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Digital Competence and Computational Thinking of Indonesian Prospective Teachers

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ABSTRACT

Digital competence is a skill in a high demand and includes various aspects, such as technology skills, knowledge of information, communication, and multimedia. In recent years, various institutions have adopted computational thinking in various fields as a part of digital competence. This study analyzed the level of digital competence and computational thinking of two students (male and female) in Indonesia, exploring the relationship between abilities and differences. There was a correlation between computational thinking and digital competence, especially in the communication and technological fields. The result showed that digital abilities of the prospective male teacher (bachelor degree student) were thoroughly examined, including their ability to use technology, understand digital literacy, and use digital tools to solve mathematical problems, and the digital skills of prospective female teacher (master degree student) were thoroughly examined for her digital competencies, including information and data literacy, communication and collaboration, use of digital applications, and problem-solving. The results of this study provide relevant information, including the development of teaching materials that can facilitate digital competence and computational thinking skills for prospective mathematics teachers.

Keywords:
Computational thinking; Digital competence; Prospective teachers

1. Introduction

In this 21st century, science and technology have evolved rapidly. Most of the devices that humans use today rely on computers and the internet, making life easier. Besides, computers allow everybody to learn things that were previously too small, too big, too far, too fast, too complicated, or too complex. The enormous development of information and communication technology (ICT) means that individuals face daily situations requiring new technical, cognitive, and social skills. That is why many research regarding ICT have been reported [1-12]. The skill is called ‘digital competence’. Over the last few decades, many authors have tried to define digital competence by emphasizing various aspects of technology, information, and media [13]. In addressing the challenges and opportunities of the digital era, it is crucial for 21st-century learning environments to equip future generations with

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adequate technology skills. Teacher training institutions play a pivotal role in this effort, as they are responsible for providing aspiring teachers with the knowledge and skills needed to integrate technology into the educational process. Consequently, the curriculum in teacher training institutions must include intensive training in the use of educational technology, digital learning strategies, and an understanding of the latest technological tools and platforms. This approach will ensure that future teachers are capable of creating relevant, interactive, and effective learning experiences for their students, thereby preparing them for success in an increasingly interconnected digital world [14].

Developing the 21st century skills, known as 4C skills (known as communication, collaboration, critical thinking and problem solving, and creativity and innovation), is essential to confronting the reality of the 21st century [15]. In 2018, Grover mentioned that computational thinking skill is a skill individual should have in the 21st century. Computational thinking (CT) improves the ability of students to solve complex problems using computer science techniques, such as abstraction, pattern recognition, decomposition, and logarithms [14]. Computational thinking is a part of Higher Order Thinking (HOT), which helps facilitate problem-solving and improve the student mathematical performance [16]. Computational thinking can make it easier for students to make decisions and solve problems in mathematics [17-19].

The demand of these skills requires future teachers to be prepared for acquiring the digital competence and computational thinking skills. The key to the 21st century skills is the digital competency that individuals must have [20-22] before they dive into society [23]. The application of this digital competence is not only for working people but also for students in different education levels and various fields of science [21]. Applying digital competencies will greatly help educators evaluate the learning outcomes of students maximally. Digital literacy is essential to improve the quality of education, especially in mathematics learning [24]. Educators can easily categorize student learning abilities through digital competence levels [25,26] to further determine the improvement measures to be taken to improve the student learning outcomes [25] including in learning mathematics. Mathematics has become one of the compulsory learning for students at all education levels. Therefore, the judgment on mathematical learning becomes a separate problem associated with the learning process in the network [25-27].

On the other hand, different research shows that although the students use technology in general, its use is mainly for communication and social activities [28] with adequate information and a complete level of digital competence [29]. On the other hand, research on the computational thinking of students and prospective teachers still needs to be improved. Only a few of publications explored deeply the relationship between computational thinking and digital competence. Even though the development of these skills has been introduced in the training of future teachers [30], there is still a gender gap even to this day [30]. Gender differences in terms of computational thinking and digital competence have been highlighted by many authors with different results and, sometimes, contradictory [29].

