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EXPLAINING SCIENCE PROBLEM SOLVING SKILLS THROUGH CRITICAL THINKING, COLLABORATION, AND TECHNOLOGY USE

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Abstract: This study examined the structural relationships among critical thinking, collaboration, technology use, creativity, and science problem-solving skills using Partial Least Squares Structural Equation Modeling (PLS-SEM). The model positioned critical thinking, collaboration, and technology use as exogenous constructs, creativity as the mediating construct, and science problem-solving skills. The measurement model showed that the indicators had acceptable outer loading values, indicating adequate representation of their respective latent constructs. The structural model demonstrated substantial explanatory power, with R-square values of 0.678 for creativity and 0.747 for science problem-solving skills, showing that the model explained a considerable proportion of variance in both endogenous constructs. Path coefficient analysis revealed that critical thinking had the strongest effect on creativity (0.421), followed by technology use (0.243) and collaboration (0.218). In contrast, the direct effects on science problem-solving skills were relatively weak, as indicated by the coefficients from critical thinking (0.151) and creativity (0.096). These findings suggest that the model contributes most strongly to explaining creativity, while science problem-solving skills are shaped through a more complex process.

Keywords: Collaboration, Technology Use, Creativity, Science Problem-Solving Skills

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INTRODUCTION

In the 21st-century educational landscape, learning is no longer oriented solely toward content mastery, but also toward the development of higher order thinking skills commonly referred to as the 4Cs: critical thinking, collaboration, creativity, and communication (Stanikzai, 2023). These skills are essential to prepare students to face increasingly complex global challenges. In the context of science education, students are not only required to understand scientific concepts but also to apply them in everyday life through critical thinking and problem-solving skills (Sastradewi & Agung, 2022) Critical thinking is one of the essential skills that students must possess in science learning. This ability includes understanding information, analyzing, evaluating, and drawing logical conclusions (Huda, et al., 2020a; Huda et al., 2026; Hardini et al., 2026). However, in reality, students' critical thinking skills in Indonesia are still relatively low. Many students tend to passively receive information without being able to relate the concepts learned to real-life phenomena. This condition indicates that science learning needs to be designed more innovatively to optimally train students' critical thinking skills(Jannah & Atmojo, 2022). This interpretation is supported by Yusal et al. (2025), who found that collaborative problem-solving assisted by varied visual media significantly improved students’ critical thinking skills.

In addition to critical thinking, collaboration skills also play an important role in the learning process. Collaboration allows students to work together in groups, exchange ideas, and build shared understanding in solving problems. Through collaboration, students can learn to respect different opinions and develop effective communication skills (Sastradewi & Agung, 2022). However, in practice, students' collaboration skills are still not optimally developed, especially when learning does not provide sufficient opportunities for active interaction (Nurulsari et al., 2020; Usman et al., 2025; Huda, et al., 2020b).

On the other hand, technological advancements offer significant opportunities to improve the quality of science learning. The use of technology, such as interactive learning media, educational videos, and digital platforms, can help students understand abstract concepts more concretely (Sari et al., 2021). In addition, technology can increase student engagement in learning and encourage them to be more active in seeking and processing information (Stanikzai, 2023). Therefore, the integration of technology in science learning is an important factor in enhancing students' critical thinking and problem-solving abilities. Generative artificial intelligence can also support technology-enhanced assessment; Maiyanti et al. (2023) showed that ChatGPT can help educators develop HOTS questions more quickly and easily,

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while the resulting items still require academic verification (Munifah et al., 2019; Lestari et al., 2021; Saregar et al., 2025).

Student creativity is another important aspect in supporting the learning process. Creativity enables students to generate new ideas, think flexibly, and develop innovative solutions to problems (Sastradewi & Agung, 2022). In science learning, creativity can act as a mediating variable that links critical thinking, collaboration, and the use of technology with problem-solving abilities (Ariastika, 2022). With creativity, students are not only able to understand problems but also to generate various effective alternative solutions.

Science problem-solving ability is the ultimate goal of the learning process. Students who possess strong problem-solving skills will be better prepared to face various challenges, both in academic contexts and in everyday life. Therefore, it is important to examine the factors influencing this ability, particularly critical thinking, collaboration, and the use of technology, by considering the role of creativity as a mediating variable. Based on the above description, this study aims to analyze the influence of critical thinking skills, collaboration, and the use of technology on science problem-solving abilities through student creativity among seventh-grade students of MTs Raudlatut Thalabah. The results of this study are expected to contribute to the development of more effective and innovative science learning strategies (Huda et al., 2019; Yasin et al., 2020; Putra et al., 2024).

