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Exploration of digital book learning media design for improving students' mathematical literacy abilities with the design thinking method

Lutfiyana, FX Didik Purwosetiyono*, Muhtarom

Universitas PGRI Semarang, Central Java, 50232, Indonesia
*Corresponding Author: didikpurwo@upgris.ac.id

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Abstract
This study aims to investigate solutions to the challenges students face in learning mathematics, particularly difficulties in understanding complex material that led to decreased motivation and low mathematical literacy during the learning process. The research employs a design thinking approach, which comprises five stages: empathize, define, ideate, prototype, and test. This study specifically focuses on the first three stages—empathizing, defining, and ideating—to identify the needs of both students and teachers and to develop appropriate solution concepts. The study population includes students from State Middle Schools (MTsN) 2 and 3 in Grobogan, with a sample size of 132 students, alongside six mathematics teachers. Data were collected via questionnaires distributed through Google Forms and supplemented by interviews. The findings reveal that both students and teachers require instructional methods supported by interactive media that are accessible online.

Keywords: mathematical literacy; android media; design thinking.

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I. Introduction

Innovation in education is essential to achieving the educational objectives in Indonesia. This is evident with the implementation of the Independent Curriculum, which follows the revised 2013 Curriculum (Khadijah, 2023). Mathematics instruction in schools aims to enhance students' skills in calculation and reasoning, thereby fostering logical and critical thinking abilities necessary for problem-solving in everyday life (Siagian, 2017). According to the results of the PISA study, literacy and mathematics questions emphasize the development of critical thinking skills and the capacity to solve complex, real-world problems and situations (Astuti, 2018). The competencies assessed by PISA are categorized into several cognitive process components, including problem-solving,

reasoning, and communication (Taneo, Suyitno & Wiyanto, 2015). Mathematical literacy among Indonesian students is categorized as low, as evidenced by the results of the PISA survey. The Program for International Student Assessment (PISA) is an international study that evaluates student performance in reading, mathematics, and science (Azmi, Sukestiyarno & Rochmad, 2020). PISA defines six proficiency levels that represent the average mathematical literacy scores of students worldwide. According to the 2022 PISA results, the problem-solving skills of Indonesian students require urgent attention and improvement, as scores have declined by 12–13 points compared to 2018. Of particular concern is that only 18% of Indonesian students demonstrate minimal proficiency in mathematics (OECD, 2006). Mathematical literacy is defined as an individual's ability to formulate, employ, and interpret mathematics in various contexts (OECD, 2022).

Literacy encompasses mastery of language skills, including effective communication. In the context of mathematics, literacy refers to an individual's ability to formulate, interpret, and reason mathematically across various contexts (Lutfiyana, Dwijayanti, Pramasdyahsari, 2022). Mathematical literacy is essential for learning mathematics, as it enables individuals to interpret data and solve problems encountered in daily life (Masjaya & Wardono, 2018). Despite its importance, mathematical literacy remains at a low level among students. One contributing factor is the continued reliance on conventional teaching materials, highlighting the need for instructional resources that better support the development of mathematical literacy skills (Atiyah & Priatna, 2023).

The quality of teaching materials is a significant factor inhibiting students' mathematical understanding (Romadhani & Harahap, 2022). One key cause of students' weak mathematical skills is the inadequate use of teaching materials and learning media (Taneo et al., 2015). In Indonesia, the implementation of teaching materials has not yet achieved a balance between scientific rigor and accessibility (Sugianto, 2017). The use of unsupported or ineffective teaching materials negatively affects students' mathematical literacy and understanding (Hasanah, 2019). Given these issues, educational innovation is imperative to enhance students' mathematical literacy. Various approaches can be employed to improve mathematical literacy among students.

