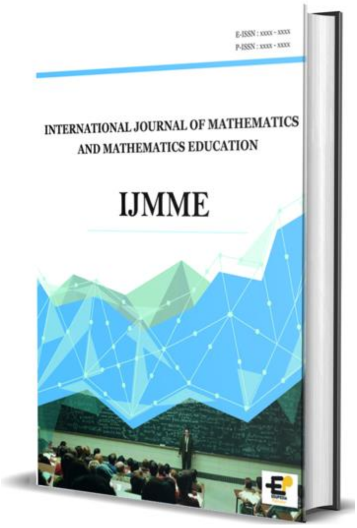

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Abstract

The main objective of this study was to measure the level of computational thinking readiness in prospective first-year mathematics education students. In addition, this study also aims to identify factors that influence their level of readiness towards computational thinking. This research is qualitative and descriptive. This study describes first-year mathematics education students' mathematical computational thinking ability based on the theory of mathematical computational thinking. This study was conducted on first-year mathematics education students in 2023/2024. There were 16 first-year mathematics education students, all of whom were taken as samples in this study to obtain more in-depth information about the computational thinking ability of first-year mathematics education students for further research development. The instruments used to collect data on first-year mathematics education students' mathematical computational thinking ability are (1) a mathematical computational thinking ability test and (2) an interview. The data obtained were calculated using statistical tests, and the results will be explained in depth. The mean score of the first-year mathematics education student's computational thinking ability test was 59.68, indicating that students generally have a fairly good level of computational thinking ability.

Introduction

Computational thinking is becoming an important skill in mathematics education due to dramatic changes in how we interact with information and problems in the digital age. Information and communication technologies have changed the educational and occupational landscape, driving the need for broader and more relevant skills. Mathematical problems in the modern world are often complex and involve big data. Computational thinking enables students to formulate, analyse and solve problems efficiently through algorithmic approaches (Angeli & Valanides, 2009; Brown & Brown, 2017; Deng et al., 2020; Margolis et al., 2016).

Computational thinking allows students to apply mathematical concepts in a real-world context. Through modelling and simulation, they can describe real situations and see how mathematics is used to understand and solve problems in everyday life. In this technological era, changes and innovations happen quickly. Computational thinking equips students to adapt to technological changes and design solutions to problems that have never been faced before (Brown & Capper, 2019; Dikici & Ocak, 2017; Grover & Pea, 2018).

In addition to understanding mathematical concepts, students must develop 21st-century skills such as critical thinking, teamwork, and creativity. Computational thinking integrates all of these in the context of problem-solving. Many modern jobs require an understanding of computing and technology. Computational thinking skills open up wider career opportunities and increase students' competitiveness in the job market. Technology and computational tools in mathematics learning can make learning more interesting and interactive for students, increasing their engagement and understanding.

Students who are proficient in computational thinking can become role models for students in the future. They can demonstrate how technology and computational thinking can be used to understand and solve mathematical problems, encouraging students to adopt similar approaches. Students who are proficient in computational thinking can better integrate technology in mathematics learning. They can design activities involving modelling, data analysis, and computational tools in teaching mathematical concepts (Gadanidis, 2017; Kim & Voogt, 2018; Lee & Yadav, 2016; Sari & Yalçın, 2016).

Computational thinking promotes a deeper understanding of mathematical concepts. Students who have a deep understanding of mathematical concepts can teach them more effectively to students (Hanid et al., 2022; Barr & Stephenson, 2011; Voogt et al., 2015; Yadav et al., 2016) as education is increasingly influenced by technology, first-year mathematics education students need to have an understanding of how technology can support learning, including in the aspect of computational thinking. The world of education is constantly evolving with new technologies. First-year mathematics education students with computational thinking skills will be better prepared to face changes and adapt to evolving learning methods.

Research on the level of computational thinking readiness in first-year mathematics education students is very important for many reasons: (1) With the development of technology in education, mathematics education students should be prepared to integrate computational tools in teaching. This research can identify their level of readiness and help design appropriate training programs; (2) First-year mathematics education students who have computational thinking readiness tend to be more skilled in designing innovative and interactive learning approaches, which can improve the quality of learning in each course; (3) The world of education is constantly evolving with new technologies. First-year mathematics education students need to be ready to face this challenge and understand how computational thinking can be applied in learning; (4) Computational thinking involves algorithmic problem-solving. First-year mathematics education students trained in computational thinking can develop better problem-solving skills; (5) This research can provide insight into how computational thinking concepts can be integrated into the mathematics education curriculum to prepare more competent future educators.