Although previous studies have highlighted the importance of critical thinking, collaboration, technology integration, and creativity in science learning, most of them have tended to examine these variables separately or only in limited combinations. Some studies focus primarily on the role of digital media in strengthening critical thinking, while others emphasize problem-solving through interactive multimedia or ethnoscience-based learning (Jannah & Atmojo, 2022; Sari et al., 2021; Sastradewi & Agung, 2022). As a result, the structural relationship among these variables remains insufficiently explained, especially when they are positioned simultaneously in one empirical model. In particular, limited attention has been given to how creativity functions as an intervening mechanism linking collaboration and technology use to science problem-solving skills. This indicates that the current body of literature still lacks an integrative explanation of how 21st-century competencies work together in shaping students' science learning outcomes (Ariastika, 2022; Stanikzai, 2023).

In addition, findings from previous research are not always consistent. On the one hand, critical thinking is often assumed to be a major predictor of problem-solving ability in science learning (Jannah & Atmojo, 2022; Sastradewi & Agung, 2022). On the other hand, classroom practice suggests that students who are expected to think critically do not always demonstrate strong problem-solving performance when learning activities are not supported by collaborative interaction, meaningful technological tools, or opportunities for idea generation. Likewise, creativity is frequently discussed as an important 21st-century skill, but its empirical role in strengthening science problem-solving has not been firmly established (Huda et al., 2019; Yasin et al., 2020; Putra et al., 2024). In many cases, creativity is treated merely as a parallel outcome of learning rather than as a mediating variable that may explain how students transform interaction and technological support into effective solutions (Ariastika, 2022; Damayanti et al., 2017). This inconsistency opens an important space for further empirical investigation.

The context of this study also deserves specific attention. Most discussions on 21st-century skills are presented at a general level, whereas the implementation of these skills may differ substantially across educational settings. Students at the seventh-grade level of Madrasah Tsanawiyah are in a transitional stage of cognitive and social development, where they begin to move from concrete learning experiences toward more abstract and reflective thinking (Azis et al., 2022). In this phase, science learning does not only require conceptual understanding, but also structured support that enables students to collaborate, use technology meaningfully, and generate ideas creatively when facing scientific problems. Therefore, testing this model in the context of MTs students is important, because the characteristics of Islamic junior secondary education may shape the interaction among these variables differently from findings reported in broader or more general school contexts.

Based on these considerations, the novelty of this study lies in its attempt to examine an integrated model that connects critical thinking, collaboration, and technology use with science problem-solving skills through creativity as a mediating variable in the context of seventh-grade MTs students. Rather than viewing these variables as isolated competencies, this study positions them as interconnected dimensions of 21st-century science learning (Stanikzai, 2023). This model is expected to contribute not only to the empirical understanding of science problem-solving skills, but also to the design of more contextual, collaborative, and technology-supported learning strategies for junior secondary science education.

METHOD

This study is a quantitative research with a confirmatory approach aimed at examining the relationships between critical thinking skills, collaboration, and the use of technology on science problem-solving abilities, with creativity as a mediating variable. The research was conducted at MTs Raudlatut Thalabah Ngadiluwih, Kediri Regency. The population of this study consisted of all students of class VII A and VII B at MTs Raudlatut Thalabah, totaling 37

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students, including 20 students from class VII A and 17 students from class VII B. The sampling technique used was saturated sampling, in which the entire population was used as the research sample. This technique was chosen due to the relatively small population size, allowing for more accurate results (Rachman et al., 2024).

Data were collected through questionnaires as primary data, which were administered directly to students, and secondary data obtained from literature review. The research instrument used a Likert scale with four levels of responses, ranging from strongly disagree (1) to strongly agree (4) (Pertiwi & Rusyda Firdausi, 2019). The variables in this study consisted of critical thinking skills, collaboration, and the use of technology as independent variables, science problem-solving ability as the dependent variable, and student creativity as the mediating variable.

Data analysis was carried out using Structural Equation Modeling based on Partial Least Squares (SEM-PLS) with the assistance of SmartPLS software. The analysis included the measurement model (outer model), which covered convergent validity, discriminant validity, and construct reliability tests, as well as the structural model (inner model), which involved testing path coefficients, R-square values, and effect size (f-square) to determine the strength of relationships between variables. The research model used in this study is presented in **Figure 1**.