Data collected through questionnaires and interviews with students from two schools, State Junior High School 2 Grobogan and Madrasah State Junior High School 3 Grobogan, revealed common challenges faced during mathematics learning. Many students perceive mathematics as a difficult subject to comprehend (Ayu, Ardianti & Wanabuliandari, 2021). Additionally, teaching methods tend to be conventional, primarily relying on lectures, questioning, and limited use of learning media (Adawiyah, 2021). These factors contribute to low student motivation in mathematics, which ultimately impacts their mathematical literacy skills (Indrawati, Annisa & Wardono, 2019). Addressing these challenges is critical for developing effective solutions that support both students and teachers in adapting to modern learning environments (Harahap, Silalahi, Hutagalung, Purba & Tansliova, 2024).

One recommended approach is the implementation of innovative learning strategies that emphasize the use of technology, providing greater flexibility in the learning environment. Such studies demonstrate that learning does not necessarily have to occur exclusively within the school setting (Chastanti et al., 2017). Based on this premise, two key research questions arise: (1) How can the design and development of interactive media, grounded in an appropriate design thinking framework, enhance students' mathematical literacy skills? (2) How can the implementation of a mathematics learning model based on design thinking improve the effectiveness of the teaching-learning process and actively engage students in enhancing their mathematical literacy?

Previous studies have consistently highlighted low mathematical literacy among students as a critical issue. For example, research by Juniansyah, Mariyam & Buyung (2023) identifies personal, environmental, and educational factors as significant influences on students' mathematical literacy. Personal factors include students' attitudes towards mathematics and their confidence in their abilities, while environmental factors encompass the availability and use of learning media.

Furthermore, this study confirms the importance of creating an engaging and enjoyable learning environment through the appropriate use of interactive media to make mathematics instruction more meaningful for students. Technology-based media such as application-assisted Google Sites, digital books, and Edupuzzle have shown promise in this regard. Digital books, as a form of educational media, can motivate learners and support the development of mathematical literacy (Purba et al., 2023). With technological advancements, various teaching materials have been developed to facilitate active learning, including digital books (Farhana, Suryadi & Wicaksono, 2021). The use of digital books can enhance students' mathematical literacy by providing accessible learning resources (Ancient, 2023). Digital books offer convenience, allowing students to access materials anytime and anywhere using their devices. Additionally, digital books can foster increased interaction between students and teachers in distance learning contexts(Haslinda, Maghfiroh & Fadillah, 2022). Students also benefit from reduced physical storage needs, lower costs related to replacing textbooks, and greater flexibility in remote learning (Nuzulia, 1967).

The objective of this study is to explore the design and development of interactive media in the form of a digital book aimed at improving students' mathematical literacy through the application of the design thinking method. This approach provides a deeper exploration of mathematics learning by encouraging creative and collaborative problem-solving (Sulistyowarno & Dwijayanti, 2025). Leveraging modern technology and the characteristics of the millennial generation, design thinking serves as a bridge between emerging educational needs and student achievements in mathematics (Mulyani, 2019). Interactive media based on current technology can help students gain a deeper understanding of mathematical concepts. Its effectiveness is maximized when combined with innovative approaches, such as design thinking, which promote critical and creative thinking among students (Sawitri, Novita, Karo, Mutiara & Barus 2024).

II. Research Method

The data collection and analysis method employed in this study is qualitative, utilizing a design thinking approach (Muhaemin & Lugis, 2023). This approach is specifically aimed at generating solutions to existing problems by developing ideas, products, or systems that address complex challenges and cater to the needs of particular groups (Azhari, 2020). Design thinking can be defined as a problem-solving methodology that involves creative and iterative processes for designing and developing effective solutions (Razzouk & Shute, 2012).

