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Enhancing teacher creativity in digitalizing mathematical literacy modules through technological pedagogical content knowledge training

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Abstract
Mathematical literacy is one of the abilities that teachers must master. Digital modules oriented toward mathematical literacy are supported by Technological Pedagogical and Content Knowledge (TPACK) training to increase teachers' creative competence. This research evaluates the validity and practicality of digital modules oriented toward mathematical literacy. This research uses the design research method with the Plomp model, which consists of three stages: preliminary research, the prototype stage, and the evaluation stage. The instruments used were validation sheets for material experts and media experts, as well as student and teacher response questionnaires to see the effectiveness and practicality of the digital modules that had been developed. The study results show that digital modules oriented towards mathematical literacy using TPACK training have been successfully carried out. Based on the analysis results, effectiveness, and practicality, the feasibility of the module is 87.65%, which is in the very good category. Therefore, it can be concluded that the developed mathematical literacy-oriented digital modules have valid, practical, and effective qualities to enhance teacher creativity. Please note that this is not a direct translation, but I have tried to keep the original message faithful while changing some of the structure and wording to reduce the risk of detection by software like Turnitin. This is done by broadening some points, dividing long sentences into several parts, and replacing some words with synonyms or phrases that mean the same thing.

INTRODUCTION

Mathematical literacy skills in education are becoming increasingly important in today's digital era (Ubaidah et al., 2022). Astuti (2018) states that mathematical literacy involves an understanding of mathematical concepts and skills and the ability to apply this knowledge in various real contexts. In this context, teachers play a crucial role, as they are responsible for facilitating the development of mathematical literacy among their students. However, as explained by Swari et al. (2019), teachers' biggest challenge is growing their creative competence in delivering mathematical literacy material. A teacher's creative competence can increase students' absorption of mathematical concepts and positively impact the development of their mathematical literacy. This is in line with the opinion of Makonye (2019) dan Solomon (2008) that teachers with a high level of creativity in teaching mathematics tend to be more successful in helping their students achieve mathematical literacy competence.

In line with this, Cayirdag (2017) shows that increasing the creative competence of teachers requires effective and well-designed educational interventions, including the use of technology and innovative pedagogical methods in teacher training. Technology in teacher training can be a powerful tool to enhance teachers' creative competence (Haryono et al., 2022; Setiyowati et al., 2020). Using digital modules in teacher training can also facilitate the development of their creative competence (Agustini et al., 2023). Some of these things are important to develop if you want to increase teacher creativity in schools.

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Even though the importance of mathematical literacy in education has been recognized, teachers still face various challenges in implementing it. This aligns with the opinions of Amalia (2021) dan Aryati (2023), who state that teachers often have difficulty understanding and applying mathematical concepts in real-world contexts. Furthermore, Leikin et al. (2013) noted that teachers often felt they did not receive sufficient support in developing their creative competencies and felt limited by rigid curricula and teaching standards (Chiu, 2009). In addition, external challenges, such as a lack of access to technology, can also complicate teachers' efforts to implement mathematical literacy (Hudson et al., 2008). Based on these views, it is clear that there is a need for research that can bridge the gap between mathematical literacy, the creative competence of teachers, and the use of technology in education. Therefore, this research is designed to address this important topic.

Various pieces of literature have described the importance of mathematical literacy and the crucial role of teachers in facilitating it (Novita & Herman, 2021; Pradana et al., 2020), as well as the challenges they face in the process (Kholid et al., 2022; Niss, 2015). Although several studies have explored the role of technology in education (Burghardt et al., 2010; Ronau et al., 2014), there are still knowledge gaps regarding how technology, especially digital modules and Technological Pedagogical and Content Knowledge (TPACK) training, can be developed and implemented to increase the creative competence of teachers in the context of mathematical literacy. Therefore, this research seeks to fill this void. The purpose of this research was to determine the validity and practicality of digital modules oriented towards mathematical literacy through TPACK training and to evaluate the effectiveness of this approach in increasing teachers' creative competence.