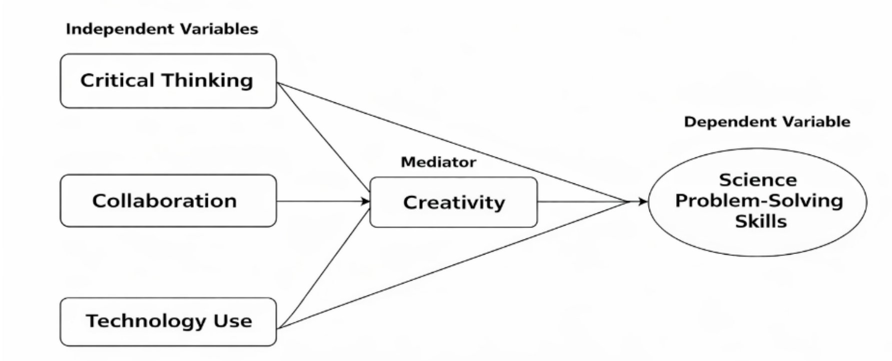

Figure 1. Proposal reasearch model

The research model in **Figure 1.** illustrates the relationships between critical thinking skills, collaboration, and the use of technology on science problem-solving abilities, with creativity as a mediating variable. Critical thinking, collaboration, and the use of technology are assumed to have direct effects on science problem-solving ability, as well as indirect effects through student creativity.

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FINDING AND DISCUSSION

The discussion begins by clarifying the meaning of each construct included in the model. In this study, CRI refers to critical thinking, which represents students' ability to analyze information, evaluate evidence, make reasoned judgments, and solve academic problems logically. COL refers to collaboration, which reflects students' ability to work with others, exchange ideas, participate in shared tasks, and build understanding through social interaction. TECH refers to the technology-related dimension, including students' ability to access, use, and benefit from technology in the learning process. Meanwhile, CRE refers to creativity, which functions as the mediating construct and represents students' ability to generate ideas, develop alternative solutions, and express original thinking. Finally, PRO refers to the final outcome construct in the model, namely the performance-oriented outcome that becomes the ultimate target of the structural relationship.

Conceptually, these constructs form a developmental pathway rather than a set of isolated variables. Critical thinking, collaboration, and technology-related competence are positioned as exogenous variables because they are assumed to contribute to the development of creativity. In this framework, creativity is not treated merely as an independent skill, but as an intermediary capacity that may translate prior competencies into a stronger final outcome. This means that students' creativity is expected to grow when they are equipped with stronger critical thinking, better collaboration, and more effective engagement with technology.

The role of CRI is particularly important because critical thinking provides the cognitive foundation for deeper intellectual work. Students who think critically are generally better able to question assumptions, compare alternatives, identify relationships, and construct logical responses to academic challenges. In the context of this model, critical thinking is therefore understood as a driving force that can stimulate the emergence of creativity. Creative performance is often not spontaneous; rather, it develops from the ability to examine problems carefully and reorganize knowledge into new forms. For this reason, the relationship between CRI and CRE is theoretically meaningful and becomes one of the key points in interpreting the results.

Similarly, COL and TECH also play supporting roles in the formation of creativity. Collaboration creates opportunities for students to exchange perspectives, refine ideas, and co-construct solutions through interaction with peers. Technology, on the other hand, expands access to information, tools, and learning resources that may support idea generation and innovation. When these dimensions work together, students are more likely to develop stronger creativity, which may eventually contribute to the final outcome represented by PRO. Thus,

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before discussing the numerical findings, it is important to understand that the model assumes a layered process in which critical thinking, collaboration, and technology first strengthen creativity, and only then contribute to the final outcome.

The evaluation of the measurement model began by examining the outer loading values of all constructs included in the study. In general, the results indicate that the indicators had acceptable loading values and were sufficiently representative of their respective latent variables. This suggests that the measurement model was adequate for further structural analysis.