Research on the level of computational thinking readiness in first-year mathematics education students can make valuable contributions: (1) The results of the study can assist in developing curricula that incorporate a computational thinking component, ensuring that mathematics education first freshmen are ready to integrate technology in learning; (2) The study can lead to the development of appropriate training programs to improve the computational thinking skills of mathematics education first freshmen; (3) The results of the study can assist mathematics education first first-year students in designing more engaging and interactive learning experiences.

The main purpose of this study was to measure the level of computational thinking readiness in first-year mathematics education students and identify the factors that influence their readiness level. Thus, this research not only focuses on measuring the level of readiness but also on understanding the factors that can influence their readiness in computational thinking.

Method

This research is qualitative and descriptive. This study describes first-year mathematics education students' mathematical computational thinking ability based on the theory of mathematical computational thinking. The data analysis technique used was interpretative analysis. Interpretive analysis involves the interpretation and in-depth understanding of the collected data. Researchers seek to understand the context, meaning, and relationships arising from the analysed data. This understanding can be based on the theory of mathematical computational thinking and relevant frameworks and supported by the findings that emerge from the data analysis.

This study was conducted on first-year mathematics education students in the 2023/2024 academic year. There were 16 mathematics education first-year students, all of whom were taken as samples in this study to obtain more in-depth information about the computational thinking ability of first-year students for further research development. The first-year mathematics education students were divided into three categories of prior mathematical knowledge based on the scores obtained from their previous school mathematics scores: low, medium and high.

In this study, mathematical computational thinking ability refers to the following indicators: (1) Students can formulate problems; (2) Students can identify the right information to solve problems; (3) Students can reformulate or model problems into solvable problems; (4) Students can break down problems into smaller parts so that complex problems are easier to understand; (5) Students can evaluate data sets to ensure that the data obtained can facilitate the discovery of patterns and relationships; (6) Students can create a series of sequential steps to solve problems or achieve goals; (7)

Students can re-examine solutions, and formulate them into general forms that can be applied to other problems.

The instruments used to collect data on first-year mathematics education students' mathematical computational thinking ability are (1) a mathematical computational thinking ability test and (2) an interview guide. The interview was conducted directly between the researcher and the respondent, where the researcher asked questions and received verbal answers from the respondent. The interviews were semi-structured (some questions were predetermined, but there was flexibility in asking additional questions) and conducted after the test administration. The data obtained was calculated using statistical tests, and the results will be explained in depth. The following is one of the questions in the computational thinking skills test for first-year mathematics education students taken from the 2018 Bebras – International Contest on Informatics and Computational Thinking:

> "Ari has a street in his yard that is quite long. His neighbour can park on the street but only back out because the street is narrow. Since he only has one car, the neighbour also asks permission to park on the street. He made a table for when the neighbour could park and when to leave to ensure no one was blocked. The cars leaving had to leave every morning before the other cars entered. As seen in the table, no one left the street on Monday. Ari parked first, then Bob parked after Ari."

Table 1. A Table of When the Neighbor Could Park and When to Leave

Days	Number of cars leaving	Number of Cars Entered	Car Owners and Their Order of Entry
Monday	0	2	Ari, Bob
Tuesday	1	3	Kati, Ben, Roi
Wednesday	2	1	Desi
Thursday	0	2	Fina, Rosa
Friday	3	1	Vino

The question: Whose car will be parked on the street at the end of Friday?