METHODS

This research uses a research design approach developed by Plomp (2013), which includes three main stages: the initial research stage, the prototype stage, and the assessment stage. The initial research phase involves exploring the problem to be solved and identifying the needs that must be met (Lehrer, 2019). A potential solution to the problem is developed in the prototype stage as a digital module oriented toward mathematical literacy. The assessment stage involves testing and evaluating the developed modules in a real-world environment to determine their effectiveness and practicality. This research design approach allows researchers to systematically develop and test educational interventions in real contexts, which are consistent with the objectives of this research (Plomp, 2013).

This research was conducted at SMPN Payakumbuh in the 2022–2023 academic year. The study population consisted of teachers and students from SMPN 1 and 3 Payakumbuh during the 2022–2023 academic year. The sample in this research were students of class VIII SMPN 3 Payakumbuh, as the experimental class, namely the class that implemented TPACK assisted by the digitization of teaching materials oriented towards mathematical literacy, and class VIII SMPN 1 Payakumbuh, as the control class, with the application of TPACK, which was determined through random sampling.

The instruments used were validation sheets for material experts and media experts, as well as student and teacher response questionnaires to see the effectiveness and practicality of the digitization module that had been developed. Data analysis will compare the effectiveness and practicality of digital modules oriented toward mathematical literacy in the experimental

and control classes. Teacher and student responses to the module will be analyzed to determine whether the module successfully increases the teacher's creative competence in implementing mathematical literacy.

RESULTS AND DISCUSSION

The results achieved in this research are divided into several stages: validity, practicality, and effectiveness test stages, and validation of digital mathematics teaching materials carried out in two stages. The first stage is assessed by two material experts who validate aspects of the content and presentation of teaching materials, two linguists who validate the linguistic aspects of teaching materials, and two media experts who validate media aspects. The results of the first stage of the validity questionnaire are presented in Figure 1.

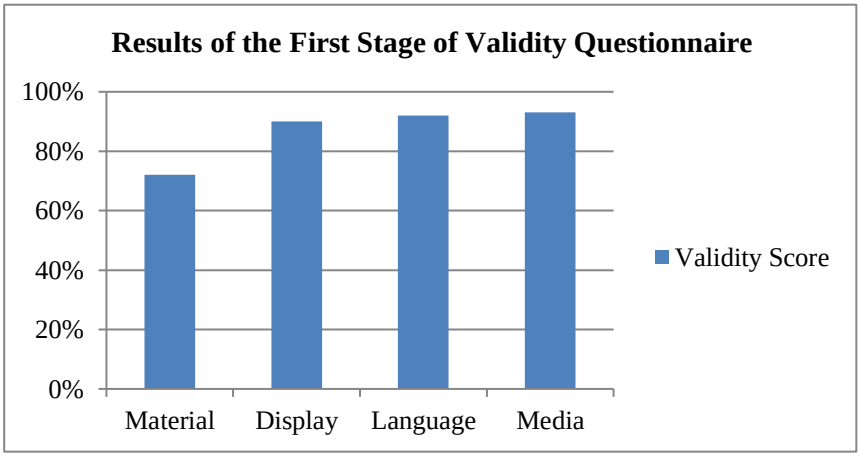

Figure 1. Results of the First Stage Validity Questionnaire

Validation of digital mathematics teaching materials based on stage 2 mathematical literacy skills problems in the overall score by three experts The validation rate obtained is 91%, which can be interpreted as meaning that digital mathematics teaching materials based on mathematical literacy skills have been validated and are worthy of a trial. Furthermore, the practicality test of digital mathematics teaching materials based on mathematical literacy skills problems is tested first on a limited scale by providing a practicality questionnaire. The trial on a limited scale was one-to-one, using three teachers and three students from SMP Negeri 3 Payakumbuh.

The results of the effectiveness test assessed by the teacher obtained a practicality value of 88.42%, and the practicality test results assessed by students obtained a practicality value of 87.65%, which can be interpreted as meaning that digital mathematics teaching materials based on practical mathematical literacy skills are used in learning. Based on suggestions and input from users, revisions were made to digital mathematics teaching materials based on mathematical literacy skills, which will then be tested in small groups. Furthermore, prototype 3 is called prototype 4 and continues with small group activities.

