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Exploring mathematics teacher's perceptions of students' computational thinking and attitudes towards STEAM-AR: A need for module development

Masduki*, Rita P Khotimah, Sukirman, Salsabila Kurniawati, Isnaini Nurul Hidayati

Universitas Muhammadiyah Surakarta, Indonesia

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ABSTRACT

Computational thinking (CT) skills are vital for addressing future challenges. The integration of the Science, Technology, Engineering, Arts, and Mathematics (STEAM) can assist students to foster CT abilities. Furthermore, incorporating technology into education such augmented reality (AR) can improve the quality of the students' learning experience. Consequently, it is essential to develop a STEAM-AR-based learning module to foster CT abilities. This study seeks to ascertain teachers' perceptions concerning students' CT abilities, attitudes towards STEAM learning principles, attitudes towards the technology integration in mathematics learning, and the need for a STEAM-AR-based mathematics module. An online survey was administered to 105 secondary mathematics teachers in the Sukoharjo District, Indonesia. The findings indicated that the teachers' perceptions were predominantly high. The high-level perceptions suggest that teachers view students as deficient in CT and STEAM-related learning activities. Furthermore, the findings demonstrate that the learning process will achieve higher quality by utilizing technology-based learning modules that integrate STEAM. In addition, there is no significant variation in teachers' perceptions based on gender and teaching experience across all perceptions. Finally, the results suggest that in order to improve students' CT abilities, teachers must integrate STEAM and technology into their classroom.

INTRODUCTION

Computational thinking (CT) is an essential skill in the era of the 21st century (Park & Kwon, 2022; Selby, 2015). Facilitating learning that enables students to cultivate critical thinking is a crucial aspect of mathematics education (Fadel et al., 2015; Vourletsis & Politis, 2020; Yadav et al., 2017). Various global organizations, including the European Commission, the United Nations Educational, Scientific and Cultural Organization (UNESCO), and the Organization for Economic Co-operation and Development (OECD), regard CT as a crucial competency linked to the growing demand for students' digital literacy skills, necessitating its prioritization in education and curriculum development (Bocconi et al., 2022; Lee et al., 2023; OECD, 2018; UNESCO, 2021). International assesment, such PISA and TIMSS, have incorporated technological advancements by offering exam content and forms that necessitate CT abilities for accessing assessments and solving problems (Jameson et al., 2019).

The PISA 2022 findings indicate that Indonesian students' mathematics scores fall below the international average score (OECD, 2023). PISA evaluates students' competencies in problem-solving and reasoning (Apriandi et al., 2023; Rosana et al., 2020). Consequently, PISA findings serve as a benchmark for evaluating students' competencies in addressing intricate problems and advanced

*Corresponding author: masduki@ums.ac.id

reasoning. The capability of CT is evident in an individual's approach to solve mathematical problems (Supiarmo et al., 2022). The PISA results indicate that the CT abilities of Indonesian students are classified as low.

Previous studies revealed the students' shortcomings in CT abilities for addressing mathematical problems. A multitude of students struggles to dissect complex problems into manageable elements, faces difficulties in recognizing patterns, and finds it challenging to identify relevant information (Hartawan et al., 2024; Nurwita et al., 2022). Further research reveals that students find it challenging to distinguish between familiar and unfamiliar material, translate problems into mathematical equations, perform procedures systematically and accurately, and commence evaluating the validity of the obtained solutions (Vidad & Quimbo, 2021). Moreover, students face difficulties in transforming data into variables, incorporating irrelevant knowledge to tackle challenges, and articulating real-world problems into mathematical terminology or models (Dwita & Retnawati, 2022). These results present a challenge in assisting students in the development of CT abilities. Proficiency in CT abilities will enable students to tackle more intricate and demanding mathematical problems.

A hallmark of 21st-century learning is STEAM-based education. STEAM is crucial for cultivating the competences required to navigate the 21st century era. STEAM is a contextual learning approach that amalgamates various disciplines to guide students in cultivating problem-solving abilities, CT, and creativity (Conradty et al., 2020; Herro et al., 2022; Karampelas, 2023). Furthermore, the incorporation of STEAM in education can enhance student engagement, motivation, and academic performance (Cabello et al., 2021; Hong et al., 2020; Juškevičiene, 2020). Consequently, the inclusion of STEAM in education is anticipated to enhance students' CT abilities.

The implementation of STEAM-based learning is aligned with the Indonesia's Curriculum which emphasizes on students' 21st century skills, including critical thinking, creativity, collaboration and communication (Kemdikbudristek, 2021). Previous research has examined the implementation of STEAM-based learning in Indonesia. In physics education, the implementation of STEAM-based learning enhances creative and critical thinking skills, facilitating students' comprehension of subjects (Amiruddin et al., 2022). The integration of STEAM-based learning in secondary school science has also enhanced conceptual mastery and creativity (Wandari et al., 2018). Furthermore, the implementation of STEAM-based learning can cultivate students' interest in STEAM courses and promote the integration of technology within the educational environment (Huda et al., 2024). Even though STEAM-based learning offers significant advantages in enhancing students' 21st-century competencies, its implementation in Indonesia faces several constraints. The majority of teachers are insufficiently informed on the principles and methodologies for executing STEAM-based learning (Roshayanti et al., 2022). The absence of specialized training, resources, insufficient learning materials, and support systems hinders the efficient implementation of STEAM approaches in educational settings (Amiruddin et al., 2022). Consequently, it is imperative to facilitate teachers in the integration of STEAM-based learning within their classrooms, for instance a module as part of learning material.

