Digital technology in learning mathematical literacy, *can it helpf ul?*

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**Abstract.** Literacy is a critical skill and is quite a concern in the world of education, especially mathematics education in the 21st century. Literacy in mathematics illustrates how a student identifies and understands the problems in which mathematics he has learned plays a role in all aspects of life. On the other hand, the 21st-century digital era demands the realm of education to be able to utilize ICT (Information and communication technologies) in the learning process, not least in mathematics. Digital technology, as a tool that is believed to make a significant contribution to the development of education, is also a challenge in its application, especially concerning the development of mathematical knowledge and skills, mathematical literacy. A question that arises is, can the use of digital technology develop mathematical literacy in the process of learning mathematics? If the answer can, then how should such integration be carried out. This article aims to provide an overview of the answers to these questions by giving an overview of the importance of mathematical literacy and digital technology in developing mathematical literacy.

1. **Introduction**

21st-century education projections are based on three main components, namely character, competence, and literacy, that must be developed and integrated with education, especially in Indonesian [1]–[3]. Of course, this requires changes in all areas. Educational reform itself fosters a new paradigm in every aspect of mathematics learning. If the old standard is still debating related to the need for skilled performance (be successful in mathematics if it can calculate quickly and accurately) or the need for mastery of procedures with understanding [1], then the 21st-century education orientation answers that both of these are important to be mastered by students in learning mathematics in school. Indonesian education standards also put the same thing where school education is directed to encourage students to
develop their potential and have spiritual strength, self-control, personality, intelligence, noble character, and qualified skills [2].

Regarding mathematics itself, of course, the ability to count and mastery of procedures is no longer sufficient but how these abilities can be used by students as a tool for problem-solving and facing all challenges of the knowledge society [4]–[9]. Related to real-life challenges, of course, is not an easy thing to solve. As an illustration, the problem that mathematicians work on, in academia or industry, is not the type of exercise that can be completed in a few minutes or hours. Still, it takes days, weeks, months, or years to solve it. The condition shows that, in addition to having a large amount of specific specialized knowledge, a mathematician also has other things as a reliable problem solver [6], which is closely related to competence and proficiency [1], [5]. NCTM states that mathematics skills are essential to be integrated into learning mathematics in the classroom, covering various competencies to ensure the realization of the objectives of mathematics education for students [5].

The 21st century is also known as the digital era, where the use of technology as a learning medium becomes a critical component in learning. Technology has presented a new tool in education that can strengthen student skills in all fields of study and age groups. Technology integration provides many advantages, among the positive effects of the use of technology in the learning process is to increase student motivation in learning [10]. The event so, it is also undeniable that there are opinions that mention that technology hurts the learning process. The use of technology in early mathematics classes (kindergarten and low-grade of elementary school), for example, is still being debated, a concern occurs because remembering children at this age still need a touch of real experience in learning mathematics [11].

As technology and education progress, much progress has been made in articulating better technological design choices that allow a positive influence on the cognitive and affective dimensions of mathematics learning [11]. Some studies also focus on developing and using digital technology design in exploring mathematical conceptualism, including DeCoito & Richardson [12]. They have tried to prove that exploring technology through integrated STEM content through digital online games can increase mathematical literacy and scientific literacy and develop a positive attitude towards teaching STEM content through digital technology. This integration is not an obstacle to learning mathematics; instead, it provides an excellent learning opportunity.

The research of DeCoito & Richardson is one of the shreds of evidence of Papert's [13] statement, which states that ICT (Information and Communications Technology) has a fascinating relationship with literacy because it can support and promote essential reading and writing skills (in terms of basic literacy definitions). However, what if related to the broader and dynamic interpretation of literacy, where the meaning is not just reading and writing, especially in mathematics, is interesting to discuss further. Besides, some questions that might arise, such as how technology should be applied in mathematics learning, how technology can influence and develop mathematical literacy, or what impact the application of technology has on mathematical literacy learning, can also be reviewed in depth. Based on the description above, this paper will try to provide a review that would be able to answer the three questions.

