



# The Role of Digital Technology in Enhancing 4C Competencies in 21st Century Mathematics Learning: Systematic Literature Analysis

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## Keywords:

21st century skills;  
4C competencies;  
digital technology;  
systematic literature  
analysis.

## Abstract:

This study aims to prepare students for the challenges of the 21st century by developing critical thinking, communication, cooperation, and creativity. The research method in this article is the systematic literature analysis method. The research stages consisted of formulating research questions, searching literature, setting standards for inclusion and exclusion, presenting data, processing data, and making conclusions. The results show that the integration of digital technology is considered to have a positive impact on students, ensuring they are technologically literate. By emphasizing critical thinking, communicating well, working collaboratively, and developing creativity, students become more prepared and skilled to tackle complex problems in modern society and the world of work.

## INTRODUCTION

As the result of scientific innovation, new technologies have characterized the present society. In Indonesia, the movement to utilize technology to facilitate work in all sectors, including education. The rapid development of technology in today's global era is inseparable from the impact it has on the education system. The development of digital technology provides an opportunity for teachers to develop and master skills that are relevant and efficient in learning.

The four pillars of education, as defined by the United Nations Educational, Scientific and Cultural Organization (UNESCO): 1) Learning to how, 2) Learning to do, 3) Learning to be, 4) Learning to live together. The education that builds competencies "21st Century Learning partnership" is a 21st century learning framework that requires students to have knowledge, skills, and abilities in the fields of technology, media, and information, learning skills, innovation, and life skills (Simanjuntak, 2019, p. 921). The

How to cite      Hafizhah, D. P., Maharani, S. F., & Salamah (2024). The Role of Digital Technology in Enhancing 4C Competencies in 21st Century Mathematics Learning: Systematic Literature Analysis. *Discourse: Journal of Multidisciplinary Studies*, 1(1). <https://doi.org/10.69493/discourse.v1i1.35>

Published by      PT. Diwan Media Pustaka | Diwan Research Center

21st century learning emphasizes students' ability to think critically, connect knowledge with the real world, master information technology, and communicate and collaborate (Sriyanto, 2021, p. 126).

With the development of technology and lifestyle in this information technology era, teachers should consider to not only transform their teaching media from paper and blackboard to digital media, but also develop students' ability to think critically in an independent manner. It is certainly not easy for teachers to fulfill these needs, as the mastery of international languages and information and communication technology is the most important literacy element to be passed by students. Thus, they are expected to be able to compete in the 21st century (Sugiarni, 2019, p. 85). Hence, the delivery of learning leads to skills that exist in the 21st century, one of which is 4C skills.

The 4C skill represents the term for Critical Thinking (CT) or having an ability to think critically, Collaboration or cooperating well, Communication the ability to effectively express themselves, and Creativity or the ability to develop ideas. Essentially, CT skills are considered as the ability to think in order to solve problems or make decisions about the actual problem at hand. Through challenging students with contextual problems from everyday life, their CT skills can be nurtured. The skills of creative thinking (Creative Thinking Skills) are the ability to generate new ideas or insights that are different from the existing ones. This skill can be trained by providing challenges in the form of problems that demand creative ideas, ideas, or work to solve problems (Arnyana, 2019, p. 6).

Communication skills represent the ability to convey thoughts, ideas, ideas, knowledge, and new information to others through oral, written, symbols, pictures, graphics, or numbers. These skills can be practiced by improving skills by challenging others to convey ideas or ideas to others. Communication is successful if others understand or agree with what is conveyed. Collaboration skills are the ability to work together, synergize, adapt to various tasks and roles, and respect differences. This skill can be trained by inviting students to work together in solving problems in learning (Arnyana, 2019, p. 7). Of these four skills can not only answer the challenges in the world of education. However, it can answer the challenges in the era of digital technology today.