Rapid technology breakthroughs, such as augmented reality (AR), exert a substantial influence across all domains, including education. AR is a technology that facilitates the visualization of objects in the physical environment, enhancing the interactivity of the learning experience (Lai & Cheong, 2022; Sousa & Rocha, 2019). The incorporation of augmented reality in education can assist students in comprehending complex and challenging problems (Sungkur et al., 2016). Furthermore, the integration of augmented reality can enhance communication abilities, mathematical reasoning, mathematical literacy, and CT abilities which essential for addressing complex problems (Pujiastuti & Haryadi, 2023; Schutera et al., 2021; Suwayid Alqarni & Rezqallah Alzahrani, 2022). Unfortunately, the integration of technology in education in Indonesia faces several significant challenges that hinder its effectiveness and accessibility. Students face internal challenges like self-regulation and digital literacy. Besides, teachers also struggle with skills and experience in IT-based learning (Rasimin et al., 2024). Moreover, limited access to technological resources, especially in remote areas, lack of training program, technical support, and lack of time poses a significant barrier to effective technology integration (Habibi et al., 2020, 2023). Therefore, it is imperative for all stakeholders to facilitate teachers to integrate technology into education. This research merged AR

technology with STEAM-based modules to provide teachers with learning materials aimed at enhancing students' CT abilities.

Various strategies have been employed to foster students' CT abilities, including the use of virtual reality (VR)-based gaming media (Agbo et al., 2023; Sukirman et al., 2022, 2024), augmented reality (AR) (Abdul Hanid et al., 2022; Hanid et al., 2022; Lin et al., 2021), and integration with the STEAM approach (Bati et al., 2018; Sun et al., 2023; Tan et al., 2021). Previous studies revealed that integrating STEAM education with AR offers several key benefits. The integration AR in STEAM education has been shown to motivate students and enhance their understanding of key concepts (Delgado-Rodríguez et al., 2023; Demitriadou et al., 2020; Wang et al., 2024). AR also promotes students the use of CT by facilitating the decomposition of problems and the construction of logical answers. These competencies are essential throughout STEAM disciplines, equipping students for difficulties in both engineering and creative domains (Demitriadou et al., 2020). Nonetheless, the incorporation of AR in STEAM education is primarily focused on science education. There are few studies that concentrate on mathematical education. In this context, the integration of AR and STEAM in mathematics education is essential to cultivate students' 21st-century skills, particularly CT.

Learning modules that incorporate specific pedagogical strategies, i.e. discovery and project-based learning, can foster students' mathematical reasoning, critical thinking, communication skills, CT, and creativity, which are essential for addressing complex mathematical problems (Khotimah et al., 2023; Siregar et al., 2020; Wardani et al., 2021). Nevertheless, there is still room for further investigation into the development of mathematics learning modules that integrate STEAM-AR. Consequently, it is essential to develop a mathematics learning module that integrates STEAM-AR to enhance students' CT abilities.

However, the decision to integrate the innovative teaching methods in the classroom significantly influenced by the teachers' perceptions (Akram et al., 2022; Boonmoh et al., 2021; Celeste & Osias, 2024). Positive perceptions can encourage the teachers to adopt the new instructional methods in the classroom, while negative views may hinder them (Abel et al., 2022; Al-Takhayneh et al., 2022). In addition, the quality of students' learning can be influenced by teachers' perceptions and attitudes toward teaching and learning processes (Edson & C. K. Shawa, 2021).

Thus, the current study investigates teachers' perceptions about the need for STEAM-AR learning module to enhance the student's computational thinking. In addition, the influence of gender differences and teaching experience on teacher perceptions was also examined. To achieve this aim, six research questions were formulated, as follows:

1. What are the teachers' perceptions of students' CT abilities?
2. What are the teachers' perceptions of students' attitudes toward STEAM learning principles?
3. What are the teachers' perceptions of student's attitude toward integration technology in mathematics learning?
4. What are the teachers' perceptions of the necessity for a STEAM-AR based mathematics module?
5. How do gender differences affect teacher perceptions?
6. How do teaching experience influence teacher perceptions?

METHODS

Research Design

This research employed a quantitative methodology utilizing a survey design to get data from participants. The research instrument comprised a questionnaire with 25 items divided into five sections: A) Self-Information, B) Teachers' perceptions of Students' CT Ability, C) Teachers' perceptions of students' attitudes toward STEAM learning principles, D) Teacher's perceptions of student's attitude toward integration technology in mathematics learning, and E) Teachers' perceptions of the necessity for a STEAM-AR based mathematics module. Sections B - E employed a Likert scale comprising five levels: 1: Strongly Disagree (SD), 2: Disagree (D), 3: Neutral (N), 4: Agree (A), 5: Strongly Agree (SA). The instrument was evaluated by three experts: STEAM professionals, CT experts, and learning technology experts. The experts evaluated the instrument for relevance, clarity, and alignment with the study objectives of each question item. Furthermore, the questionnaire was evaluated by three mathematics teachers to offer recommendations on the clarity of the language

Table 1.
Cronbach alpha value of instruments

Instrument	Elements	Cronbach Alpha value	Number of Item
Section B	Teacher's Perceptions of Student's CT Ability	0.878	5
Section C	Teacher's Perceptions of Student's Attitude Toward STEAM Learning Principles	0.893	7
Section D	Teacher's Perceptions of Student's Attitude Toward Integration Technology in Mathematics Learning	0.743	5
Section E	Teacher's Perceptions of the Need for STEAM-AR Based Mathematics Module	0.916	5

Table 2.
Demographic characteristic of respondents

Characteristic	Categories	Percentage (%)
Gender	Male	36.2
	Female	63.8
Teaching experience	0 to 5 years	21.9
	6 to 10 years	12.4
	10 years and above	65.7

Table 3.
Interpretation of mean score Likert scale

Mean Score	Level
1.00 – 2.33	Low
2.34 – 3.67	Moderate
3.68 – 5.00	High

employed in each question, ensuring comprehensibility for the instructors as potential respondents. Following revision, the instrument was evaluated with 20 secondary mathematics teachers to ensure its validity and reliability. Not all teachers are participating in the primary research. By employing IBM SPSS Statistics Version 20, the product moment correlation coefficient value of all items in sections B to E was determined to be valid. Moreover, the reliability test yielded a Cronbach Alpha value, as presented in Table 1, indicating that the instruments are reliable as all values exceed 0.6. As a result of the evaluation of validity and reliability, the instrument is considered both valid and reliable, making it appropriate for data collection.