2. Method
Data in this article were collected using the literature review method. The literature review is carried out by combining the literature, organizing it into a series of related topics, and summarizing it by pointing out the main issues discussed [14]. In this article, the Literature review method aims to gather all relevant information from written documents such as journals and published books related to mathematical literacy, digital technology in mathematics learning, and the relationship between them. Records are tracked through websites such as google scholar, SpringerLink, ScienceDirect, and ResearchGate. This
literature review reviews articles and books with the keywords "competencies of the 21st century", "mathematical literacy" and "technology in literacy mathematics."

3. Results and Discussion

3.1 Mathematical Literacy

Some studies and literature said that modern society in this century not only requires content knowledge, but also requires skills including critical thinking, problem-solving, creativity, innovation, communication, collaboration, flexibility, adaptability, initiative, self-diversion, social, cross-cultural, productivity and accountability, leadership and responsibility, and information literacy [7], [15]–[20]. The intended ability is closely related to what is called literacy [21]–[24].

This time, mathematical literacy has developed through a long process, especially from the definition of mathematical literacy itself. Steen [24] states that literacy does not have a permanent and constant description over time and place; this can be a benchmark in valuing the differences that arise in describing literacy. In general, literacy refers to reading and writing [25], [26]. More specifically, UNESCO [23], who pioneered literacy, also defined it as the ability to identify, understand, interpret, create, communicate and count, using printed and written (even visual) material related to various contexts. Literacy involves continuous learning (livelong education) to enable a person to achieve his goals, develop his knowledge and potential, and participate fully in the wider community [27]. However, as societal and technological change, the definition of literacy also increases [18], [28], this is because technology has increased the intensity and complexity of the literacy environment. In the context of the 21st century, a literate individual is required to have various abilities and competencies, related to literacy which of course is not only limited to literacy which is interpreted traditionally, namely reading, writing and laying but more than that [7], [26], [29]. This new literacy includes traditional literacy skills together with new literacy skills, such as critical thinking, scientific reasoning, and multi-cultural awareness [15].

Literacy is a complex problem and not a simple problem. There are small but significant differences to study regarding the definition of existing literacy as well as the variation in terms used by various pieces of literature in expressing synonyms of mathematical literacy such as mathematical or mathematical literacy, numeracy, or quantitative literacy [28]. The condition arises from different perspectives on mathematical literacy that vary with the values and reasons of the stakeholders who promote it. For example, NCES [29] uses the term "quantitative literacy" to emphasize the importance of investigating arithmetic meaning in a society that continues to increase quantitative numbers and information use. On the other hand, Jablonka [28] and some other literature [30]–[32] chose to use the term "mathematical literacy" to focus attention on its relationship with mathematics and becoming literate.

Most existing definitions mention, giving explicit attention to numbers, arithmetic, and quantitative situations [30]. Initially, literacy in mathematics was only limited to numerical skills, which included mathematical operations. Related to this, NCES tries to define two phrases, namely literacy, and numeracy [29]. Literacy is defined as the knowledge and skills needed to understand and use information from the text and other written formats. At the same time, numeracy applies to the knowledge and skills required to manage various situations' mathematical demands. However, dissatisfaction with this definition, in its development of mathematical literacy, came to be known as "quantitative literacy" [24], which emphasizes the importance of investigating the meaning of arithmetic in a society that continues to increase the use of quantitative numbers and information.

However, the complexity of mathematical problems in people's lives cannot only be handled by numbers and data, so this definition of mathematical literacy must be interpreted more broadly. De Lange [30] tries to link literacy in the field of mathematics by defining mathematical literacy as mathematical knowledge, methods, and processes that are applied in various contexts in insight and thoughtful ways. De
Lange then illustrates the correlation between mathematical literacy and other parts of literacy based on phenomenological categories, which certainly have apparent differences from the previous definition where mathematical literacy includes spatial literacy (space and form), numeracy (quantity), and quantitative (quantity, changes and relationships, and uncertainties).