Digital competence frameworks for educators should be developed according to the pedagogical education development concept. Women are considered less digitally competent than men and have lower computational thinking outcomes. It is essential to evaluate the suitability of the technology acceptance model (TAM) in the vocational education context and to assess the relationship between the teacher belief in the digital competence and their acceptance and desire to use technology in their classrooms [30]. The novelty of this research is that the prospective teacher digital competence studied in this research was the computational thinking skill. The study conducted an analysis of the digital competence abilities of prospective teachers (male and female), described their computational thinking levels, and explored the relationship between the two.

2. Methodology

The research used a qualitative approach to identify the level of the student digital competence, specifically on the computational thinking test (TCT). Two students were selected as research subjects representing the gender of male (bachelor degree student) and female (master degree student). The reason for choosing the subjects was that the students had an active tendency to communicate the results of observations and work on issues using digital applications or software when completing the computational thinking test. The data were collected from the TCT. The test given was an open matter with various ways and solutions. The TCT given was had never been given in previous study.

When the subject performed the assigned task, the observer observed the topic and clarified unclear matters. The subject works were analyzed by identifying the answer and examining the digital competence aspects of the solved subject. Data were analyzed by the fixed comparison method [31,32]. The digital competence level of the topics was estimated by applying the qualitative analysis method based on the results of the TCT. Data collection techniques used mathematical computational thinking instruments on the linear program material. The problem is presented in Figure 1 and the indicator of computational thinking skill showed in Table 1.

A furniture businessman is finishing two sets of chairs, a guest chair and a dining chair. A guest chair takes four hours to scrub and four hours to colour. A dining chair requires three hours to scrub and two hours to colour. The entrepreneur has 150 hours to work on orders for scrubs and 100 hours for colouring. If the net profit of each seat is Rp. 50,000.00 and Rp. 40,000,00, using algebra methods, determine the highest profit the entrepreneur could obtain! (Please use your math application or software!)

Fig. 1. Computational thinking concept in linear program test

Table 1
Indicators of computational thinking skill

Components of Computational Thinking	Indicators of Computational Thinking Skill
Decomposition	Students can identify the known and asked linear program from the given problem.
Abstraction	Students can find conclusions by removing unnecessary elements when implementing a linear program troubleshooting plan.
Algorithm	Students can illustrate the logical steps used to find the solution to the problem of linear programming.
Generalization	Based on their learning, the student can determine a quick and accurate solution to a new problem.

The technique used in data analysis of this study was the qualitative data analysis using the Miles and Huberman model [30], including:

i. data reduction
ii. data display
iii. conclusion drawing

Next, to find out the category of the digital mathematical competence of the prospective teachers, the analysis of the student answers based on the mathematics digital competence knowledge indicators was conducted. The indicators are presented in Table 2.

Table 2
Student digital competence

Digital Competence Components	Indicators
Information and data literacy	Subjects use one of the mathematical applications to access, choose, and find ways to solve math problems.
Communication and collaboration	Subjects are able to interact, communicate, and collaborate through digital mathematics applications and participate in solving mathematical problems.
Use of digital applications	Subjects choose and use hardware or software to help solve mathematics problems.
Problem solving	Subjects solve mathematical problems with the help of digital mathematics applications.

3. Results and Discussion

The description of digital competence and mathematical computational thinking of students in solving issues on the linear program material was assisted by Geogebra and Desmos software applications.

3.1 Description of Subject 1 Answer

Subject 1 was a male bachelor degree student. On the decomposition indicator, students were asked to identify problems to be simpler. Thus, the problems could be understood. For the problem representing the decomposition ability indicator, they should write down any information on the given situation. By writing a variety of information, the male subject was expected to be able to understand the problem more efficiently (See Figure 2).