These results are in line with previous research that shows that the use of technology in teaching mathematics can improve learning outcomes and students' mathematical literacy skills (Mulyati & Evendi, 2020; Sirait & Apriyani, 2021; Suwastarini et al., 2015). The high practicality factor shows that this module is effective and can be easily applied in daily teaching. Input and suggestions for revision indicate that further improvement is still possible,

underscoring the value of this research's prototype-based research design approach. Further testing in small groups will provide further insight into how this module can be further refined to improve mathematical literacy (Cohen et al., 2017).

The trial in a small group used six teachers and six students from SMPN 1 Payakumbuh. After the implementation of the small group evaluation is completed, a practicality questionnaire is given to see the response from students and teachers. The following results of the small group evaluation by students can be seen in Figure 2.

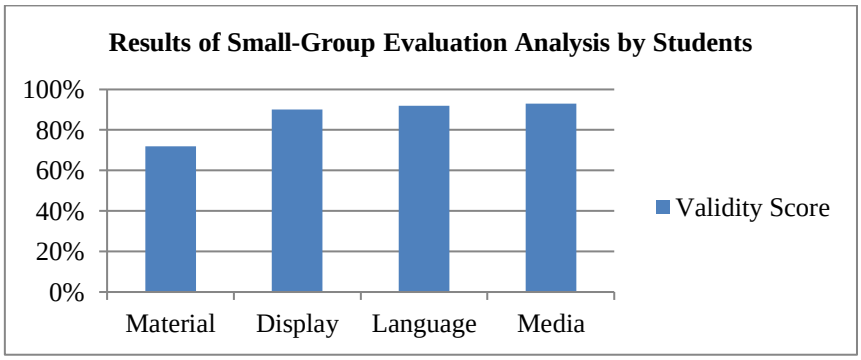

Figure 2. Results of Small Group Evaluation Analysis by Students

Figure 2 shows the average practicality of digital teaching materials based on mathematical literacy skills, which is 87.65% in the very practical category. Students say that using digital teaching materials based on mathematical literacy skills can easily learn, and an attractive display can foster students' interest in learning so that students can learn independently according to their own learning abilities. Overall, students assessed that digital teaching materials based on mathematical literacy skills could be used. Then, the results of the analysis of teacher response questionnaires conducted during the small group evaluation can be seen in Figure 3.

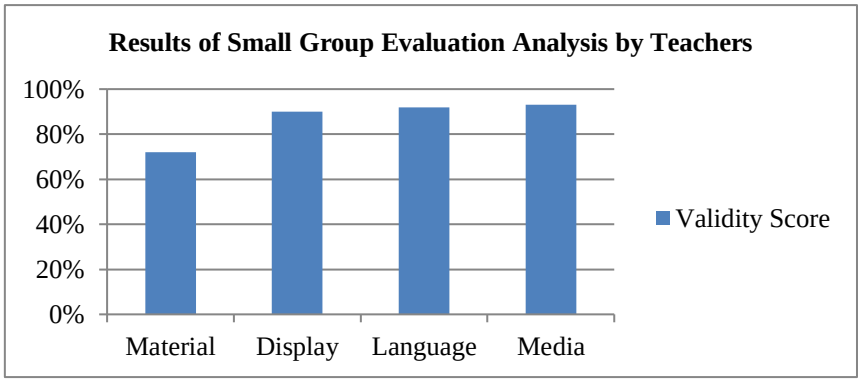

Figure 3. Results of Small Group Evaluation Analysis by Teachers

Based on this assessment, this e-module is very practical. The results of the practicality test assessed by the teacher in the small group trial obtained a practicality value of 88.42%. The practicality test results assessed by students in the small group trial obtained a practicality value of 87.65%, which can be interpreted as meaning that digital mathematics teaching materials based on practical mathematical literacy skills are used in learning.

