further confirm the reliability of the constructs, with all values exceeding 0,7. Collaborative Problem-Solving Based STEAM (CR = 0,847), Academic Ability (CR = 0,856), Support (CR = 0,882), Engagement (CR = 0,765), and Creative Thinking Skills (CR = 0,890) indicate that the items adequately capture their respective constructs.

In terms of validity, most constructs demonstrate satisfactory convergent validity, with AVE values exceeding the threshold of 0,5. Collaborative Problem-Solving Based STEAM (AVE = 0,582), Academic Ability (AVE = 0,592), Support (AVE = 0,658), and Creative Thinking Skills (AVE = 0,666) meet the criteria. However, Engagement shows a slightly lower AVE value of 0,473, suggesting marginal convergent validity that may require further investigation or refinement of the measurement items.

Overall, the reliability and validity tests confirm that the constructs used in this study are robust and reliable for further analysis. These results provide confidence in the measurement model and its application in examining the hypothesized relationships among variables.

Model Fit Analysis

The model fit indices, as presented in table 4, indicate that the hypothesized model provides an excellent fit to the data. The Chi-Square/Degrees of Freedom ratio (X^2/df = 1,328) is well below the recommended threshold of 3,0, demonstrating a strong fit between the model and the observed data. Similarly, the Goodness of Fit Index (GFI) value of 0,997 exceeds the recommended value of 0,9, further supporting the model's suitability.

Table 4. Model fit indices

Fit Index	Recommended Value	Fit Value
X^2/df	< 3,0	1,328
GFI	> 0,9	0,997
RMSEA	< 0,08	0,033
NFI	> 0,9	0,973
IFI	> 0,9	0,993
CFI	> 0,9	0,993

Note: * Estimation Method: Robust Weighted Least Square (WLSMV)

In terms of error approximation, the Root Mean Square Error of Approximation (RMSEA) is 0,033, which is significantly below the threshold of 0,08, indicating a close fit to the data. Other incremental fit measures, such as the Normed Fit Index (NFI = 0,973), Incremental Fit Index (IFI = 0,993), and Comparative Fit Index (CFI = 0,993), all exceed the minimum recommended value of 0,9, demonstrating strong improvements over the null model and confirming the robustness of the hypothesized model.

Overall, the results from the model fit indices suggest that the structural model provides an accurate representation of the relationships among the constructs. Using the Robust Weighted Least Square (WLSMV) estimation method ensures reliable parameter estimates, particularly for non-normal data. These findings provide confidence in proceeding with hypothesis testing and structural analysis based on the validated model.

Hypothesis testing

The results of the hypothesis testing were evaluated using Structural Equation Modeling (SEM), which provided standardized path coefficients (β), standard errors (SE), and significance levels (p-values). These results allowed for the determination of which hypothesized relationships were supported by the data.

Each hypothesis was tested by examining the path coefficients, and the analysis revealed the following results:

H1: Collaborative Problem-Solving Based STEAM → Engagement

The path coefficient was 0,4630 (β), with a p-value of <0,001. This result indicated that Collaborative Problem-Solving Based STEAM significantly influenced engagement, confirming the positive relationship hypothesized in H1.

H2: Academic Ability → Engagement

The path coefficient was 0,0163 (β), with a p-value of 0,732. This result showed that academic ability had no significant direct effect on engagement, meaning that H2 was not supported by the data.

H3: Support → Engagement

The path coefficient was 0,4050 (β), with a p-value of <0,001. This result confirmed that support positively influenced engagement, supporting H3.

H4: Collaborative Problem-Solving Based STEAM → Creative Thinking Skills

The path coefficient was 1,0422 (β), with a p-value of <0,001. This result showed a significant positive influence of STEAM-based learning on creative thinking, confirming H4.

H5: Academic Ability → Creative Thinking Skills

The path coefficient was 0,0483 (β), with a p-value of 0,217. This result indicated that academic ability had no significant direct effect on creative thinking skills, meaning that H5 was not supported by the data.

H6: Support → Creative Thinking Skills

The path coefficient was -0,3600 (β), with a p-value of <0,001. This result indicated that support negatively impacted creative thinking skills, thus supporting H6, but in an unexpected direction, suggesting that excessive support may limit independent creativity.

H7: Engagement → Creative Thinking Skills

The path coefficient was 0,4630 (β), with a p-value of 0,029. This result demonstrated that engagement positively influenced creative thinking skills, supporting H7.

The overall analysis revealed that five of the seven hypotheses (H1, H3, H4, H6, and H7) were supported, while two hypotheses (H2 and H5) were not supported by the data. The significant relationships found between STEAM-based learning, support, engagement, and creative thinking skills highlighted the importance of fostering student engagement and creativity through a balanced learning environment. The results of the hypothesis testing, as illustrated in figure 2 and detailed in table 5, provide insights into the relationships among the variables in the study.