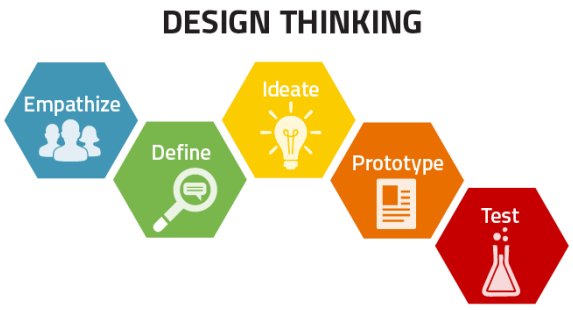

Figure 1. Design thinking stages

Design Thinking involves five stages, as developed by the Stanford School of Design Thinking: Empathize, Define, Ideate, Prototype, and Test/Evaluate (Kelley & Brown, 2018). In the context of learning, these stages facilitate

students' ability to understand and solve problems creatively and innovatively, thereby enhancing mathematical literacy (Widianti, 2023). Broadly, design thinking is a comprehensive process that engages students in multidisciplinary learning activities, enabling them to develop effective solutions to complex problems, even those that are difficult to understand (Utomo, Muhtarom, Dwijayanti, 2024).

The study employs the design thinking approach, which consists of the following five main stages: (1) Empathize: At this stage, researchers develop a deep understanding of users' characteristics and needs through direct interactions such as interviews, observations, and experience gathering. The primary objective is to view the problem from the users' perspective to design appropriate solutions (Sulistyowarno & Dwijayanti, 2025). (2) Define: The data collected during the empathize stage is analyzed and synthesized to identify clear and specific problems that need to be addressed. This stage involves setting detailed user needs to guide the design process (Tobing, Sulistiyowati & Siska, 2024). The principal main stage, namely, sets the needs user in a detailed way For guiding the design process (Satria & Muntaha, 2021). (3) Ideate: Designers generate multiple creative and innovative solutions. The aim is to explore a broad range of possible alternatives to address the defined problems (Margaretta, Despayani, Amri, Watunglawar & Taryana, 2024). (4) Prototype: At this stage, initial prototypes are developed and presented to users for testing. Prototypes serve to evaluate various design concepts and gather user feedback, which is essential for further refinement (Sagala, Persada & Arifin, 2024). (5) Test: The final prototype is tested extensively with users to obtain additional feedback. Based on the input received, necessary revisions are made to improve the solution before final implementation.

The population of this study comprises students and teachers from junior high school level institutions, specifically from State Junior High School (MTsN) 2 Grobogan and State Junior High School (MTsN) 3 Grobogan, located in the Grobogan Regency. The research was conducted on November 23, 2023. Data were collected using questionnaires distributed to both students and teachers to gather information related to learning needs, motivation, and preferred learning models. Additionally, interviews were conducted with selected respondents to obtain more in-depth insights into their experiences studying mathematics in the classroom. The instruments were validated by two experts to ensure reliability and validity. Both validators confirmed that the instruments met the required standards for use in this study (Aini, Munahefi, Pramasdyahsari & Setyowati, 2024)

Table 1. Respondents' student

No	School name	Number of Respondents	Percentage
1	MTsN 2 Grobogan	88	66%
2	MTsN 3 Grobogan	44	34%
amount		132	100%

The respondents in this study consist of 132 students selected as the sample from two different schools. Specifically, 88 students (66%) are from MTsN 2 Grobogan, while 44 students (34%) are from MTsN 3 Grobogan.

Table 2. Teacher respondents

No	School name	Number of Respondents	Percentage
1	MTsN 2 Grobogan	4	72%
2	MTsN 3 Grobogan	2	28 %
amount		6	100%

The teacher respondents involved in this study were drawn from two different schools, with a total sample of six teachers. Specifically, four teachers (67%) were from MTsN 2 Grobogan, while two teachers (33%) were from

MTsN 3 Grobogan.