For the CRI construct, the outer loading values ranged from 0.639 to 0.899, indicating that most indicators made strong contributions to the construct, although one indicator showed a relatively moderate loading. Similarly, the COL construct demonstrated acceptable outer loading values, ranging from 0.624 to 0.862, which suggests that its indicators were reasonably well aligned with the latent construct. The TECH construct also showed satisfactory outer loading values, ranging from 0.673 to 0.850, indicating good indicator reliability. Likewise, the PRO construct had loadings between 0.632 and 0.867, suggesting that its indicators were sufficiently valid in representing the endogenous construct and supporting adequate convergent validity. Compared with the other constructs, the CRE construct, which functioned as the mediating variable in the model, showed relatively lower loading values, ranging from 0.589 to 0.747. Although these values were lower than those of the other constructs, they were still within an acceptable range for exploratory analysis. This finding suggests that the CRE construct was empirically represented by its indicators, although some items may require refinement in future studies to strengthen the construct measurement.

Table 1. presents the summary of the outer loading values for each construct in the measurement model. These values were used to evaluate the extent to which the indicators represented their respective latent variables. Overall, the results show that all constructs achieved acceptable outer loading ranges, indicating that the indicators were sufficiently adequate to measure the intended constructs.

Tabel 1. Summary of outer loadings by construct

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Construct	Role in Model	Range of Outer Loadings	Interpretation
CRI	Exogenous construct	0.639–0.899	Most indicators show strong contributions, although one indicator is relatively moderate.
COL	Exogenous construct	0.624–0.862	Indicators demonstrate acceptable outer loadings.
TECH	Exogenous construct	0.673–0.850	Indicators indicate good reliability.
CRE	Mediating construct	0.589–0.747	Loadings are relatively lower than other constructs, but still acceptable for exploratory analysis.
PRO	Endogenous construct	0.632–0.867	Indicators show adequate convergent validity.

The structural model was evaluated by examining the coefficient of determination (R-square) for each endogenous construct. The R-square value indicates the extent to which the variance of an endogenous variable can be explained by its predictor constructs in the model. In this study, the R-square values were used to assess the explanatory power of the proposed model for both CRE and PRO.

As presented in **Table 2**, the CRE construct obtained an R-square value of 0.678, which means that 67.8% of its variance was explained by the exogenous constructs included in the model. This result indicates that the predictors contributed substantially to the development of CRE, suggesting that the model had good explanatory capability for the mediating construct. Meanwhile, the PRO construct showed an R-square value of 0.747, indicating that 74.7% of its variance was explained by the predictors in the model. This finding suggests that the structural model had strong explanatory power for PRO as the final endogenous construct. Overall, the R-square values demonstrate that the proposed model was able to explain a considerable proportion of variance in both endogenous variables.

Table 2. Summary of endogenous constructs (r-square)

Endogenous Construct	R-square	Variance Explained	Interpretation
CRE	0.678	67.8%	The exogenous constructs explain a substantial proportion of variance in CRE.
PRO	0.747	74.7%	The model has strong explanatory power for PRO.

As shown in **Table 3**, CRI had the strongest effect on CRE, with a path coefficient of 0.421. This finding indicates that CRI was the most influential predictor of the mediating construct in the model. In comparison, TECH and COL also showed positive effects on CRE, with coefficients of 0.243 and 0.218, respectively, suggesting that both constructs contributed to CRE, although to a lesser extent than CRI. The results also show that the direct effects on PRO were relatively weaker. The coefficient from CRI to PRO was 0.151, while the effect of

CRE on PRO was 0.096. These findings suggest that the strongest structural relationships in the model were found in the pathways leading to CRE, whereas the direct contributions to PRO were comparatively limited. Overall, the path coefficient analysis indicates that CRE played an important intermediary role in the structural model.

Table 3. Summary of path coefficients

Path	Coefficient	Interpretation
CRI → CRE	0.421	Strongest effect on CRE
TECH → CRE	0.243	Positive effect on CRE
COL → CRE	0.218	Positive effect on CRE
CRI → PRO	0.151	Relatively weak direct effect on PRO
CRE → PRO	0.096	Weak direct effect on PRO

Table 4 presents the ranking of the exogenous constructs based on the magnitude of their path coefficients toward CRE. This ranking was developed to provide a clearer picture of the relative contribution of each predictor in explaining the mediating construct. By comparing the coefficients, the analysis helps identify which construct played the most dominant role in shaping CRE within the proposed structural model.