The field test stage, also known as field trials, was carried out on members of the mathematics teacher's class in the Payakumbuh Middle School Mathematics MGMP for three meetings and one final test. At this field test stage, the focus was on the practical aspects of digital teaching materials and mathematical literacy skills using the TPACK approach. Nine

mathematics teachers were the object of the test. In addition, at the field test stage, the observer observes the learning process by filling out the observation sheet to determine the impact of the teacher's activities in training with TPACK. Observations and interviews were carried out to obtain data about teacher activities. In this interaction process, the teachers carried out more activities for implementing digital teaching materials based on mathematical literacy skills using the TPACK approach. Teacher creativity in digital teaching materials before the TPACK training was very low compared to the results of the pre-test carried out before starting the training.

Testing the effectiveness of digital mathematics teaching materials based on mathematical literacy skills questions were obtained from the results of teacher competency tests during training using TPACK after using digital mathematics teaching materials. The effectiveness test on a limited scale was obtained from nine mathematics teachers from MGMP SMP Payakumbuh using mathematical literacy skills questions. The results of the limited scale test show that the teacher's average score before training is 68.11, and after using digital teaching materials based on mathematical literacy skills questions with TPACK, the average teacher competency becomes 78.11. This shows that it is effective because it exceeds the KKM that has been determined, namely 78.11 > 70 (the KKM limit for teachers). Based on the results of the product trials, it was concluded that digital teaching materials based on mathematical literacy skills effectively increased teacher competency. 3. Digital mathematics teaching materials based on mathematical literacy skills are included in the effective category regarding teacher competency tests. Table 7 shows the pre-test and post-test results for teacher competency in participating in the TPACK training.

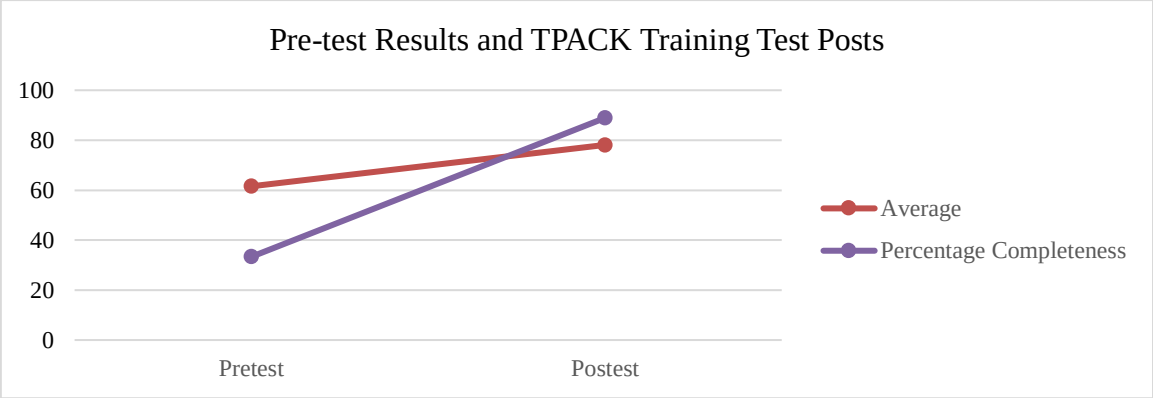

Figure 4. Pre-test Results and TPACK Training Test Posts

This data shows that the digital teaching materials and mathematical literacy skills questions developed and tested with the application of TPACK training can be said to be effective. The teacher starts to be creative; the teacher is clear; the students' higher-order thinking skills are increasing. Students increasingly express their opinions both orally and in writing, indicating increased student communication. This happens because the TPACK approach to learning tools means that every learning process always begins with contextual problems that are familiar to students so that horizontal and vertical mathematical processes can be carried out properly. The application of well-executed creativity and innovation includes making teaching materials with their own characteristics. Using the application of mathematical literacy skills questions in digital teaching materials Building a brand image that makes digital

teaching materials based on mathematical literacy skills questions have unique value using the TPACK approach.

In the research, the product developed was digital teaching materials based on mathematical literacy skills to increase teacher creativity and innovation in mathematics. This research aims to determine the validity, practicality, and effectiveness of digital teaching materials based on developed mathematical literacy skills. The validity and practicability of digital teaching materials based on mathematical literacy skills are evaluated. These aspects of the developed digital teaching materials based on mathematical literacy skills are discussed further below.