Results

This study aims to measure the computational thinking readiness of first-year students in mathematics education. In addition, this study also aims to identify the factors that influence their readiness level towards computational thinking. Thus, this research not only focuses on measuring the level of readiness but also on understanding the factors that can affect their readiness in the aspect of computational thinking. The following is an overview of the results of the computational thinking readiness test on prospective first-year mathematics education students:

Table 2. New Student Computational Thinking Readiness Test Results

Descriptive statistics	Students
N	16
Means	59.68
sd	5.06
Max	75
Min	10

Based on Table 1 above, we can see considerable variation in students' computational thinking ability. The average score of 59.68 indicates that most students have a fairly good understanding, but some have a lower understanding. In addition, the highest score of 75 indicates the potential for students to achieve a high level of competence in computational thinking if they continue to develop their skills. In this case, it is important to plan an appropriate training program to assist students in improving their overall computational thinking ability. The following is an overview of the computational thinking test answers of first-year mathematics education students:

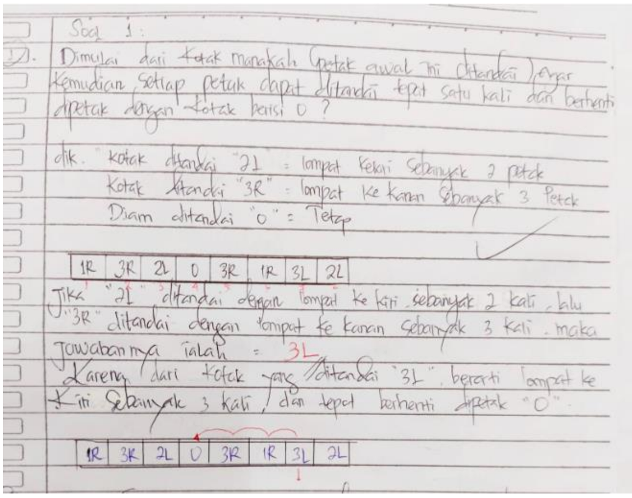

Figure 1. The results of the student's computational thinking on question number 1

The following are the results of interviews related to the answers above:

L: How do you understand question number 1?
S: I understand that L = Left and R = Right, 1L = 1 step to the left, and 1R = 1 step to the right. The question asks from which step we get to point 0.
L: Why did you choose 3L?
S: Because 3L = three steps to the left, and when it stops exactly at point 0, whereas if we choose the other, the stopping point is not point 0.

The answers above are the correct answers of students, but there are still many students who do not answer question number 1; some of the reasons stated by students are: 1) confused in understanding the problem; 2) confused about where to start working; 3) understand the meaning of the problem, but confused about solving the problem; 4) can work after discussing with friends who have done it first. Furthermore, the following is a description of the answer to question number 2:

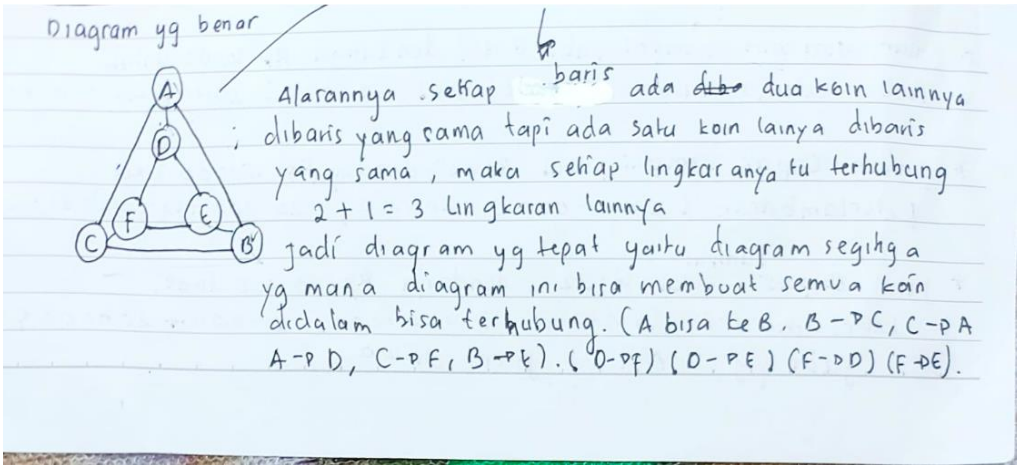

Figure 2. The results of the student's computational thinking on question number 2

The following are the results of interviews related to the answers above:

L: How do you understand question number 2?
S: I understand the question about drawing a game board with six coins was asked.
L: Why did you make a drawing like the answer above?
S: Because each coin has two other coins in the same row and another in the same column. Therefore, each circle must be connected to 3 other circles in the diagram.