III. Results and Discussion

The design thinking approach provides a comprehensive framework for creative work, enabling a deep understanding of users' needs, precise problem formulation, and the generation of relevant solutions in the development of interactive media. In this study, data analysis techniques were employed to thoroughly assess students' responses and evaluate the effectiveness of the developed media (Manurung, Agung & Suartama, 2024). A mixed-methods approach, combining both qualitative and quantitative analyses, was utilized to ensure the validity and reliability of the study, thereby maximizing the potential impact of the solution on learning outcomes at the junior high school level (Sarah, 2024).

a. *Empathize* – build empathy

In the empathize stage, researchers seek to develop a deep understanding of users' characteristics and needs. The initial phase involved designing a questionnaire to explore students' difficulties and feelings related to learning mathematics. The target respondents were students of Madrasah Tsanawiyah, equivalent to junior high school students. The questionnaire comprised several items aimed at gathering preliminary data from both students and teachers. Prior to distribution, the questionnaire was reviewed and validated in consultation with a panel of experts.

The results, presented in a bar chart, reveal that 43.9% of students reported feeling fearful due to the perceived difficulty of the material, 10.5% frequently received low grades, 27% indicated they struggled to understand mathematical concepts clearly, and 18.9% expressed a lack of confidence in answering questions. These findings illustrate significant emotional and cognitive barriers faced by students in mathematics learning (see Figure 1).

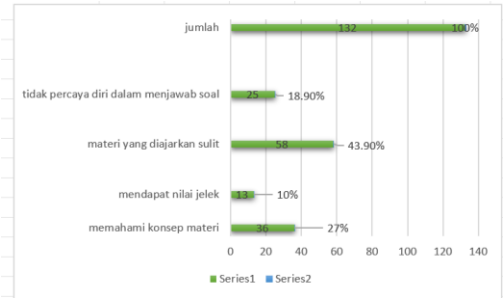

Figure 1. Build empathy

Analysis of Students' Learning Difficulties:

Among the 132 respondents, 77% indicated that the use of technology positively supports their learning process, while 9% reported that technology provides only limited assistance. Meanwhile, 14% of students felt that technology does not aid their learning at all.

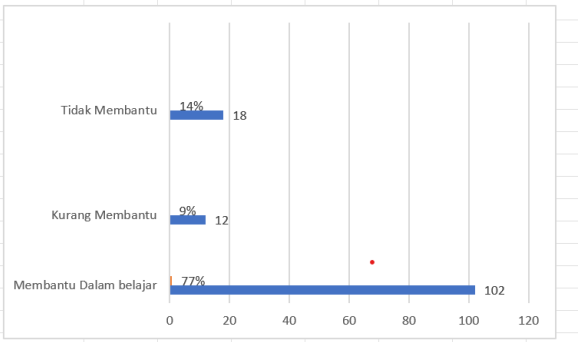

Figure 2. Utilization analysis technology

Additionally, 88% of respondents reported using supplementary learning resources, while 12% indicated that they do not utilize any additional study materials.

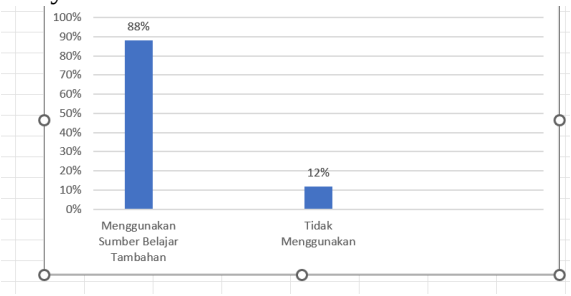

Figure 3. Usage analysis source study addition

Among the teacher respondents, 34.5% indicated that students' interest in studying was low, 25% observed that students had difficulty understanding mathematical concepts, 16.7% reported challenges in the application of these

concepts, 17% noted variability in students' abilities, and 8.3% identified inconsistencies in students' learning behaviors.