Table 5. Path testing and standardized path coefficients

Research Hypothesis	Path	SE	ß	z	*p*	Hypothesis Direction	Inspection Result
H1	ST→EN	0,3800	0,1073	0,4630	3,541	<0,001*	Positive	Positive
H2	AB→EN	0,0140	0,0408	0,0163	0,342	0,732	Positive	Positive
H3	SU→EN	0,3457	0,1034	0,4050	3,343	<0,001*	Positive	Positive
H4	ST→CT	0,8987	0,1335	1,0422	6,731	<0,001*	Positive	Positive
H5	AB→CT	0,0434	0,0351	0,0483	1,235	0,217	Positive	Positive
H6	SU→CT	-0,3229	0,0861	-0,3600	-3,750	<0,001*	Positive	Negative
H7	EN→CT	0,2783	0,1278	0,4630	3,541	0,029*	Positive	Positive

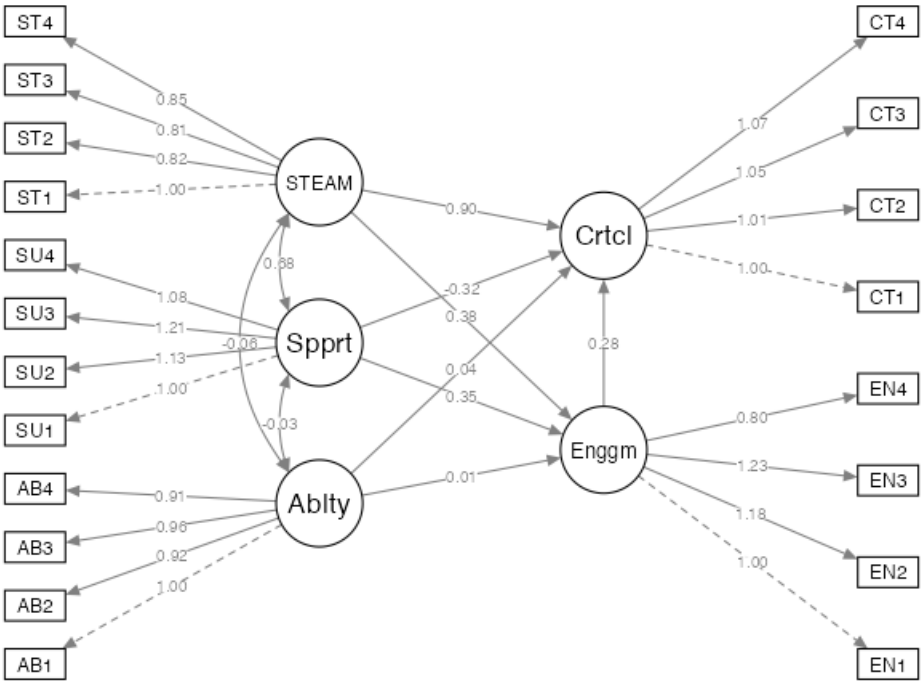

Figure 2. Path diagram

R-Square Analysis

The R-Square (R^2) values, as presented in table 6, indicate the proportion of variance in the dependent variables that is explained by the predictors in the model. These values highlight the explanatory power of the independent variables in predicting the outcomes.

Table 6. R-Square score

Variable	R^2
Engagement	0,683
Creative Thinking Skills	0,957

- Engagement (R^2 = 0,683): This value indicates that 68,3 % of the variance in engagement is explained by Collaborative Problem-Solving Based STEAM, academic ability, and support. This suggests that the model has a strong capacity to predict students' engagement based on these predictors.

- Creative Thinking Skills (R^2 = 0,957): With value of 95,7 %, the model demonstrates excellent explanatory power for creative thinking skills. This implies that engagement, Collaborative Problem-Solving Based STEAM, academic ability, and support collectively provide a comprehensive explanation of the variance in creative thinking skills.

The high R^2 values reported in table 6 reflect the robustness of the structural model. Engagement is well-explained by its predictors, while creative thinking skills are almost entirely accounted for by the independent and mediating variables. These findings underscore the importance of STEAM-based learning and engagement as key drivers in enhancing creative thinking skills among students.[26,27]

The unusually high R^2 value for creative thinking skills (0,957) requires careful consideration to rule out overfitting or model misspecification. However, the model's overall fit, as presented in table 4, indicates that the model is well-specified. The Chi-square to degrees of freedom ratio (X^2/df) was 1,328, well below the recommended threshold of 3,0, suggesting a good model fit. Additionally, the Goodness-of-Fit Index (GFI), Normed Fit Index (NFI), Incremental Fit Index (IFI), and Comparative Fit Index (CFI) all exceeded the recommended value of 0,9, with values of 0,997, 0,973, 0,993, and 0,993, respectively. The Root Mean Square Error of Approximation (RMSEA) was 0,033, which is well below the threshold of 0,08, further confirming the model's adequacy. Given these results, it can be concluded that the high R^2 value for creative thinking skills is not indicative of overfitting, and the model's overall fit suggests that the relationships between the predictors and the outcomes are meaningful and well-supported by the data.