A comprehensive study conducted by Jablonka [28] states that the diverse perspectives of mathematical literacy make different meanings different from mathematical literacy. The different perspective is strongly influenced by the principles and values that underlie the stakeholders. Various concepts of mathematical literacy are related to relationships and factors, for example, culture and context [28]. Furthermore, other comprehensive research conducted by Haara [33] places more emphasis on the development of student literacy, which states that mathematical literacy still needs to be studied in more depth (qualitatively), especially related to what is the priority of literacy. Besides that, how to teach mathematical literacy in class also needs to be studied theoretically and practically. The condition is motivated by the limited comprehensive review of some current studies about priorities in mathematical literacy research that has been conducted. Haara further explained that the situation above was driven by the results of an analysis of several studies that stated that there were facts in which teachers and researchers were still unsure how to develop mathematical literacy in classroom learning. Besides, the results of research that state that mathematical literacy cannot be improved if it only involves mathematics (mathematics lessons) alone, the development of mathematical literacy requires more modern methods (not traditional) in the process of learning mathematics.

Furthermore, there is an understanding of mathematical literacy that goes beyond just applying arithmetic operations. Still, literacy in mathematics is associated with one's ability to identify and understand problems in which mathematics plays a role in all realms of life [30], [31], [33], [34]. Meanwhile, Jablonka [28] determines the broader term by stating that the primary purpose of literacy is to see the world through mathematics so that mathematics in literacy is placed as a high-level thinking activity that includes the ability to solve problems. The same thing is also reflected in the definition of mathematical literacy provided by the OECD (1999-2013). This definition then forms the basis of the assessment and analytical framework of the Program for International Student Assessment (PISA) in each of its assessment years.

As a reference to the definition of literacy that is commonly used by several studies [29], the definition of literacy provided by the OECD in the intervals of 1999-2017 has also changed (though not too significantly), but this shows that the definition of mathematical literacy also follows demands current development. The definition of mathematical literacy provided by the OECD in the period 1999-2009 only uses the terminology of the use of mathematical knowledge as a means of solving everyday life problems. Significant differences from the definition of mathematical literacy occur at intervals of 2013 and 2017, where this definition becomes to stands out to explain mathematical literacy carried out by someone. The definition of literacy in the OECD 2013-2017 definition requires a person to apply mathematical abilities such as formulating, doing, and interpreting mathematical things in various contexts. Implicitly, it can be seen that literacy demands have shifted from the use of mathematics to predict the phenomenon of situations faced by an individual to the use of some competencies from the use of mathematics [29]. This shift is essential considering the role of mathematics can not only be used in observing situations that occur but also to train some abilities needed according to context.

The shift in the meaning of mathematical literacy used by the OECD also occurs due to changes in the times' demands. This is what was delivered by Jablonka [28], where the shift in the meaning of mathematical literacy is determined by cultural changes and the context of which is related to the use of computational skills in daily life. This is then by what was delivered by NCTE [15] and IRA [18], where the development of literacy-related to the context of experience in the 21st century will always be related to the use and application of technology. In detail, NCTE states that the literacy of the 21st-century global
society increasingly reflects the ability to use technology to collect and communicate information. Even the literacy used by students today is far different from their parents or even those of students just a decade ago. The IRA position statement reports that to "become fully literate in today's world, students must become proficient in 21st-century technology literacy". Literacy abilities cover something broad, complex, and varied according to social and cultural contexts and education [29]. This is what then demands us to understand more deeply the direction of the development of mathematical literacy based on this latest definition and its relation to digital literacy, namely how technology is used for the needs of solving life's problems.

3.3 Digital Technology and Mathematical Literacy

Technology has become an essential aspect in the world of education, one of which is shown by the integral relationship between humans and various technological devices in this life. Indeed, the ability to utilize multiple technological tools is a demand for success in this global information society [17], [35], [36]. That is why digital technology is one tool that might play an essential role in developing mathematical literacy. Basically, digital technology offers a very efficient tool for learning and is expressive [37]. The use of ICT-based digital technology in teaching has long been carried out, so the relative newness in this field is what is called the new generation class, which means the use of tablets and other modern technology in the classroom. However, the intended classroom does not eliminate the teacher's role, but rather the part of the teacher changes and becomes a facilitator. Students then actively manage their learning steps and develop valuable stimuli [11]. In general, the relationship between mathematical literacy and digital technology can be shown in Figure 1.

![Figure 1: The relationship between mathematical literacy and digital technology [37].](image)

In general, it is not easy to build digital literacy. The first thing to note is the availability of technology, namely hardware, software, and internet connections, including time management. The second thing is to have adequate skills, namely, skills related to the ability to use technology for self-improvement.
(learning). This includes information and ICT literacy (digital literacy), including metacognitive skills that lead to understanding the role of technology in building one's educational environment [26].