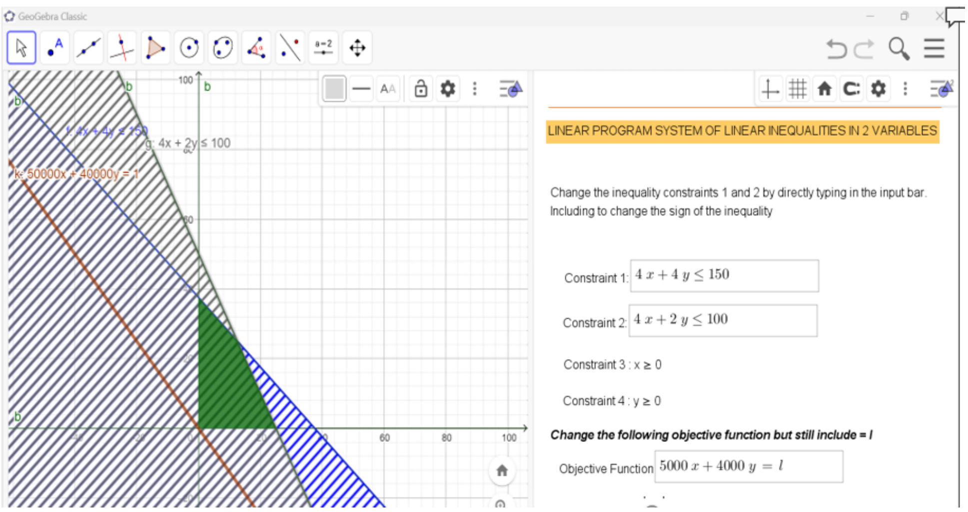

Fig. 2. The answer of male subject using Geogebra

The male subject could find conclusions at the abstraction stage by removing unnecessary elements when implementing a linear program problem-solving plan. In the matter representing the abstraction capability indicator, the male subject was asked to write down any information that could be used in solving the problem of objective constraints and functions. By writing the necessary information, the student was expected to be able to understand the information to solve the problem. At the algorithm level, on this indicator, the student was asked to make the solution steps before solving the given problem. In the matter representing the algorithm ability indicator, the male subject was requested to outline the steps to solve the problem based on the information obtained.

For the subject representing the algorithm ability indicator, the male subject was asked to write the steps to determine how to solve the number pattern problem. By writing problem-solving steps, the student was expected to understand how to identify the most effective measure for resolving such problems.

The male subject determined a quick and accurate solution to a new problem in the generalization phase based on what he had learned. For the subject representing the indicator of the ability to generalize, the male subject was asked to solve the new problem related to a linear program studied on the previous topic. By solving a new issue, the male subject was expected to be able to better master the material that they had learned and solve various problems related to the linear program. Computational thinking encourages people to solve mathematical problems in sequence because they detail problems into smaller and more understandable parts. It facilitates the systematic understanding and resolution of problems [33-35]

The male subject used mathematical applications to solve math problems, such as Geogebra software (information and data literacy). Information literacy is a set of skills that requires subjects to recognize when information is needed and to have the ability to find, evaluate, and effectively use the data required [36]. The informed male subject determined the use of digital applications and the information needed [37] for solving mathematical problems. The male subject also interacted, communicated, and collaborated through digital mathematics applications and could participate in solving mathematical problems through Geogebra software (communication and collaboration). Geogebra is a suitable application to enhance the user experience and to help solve a problem (use of digital applications). The male subject solved mathematical problems with the help of digital mathematics applications (problem-solving). GeoGebra is a dynamic geometry software that helped the male subjects learn mathematics by forming points, lines, and curve shapes. The software dramatically helped the male subject become more active and understand mathematical concepts. GeoGebra can also help teachers in describing mathematical concepts and procedures. In addition, GeoGebra can enhance the student understanding of the concepts learned or constructing new concepts [38]. This subject had a complete and systematic digital competence.

Students use a graphical representation of the problem created in GeoGebra to analyze the solution. They should be able to interpret the purpose and limit function graphs and identify the optimal points that represent the best solution. Computational thinking tests evaluate the student ability to scale mathematical components, programming, and visualization using GeoGebra software. It is also the ability to apply mathematics concepts, use computational tools, and conduct systematic analysis focusing on measuring student computational thinking skills. Students can also use the GeoGebra software to manually evaluate the graphical images of the settlements they are drawing. They can also explore any possibilities when the graphic images are changed. Therefore, this learning medium can use a problem-based learning model to enhance the student ability to think critically about linear curriculum materials [39].

3.2 Description of Subject 2 Answer

The subject 2 was a female master degree student completing a linear program using the Desmos application (Figure 3).

Fig. 3. The subject answer using desmos

Desmos is one of the mathematical applications that can be used as a learning medium and a tool to work on mathematics-related matters. Desmos is an online graphing utility that requires no downloads or special hardware. It works on any computer, tablet or phone [33]. Desmos can also display some examples of graphics, such as simple function graphics, function graphics, trigonometric graphics, and polygons. It works on any computer, tablet or phone [40].