Participants

This study's population comprised 105 secondary mathematics teachers from the Sukoharjo District in Central Java, Indonesia. Table 2 displays the demographic characteristics of the respondents. The responses are predominantly female teachers in comparison to male teachers. Furthermore, the majority of respondents possess over 10 years of teaching experience.

Data Analysis

The data was analyzed descriptively by evaluating the mean score of each statement in sections B to E. This study utilized three levels to interpret the mean score on the Likert scale, as detailed in Table 3 (Lendal, 1997). Additionally, the independent samples t-test was employed to analyze the differences in teachers' perceptions based on gender. The one-way ANOVA test was employed to analyze the variations in teachers' opinions based on their teaching experience.

FINDINGS

Teacher's perceptions of student's computational thinking ability

The results presented in Table 4 indicates that students' challenges in applying CT techniques to mathematical problem solving fall into the high category (M=3.80). This demonstrates that students' aptitudes for solving real-world mathematical problems remain inadequate, as perceived

Table4.
Teacher's perceptions of student's computational thinking ability

No	Item	Mean Score (M)	Level
1	Students struggle to discern essential information (known, asked) from real-world problems.	3.83	High
2	Students struggle to recognize overarching patterns for solving real-world problems.	3.72	High
3	Students struggle to represent real-world problems as mathematical models.	3.87	High
4	Students have challenges in formulating well-organized solution steps for real-world problems.	3.87	High
5	Students struggle to derive general inferences from the solution of real-world problems.	3.71	High
	Average	3.80	High

Table 5.
Teacher's perceptions of student's attitude toward STEAM learning principles

No	Item	Mean Score (M)	Level
1	Students struggle to connect mathematical concepts with subjects beyond mathematics.	3.73	High
2	Students encounter challenges in identifying mathematical concepts through investigative, exploratory, or experimental techniques.	3.61	Moderate
3	Students have challenges in fulfilling assignments and projects that include research and data gathering	3.42	Moderate
4	Students have challenges in employing diverse strategies to solve mathematical problems	3.72	High
5	Students encounter challenges in solving mathematical problems that necessitate reasoning and critical thinking.	3.99	High
6	The majority of students rarely participate in group projects	3.20	Moderate
7	The majority of students fail to offer suggestions or ideas when doing group work	3.26	Moderate
	Average	3.56	Moderate

by their teachers. The most significant challenges for students lie in their capacity to represent real-world problems as mathematical models and formulating well-organized solution steps for real-world problems (M=3.87) followed by discern essential information (known, asked) from real-world problems (M=3.83). Subsequently, lesser issues manifest in two aspects: students encounter challenges in deriving general inferences from the solutions to real-world problems (M=3.71) and in recognizing overarching patterns for addressing real-world problems (M=3.72). Nevertheless, the high category encompasses all items that are associated with students' challenges in solving real-world mathematical problems, as determined by the CT ability indicator.

Teacher's perceptions of student's attitude toward STEAM learning principles

Table 5 illustrates that the teacher's perceptions regarding the students' attitudes toward STEAM learning principles are moderate (M=3.56). The highest mean score was seen in the item regarding students facing obstacles in solving mathematical problems that require reasoning and critical thinking (M=3.99). Teacher observations indicate that students' reasoning and critical thinking skills in addressing tough and complicated mathematics problems are the weakest elements relative to other components associated with STEAM learning principles. Additional problems at a

Table 6.
Teacher's perceptions of student's attitude toward integration technology in mathematics learning

No	Item	Mean Score (M)	Level
1	Students struggle to visualize abstract mathematical entities, including graphs, functions, and two-dimensional and three-dimensional objects.	3.54	Moderate
2	Students derive pleasure from studying mathematics through interactive technology applications, which allow them to manipulate objects.	3.96	High
3	Students enhance their comprehension of abstract mathematical ideas through the utilization of technology.	3.88	High
4	Students are motivated to engage in autonomous learning through technology.	3.75	High
5	Students can collaborate and engage to solve mathematical challenges through the use of technology.	3.86	High
	Average	3.80	High

Table 7.
Teacher's Perceptions of the Need for STEAM-AR Based Mathematics Learning Module

No	Item	Mean Score (M)	Level
1	Mathematics learning modules must incorporate mathematical content with other scientific disciplines	4.23	High
2	Mathematics learning modules should feature mathematical problems that necessitate solutions through reasoning and critical thinking.	4.28	High
3	Mathematics learning modules must systematically offer examples of the steps required to solve complex mathematical problems.	4.42	High
4	Mathematics learning modules must enable collaborative student activities for problem-solving exploration.	4.38	High
5	Mathematics learning modules must enable learning activities that utilize technology for problem-solving.	4.29	High
	Average	4.32	High

higher level include students' difficulties in linking mathematical concepts to disciplines outside of mathematics and students' difficulties in utilizing various ways to solve mathematical issues (M=3.72). Conversely, the four aspects exhibiting moderate level, namely recognizing mathematical concepts through investigative, exploratory, or experimental methods (3.61), challenges in fulfilling assignments and projects that include research and data gathering (M=3.42), failure to provide recommendations or ideas during group work (M=3.26) and infrequent participation in group projects (M=3.20). This signifies that numerous students have engaged and provided ideas during debates or collaborative activities during learning mathematics.