The answers above are the correct answers of students, but many students still do not answer question number 2; some of the reasons stated by students are: 1) they could not understand the problem; 2) they had no idea about the right form of drawing. Furthermore, the following is a description of the answer to question number 3:

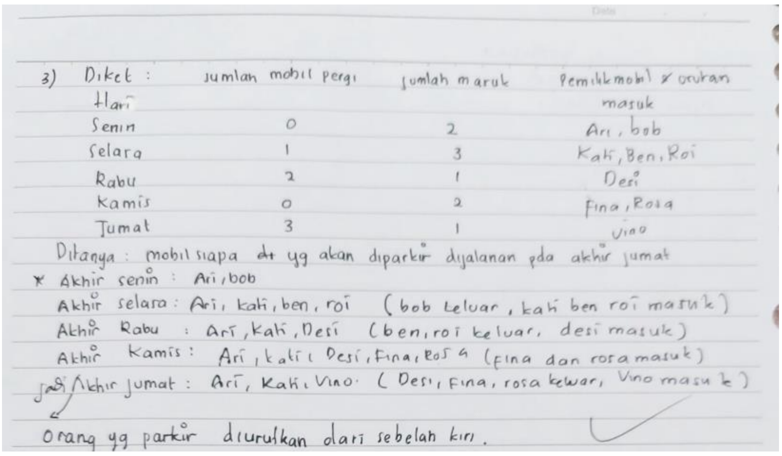

Figure 3. The results of the student's computational thinking on question number 3

The following are the results of interviews related to the answers above:

L: How do you understand question number 3?

S: I understand that the question was asked to determine whose car was parked on Friday.
L: Why did you answer "Ari, Kati, Vino"?
S: Because they can only park backwards, I calculated that the car that had to come out was the car that parked at the back, so I got the answer.

The answer above is the correct student answer: the average student can answer question number 3. Furthermore, the following is a description of the answer to question number 4:

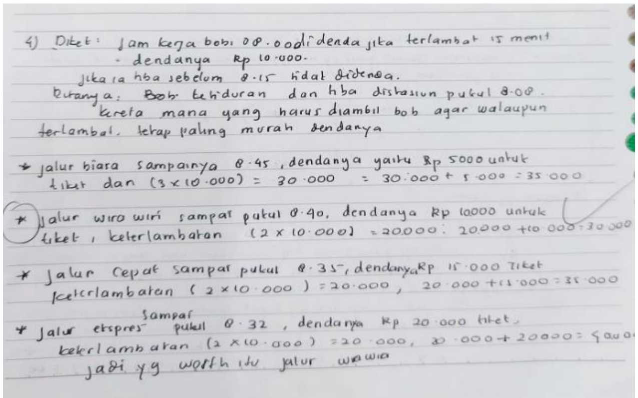

Figure 4. The results of the student computational thinking test answers on question number 4

The following are the results of interviews related to the answers above:

L: How do you understand question number 4?
S: I understand the question about choosing the train with the cheapest fine is asked if there is a delay.
L: Why did you answer Wira-Wiri train?
S: After I calculated each train, the Wira-Wiri train obtained the lowest fine calculation from the others.

The answers above are the correct answers of students, but there are still many students who do not answer question number 4; some of the reasons stated by students are: 1) could not understand the problem; 2) not having enough time to finish; 3) confused about where to start working from; 4) understand the meaning of the problem, but confused about solving the problem. The following is the process of conducting interviews on the results of the computational thinking test of new mathematics education students:

Figure 5. Interview process related to the answers to the computational thinking test results

The average score of the f first-year mathematics education students' computational thinking test was 59.68. This suggests that, overall, students have fairly good computational thinking skills at an average level. However, this figure also reflects the variation in ability levels among students. A high score of 75 and a low score of 10 were scored on the computational thinking test. This indicates a significant difference in computational thinking skills between the best and lowest-skilled students. Students scoring 75 may have a strong understanding of computational thinking concepts, while those scoring ten may need additional support.