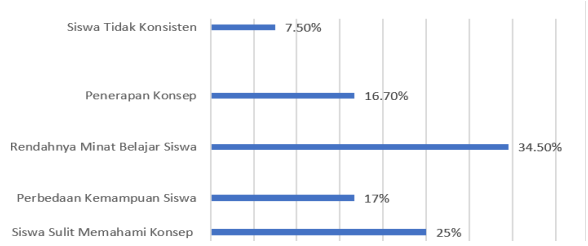

Figure 4. Analysis of teacher difficulties in teaching

According to the teacher respondents, the teaching methods employed include technology-based learning (40%), problem breakdown or problem-solving approaches (19%), group discussions (10.3%), project-based learning (25.2%), and question-and-answer sessions (6.1%).

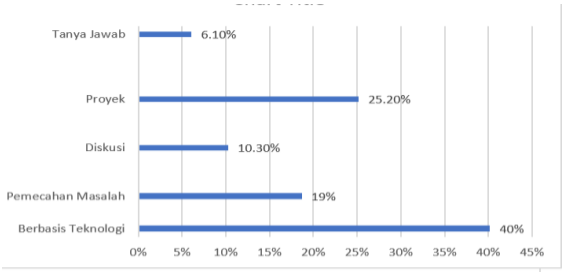

Figure 5. Analysis of the teacher's teaching method needs

Based on the survey results, the researchers analyzed the challenges encountered in teaching mathematics by mapping the empathy between students and teachers. The following empathy map was developed from the questionnaire and interview data analysis:

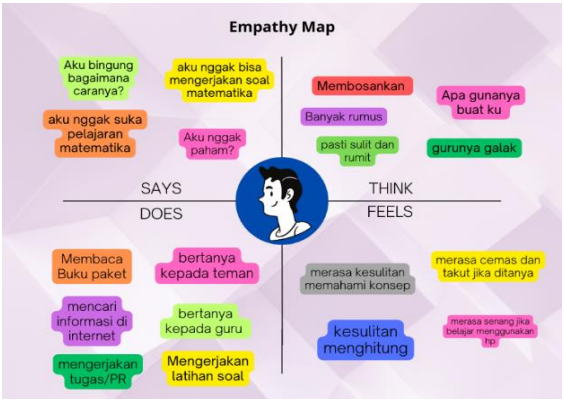

Figure 6. Empathy map results

From the empathy map results, researchers find that most students consider Mathematics difficult lessons, and many disliked students, confused and scared, ask for momentary experience difficulty, especially part numeracy (Benamen, Buchori & Purwosetiyono, 2025). Students often associate mathematics with complex formulas and tedious calculation processes. Additionally, some students view mathematics teachers as strict and delivering lessons in a monotonous manner. To make mathematics more engaging, strategies such as forming discussion groups for collaborative problem-solving and peer presentations have been suggested to deepen understanding. Moreover, the use of mobile phones as learning tools in the classroom is also encouraged (Riyadi, Dwijayanti & Purwsetiyono, 2024).

From the teacher questionnaire results, a significant portion of respondents acknowledged a lack of full understanding of their students' learning needs (Witraguna, Suryawan, No, Tegal & Buleleng, 2025). Teachers recognize that students face challenges in learning mathematics in class (Rizkyta & Astriani, 2024). Teaching methods are still predominantly lecture-based, with limited use of alternative approaches such as Android-based learning applications (Muthiah & Al-bahij, 2024). The integration of Android-based applications is viewed as a promising method to address students' difficulties in mathematics. Teachers also realize that many students struggle to learn mathematics effectively (Iksan, Farida & Ferdiani, 2023).

b. Define

The define stage involves analyzing and synthesizing the information gathered during the empathize phase. Researchers identify and select a specific problem to address through digital learning development (Mosuka et al., 2024). The "point of view" method is employed to capture the user's perspective, aiming to uncover their particular needs and challenges (Sitorus, Ibrahim, Utama & Novianti, 2024). This approach helps designers formulate clear

problem statements that serve as the foundation for developing effective design solutions. The following summarizes the analysis results from both students and teachers (Ghayatri, 2024).