But researchers still have differences of opinion on the use of technology in primary education (kindergarten and early elementary school). Steffani & Sylvester [38], and Snow [39] research concluded that students who learn by on-line instruction (online-only instruction) show better learning achievement compared to students who study face-to-face. Students who learn by using these two alternatives (online and face-to-face together) have better performance than just using online only. However, research conducted by Steffani and Snow was undertaken in higher education, and cannot yet be generalized in primary school.

Utilizing technology in mathematics classrooms plays a role in learning and academic progress as well as literacy. If in kindergarten or primary education, the use of technology begins with technological literacy, namely introducing tools to solve problems [40], [41]. An important issue is how to utilize technology in mathematics learning to develop a variety of competencies and student skills. In this digital age, our access to technology is not something foreign and complicated, so there is a demand for every educator to be able to integrate technology into learning. For example, in Indonesia, teachers are required to be able to use information and communication technology-based media (ICT) [42].

On the other hand, Dunlosky [43] said, "Teaching practice must guarantee the development of children both cognitively and linguistically to enhance their development and build on their previous strengths in each student". Mathematics must be integrated with other activities, organized by the way students actively explore their environment, work through and engage in manipulation of real-world tasks, and also exploration activities in learning environments are carried out based on games [44]. Indeed, creating unusual combinations and collaborations, making fun, and providing space for students to interact with each other is a challenging endeavor. Still, it is believed to create success in learning.

Goodwin and Highfield [45], in their research, offer a slightly different characterization, where digital technology is focused on the constraints of the underlying pedagogical aspects, namely: instructive, manipulable, and constructive. Instructive digital technology tends to promote procedural learning, relying on evaluative feedback and repeated interactions with forced representations. Meanwhile, digital technology that can be manipulated allows forced images to be manipulated to involve students in discovery and experimentation. Furthermore, the latter is constructive digital technology where students make their representations, which are often the goal of the activity, promoting mathematical modeling and what is characterized by Noss and Hoyles [46] as meaningful use of technology. In this regard, Goodwin and Highfield [45] argue that while instructive technology might be suitable for procedural learning, manipulable and constructive technology better supports conceptual knowledge.

The importance of using technology in mathematics can help students to realize the mathematical concept. Technology contains the power to have a considerable influence on students' attitudes and behavior, in addition to increasing student involvement and motivation. The contribution of technology in developing school literacy has excellent potential. Therefore, the most crucial idea in using technology in developing mathematical literacy is the teacher's attempt to find the best way to integrate various applications of educational technology into classroom settings. The teacher must consider the pedagogic aspects arising from the various technological devices used (whether in the form of instructive, manipulable, or constructive) when they design the mathematical learning process. Technology still acts as a tool in learning mathematics, where technology has not yet become a breakthrough (Cheung & Slavin, 2013). The use of new and better tools is needed to utilize the power of technology in improving the achievement and various mathematical competencies of all children. The learning process with the use of technology is increasingly believed to be its usefulness, so it is recommended that educators and teachers be able to integrate various appropriate technology applications in the learning process. The
success of the learning process is very dependent on the planning process, so it is recommended that the planning and design process is carried out correctly and structured.

Even with proper planning and design, technology has been used by early childhood education (kindergarten). Teachers can utilize technology in kindergarten and also start children on the road to technological literacy: knowing to use tools to solve problems [40], [41].

4. Conclusion

Literacy skills can develop with the consistent use of technology to improve students' exploration and relation to mathematics. Some studies mention that the use of technology has a vital role in learning mathematics and the practice of mathematical literacy. But, the instrument used in the integration of technology in developing mathematical literacy must consider the pedagogical aspects and mathematical concepts themselves. The use of digital technology does not mean the presence of teachers in learning is no longer needed. Instead, its role has changed to become a designer and facilitator who will guarantee the creation of learning that can cover mathematical literacy and digital literacy adequately.

Acknowledgment

The authors would like to thank and give a high appreciation to our lecturers in mathematics education program, Postgraduate Schools of Universitas Pendidikan Indonesia for helping and supporting during the writing of this article.

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