Teacher's perceptions of student's attitude toward integration technology in mathematics learning

Table 6 indicates that the general level of teachers' perceptions regarding students' attitudes toward the incorporation of technology in mathematics education is high (M=3.80). The item indicating that students receive enjoyment from studying mathematics using interactive technological programs, which enable object manipulation, has the highest mean score (M=3.96). This indicates that students have a greater interest in learning mathematics using technology-driven interactive media. Additional elements classified in the high category concerning students' attitudes towards technology encompass the enhancement of comprehension of abstract mathematical concepts (M=3.88), the ability to collaborate and engage in solving mathematical problems (M=3.86), and the motivation to participate in autonomous learning through technology (M=3.75). On the other

Table 8.
T-test results of comparing male and female teacher's perceptions

Section	Elements	F	Levene Sig	t	Sig. (2-tailed)
B	Teacher's Perceptions of Student's CT Ability	0.304	0.582	2.168	0.032
C	Teacher's Perceptions of Student's Attitude Toward STEAM Learning Principles	1.262	0.264	1.812	0.073
D	Teacher's Perceptions of Student's Attitude Toward Integration Technology in Mathematics Learning	0.666	0.416	1.068	0.288
E	Teacher's Perceptions of the Need for STEAM-AR Based Mathematics Module	0.003	0.953	1.612	0.110

Table 9.
One-Way ANOVA results of teacher's perceptions based on teaching experiences

Section	Elements	F	Sig.
B	Teacher's Perceptions of Student's CT Ability	0.668	0.515
C	Teacher's Perceptions of Student's Attitude Toward STEAM Learning Principles	2.141	0.123
D	Teacher's Perceptions of Student's Attitude Toward Integration Technology in Mathematics Learning	0.160	0.852
E	Teacher's Perceptions of the Need for STEAM-AR Based Mathematics Module	0.765	0.468

hand, students encounter difficulties in visualizing abstract mathematical concepts, such as graphs, functions, and two and three-dimensional objects are classified in the moderate group (M=3.54).

Teacher's perceptions of the need for STEAM-AR based mathematics learning module

Table 7 demonstrates that teachers generally have a high degree of perception of the necessity of STEAM-AR based mathematics learning modules (M=4.32). The item mathematics learning modules must frequently offer examples of the steps required to solve complex mathematical problems received the highest mean score (M=4.42). Additionally, all items exhibit a high standard, with a mean score exceeding 4. This indicates that teachers require mathematics learning modules that consistently provide examples of the procedures necessary to resolve intricate mathematical issues, facilitate collaborative student endeavors for problem-solving exploration, incorporate technological tools for problem-solving activities, present mathematical challenges necessitating reasoning and critical thinking for solutions, and integrate mathematical concepts with other scientific fields.

Differences of teacher's perceptions based on gender

Table 8 presents the outcomes of the independent sample t-test conducted to evaluate the variations in perceptions between male and female instructors concerning teacher perceptions. The Levene's test indicated a ρ-value of 0.032 for teacher's perceptions of students' CT ability. Since the ρ-value less the significance level ($\alpha = 0.05$), the null hypothesis (Ho) is rejected, indicating that there is a significant difference in the perceptions of male and female teachers concerning students' CT ability in mathematical problem-solving. The ρ-value of teacher views concerning students' attitudes toward STEAM learning principles is 0.073 ($> \alpha$), indicating no significant difference between male and female teachers' opinions of students' attitudes toward these principles. Following this, the ρ-value of teacher perceptions regarding students' attitudes toward technology integration in mathematics learning is 0.288 ($> \alpha$), indicating that there is no significant difference in the perceptions of male and female teachers regarding students' attitudes toward technology integration in mathematics learning. Moreover, the ρ-value of the perceptions of teachers regarding the necessity

of STEAM-AR-based learning modules is 0.110 ($> \alpha$), indicating that there is no substantial difference in the perceptions of male and female teachers regarding the necessity of STEAM-AR-based mathematics modules.

Differences of teacher's perceptions based on teaching experience

The results of the one-way ANOVA test, which was conducted to investigate the variations in teacher perceptions based on their teaching experience, are presented in Table 9. The ρ-value for teacher's perceptions of students' CT ability was 0.515 (>α=0.05), which led to the rejection of Ho based on the results of the ANOVA test. This indicates that teacher views of students' CT abilities in solving mathematical problems do not significantly alter dependent on the teaching experience. Following this, the ρ-value of the teacher's perceptions of the student's attitude toward STEAM learning principles is 0.123 ($> \alpha$), indicating that there is no significant difference in the teacher's perceptions of the student's attitude toward STEAM learning principles based on the teaching experience. Moreover, the ρ-value of teacher perceptions regarding students' attitude toward the integration of technology in mathematics education is 0.852 (>α), indicating no significant difference in these perceptions based on the teachers' teaching experience. Next, the ρ-value of teachers' perceptions of the necessity of a STEAM-AR-based mathematics module is 0.468 (>α), indicating that there is no substantial difference in teachers' perceptions of the necessity of a STEAM-AR-based mathematics module based on their teaching experience. Consequently, the findings of the one-way ANOVA indicate that there is no significant difference in teachers' perceptions for all sections of the instrument relative to their teaching experience.

DISCUSSION

The findings revealed that teachers recognize students' deficiencies in CT for solving mathematical problems. This view aligns with findings from prior research. Numerous students are unable to decompose intricate problems into manageable components, encounter challenges in seeing patterns, and find it difficult to ascertain which information is pertinent (Hartawan et al., 2024; Nurwita et al., 2022). Additional research indicates that students struggle to differentiate between known and unknown information, convert problems into mathematical equations, execute procedures systematically and accurately, and initiate the assessment of the correctness of the derived solutions (Vidad & Quimbo, 2021). Furthermore, students encounter challenges in converting data into variables, including extraneous information to address difficulties, and translating real-world issues into mathematical language or models (Dwita & Retnawati, 2022). The teacher's insights and prior studies indicate a pressing necessity for the enhancement of students' CT abilities which is essential in the 21st century (Park & Kwon, 2022; Selby, 2015).

Other findings revealed that students encountering challenges in solving mathematical problems that necessitate reasoning and critical thinking. Prior studies indicates that students facing obstacles in solving real-world mathematics problems (Ali, 2021; Baidoo & Ali, 2023). Additionally, students continue to exhibit deficiencies in their ability to connect mathematical concepts to real-world contexts (Pascual & San Pedro, 2018; Tangkawsakul et al., 2024) and in their problem-solving abilities (Pavković & Marangunić, 2024; Yeni et al., 2020). In addition, prior research has also demonstrated that students encounter challenges when confronted with mathematical problems that necessitate critical and creative thinking abilities (Dhungana & Thapa, 2023; Polat & Aydın, 2020; Silberman et al., 2021). The study's findings align with teachers' perceptions of students' inadequate skills in problem-solving, critical thinking, creativity, and the application of mathematical principles to real-world scenarios. Consequently, the integration of STEAM-based learning is essential for cultivating the skills required to confront intricate future challenges

The incorporating technology in education is currently indispensable for enhancing the quality of the learning experience. Moreover, proficiency in technology is important alongside the progression of technological advancements. Teachers' high perception of student's attitude toward the use of technology in the classroom aligns with earlier research showing students' positive responses to the use of technology in math classes (Gallegos-García et al., 2022; Gqoli, 2024; M. Canilao & G. Gurat, 2023). Furthermore, the incorporation of technology in education also enhances students' motivation (M. Canilao & G. Gurat, 2023) and improves students' mathematical visualization skills (Aini Jaafar et al., 2022).