Digital technologies are currently being utilized in educational institutions as an instrument to enhance learning, both as an instructional aid that facilitates information access, as well as a learning resource to assist in learning activities and assignment process. Through various applications such as Zoom, Google Classroom, Google Meet, Quiz, Telegram, and WhatsApp groups, teachers can use technology as a learning tool or facilitator (Nurillahwaty, 2022). Furthermore, the teacher can utilize the present application to improve students' skills in projects that are in accordance with the learning material through applications such as Animoto, Seesaw, Mathigon, and Scilab. Through these learning media, teachers can ensure that the material is explained in an interesting and simple way and improve students' skills through learning projects in order to sustain their interest in learning and classroom activities. Considering the exposure of described information, this study was conducted to explore the role of digital technology in dealing with education in the 21st century.

## METHOD

This study adopted a systematic literature analysis method. The research stages consisted of formulating research questions, searching the literature, setting standards for inclusion and exclusion, presenting data, processing data, and making conclusions.

### *Research Questions*

Research questions are the central piece of a scientific article and serve a number of critical roles. It helps to direct the focus of the research by defining a specific topic area, identifying research objectives, and guiding the research design. In the context of a theoretical framework, it assists researchers to link the studies to the relevant literatures and theories. In addition, it plays a significant role in directing data collection and analysis, ensuring that the data collected can provide an answer that accomplishes the research objectives. Moreover, the research questions make a scientific contribution by forming the basis for presenting the research results in a systematic way, and often open up opportunities for follow-up research or further theory development.

Population	: Junior and Senior High School Student
Intervention	: The role of digital technology
Comparative	: Application of 4C skills in the 21st century
Outcome	: The role of digital technology in facing the 21st century by applying 4C skills
Context	: Mathematics Learning in Junior and Senior High School

### *Inclusion and Exclusion Criteria*

Inclusion and exclusion criteria are key elements in the design of a research study and are used to define the characteristics of the participants or subjects that will be included or excluded from the study. These criteria are established to ensure that the study sample is representative of the population of interest and that the research findings can be appropriately generalized. The research inclusion and exclusion criteria are presented in table 1.

Table 1. Inclusion and Exclusion Criteria

<b>Inclusion</b>	<b>Exclusion</b>
Articles published in the range of 2018 to 2024	Articles published outside the range of 2018 to 2024

## RESULTS AND DISCUSSION

This study searches for desk of studies related to data collection and research results in the period 2018 to 2024. The literature search was obtained from the google scholar database. The researchers recorded the literature obtained in the form of a table to review the articles as research results. The researchers compared the findings of the several articles and made a conclusion of the study. All selected papers after exclusion process are presented in table 2.

Table 2. Summary of selected papers

<b>Authors</b>	<b>Results</b>
Aprida & Pramita, (2021)	Digital technology has an important role in improving 21st century skills. In digital technology, access to information is easy and fast in sharing information and learning resources. Learning will be more interactive and interesting, so it can increase learning motivation and student engagement in the learning process.
Jannah & Atmojo, (2022)	Learners can develop CT skills through extensive information access, interactive learning experiences and collaboration on shared projects. Digital technology also helps in improving the efficiency and effectiveness of learning. So that teachers can maximize learners' potential in facing 21st century challenges.
Partono et al., (2021)	4C competencies, namely CT, Creative, Communication, and Collaborative, are needed to face the complex and changing demands of the world of work. By improving 4C competencies, students will be better prepared to compete in the era of digital technology and face increasingly complex tasks.
Wahyuning, (2022)	Digital learning media can facilitate student collaboration and enrich the learning experience in science education by providing an interactive platform that allows for real-time communication and sharing of ideas between students. This can lead to increased engagement, peer-to-peer learning and the development of teamwork skills.
Satriani et al., (2022)	Digital technology has important roles in education, such as facilitating distance learning, expanding access to learning resources, increasing student engagement through interactive media, and facilitating the development of 21st century skills such as the 4Cs (communication, collaboration, CT, creativity).
Said, (2023)	Technology has an important role in improving the quality of learning. In education, technology-based learning media can play a role in improving accessibility, flexibility, effectiveness, interactivity and student engagement during the learning process.
Firdaus et al., (2023)	4C skills in the digital age are divided into 4 aspects, namely digital CT skills, digital creative skills, digital collaboration skills, and digital communication skills. However, UNSIQ survey results found that students' digital creative ability is the lowest aspect compared to other aspects.
Gunanto & Supriyadi, (2021)	The Pedagogic Technology and Content Knowledge component of pre-service teachers is able to utilize technology to guide students well. However, the ability of pre-service teachers regarding the knowledge component is still low and needs to be improved so that teachers can integrate technology learning well.