DISCUSSION

The findings of this study provided valuable insights into the factors influencing student engagement and creative thinking skills, particularly within the context of Collaborative Problem-Solving Based STEAM. These results are consistent with previous research that emphasized the role of interdisciplinary and collaborative learning in enhancing creativity and engagement.

The significant positive effects of STEAM-based learning on both engagement (β=0,4630, p<0,001) and creative thinking skills (β=1,0422, p<0,001) highlighted its potential to foster higher-order thinking. While STEAM enhanced engagement, the relationship between academic ability and engagement (H2) was not significant (β=0,0163, p=0,732), suggesting that factors like intrinsic motivation and the learning environment may be more important in fostering engagement. The study also found a negative relationship between support and creative thinking (H6), indicating that excessive support might limit independent creativity. Additionally, engagement served as a key mediator between STEAM and creativity (H7), reinforcing its role in enhancing creative thinking. These findings suggest that a supportive, engaging learning environment may be more critical for nurturing creativity than simply focusing on academic performance.

Engagement itself was found to positively influence creative thinking skills (β=0,4630, p=0,029), confirming its role as a critical mediator in the learning process. The R^2 value of 0,683 for engagement (table 6) indicates its strong dependence on the predictors, particularly STEAM and support.[28] These findings are consistent with prior research suggesting that active involvement in the learning process fosters cognitive and emotional readiness, both of which are crucial for enhancing creative thinking.

The results suggest several practical implications for educators and institutions. First, incorporating Collaborative Problem-Solving Based STEAM into curricula can effectively enhance engagement and creativity among students.[29] Second, while support is crucial for fostering engagement, care should be taken to encourage students' independence and critical thinking.[30] Finally, creating learning environments that promote engagement through hands-on, interdisciplinary, and collaborative activities is vital for nurturing creative thinking skills.

While the study provides robust findings, several limitations must be noted. First, the data were collected from a single university, which may limit generalizability. Second, the negative relationship between support and creative thinking requires further exploration to identify contextual factors influencing this dynamic. Future research could investigate these relationships in broader educational contexts and examine other potential mediators or moderators, such as motivation or self-efficacy.

Indonesia's educational infrastructure played a crucial role in shaping the effectiveness of STEAM-based learning. The challenges faced by the Indonesian education system, such as limited resources, inadequate teacher training, and inconsistent access to educational technologies, significantly affected the successful implementation of STEAM programs. Despite attending professional training, many teachers still struggled with a lack of adequate learning media and support, impacting the quality of STEAM education.[31]

In urban areas, schools had better access to resources and trained educators, but in rural areas, students faced infrastructural challenges that hindered their exposure to STEAM-related activities.[32]

Unlike Western contexts, where STEAM education was often supported by advanced technological tools and extensive access to interdisciplinary resources, Indonesian schools struggled with insufficient funding for

educational tools, which limited the hands-on and experimental nature of STEAM activities. Research revealed that while STEAM had been shown to improve critical and creative thinking skills, its implementation was still lacking in many parts of Indonesia due to the insufficient preparation of teachers and the lack of specialized training.[33,34,35]

However, there are several limitations to consider. The data were collected from four university, which may limit the generalizability of the findings. Additionally, the negative relationship between support and creative thinking requires further exploration to identify contextual factors that may influence this dynamic. Future research should examine these relationships in a broader range of educational contexts and explore potential mediators or moderators, such as motivation or self-efficacy, that might influence the outcomes.

CONCLUSION

This study highlighted the significant role of STEAM-based learning in enhancing both student engagement and creative thinking skills. The findings supported the idea that active participation and interdisciplinary learning through STEAM fostered higher-order thinking. However, the study also suggested that the relationship between academic ability and engagement was not significant, emphasizing that intrinsic motivation and the quality of the learning environment could be more influential.

Additionally, the study revealed that while support positively influenced engagement, excessive support might hinder independent creativity. This underscores the need for a balanced approach that encourages student autonomy while providing necessary guidance. The role of engagement as a mediator between STEAM and creative thinking reinforced the importance of active participation in learning. The study's findings highlighted the value of creating an engaging, supportive, and challenging learning environment to foster both creativity and engagement.

However, this study is limited by its focus on these four universities, and the findings may not be directly applicable to other regions or institutions. Future research should explore these dynamics across different educational contexts and student populations, examining how contextual factors like motivation, self-efficacy, and cultural differences may influence the outcomes of STEAM-based learning.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

DATA AVAILABILITY STATEMENT

The data generated and/or analyzed during this study are available from the corresponding author upon reasonable request.

INFORMED CONSENT STATEMENT

Written informed consent was obtained from all participants after they received explanations about the study's purpose, procedures, benefits, and potential risks. For participants under the age of 18, written consent was obtained from their parents or legal guardians.

ETHICS STATEMENT

This study did not undergo formal ethics committee review as it did not involve clinical interventions or sensitive personal data. Ethical considerations were reviewed and approved by STIKIP PGRI Situbondo and Ahli Media Consultant, an educational consultancy firm, to ensure compliance with ethical standards, including informed consent, confidentiality, and participant protection.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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