At the decomposition stage, the female student could write down any information available to both known and correctly asked. On abstraction indicators and logarithmic thinking, students described graphs accurately but did not write conclusions and could answer using appropriate steps. This is in line with the study of [41], stating that the cause of student error in writing final answers is not making corrections to the steps already taken.

Confirmation results of the subject show that they solved the issue by accessing information and data literacy. The subject chose the appropriate Desmos application to solve problems and explained how to access them to her classmates (communication and collaboration). Besides, the subject could also use Desmos as a digital application (use of digital applications). The subject also solved conspicuous and unusual problems. In addition, they could describe linear program charts and organize and explain how to use them.

In this study, the digital term was related to competence and did not stand alone. Therefore, in this research, the digital technology the subjects wanted to use to solve their problems was unlimited. However, they still wrote down the general characteristics of each level based on the description and the type of task assigned. Digital competence concerns the use and development of the subject relevant digital technologies. The research subjects were already familiar with the use of technology as they often used the technology in their everyday lives [42-44]. Learning that requires information and communication technology implies practical learning, requiring an intensive learning as digital literacy [45].

Students need to start using digital technology to learn. They will only perform tasks according to the instructions of lecturers and textbooks. Given the demands of the times and current environmental conditions, the distance learning model is the best choice to apply. According to research carried out [46-48], using technology in learning will make learning in the classroom more effective and acceptable to students. It also encourages researchers to research the student digital abilities. By knowing the student digital skill level, teachers can predict how much knowledge the students will receive, especially the knowledge related to digital skills. Students can use Desmos software to model and solve linear program problems. They will insert similarities they have previously formulated into the software. Desmos will generate graphics that visualize the function of purpose and impediment. Students can share ideas, ask questions, and challenge each other in a productive and exciting way through Desmos activities [49].

Desmos is an interactive mathematical tool that allows students or problem solvers to view and analyse linear program problems with graphs that show the function of purpose and obstacles in linear program problems. In addition, the user must indicate the constraints or limitations of the linear program problem. These can be production limits, resource amounts, or other constraints. This limitation is represented as a mathematical equation or inequality. This equation is also inserted into Desmos by the user. Using demos, users can try different solutions by changing equations or coefficient values. This allows them to see how solutions can change when obstacles or goals change. Desmos is a handy tool for viewing linear program problems. Graphics help solve linear program problems and facilitate a better understanding of the problems. It allows users to quickly and easily understand the relationship between the purpose functions and obstacles and find optimal solutions. Demos Activity Builder has proven useful by enabling teachers to allow students to struggle productively, make and check errors, and think deeply to learn mathematics [50].

In the digital world and technology, two interrelated concepts are digital competence and computational thinking. Both concepts are essential in preparing people for the challenges and opportunities emerging in the digital age. Computational thinking helps people understand how technology works behind screens, while digital competence helps them know the devices and software they use in various aspects of life (technology understanding) (problem-solving). The ability to think computationally can drive creativity and innovation in creating new technological solutions, while digital competence ensures that people can implement these solutions in a digital environment (creativity and innovation). Digital competence facilitates collaboration and communication in a digital environment, while computational thinking helps design and develop more effective collaborative and communication tools (collaboration and communication). Computational thinking complements thinking in mathematics and engineering, focusing on designing systems that help solve complex problems faced by human beings [33].

Computational thinking is a stage in solving problems inspired by how computers work, such as decomposition, abstraction, algorithms, and generalization. Computational thinking provides a framework for solving problems systematically, which is necessary for developing digital competencies to address the challenges in using technology. Computational thinking can stimulate creativity in designing new solutions, while digital competence allows individuals to implement these ideas through digital tools. Understanding computational thinking can help individuals use digital tools more effectively because they have a deeper understanding of how technology works behind the user interface. Computational thinking can help identify valid information and recognize online fraud or manipulation patterns. Digital competence facilitates collaboration and communication, while computational thinking helps develop tools that support more effective collaborations and communications. By combining digital competence and computational thinking, one can better understand, adapt, and contribute to an increasingly digitally connected world. This may be because all of the information has been digitized by digital technology so that one can easily find the reference, they want in real-time through the search engines, use it, and share it again [51]

Effectively utilizing digital tools, accessing and evaluating information online, and engaging in various online activities are all examples of digital competence, which allows people to communicate, create, and participate in the digital world. With digital competence, people can use social media, email, messaging platforms, and other communication tools to connect and share ideas and information. Being a digital genius for teachers is crucial for supporting digital teaching because digital tools fundamentally change the nature of knowledge. They enable a more creative, active, collective, and personal way of building and communicating knowledge through digital media.