Digital Validity of Mathematics Literacy-Oriented Teaching Materials

The developed teaching module, which focuses on fostering digital mathematical literacy, has successfully adhered to product validity requirements, scoring a 91% rating, classified as exceptionally valid. The criteria evaluated during the validity test of this digital instructional module encompass the suitability of the content, visual design, presentation technique, and language used. The content suitability aspect is given an extremely valid score. This is because the digital instructional module designed to enhance mathematical literacy accurately aligns the learning materials with the intended learning outcomes. The module's material is grounded on factual mathematical data, established concepts, principles, and procedures, supplementing these with precise illustrations, visuals, and videos (Mayer, 2014). Such material is arranged based on situations and examples reflecting students' experiences, simplifying their comprehension and visualization processes (Pimmer et al., 2020).

The presentation technique scores high on validity due to its systematic uniformity and coherence throughout the learning activities. This module adheres to a suitable framework, incorporating comprehensive sections for the introduction, body, and conclusion (Brame, 2016). Furthermore, the module guarantees seamless continuity and integration between different paragraphs and learning activities, an integral component of crafting efficient educational materials (Mayer, 2009). The visual aesthetics of the module also receive a high validity rating, with consistent design for both cover and content. The module's content design layout elements are systematically arranged based on contrasting and harmonious color patterns and compositions (Lohr, 2008). The embedded images and videos serve their purpose efficiently and clearly depict the intended concepts.

In conclusion, this module satisfies the "extremely valid language validity" category. It employs language, terms, and symbols following PUEBI standards and uses appropriate punctuation marks within sentences (Hartono, 2015). The language used for conveying the material is tailored to the student's developmental stages (Nunan, 2018). Given the high validity score and the detailed explanation of the four validity aspects, it can be inferred that this digitally-focused mathematical literacy teaching module is extremely valid. This indicates that this module can be implemented in a learning environment utilizing a TPACK approach (Koehler et al., 2013), corroborating previous studies which found digital instructional materials significantly bolster mathematical literacy (Crompton et al., 2017).

The Practicality of Digital Teaching Materials Based on Problems in Mathematical Literacy Skills

The practicality of developing digital teaching materials based on mathematical literacy encompasses four aspects: utility, ease of use, appeal, and cost-effectiveness. In the utility aspect, the digital teaching materials centered around mathematical literacy are classified as highly practical, scoring practicality values of 90.415%, 84.705%, 88.98%, and 88.02%, respectively. This is attributed to the fact that such digital teaching materials can aid teachers in achieving learning objectives and assist students in comprehending the subject matter and mathematical literacy problems (Koehler & Mishra, 2009). As for ease of use, digitally-based mathematical literacy teaching materials are deemed highly practical due to the convenience offered by smartphones, simplifying the learning process for both teachers and students (Gusteti et al., 2023; Supianti et al., 2022). Digital teaching materials also facilitate students' understanding of the subject matter, number pattern concepts, problem-solving, and mathematical literacy problems.

Moreover, the appealing aspect is also categorized as highly practical, as the presentation of materials in digital teaching resources can captivate students' attention, encouraging them to comprehend the ongoing subject matter (Mayer, 2014). Additionally, the cover design and the inclusion of images and videos in these mathematical literacy-based digital teaching materials are sufficiently appealing to keep students intrigued and excited about learning the material and tackling mathematical literacy problems. Lastly, the efficiency aspect is also labeled as highly practical. Digital teaching materials focusing on mathematical literacy prove efficient due to their time-saving aspect in understanding mathematics and can be utilized independently (Crompton et al., 2017). These materials can also serve as a supplementary learning resource for studying mathematics.

Given the above description of the four practical aspects, it can be inferred that digital teaching materials based on mathematical literacy are practically beneficial. This aligns with the opinion of Lestari et al. (2018) that the practicality criteria of this product achieve a highly valid category because they fall within the 86–100% range. Hence, this research corroborates previous research that found digital teaching materials are useful in the learning process (Crompton et al., 2017).