Table 4. Ranking of Predictors of CRE

Rank	Predictor	Path to CRE	Coefficient
1	CRI	CRI → CRE	0.421
2	TECH	TECH → CRE	0.243
3	COL	COL → CRE	0.218

As shown in **Table 4**, CRI ranked first with a path coefficient of 0.421, indicating that it was the strongest predictor of CRE. This result suggests that CRI made the greatest contribution to the formation of the mediating construct compared with the other exogenous variables. In contrast, TECH ranked second with a coefficient of 0.243, while COL ranked third with a coefficient of 0.218. These findings indicate that although all three constructs contributed positively to CRE, their levels of influence were not equal. The stronger contribution of CRI shows that it had a more substantial role in explaining variation in CRE, whereas TECH and COL functioned as supporting predictors with comparatively smaller effects. Overall, the ranking confirms that CRI was the most influential determinant of CRE in the structural model.

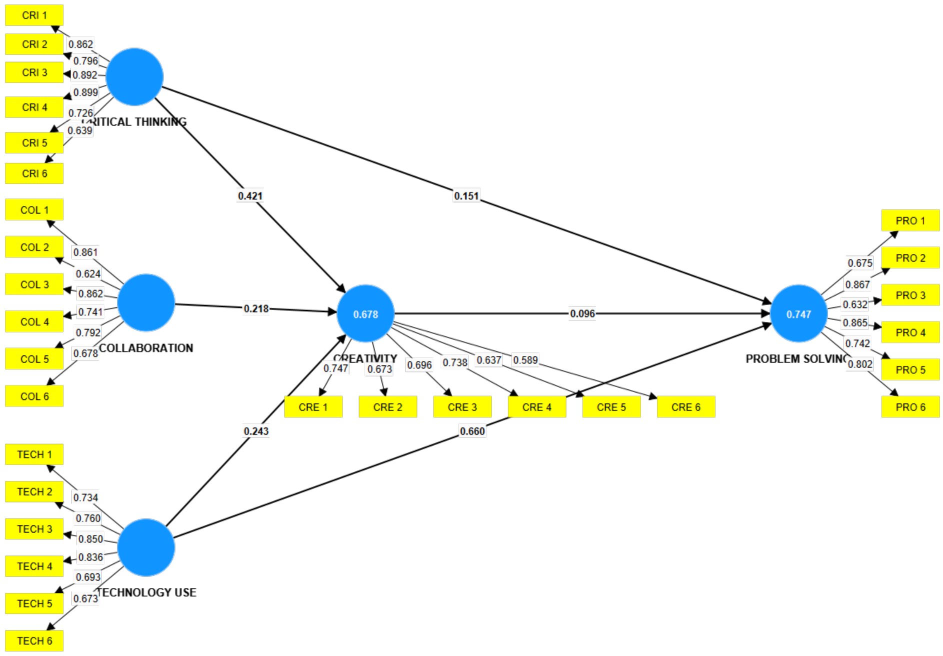

Figure 2. Final PLS-SEM model illustrating the effects of CRI, COL, and TECH on CRE, and the subsequent effect of CRE on PRO, together with indicator loadings and explained variance

The PLS-SEM model shows that the measurement and structural models provide an adequate basis for explaining the relationships among the constructs. The outer model indicates that most indicators have acceptable loading values, suggesting that the indicators are sufficiently representative of their respective latent variables. For the CRI construct, the loading values range from 0.639 to 0.899, indicating that most indicators have strong contributions, although one indicator remains relatively moderate. The COL construct also demonstrates acceptable outer loadings, ranging from 0.624 to 0.862. Similarly, the TECH construct shows loading values between 0.673 and 0.850, suggesting good indicator reliability. The PRO construct has loading values ranging from 0.632 to 0.867, which also indicates adequate convergent validity.

The CRE construct, which functions as the mediating construct in the model, has indicator loadings ranging approximately from 0.589 to 0.747. Compared with the other constructs, the loadings of CRE are relatively lower, although still within an acceptable range for exploratory analysis. This suggests that the CRE construct is empirically represented by its indicators, but some items may need refinement in future studies to improve construct strength.

In the structural model, the endogenous construct CRE has an R-square value of 0.678, meaning that 67.8% of the variance in CRE is explained by the exogenous constructs included in the model. This indicates substantial explanatory power. Meanwhile, the PRO construct has

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an R-square value of 0.747, indicating that 74.7% of its variance is explained by the predictors in the model. This value suggests that the model has strong predictive relevance for the final endogenous construct.