Computational thinking involves problem-solving skills that refer to the principles of computer science. Computational thinking is not confined to coding. It is a way of thinking that drives logical, structured, and troubleshooting thinking. It helps people identify patterns and create algorithms to solve problems. Using computational thinking in solving linear program problems using Desmos involves using an interactive and visual math software to formulate, model, and solve mathematical problems related to linear programs. There are many interrelated variables in linear program problems. Students can see how these variables interact with graphs created by Desmos. They can also easily see how changes in one variable affect other variables in a problem. Interacting with graphs allows students to explore further by changing coefficients, limits, or other mathematical equations. They can see the effect of this change on the solution quickly. This is in line with [52] research that Desmos Activity Builder is a site-based technology that is useful to encourage students to participate actively in mathematics learning. It has many advantages compared to other programs or applications, such as free, easy to use, understandable, and has powerful graphics tools.

However, a lack of knowledge and experience of effective mathematical learning methods can also hinder technological integrations [53]. The teacher interrelated and specialized knowledge is required to use technology effectively in the teaching and learning process**.** Prospective teachers should enhance their understanding of mathematics, how students see and learn math with and without technology, and how technology can teach math. However, prospective teachers must combine all content, pedagogy, and technology areas in the same belief and knowledge. Prospective teachers also should see math as an ever-growing field where students can build their knowledge through active involvements. Technology can help implement a student-cantered approach and teachers can help students learn concepts. The advent of Industry 4.0 has ushered in a new era of education, demanding resources that are not only inventive but also competitive and progressive. In this dynamic educational landscape, the digitization of education has become a primary focus. It is essential to incorporate cutting-edge technologies and innovative teaching methods to stay ahead. This includes leveraging artificial intelligence, virtual and augmented reality, and advanced data analytics to enhance the learning experience. The goal is to create an educational environment that fosters creativity, critical thinking, and adaptability among students, preparing them for the ever-evolving demands of the modern workforce. Consequently, educational institutions must prioritize the integration of digital tools and resources, ensuring that both teachers and students are equipped with the skills and knowledge needed to thrive in the digital age [54]. In the realm of tertiary education, educational innovation is paramount for the development of multidisciplinary technological strategies. The integration of various subjects fosters an environment where problem-solving, critical thinking, and creativity are at the forefront of the learning experience. By adopting learning-centered methodologies, educators can ensure that students are actively engaged and able to apply their knowledge in practical, real-world scenarios.This multidisciplinary approach is intrinsically linked to the enhancement of digital competence. As students engage with diverse subjects, they are exposed to a variety of technological tools and resources that are critical for their future careers. The ability to navigate and utilize these digital tools effectively is a key component of digital competence. Technological resources, such as data analytics, artificial intelligence, and digital collaboration platforms, further enrich this integrated approach. These technologies enable more interactive and personalized learning experiences, which are crucial for developing digital competence. Students learn to adapt to new digital environments, troubleshoot issues, and utilize technology to solve complex problems, thereby honing their digital skills [55].

4. Conclusions

The results of the research provide three conclusions. First, digital abilities of the prospective male teacher (bachelor degree student) were thoroughly examined, including their ability to use technology, understand digital literacy, and use digital tools to solve mathematical problems. He had acquired digital competencies, including information and data literacy, communication and collaboration, and use of digital applications and troubleshooting. The subject could also understand basic computational thinking concepts, such as decomposition, abstraction, algorithms, and generalization. Students can create algorithms or sequences of actions necessary for a solution, including calculating or manipulating variables. Second, the digital skills of prospective female teacher (master degree student) were thoroughly examined for her digital competencies, including information and data literacy, communication and collaboration, use of digital applications, and problem-solving. The subject applied solutions to mathematical issues using Desmos. The subject could test and analyse solutions to ensure that the expected results corresponded to the real ones. Third, further research is suggested to describe the level of digital competence and computational thinking on other mathematics materials and involve primary or secondary school level research subjects.

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