Table 3. Students' point of view

	Point of View
Needs	1. There is a need for enhanced academic support and motivational strategies in mathematics, as students frequently encounter difficulties in problem-solving. 2. Accessible learning materials that require only an internet connection are needed to facilitate problem-solving activities. 3. Engaging, technology-based learning resources tailored to the preferences of Generation Z learners are essential to increase student interest and participation.
Insight	1. Students require engaging learning models that effectively support them in completing mathematical problems. 2. A lack of motivation among students contributes to difficulties in successfully solving problems. 3. Students need accessible learning materials that can be utilized through technology to aid their understanding and problem-solving.

Based on the points of view gathered, the researcher defines the problem through an empathy map. Students commonly perceive mathematics as complex and unengaging, highlighting the need for innovation in how the material is presented. They express a preference for materials that are accessible online to facilitate discussion, enable repetition, and enhance conceptual understanding. This finding aligns with Mukhtar, Maimunah, and Yuanita (2022) who demonstrated that the appropriate use of technology in learning can increase students' engagement, perceived relevance, and motivation, thereby fostering more active participation in mathematics learning.

Table 4. Teacher's point of view

	Point of View
Needs	1. There is a need for a technology-based learning model that effectively engages students. 2. A strategic approach to teaching mathematics is required to make the material more accessible and to motivate students in their studies.
Insight	1. Teachers report that they have not yet identified an optimal strategy that facilitates student comprehension and motivation. 2. Teachers perceive a gap in finding a technology-based learning model that adequately addresses the specific needs of Generation Z students.

Based on the teachers' perspectives, difficulties in delivering the material often result in students' incomplete understanding of the concepts taught. Therefore, it is essential for teachers to implement more innovative learning strategies that leverage internet-based technology, providing engaging content accessible to students anytime and anywhere (Tampubolon, Thesalonika, Nathasya & Rustini, 2022).

Table 5. Appropriate point of view with the need

	Point of view
Needs	1. Learning media that adapt to individual learning styles and incorporate advanced technologies such as artificial intelligence are needed. 2. A structured integration of strategies fostering critical thinking, creativity, collaboration, and communication should be applied within the learning process.
Insight	1. Microlearning, characterized by short-duration learning sessions, aligns well with contemporary students who tend to have shorter attention spans but are proficient multitaskers. 2. A learning approach utilizing digital books enables students to study theoretical content at home

	through embedded video links, allowing classroom time to be dedicated more effectively to discussion and practical activities.

Based on the identified perspectives, the researcher defines key needs and insights crucial for designing effective and engaging learning experiences. From the students' perspective, there is a demand for learning media that leverage technologies such as artificial intelligence (AI) and digital books, which can adapt to their individual abilities and learning styles (Putri & Mahfudzah 2024). Additionally, structured learning strategies should integrate the development of critical thinking, mathematical literacy, creativity, collaboration, and communication skills (Jupri & Rosjanuardi, 2020). Insights also reveal that contemporary students tend to have short attention spans but possess strong multitasking abilities(Fatharani, Ariani & Utomo, 2022). Furthermore, the use of digital books facilitates flexible learning, allowing students to engage with theoretical material at home through embedded video links (Sitepu, 2021). Consequently, classroom time can be effectively allocated to discussions and practical exercises. This approach aligns with the characteristics of modern students and has the potential to enhance students' mathematical literacy, engagement, and overall learning outcomes (Pertiwi, Nurfatimah & Hasna, 2022).

How Might We

The "How Might We" method is a problem-solving technique used to generate ideas by reframing challenges into exploratory questions (Kurnianto, 2021). This approach involves formulating questions and potential solutions based on observations of user problems identified in prior implementations (Rengga & Alit, 2024). Each question is designed to transform problems into thought-provoking prompts that stimulate mathematical literacy and creative thinking, enabling the identification of viable solutions (Afandi & Ningsih, 2020). The primary goal of this approach is to help researchers maintain focus on addressing the core problems identified (Sulistyawati, 2023). By employing the "How Might We" technique, the process of analyzing and formulating solutions becomes more structured and goal-oriented (Interaction Design Foundation, 2022).