The finding also revealed that teachers typically possess a strong awareness of the importance of STEAM-AR oriented mathematics instruction modules. Numerous researchers have examined the necessity of modules to enhance the quality of learning. Primary school teachers necessitated STEM project-based learning modules to cultivate essential 21st-century abilities, including scientific literacy and critical thinking (Septiadevana & Abdullah, 2024). A survey of 124 prospective mathematics teachers revealed that 95% of respondents believe that the use of STEM-based mathematics modules can enhance the quality of mathematics instruction (Khotimah et al., 2021). Additionally, a survey of 146 high school students revealed a strong interest in mathematics learning combined with the STEAM approach (Muzakkir et al., 2024). They consider that the STEAM-based module is one of the best learning media for learning mathematics. The findings of prior studies align with the outcomes of the need's analysis concerning the development of STEAM-AR modules (Table 7), which are at a high level. Consequently, STEAM-AR learning modules are essential for teachers to enhance the quality of education, specifically to cultivate students' CT abilities.

CONCLUSIONS

This study has yielded results indicating the necessity for STEAM-AR-based mathematics instruction modules to foster students' CT abilities. In sections B and C, the mean score instruments indicate a high level, suggesting that teachers perceive students as lacking proficiency in CT and STEAM-based learning activities. Then, in section D, the mean score instrument is at a high level, suggesting that the learning process will be of higher quality if integrated with technology. Additionally, learning modules that integrate the STEAM and technology approaches are much required as presented in section E. The research findings also indicate that there is no disparity in teacher perceptions concerning gender and teaching experience. This study's findings indicate that teachers must incorporate STEAM and technology in classroom instruction to foster students' CT abilities. Finally, students might gain confidence in addressing complex problems, particularly in the future workplace.

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AUTHOR'S DECLARATION

Authors' contributions	:	M: formulating research framework, developing instrument, developing module; analyzed data, and write manuscript; RPK: formulating research framework, developing instrument, developing module, analyzed data, and write manuscript; S: developing instrument, analyzed data, and write manuscript; SK: developing instrument, gathering data, analyzed data; INH: developing instrument, gathering data, analyzed data.
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BIBLIOGRAPHY

Abdul Hanid, M. F., Mohamad Said, M. N. H., Yahaya, N., & Abdullah, Z. (2022). Effects of augmented reality application integration with computational thinking in geometry topics. *Education and Information Technologies*, *27*(7), 9485–9521. https://doi.org/10.1007/s10639-022-10994-w

Abel, V. R., Tondeur, J., & Sang, G. (2022). Teacher Perceptions about ICT Integration into Classroom Instruction. In *Education Sciences* (Vol. 12, Issue 9). MDPI. https://doi.org/10.3390/educsci12090609

Agbo, F. J., Oyelere, S. S., Suhonen, J., & Tukiainen, M. (2023). Design, development, and evaluation of a virtual reality game-based application to support computational thinking. *Educational Technology Research and Development*, *71*(2), 505–537. https://doi.org/10.1007/s11423-022-10161-5

Aini Jaafar, N., Rohani, S., Nor, M., Norrulashikin, S. M., Arina, N., Kamisan, B., & Mohamad, A. Q. (2022). Increase Students' Understanding of Mathematics Learning Using the Technology-Based Learning. In *International Journal of Advanced Research in Future Ready Learning and Education* (Vol. 28). https://doi.org/10.37934/frle.28.1.2429

Akram, H., Abdelrady, A. H., Al-Adwan, A. S., & Ramzan, M. (2022). Teachers' Perceptions of Technology Integration in Teaching-Learning Practices: A Systematic Review. In *Frontiers in Psychology* (Vol. 13). Frontiers Media S.A. https://doi.org/10.3389/fpsyg.2022.920317

Ali, C. A. (2021). Ghanaian Indigenous Conception of Real Mathematics Education in Teaching and Learning of Mathematics. *Indonesian Journal of Science and Mathematics Education*, *4*(1), 37–47. https://doi.org/10.24042/ijsme.v4i1.7382

Al-Takhayneh, S. K., Karaki, W., Hasan, R. A., Chang, bang-L., Shaikh, J. M., & Kanwal, W. (2022). Teachers' psychological resistance to digital innovation in jordanian entrepreneurship and business schools: Moderation of teachers' psychology and attitude toward educational technologies. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.1004078

Amiruddin, M. Z. Bin, Magfiroh, D. R., Savitri, I., & Sitti Maizatul Iqma Rahman. (2022). Analysis of The Application of The STEAM Approach to Learning In Indonesia: Contributions to Physics Education. *International Journal of Current Educational Research*, *1*(1), 1–17. https://doi.org/10.53621/ijocer.v1i1.139

Apriandi, D., Krisdiana, I., Suprapto, E., & Megantara, B. A. (2023). *Development and Effectiveness of STEAM-C Integrated Learning Devices to Improve Students' Creative Thinking Skills in Specific Cultural Context*. *10*(3), 440–451. https://doi.org/10.56059/jl4d.v10i3.813

Baidoo, J., & Ali, C. A. (2023). Students' mathematics and real life contexts in solving algebraic word problems. *Al-Jabar : Jurnal Pendidikan Matematika*, *14*(2), 483. https://doi.org/10.24042/ajpm.v14i2.19272