The importance of computational thinking skills for new students in mathematics education study program: a) Preparation for the world of education: Students in the Mathematics Education study program will become mathematics teachers. Computational thinking skills will help them teach mathematics more effectively, integrate technology in learning, and help students solve math problems with a computational thinking approach; b) Relevance to mathematics: Computational thinking is highly relevant in the context of mathematics. In a variety of mathematical topics, including problem-solving, statistics, and modelling, computational thinking skills are required to formulate appropriate and efficient solutions; c) Skills for the world of work: In addition to becoming teachers, Mathematics Education students may also be involved in jobs that require an understanding of computational thinking, such as data analysts, data scientists, or information technology professionals. Therefore, these skills can enhance their career opportunities; d) Improving digital literacy: Mathematics education that includes computational thinking will help students to become more literate in an increasingly digital world. They will be better prepared for technological developments in education; d) Problem-solving ability: Computational thinking strengthens problem-solving ability, a universal skill useful in all areas of life. It helps students in facing complex challenges in the real world. Thus, it is important for new students in the Mathematics Education study program to have a strong provision of computational thinking ability. This will support their development as competent mathematics teachers ready to face the demands of an increasingly technology-connected future.

Several factors can influence students' level of readiness for computational thinking. Based on the data that has been obtained with an average test score of 59.68, the number of students 16, the highest score of 75 and the lowest score of 10, the following factors play a role in influencing their readiness: a) Educational background: students with different educational backgrounds may have different levels of readiness in computational thinking. Those with prior experience or knowledge in programming or computing may be more prepared; b) Quality of instruction: the quality of teaching and subject matter in a computational thinking course can also affect students' preparedness. Good teaching can improve students' understanding and skills; c) Motivation and interest: Students' motivation and interest in computational thinking topics can affect their level of preparedness. Students who are motivated and interested in computing may be more likely to learn and develop in this aspect; d) Support and resources: The availability of resources and support, such as appropriate textbooks, lecturer assistance, and access to computing equipment, can affect students' preparedness; e) Practical experience: practical experience in solving problems using computational thinking can also play a role. Students who have faced real problems that require computational thinking may be better prepared.

Appropriate solutions to address these factors may involve the following steps: a) Curriculum development: develop a curriculum that is more in-depth in computational thinking. This can ensure that all students have a solid foundation in understanding computational concepts; b) Lecturer training: train lecturers to improve the quality of teaching computational thinking. Skilled and experienced lecturers can better motivate and guide students; c) Support program: Provide support programs, such as study groups or mentorships, for students who need additional help in computational thinking; d) Additional resources: Provide additional resources, such as access to computer labs or relevant reading materials, to strengthen students' understanding and skills.

The curriculum of mathematics education programs can contribute significantly to developing students' computational thinking skills by introducing elements of computational thinking in mathematics subjects and teaching (Barr & Stephenson, 2011; Freiman et al., 2017; Grover & Pea, 2013). Some ways the curriculum can contribute include (a) Technology integration: the curriculum can incorporate mathematical software and problem-solving tools in teaching. This helps students develop an understanding of the way computing technology is used to solve mathematical problems; (b) Math programming: integrating math-related programming or coding in the curriculum can help students understand how to develop algorithms and think in logical steps; (c) Computational problem solving: the curriculum can emphasise solving mathematical problems using computational approaches. Students can be encouraged to design algorithms for specific mathematical problems and implement them using software; (d) Understanding computational concepts: introducing computational concepts, such as variables, looping, and data structures in a mathematical context, helps students develop a deeper understanding of computing; (e) Collaborative projects: the curriculum can include collaborative projects where students work together to develop math solutions using computing. This encourages collaboration and team problem-solving.

The specific training or support program provided to students to develop computational thinking skills can cover various aspects (Barr & Stephenson, 2011; Grover & Pea, 2013; Wing, 2006). The following components can be considered in such a program: (a) Programming instruction: organise specialised programming courses that focus on developing computational thinking skills. Students can learn programming languages and develop an understanding of how to design algorithms; (b) Collaborative projects: encourage students to participate in collaborative projects that involve solving mathematical problems using computation. This allows them to apply the knowledge and skills they learn in a real context; (c) Specialized training: organise specialised training in computational problem solving, including algorithm implementation, code development, and use of mathematical software; (d) Mentorship and guidance: provide individual mentors and guidance to students who are interested in developing computational thinking skills. Mentors can help them with projects or assignments involving computing; (e) Clubs or communities: establish a club or community that focuses on developing computational thinking skills. This allows students to share their knowledge and experience; (f) Use of tools and aids: teaches students how to use problem-solving tools and aids, such as math software, spreadsheets, or programming languages, to solve math problems.