Table 6. How might we

No	Question	Answer
1.	How might we design learning strategies that make mathematics engaging and easily understandable for students?	Developing engaging and interactive learning media is essential for effective mathematics education.
2.	How might we foster and sustain student motivation in studying mathematics?	Such media should integrate learning videos, instructional materials, practice questions, and timely feedback from teachers to enhance student understanding.
3.	How might we develop and implement technology-based learning models that are easily accessible to students?	In the development process, it is crucial to incorporate appropriate technology-based learning strategies that align with the needs and preferences of students.

In the table, the researchers compile various pieces of information supporting solutions for each identified problem. First, regarding the question, "What learning strategies can be applied to make learning engaging and easily understood?", the proposed solution involves the development of interactive learning media. This media incorporates features such as videos, digital books, and interactive practice questions to enhance student motivation and improve comprehension of challenging material.

Second, to address "How can student

motivation in studying be increased?", the solution emphasizes the use of learning media that includes instructional videos, digital books, practice questions, and feedback mechanisms provided by teachers, fostering sustained engagement.

Third, concerning the question, "What learning models can be accessed that are technology-based and flexible?", the proposed solution is the application of technology-driven learning models, consistent with the findings of Iin's research. Such media applications enable students to access learning materials anytime and anywhere, including embedded video links and practice questions within digital books, which significantly contribute to enhancing the mathematical literacy skills of students (Shafa & Yunianta, 2022).

c. Ideate

At the ideation stage, the researcher conducts a brainstorming process to generate various ideas as potential solutions to meet students' needs (Kartoni & Alinurdin, 2021). From this process, the researcher narrows down the options, focusing on digital book learning and differentiated instruction to support student-centered and engaging (Sanjaya, 2022). The analysis identifies user needs, specific problems, media descriptions, and desired media features. Three main problems emerge: (1) students often feel bored when studying mathematics, (2) students have trouble understanding mathematical concepts, especially those related to everyday life, and (3) the learning approach remains largely conventional. To address these issues, the chosen media solution is an Android-based digital book application, developed following the Ideate scheme, as illustrated in Figure 7.

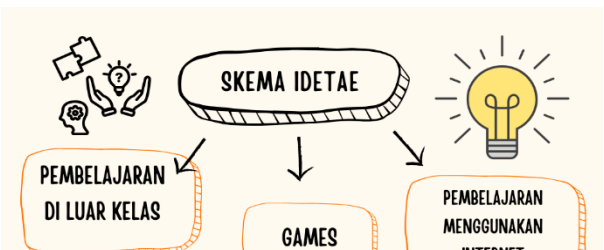

Figure 7. Mind maps ideate

Based on the previous mind map, the user has several primary needs, namely Fun learning and no boring, interactive learning that can be accessed only. One of the right solutions, namely a digital *book*-use application based on Android, was developed to help students study (Aulia, Rahmi & Jufri, 2022).

IV. Conclusion

The exploration results were analyzed according to the stages of the design thinking approach: empathize, define, and ideate. The findings indicate that both students and teachers require engaging mathematics learning experiences supported by easily accessible interactive media, particularly via mobile phones (Gula & Harefa, 2022). Based on these insights, the researchers designed an interactive Android-based learning media utilizing the design thinking framework to enhance students' mathematical literacy skills. This integrated approach systematically develops digital book-based media, which remains underutilized in efforts to improve mathematical literacy among students. Furthermore, the study will continue by employing quantitative experimental methods to test the effectiveness of the developed digital book in enhancing students' mathematical literacy, advancing through the prototype and testing stages of the design thinking process.

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