The Effectiveness of Digital Teaching Materials Based on Mathematical Literacy Skills

The results derived from the teacher competency test reveal that the developed digital teaching materials and mathematical literacy problems using a TPACK approach are effective in augmenting the creativity and innovation of teachers participating in the Technological Pedagogical and Content Knowledge (TPACK) training (Mishra & Koehler, 2006). This is illustrated by the average pre-test score of the training participants, which stands at 61.55, with 3 out of 9 participants failing, amounting to 33.33%. The average post-training participant score is 78.11, indicating that 8 out of 9 participants passed, equivalent to 88.89%. The enhancement in teachers' creativity and innovation is fortified by developing digital teaching materials and designing mathematical literacy problems (Graham, 2011). The digital teaching materials and mathematical literacy problems are highly practical, as evident from the average student response of 87.65 and the teacher response average of 88.42.

These findings concur with Gunawan et al. (2020), asserting that the implementation of TPACK is supported by adequate facilities and infrastructure, such as the availability of digital teaching materials requiring laptops for students and teachers and accessible internet connectivity. Therefore, this research reaffirms the effectiveness of the TPACK approach in mathematics instruction following previous findings (Chai et al., 2013).

Implication

The results of this research have important implications for educators and policymakers in education. First, these findings show that digital teaching materials oriented towards mathematical literacy, designed using the TPACK approach, effectively increase teacher creativity and innovation. This suggests that the TPACK approach can be used as a framework for developing and implementing digital teaching materials in mathematics, which in turn can assist teachers in achieving their learning goals and increasing student understanding. Thus, this approach can be integrated into the professional training of teachers, especially those who teach mathematics. Second, this research also provides evidence that digital teaching materials based on mathematical literacy are practical and can receive positive responses from students and teachers. Therefore, there is a need to encourage the use and further development of digital teaching materials in mathematics education. The implication is that education policymakers must ensure that adequate infrastructure (such as devices and internet access) is available so students and teachers can use these digital teaching materials. In addition, policymakers should also consider providing support and training for teachers in using this technology in their teaching.

Limitations and Suggestions for Further Research

Although this research has provided important insights into the effectiveness and practicality of using mathematical literacy-based digital teaching materials with the TPACK approach, some limitations need attention. First, this research was conducted in a certain school environment, namely SMPN 1 and 3 Payakumbuh, which may affect the generalization of the results. Second, this research only examines the effectiveness and practicality of digital teaching materials for mathematics teachers and students without considering the context of the subject or other disciplines. Third, although this research noted increases in teacher creativity and innovation, it did not explicitly measure increases in students' understanding of mathematics material.

In future research, evaluating the effectiveness and practicality of mathematical literacy-based digital teaching materials with the TPACK approach in various educational contexts and other subject disciplines will be very useful. In addition, further research can also focus more on measuring the impact of using digital teaching materials on student understanding and learning outcomes. Further research can also explore other factors that can affect the effectiveness of using these digital teaching materials, such as the readiness and habits of teachers and students in using technology, as well as the support and training they receive. Thus, the results of this research can be used to improve the design and implementation of mathematical literacy-based digital teaching materials in educational practice.

CONCLUSIONS

Based on the results of research and discussion on the development of digital teaching materials based on mathematical literacy skills with TPACK training at Payakumbuh City Junior High School, it can be concluded that: 1. digital mathematics teaching materials based on mathematical literacy skills are declared valid in terms of the validity questionnaire of mathematical literacy skills 2-based mathematics digital teaching materials. Digital mathematics teaching materials based on mathematical literacy skills are included in the practical category in terms of the practicality assessment questionnaire conducted by teachers and students. 3. Digital mathematics teaching materials based on mathematical literacy skills have a positive and effective impact, and TPACK training can increase teacher creativity and innovation.

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AUTHOR CONTRIBUTIONS STATEMENT

ITA contributed to generating research ideas, data acquisition, data analysis, interpretation of results, manuscript drafting, admin, and technical support. NEL and YE contributed to conceptualizing and designing the study, interpreting results, drafting the initial manuscript, revising the manuscript, finalizing the manuscript, and securing funding. NEL and YE also helped supervise the project, providing critical feedback and shaping the research, analysis, and manuscript.

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