Bati, K., Yetişir, M. I., Çalişkan, I., Güneş, G., & Saçan, E. G. (2018). Teaching the concept of time: A steam-based program on computational thinking in science education. *Cogent Education*, *5*(1). https://doi.org/10.1080/2331186X.2018.1507306

Bocconi, S., Chioccariello, A., Kampylis, P., Dagienė, V., Wastiau, P., Engelhardt, K., Earp, J., Horvath, M., Jasutė, E., Malagoli, C., Masiulionytė-Dagienė, V., & Stupurienė, G. (2022). *Reviewing Computational Thinking in Compulsary Education: State of play and practices from computing education*. https://doi.org/https://doi.org/10.2760/126955.JRC128347

Boonmoh, A., Jumpakate, T., & Karpklon, S. (2021). Teachers' Perceptions and Experience in Using Technology for the Classroom. *Computer-Assisted Language Learning Electronic Journal (CALL-EJ)*, *22*(1), 1–24. https://www.researchgate.net/publication/348863074

Cabello, V. M., Loreto Martínez, M., Armijo, S., & Maldonado, L. (2021). Promoting STEAM learning in the early years: "Pequeños Científicos" Program. *LUMAT*, *9*(2), 33–62. https://doi.org/10.31129/lumat.9.2.1401

Celeste, R. J., & Osias, N. (2024). Challenges and Implementation of Technology Integration: Basis for Enhanced Instructional Program. *American Journal of Arts and Human Science*, *3*(2), 106–130. https://doi.org/10.54536/ajahs.v3i2.2656

Conradty, C., Sotiriou, S. A., & Bogner, F. X. (2020). How creativity in STEAM modules intervenes with self-efficacy and motivation. *Education Sciences*, *10*(3). https://doi.org/10.3390/educsci10030070

Delgado-Rodríguez, S., Domínguez, S. C., & Garcia-Fandino, R. (2023). Design, Development and Validation of an Educational Methodology Using Immersive Augmented Reality for STEAM Education. *Journal of New Approaches in Educational Research*, *12*(1), 19–39. https://doi.org/10.7821/naer.2023.1.1250

Demitriadou, E., Stavroulia, K. E., & Lanitis, A. (2020). Comparative evaluation of virtual and augmented reality for teaching mathematics in primary education. *Education and Information Technologies*, *25*(1), 381–401. https://doi.org/10.1007/s10639-019-09973-5

Dhungana, S., & Thapa, R. (2023). Ways of Developing Creative Thinking and Reasoning of Students in Mathematics Learning. *Mathematics Education Forum Chitwan*, *8*(1), 57–75. https://doi.org/10.3126/mefc.v8i1.60476

Dwita, A., & Retnawati, H. (2022). Students' errors in solving mathematical problems. *AIP Conference Proceedings*, *2575*. https://doi.org/10.1063/5.0107794

Edson, V., & C. K. Shawa, M. (2021). Perceptions and Factors Influencing Teaching and Learning in Kyela Secondary Schools in Tanzania. *Asian Journal of Education and Social Studies*, 17–28. https://doi.org/10.9734/ajess/2021/v25i330601

Fadel, C., Bialik, M., & Trilling, B. (2015). *Four Dimensional Education*. Center for Curriculum Redesign,.

Gallegos-García, M. I. L., Gallegos-García, M., Gallegos-García, V., & Nieto-Delgado, P. G. (2022). Technology application in the mathematical learning. *Revista de Tecnología y Educación*, 1–9. https://doi.org/10.35429/jtae.2022.16.6.1.9

Gqoli, N. (2024). Digital Technologies for Mathematics Learning in Rural Higher Education: Students' Perspectives. *Research in Social Sciences and Technology*, *9*(1), 265–278. https://doi.org/10.46303/ressat.2024.15

Habibi, A., Razak, R. A., Yusop, F. D., Mukminin, A., & Yaqin, L. N. (2020). Factors affecting ict integration during teaching practices: A multiple case study of three indonesian universities. *Qualitative Report*, *25*(5), 1127–1144. https://doi.org/10.46743/2160-3715/2020.4150

Habibi, A., Sofyan, S., & Mukminin, A. (2023). Factors affecting digital technology access in vocational education. *Scientific Reports*, *13*(1). https://doi.org/10.1038/s41598-023-32755-6

Hanid, M. F. A., Mohamad Said, M. N. H., Yahaya, N., & Abdullah, Z. (2022). The Elements of Computational Thinking in Learning Geometry by Using Augmented Reality Application. *International Journal of Interactive Mobile Technologies*, *16*(2), 28–41. https://doi.org/10.3991/ijim.v16i02.27295

Hartawan, I. G. N. Y., Putri, L. H. A., & Mahayukti, G. A. (2024). Junior High School Student's Computational Thinking Ability in Solving Mathematical Problems. *Jurnal Pedagogi Dan Pembelajaran*, *7*(1), 124–133. https://doi.org/10.23887/jp2.v7i1.78001

Herro, D., Quigley, C., Plank, H., Abimbade, O., & Owens, A. (2022). Instructional practices promoting computational thinking in STEAM elementary classrooms. *Journal of Digital Learning in Teacher Education*. https://doi.org/https://doi.org/10.1080/2153294.2022.2087125

Hong, J. C., Ye, J. H., Ho, Y. J., & Ho, H. Y. (2020). Developing an inquiry and hands-on teaching model to guide steam lesson planning for kindergarten children. *Journal of Baltic Science Education*, *19*(6), 908–922. https://doi.org/10.33225/jbse/20.19.908

Huda, N., Widya Fransiska, F., Mokodenseho, S., Hidayat Tabilantang, B., & Mokodompit, A. (2024). The Influence of STEAM Education on Students' Interest in Technology at Middle Schools in Indonesia. *The Eastasouth Journal of Learning and Educations*, *02*(01), 50–62. https://doi.org/10.58812/esle.v2i01

Jameson, E., Lai, R. P. Y., Fortin, L., Gould, T., Horsman, R., Kathotia, V., Knight, R., Mcclure, L., Macey, D., Majewska, D., Rushton, N., Rycroft-Smith, L., & Stevens, B. (2019). *Case study report Representing the work of Designing a framework for computational thinking with Arm*.