Authors	Results
Prayogi, (2020)	Digital competence is a competency that must be possessed by a teacher in the 21st century. This ability includes mastering information and communication, creating learning content, and solving educational problems.
Sriyanto, (2021)	The implementation of digital literacy can improve teachers' 4C skills. Digital literacy has a positive influence on academic performance in completing tasks more efficiently with the help of technology.
Banarsari et al., (2023)	The use of technology makes teachers more innovative and creative, making it easier for students to carry out the learning process. The utilization of technology in the 21st century is expected to help teachers solve problems in the 21st century so that education in Indonesia is more advanced and able to compete with other countries.
Sugiarni, (2019)	The 21st century learning process expects 4C skills that can be improved through the application of digital teaching media. It is necessary to socialize the application of digital teaching media so that teachers can design using digital teaching media.
Sinaga, (2023)	21st century skills require students to have character and digital technology skills provide opportunities to process and enrich the experience of learners. Teachers must have new skills and innovations regarding digital technology in facing the 21st century and realizing a better future for students.
Rosidin et al., (2023)	Digital media makes it easier for students to understand mathematical concepts in visualizing complex mathematical concepts and being able to show mathematics in the context of everyday life.
Patmaningrum, (2020)	The ability to combine mathematics and technology is needed to provide ideas, a more interesting point of view so that it can bring up the 4C abilities in facing the era of the industrial revolution 4.0.
Wahyuning, (2022)	Learning media used such as virtual laboratories, flipbooks, educational games, electronic comics, augmented reality, e-books, Kahoot, animation, and flash are able to empower CT skills, creativity, communication, and science literacy.
Darmawan & Wuryandani, (2022)	The use of picture storybooks as learning media is able to foster students' creative thinking skills and student learning outcomes. The enthusiasm of students using picture storybooks can be seen when they participate in giving opinions and statements during learning.
Septi et al., (2022)	The development of digital learning video media is able to improve students' CT skills. The use of learning videos provides opportunities for students to repeat all or part of the desired material.

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<b>Authors</b>	<b>Results</b>
Arnyana, (2019)	4C skills (communication, collaboration, CT and problem solving), innovation, and creativity are skills that everyone needs to achieve the life in this century era. Therefore, learning 4C skills is essential for the 21st century.
Lestari & Hindun, (2024)	Students' ability to succeed in the world of work is influenced by the application of 4C skills. 4C skills help students become more confident, more independent, and more prepared to cope with change.
Simanjuntak, (2019)	Advances in information and communication technology have changed the human lifestyle, both in working, socializing, playing and learning. Teachers and students, lecturers and students, educators and learners are required to have teaching and learning skills in the 21st century.
Sukirwan et al., (2024)	Technology is the dominant thing in the 21st century. The 21st century demands skills such as the 4Cs. Teachers must be able to transform technology-based learning through the formulation of lesson plans. This study recommends to improve teachers' ability towards the 4Cs to be applied to technology-based learning.
Fitriati et al., (2024)	This study highlights the challenges for prospective Mathematics teachers to improve the teaching and learning of 4C skills in the classroom. Adjustments to financing, governance practices and technological advances are needed for implementation in teacher training institutions.
Rehman et al., (2023)	The research revealed that PBL has the potential to enhance 21st century skills such as collaborative, CT and problem-solving skills. These skills are important to prepare for the global challenges of the 21st century.
Sanjayanti et al., (2020)	This study concluded that the module integrated with 4C skills is feasible to use for the learning process. 21st century education is expected to create human resources who have abilities in communication, collaborative, technology, creative, innovative, and able to solve problems.
Lee & Hwang, (2022)	This research supports the readiness of 4C (CT, creative, collaboration, and communication) pre-service teachers to provide hands-on learning opportunities using new technology as a tool to fulfill continuing education.
Limna et al., (2022)	This study suggests educators, program directors, and educational leaders to pay more attention to the 21st century learning technology integration model (4Cs) to increase student interest and learning effectiveness.