The path coefficients show that CRI has the strongest effect on CRE with a coefficient of 0.421, followed by TECH with 0.243, and COL with 0.218. These results indicate that CRI is the most influential predictor of CRE in the model. Furthermore, the direct effect of CRI on PRO is 0.151, while the direct effect of CRE on PRO is 0.096, indicating relatively weak direct relationships compared with the effects found on CRE.

The findings suggest that the constructs represented by CRI, COL, and TECH contribute meaningfully to the development of CRE, with CRI emerging as the strongest predictor. This pattern indicates that the variable represented by CRI plays a central role in shaping students' creative capacity or the intermediary construct measured by CRE. In practical terms, this means that strengthening the CRI-related dimension is likely to provide the greatest contribution to the enhancement of CRE compared with the other predictors.

The effect of COL on CRE is positive but smaller than that of CRI. This indicates that although collaborative aspects contribute to the development of creativity, their influence is not as dominant as the CRI dimension in this model. Nevertheless, collaboration remains an important supporting factor because it may encourage idea exchange, social interaction, and shared problem exploration, all of which can stimulate creative performance. This nuanced pattern is consistent with Laili et al. (2025), who reported that a structured laboratory management module positively influenced critical thinking and creativity, whereas its effects on communication and collaboration were not significant.

Likewise, TECH shows a positive contribution to CRE, with a coefficient slightly higher than COL. This suggests that the TECH-related dimension also plays a relevant role in strengthening creativity. The result implies that exposure to technological resources, technological competence, or technology-supported learning activities may enhance students' ability to generate, modify, and apply ideas creatively. In this model, TECH appears to function as an enabling factor that supports the emergence of CRE.

The structural results also show that PRO is well explained by the model, as indicated by the high R-square value of 0.747. However, the direct effect of CRE on PRO is relatively weak (0.096). This suggests that although CRE is theoretically connected to PRO, its direct contribution in this model is limited. One possible interpretation is that PRO may be influenced not only by CRE, but also by other direct or indirect mechanisms not fully captured through a single pathway. In other words, creativity alone may not be sufficient to strongly predict the

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final outcome unless it is accompanied by other supporting internal or external factors. The direct effect of CRI on PRO (0.151) is also relatively modest. This indicates that the contribution of CRI to PRO may occur more meaningfully through indirect pathways, particularly through CRE, rather than through a strong direct relationship. If this pattern is confirmed by bootstrapping results, it would suggest that CRE may function as a partial mediating mechanism, although the magnitude of that mediation would need to be interpreted carefully.

Overall, the model demonstrates that the strongest explanatory pattern lies in the prediction of CRE, rather than in the direct prediction of PRO. This means that the exogenous constructs are more effective in shaping the intermediate construct first, before contributing to the final outcome. Therefore, the findings support the view that the development of the final outcome represented by PRO is a gradual process, in which CRE serves as an important but not dominant intervening variable.

From a practical perspective, these findings imply that interventions designed to improve PRO should not focus solely on the final outcome itself. Instead, greater attention should be given to strengthening the antecedent constructs, especially CRI, and to supporting the development of CRE through collaborative and technology-related learning environments. Such an approach may provide a more systematic pathway for improving students' overall performance in the domain represented by PRO.

CONCLUSION

This study concludes that the proposed PLS-SEM model has substantial explanatory power in describing the relationships among CRI, COL, TECH, CRE, and PRO. The findings show that CRI, COL, and TECH positively contributed to CRE, with CRI emerging as the strongest predictor of the mediating construct. This indicates that the development of CRE was influenced most strongly by the CRI dimension, while COL and TECH functioned as supporting predictors with smaller but still meaningful contributions.

The study also found that the model explained a considerable proportion of variance in both endogenous constructs, with R-square values of 0.678 for CRE and 0.747 for PRO. These results suggest that the proposed framework was effective in explaining both the mediating construct and the final endogenous outcome. However, the direct effects on PRO were relatively weak, as shown by the coefficients from CRI to PRO (0.151) and from CRE to PRO (0.096). This implies that the final outcome represented by PRO may be shaped through a more complex process rather than through strong direct effects alone.

Overall, the findings highlight that the strongest contribution of the model lies in explaining the formation of CRE rather than the direct prediction of PRO. Therefore, efforts to improve the final outcome should not focus only on the end result, but also on strengthening the antecedent constructs, especially CRI, while also supporting COL and TECH as complementary factors. In this way, the study provides evidence that educational outcomes are better understood as the result of interconnected and gradual processes in which intermediate constructs such as CRE play an important role.

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