Juškevičiene, A. (2020). Steam teacher for a day: A case study of teachers' perspectives on computational thinking. *Informatics in Education*, *19*(1), 33–50. https://doi.org/10.15388/INFEDU.2020.03

Karampelas, K. (2023). Examining the relationship between TPACK and STEAM through a bibliometric study. *European Journal of Science and Mathematics Education*, *11*(3), 488–498. https://doi.org/10.30935/scimath/12981

Kemdikbudristek. (2021, October 22). *STEAM: Pendekatan Pembelajaran Guna Mengembangkan Keterampilan Abad 21*. Https://Ditsmp.Kemdikbud.Go.Id/Ragam-Informasi/Article/Steam-Pendekatan-Pembelajaran-

Guna-Mengembangkan-Keterampilan-Abad-21. https://ditsmp.kemdikbud.go.id/ragam-informasi/article/steam-pendekatan-pembelajaran-guna-mengembangkan-keterampilan-abad-21

Khotimah, R. P., Adnan, M., Che Ahmad, C. N., & Murtiyasa, B. (2023). The effectiveness of the STEMDISLEARN module in improving students' critical thinking skills in the differential equations course. *Cogent Education*, *10*(2). https://doi.org/10.1080/2331186X.2023.2220233

Khotimah, R. P., Adnan, P., Ahmad, M., & Murtiyasa, C. (2021). The Development of STEM-Discovery Learning Module in Differential Equations: A Need Analysis. *Review of International Geographical Education (RIGEO)*, *11*(4), 2021. https://doi.org/10.48047/rigeo.11.04.87

Lai, J. W., & Cheong, K. H. (2022). Adoption of Virtual and Augmented Reality for Mathematics Education: A Scoping Review. *IEEE Access*, *10*, 13693–13703. https://doi.org/10.1109/ACCESS.2022.3145991

Lee, S. W. Y., Tu, H. Y., Chen, G. L., & Lin, H. M. (2023). Exploring the multifaceted roles of mathematics learning in predicting students' computational thinking competency. *International Journal of STEM Education*, *10*(1). https://doi.org/10.1186/s40594-023-00455-2

Lendal, H. K. (1997). *Management by Menu*. Wiley and Son Inc.

Lin, Y. S., Chen, S. Y., Tsai, C. W., & Lai, Y. H. (2021). Exploring Computational Thinking Skills Training Through Augmented Reality and AIoT Learning. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.640115

M. Canilao, C., & G. Gurat, M. (2023). Effect of Mobile App on Students' Mathematics and Technology Attitude. *American Journal of Educational Research*, *11*(10), 722–728. https://doi.org/10.12691/education-11-10-11

Muzakkir, M., Zulnaidi, H., & Abd Rauf, R. A. (2024). Mathematics module based on STEAM and Quranic approach: A study for student's perception. *Journal on Mathematics Education*, *15*(2), 363–384. https://doi.org/10.22342/jme.v15i2.pp363-384

Nurwita, F., Kusumah, Y. S., & Priatna, N. (2022). Exploring students' mathematical computational thinking ability in solving pythagorean theorem problems. In *Jurnal Pendidikan Matematika* (Vol. 13, Issue 2). http://ejournal.radenintan.ac.id/index.php/al-jabar/index https://doi.org/10.24042/ajpm.v13i2.12496

OECD. (2018). *The Future of Education and Skills 2030*.

OECD. (2023). *PISA 2022 Results Factsheets Indonesia*. https://oecdch.art/a40de1dbaf/C108.

Park, W., & Kwon, H. (2022). Research trends and issues including computational thinking in science education and mathematics education in the Republic of Korea. *Journal of Baltic Science Education*, *21*(5), 875–887. https://doi.org/10.33225/jbse/22.21.875

Pascual, L. E., & San Pedro, A. B. (2018). Post Secondary Students' Level of Proficiency in Solving Real World Problems in Mathematics. *Journal of Applied Mathematics and Physics*, *06*(01), 198–214. https://doi.org/10.4236/jamp.2018.61019

Pavković, I.-M., & Marangunić, N. (2024). Challenges and Stress While Teaching Problem Solving in Mathematics. *Proceedings of The International Conference on Advanced Research in Teaching and Education*, *1*(1), 25–40. https://doi.org/10.33422/icate.v1i1.170

Polat, Ö., & Aydın, E. (2020). The effect of mind mapping on young children's critical thinking skills. *Thinking Skills and Creativity*, *38*, 100743. https://doi.org/10.1016/j.tsc.2020.100743

Pujiastuti, H., & Haryadi, R. (2023). Enhancing mathematical literacy ability through guided inquiry learning with augmented reality. *Journal of Education and E-Learning Research*, *10*(1), 43–50. https://doi.org/10.20448/jeelr.v10i1.4338

Rasimin, Semma, A. B., Zakiyuddin, Ali, M., & Helmy, M. I. (2024). Multi-dimensional challenges in the Indonesian social science information technology-based learning: A systematic literature review. *Heliyon*, *10*(7), e28706. https://doi.org/10.1016/J.HELIYON.2024.E28706

Rosana, D., Widodo, E., Setianingsih, W., & Setyawarno, D. (2020). Developing Assessment Instruments of PISA Model to Measure Students' Problem-Solving Skills and Scientific Literacy in Junior High Schools. *Jurnal Pendidikan Sains Indonesia*, *8*(2), 292–305. https://doi.org/10.24815/jpsi.v8i2.17468

Roshayanti, F., Wijayanti, A., Purnamasari, V., & Sari Setianingsih, E. (2022). Analysis of Understanding and Readiness of Elementary School Teachers on the Implementation of the STEAM (Science, Technology, Engineering, Arts, Mathematics) Approach. *KnE Social Sciences*. https://doi.org/10.18502/kss.v7i14.11960