Developing effective learning strategies can improve students' computational thinking skills in mathematics education majors (Ernest, 2008; Resnick et al., 2009; Selden et al., 2014; Sherman & Richardson, 2013). Some strategies that can be used include (a) Integration of programming in mathematics learning: integrate elements of computer programming in mathematics teaching. Students can program solutions to mathematical problems using relevant programming languages; (b) Use of problem-solving tools: Introduce students to mathematical problem-solving tools, such as statistical software, mathematical applications, or mathematical programming languages such as Matlab or Python; (c) Computation-based projects: organise computation-based projects where students have to design and implement mathematical solutions using computing technology. These projects can involve solving real problems; (d) Problem-solving exercises provide problem-solving exercises that require students to design algorithms and code to solve specific mathematical problems; (e) Collaboration and discussion encourage collaboration among students in solving mathematical problems using computation. Discussion and collaboration can enrich understanding and skills; (f) Routine programming assignments: provide routine programming assignments related to mathematics as exercises to develop programming and computational thinking skills; (g) Case approach: utilise case studies in mathematics involving computation. Students must analyse the situation, design a computational solution, and evaluate the results; (h) Training in the use of mathematical tools: ensure that students understand and can use mathematical software commonly used in the research and work of mathematical practitioners.

Some research on the level of readiness of computational thinking of first-year mathematics education students was conducted by Pusat and Smith (2019), who developed a measuring tool or instrument to measure the level of readiness of first-year mathematics education students. Chen & Wang (2020) compared the level of computational thinking readiness among first-year mathematics education students with different computing backgrounds or experiences. Johnson & Martinez (2018) evaluated the impact of specialised training or courses in improving the computational thinking readiness level of first-year mathematics education students. Liu & Wang (2021) sought a correlation between the computational thinking readiness level of first-year mathematics education students and their academic outcomes in Mathematics Education courses.

Based on the information about the research that has been done before in the context of the level of computational thinking readiness of new students of Mathematics Education study programs, there are several suggestions for further research that can be taken: Research could focus on developing more effective training methods or curriculum to improve the computational thinking readiness level of first-year mathematics education students. This could include the development of more relevant teaching materials or the use of technology in learning. Research could investigate the impact of specialised computing courses or courses that focus on computational thinking on students' level of preparedness. This could help understand how such courses influence students' computational thinking ability.

Conclusion

The mean score of the first-year students' computational thinking skills test was 59.68, indicating that, in general, students have a fairly good level of computational thinking skills. However, this figure also shows considerable variation in students' ability levels. The test showed a notable difference between the highest score of 75 and the lowest score of 10. This indicates a significant difference in computational thinking ability between the most and least skilled students. While students who scored 75 may have a strong grasp of computational thinking concepts, those who scored 10 may need additional help developing their computational thinking skills.

Recommendations

The research could widen the scope by conducting case studies in various higher education institutions with Mathematics Education study programs. This could help to compare readiness levels across different educational contexts. Further research could look for factors influencing first-year students' computational thinking readiness. This could involve educational background, previous computing experience, or social and psychological factors. A more in-depth study of the correlation between computational thinking readiness level and academic outcomes in Mathematics Education courses could provide deeper insights into the impact of computational thinking on student achievement. Developing more sophisticated and valid instruments for measuring computational thinking readiness levels could be a useful research subject. Research could involve long-term monitoring of students who have undergone computational thinking training to understand whether these skills continue to develop over time and how they affect their academic and professional careers.

Research could evaluate the success of computational thinking readiness programs or initiatives implemented at different institutions and how they affect students. It is hoped that these suggestions will help to better understand, improve, and implement computational thinking in the Mathematics Education curriculum so that students can be better prepared for the demands of a world increasingly linked to technology and computing.

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