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<b>Authors</b>	<b>Results</b>
Kiryakova, (2021)	Learners need key competencies such as CT, creativity, collaboration and communication. These 21st century competencies can be developed throughout life, but their formation must begin in the classroom. Information and communication technology helps to create an enjoyable learning environment.
Afandi et al., (2019)	The implementation of 21st century education learning emphasizes each indicator of IP-21CSS, one of which is ICT (technology, media, and information literacy) as an important component for prospective science teachers in Indonesia.
Lestari & Hindun, (2024)	In the 21st century era, 4C skills are required by students. The application of 4C skills needs to be supported by educational technology such as online platforms and the use of educational applications such as collaborative platforms or graphic design applications.

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Source: Compiled by authors, 2024.

### *Digital Technology Development*

Technology has developed continuously, and even today it grows rapidly. The technological development has become unavoidable in the current era of globalization (Sriyanto, 2021). The advancements of technology in the digital era have influenced various aspects of human life, including the economy, culture, politics, and education. It provides many conveniences in carrying out daily activities. Nevertheless, regardless of the positive purpose of technology at its initial stage, it is possible to have a negative impact on the other side (Sinaga, 2023).

In education, technology has become an important information sources and references in the teaching and learning process. Towards the 21st century, UNESCO (1996) has proposed a lifelong education based on the four pillars of the learning process, which are: Learning to know, Learning to do, Learning to be, and learning to live together (Banarsari et al., 2023). It requires a qualified teacher to realize these four pillars and to be able to apply Information and communication technology during the learning process. The educational community are expected to be constantly aware of the new digital era and adapt to the development of information and communication technology. In addition, education in the digital era should be able to integrate technology into teaching and learning (Firdaus et al., 2023).

The digital technology development in education has led to several innovations in supporting the learning process. It opens a wider and more equitable access to education for everyone. Through digital technology, students are able to access the necessary information whenever and wherever they want (Zakaria et al., 2023). As such, webinars are available through internet applications including Zoom and Google Meets. These webinars are able to promote the transfer of knowledge regardless of spatial barriers (Gunanto & Supriyadi, 2021). Through the use of technology devices such as computers, smartphones, and tablets, students could more easily access a diverse and an innovative learning resources (Said, 2023).

The development and application of this technology is beneficial for education, including (Mulyani & Haliza, 2021):

1. The emergence of mass media, especially electronic media as a source of knowledge and education center. This impact causes students not only to be too fixated on the information taught by the teacher.
2. With technological advances, new methods have been created that make students understand abstract materials.
3. The learning process can be more flexible, not necessarily through face-to-face meetings.
4. The development of science and technology helps to process assessment data in a faster time.
5. Fulfillment of needs for educational facilities can be met quickly.

Rapid developments in the world of Science and Technology emphasize the importance of the readiness of educational human resources, both mentally and spiritually (Sugiarni, 2019). Teachers must be able to utilize available information technology to expand their knowledge and skills in designing innovative and diverse learning media that are able to provide ideas, interesting points of view so that students are able to think critically, creatively, and innovatively (Patmaningrum, 2020). Teachers need to improve their competence to be ready to face the development of educational technology.

### *The 21st Century Skills*

Dealing with the 21st century era, which is characterized by the widespread and continuously evolving technology utilization, is a challenging task. It is necessary to prepare human resources to be able to adapt to the demands of the current era. In this case, educational institutions play an important role, which is determining the graduates' competence in having skills according to the 21st century demands (learning and innovation skills) as well as mastering science and technology in accordance with the field of their field (Zubaidah et al., 2018). Since the development of the 21st century emphasizes certain specializations, the Indonesian national education needs to focus on preparing graduates with the appropriate skills relevant to the demands of this era.