Schutera, S., Schnierle, M., Wu, M., Pertzel, T., Seybold, J., Bauer, P., Teutscher, D., Raedle, M., Heß-Mohr, N., Röck, S., & Krause, M. J. (2021). On the potential of augmented reality for mathematics teaching with the application cleARmaths. *Education Sciences*, *11*(8). https://doi.org/10.3390/educsci11080368

Selby, C. C. (2015). Relationships: computational thinking, pedagogy of programming, and Bloom's Taxonomy. *WiPSCE '15: Proceedings of the Workshop in Primary and Secondary Computing Education*, 80–87. https://doi.org/10.1145/2818314.2818315

Septiadevana, R., & Abdullah, N. (2024). Developing STEM project-based learning module for primary school teachers: a need analysis. *International Journal of Evaluation and Research in Education* , *13*(4), 2585–2593. https://doi.org/10.11591/ijere.v13i4.28894

Silberman, D., Carpenter, R., Takemoto, J. K., & Coyne, L. (2021). The impact of team-based learning on the critical thinking skills of pharmacy students. *Currents in Pharmacy Teaching and Learning*, *13*(2), 116–121. https://doi.org/10.1016/j.cptl.2020.09.008

Siregar, N. C., Rosli, R., & Maat, S. M. (2020). The effects of a discovery learning module on geometry for improving students' mathematical reasoning skills, communication and self-confidence. *International Journal of Learning, Teaching and Educational Research*, *19*(3), 214–228. https://doi.org/10.26803/ijlter.19.3.12

Sousa, M. J., & Rocha, Á. (2019). Digital learning: Developing skills for digital transformation of organizations. *Future Generation Computer Systems*, *91*, 327–334. https://doi.org/10.1016/j.future.2018.08.048

Sukirman, S., Farhana, L., Ibharim, M., Soh Said, C., & Murtiyasa, B. (2024). Development and Usability Testing of a Virtual Reality Game for Learning Computational Thinking. *International Journal of Serious Games I*, *11*(3). https://doi.org/10.17083/ijsg.i11v3.670

Sukirman, S., Ibharim, L. F. M., Said, C. S., & Murtiyasa, B. (2022). A Strategy of Learning Computational Thinking through Game Based in Virtual Reality: Systematic Review and Conceptual Framework. *Informatics in Education*, *21*(1), 179–200. https://doi.org/10.15388/infedu.2022.07

Sungkur, R. K., Panchoo, A., & Bhoyroo, N. K. (2016). Augmented reality, the future of contextual mobile learning. *Interactive Technology and Smart Education*, *13*(2), 123–146. https://doi.org/10.1108/ITSE-07-2015-0017

Sun, L., You, X., & Zhou, D. (2023). Evaluation and development of STEAM teachers' computational thinking skills: Analysis of multiple influential factors. *Education and Information Technologies*, *28*(11), 14493–14527. https://doi.org/10.1007/s10639-023-11777-7

Supiarmo, M. G., Hadi, H. S., & Tarmuzi, T. (2022). Studentâ€™s Computational Thinking Process in Solving PISA Questions in Terms of Problem Solving Abilities. *(JIML) JOURNAL OF INNOVATIVE MATHEMATICS LEARNING*, *5*(1), 01–11. https://doi.org/10.22460/jiml.v5i1.p01-11

Suwayid Alqarni, A., & Rezqallah Alzahrani, R. (2022). The Impact of Augmented Reality on Developing Students' Mathematical Thinking Skills. *IJCSNS International Journal of Computer Science and Network Security*, *22*(3), 553. https://doi.org/10.22937/IJCSNS.2022.22.3.71

Tangkawsakul, S., Thaikam, W., & Ugsonkid, S. (2024). Bridging Gaps: Pre-Service Mathematics Teachers' Handling the Difficulties in Posing Real-World Mathematical Problems. *Journal of Education and Learning*, *13*(3), 133. https://doi.org/10.5539/jel.v13n3p133

Tan, W. L., Samsudin, M. A., Ismail, M. E., Ahmad, N. J., & Talib, C. A. (2021). Exploring the Effectiveness of STEAM Integrated Approach via Scratch on Computational Thinking. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(12). https://doi.org/10.29333/ejmste/11403

UNESCO. (2021). *Education for Sustainable Development for 2030 Toolbox*.

Vidad, D. C., & Quimbo, M. A. T. (2021). Students' problem-solving difficulties and coping strategies in mathematics: A model- building study. *International Journal of Learning, Teaching and Educational Research*, *20*(9), 136–173. https://doi.org/10.26803/ijlter.20.9.9

Vourletsis, I., & Politis, P. (2020). Effects of a Computational Thinking Experimental Course on Students' Perceptions of Their Problem-Solving Skills. *Proceedings of the 2020 9th International Conference on Educational and Information Technology*, 14–20. https://doi.org/https://doi.org/10.1145/3383923.3383935

Wandari, G. A., Wijaya, A. F. C., & Agustin, R. R. (2018). The Effect of STEAM-based Learning on Students' Concept Mastery and Creativity in Learning Light And Optics. *Journal of Science Learning*, *2*(1), 26. https://doi.org/10.17509/jsl.v2i1.12878

Wang, X. M., Yu, D. D., Yu, X. H., Hwang, G. J., & Li, F. (2024). Impacts of augmented reality-supported STEM education on students' achievement: A meta-analysis of selected SSCI publications from 2010 to 2023. *Education and Information Technologies*. https://doi.org/10.1007/s10639-024-12641-y

Wardani, D. S., Kelana, J. B., & Jojo, Z. M. M. (2021). Communication Skills Profile of Elementary Teacher Education Students in STEM-based Natural Science Online Learning. *Profesi Pendidikan Dasar*, *8*(2), 98–108. https://doi.org/10.23917/ppd.v8i2.13848

Yadav, A., Stephenson, C., & Hong, H. (2017). Computational thinking for teacher education. *Communications of the ACM*, *60*(4), 55–62. https://doi.org/10.1145/2994591

Yeni, E. M., Wahyudin, E., & Herman, T. (2020). *Difficulty Analysis Of Elementary School Students In Mathematical Problem Solving In Solutions*. *9*(3), 4447. www.ijstr.org