The intended 21st century skills mean that each person has mastered the 4Cs in order to achieve their life goals in their communities in the 21st century. Meanwhile, the 4C skills in mind are Communication, Collaboration, CT and Problem Solving, as well as Creativity and Innovation skills. This is in accordance with a report on the readiness of the younger generation for work, which found that more than 400 executives and business managers agree that CT and innovation, communication, collaboration, digital literacy, creativity, and problem solving are at the top of the list of success of the younger generation's workforce (Afandi et al., 2019).

The CT and problem-solving skills refer to the use of knowledge, data, and facts to solve any problems effectively. According to Marlina and Jayanti (Sukirwan et al., 2024), CT skills are high-level thinking skills in using and manipulating material according to the required situation. CT skills play an important role in solving problems. Someone who is faced with a problem needs to think independently, analyze the

situation, and find/develop a solution. As a result, a person with CT skills would be considered an expert in problem solving, able to provide innovative and innovative solutions to the issues that arise.

Furthermore, the Central Board for Secondary Education (CBSE) defines creativity as referring to a new way of seeing or doing a certain action (Sukirwan et al., 2024), the uniqueness of the solution to a certain situation (Mazeh, 2020). It is also the essence of innovation and novelty (Kaplan, 2019). Hence, the term creativity could not be separated from an innovation. In this case, someone who develops their creativity continuously will become an innovative thinker. Both creativity and innovation are among the most critical 21st century skills as they are considered to enhance a person's potential by bringing out positive aspects, as well as being able to express themselves in a healthy and productive manner.

However, collaboration relates to the activity of partnering with others to achieve a certain goal. According to CBSE (Sukirwan et al., 2024), collaboration is the skill of working with others effectively. Collaboration allows one to develop interest and enjoyment in the learning process that crosses environmental, social, and cultural boundaries. Thus, being an effective collaborator not only means being able to work with others but also being able to learn, share and express oneself. It also signifies the importance of openness and sharing creative ideas that can encourage more communication with each other.

The communication involves the skill of expressing ideas and offering an opinion, both verbal and non-verbal. According to the Indonesian Ministry of Education and Culture (Kemendikbud, 2017), communication is the ability to convey information, ideas, and skills using symbols, pictures, numbers, and words. It is considered to be one of the most important 21st century skills in career advancement, making people highly valued and positively engaging others. In addition, a great communication skill would support the ability to build collaboration, bring out creativity, and improve decision-making.

Considering the important role of the 4-Cs in the 21st century, the learning model and skills are innovated in reference to the changing era to engage students' interest, increase learning motivation and accommodate their learning characteristics to prepare the future life after graduation. The four components presented by the Ministry of Education and Culture as the characteristics of 21st century education are information, computation, automation and communication, causing a shifting paradigm of learning. The information literacy, computer skills, information and communication technology utilization in the communication process and communication skills are a number of skills that should be mastered by a current teacher. The teachers are expected to have technology-based teaching capabilities in the 21st century (Simanjuntak, 2019).

## CONCLUSION

As a result of this literature review, we concluded that the application of the 4C skill, i.e. CT, Communication, Collaboration, and Creativity, in learning at the formal education level is an innovative step that yields great benefits. By emphasizing CT, communicating well, collaborating, and developing creativity, students would be better prepared and skilled to handle the complex problems in the modern society and the future workplace. Also, the integration of 4C skills with digital technology could have a

positive impact on students, ensuring that they not only develop 21st century skills, but are also literate in current technologies to be used in their study. It is a forward step towards quality education in Indonesia, as stipulated in Indonesia's National Education Goals. It is recommended for the teachers to utilize the digital technology-based 4C on the teaching and learning activities to produce high quality learners.

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