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DEVELOPING PATTERNS OF STUDENTS' MATHEMATICAL LITERACY PROCESSES: INSIGHTS FROM COGNITIVE LOAD THEORY AND DESIGN-BASED RESEARCH

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ABSTRACT

This research aims to develop patterns of students' mathematical literacy processes based on the Cognitive Load Theory (MLCLT). Research using Design-Based Research (DBR) aims to design and develop learning components in the form of resulting learning patterns arranged in 4 stages. The research results show that a CLT-based mathematical literacy process domain pattern has been found. For the aspect of formulating situations mathematically, the pattern of mathematization was produced, and it resulted in some students having good communication skills. For the element of employing mathematical concepts, facts, procedures, and reasoning, the pattern of application was produced, and it showed an increase in students' literacy processes for indicators such as mathematizing, representation, reasoning, argument, devising strategies for solving problems, using symbolic, formal, and technical language and operations, as well as using mathematical tools. The pattern for the aspect of interpreting, applying, and evaluating mathematical outcomes is the reflection pattern. In this pattern, students are already accustomed to having indicators of mathematical literacy processes related to devising strategies for solving problems, using symbolic, formal, and technical language and operations, as well as using mathematical tools so that they can produce real solutions to real-world problems.

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1. INTRODUCTION

Mathematical literacy is defined as an individual's ability to use mathematical knowledge and understanding effectively in everyday life by formulating, using, and interpreting mathematics in various contexts. This includes reasoning mathematically about the world and making the necessary considerations and decisions as a citizen (De Lange, 2003; OECD, 2017). Based on this, it is clear that knowledge and understanding (content and context) of mathematics are very important, but it is even more important to be able to apply mathematical literacy to solve problems in daily life (Bansilal & Debba, 2012; Colwell & Enderson, 2016; De Lange, 2003; Ni'mah et al., 2017; Umbara & Nuraeni, 2019).

In terms of the scope of literacy, students are not only required to have cognitive understanding, but also affective and psychomotor because literacy has three domains, namely: content, context, and behavior and habits of individuals in using mathematical literacy (Bansilal & Debba, 2012; Bowie & Frith, 2006; OECD, 2017; Stacey & Turner, 2015). The importance of improving literacy skills is reflected in the goals of the 2013 curriculum, which include character, literacy, and competencies and refer to 21st century skills that consist of four main domains, namely: literacy, inventive thinking, effective communication, and high productivity (Turiman et al., 2012). The focus variable in this study is the domain of mathematical literacy processes. The process domain consists of three aspects: 1) formulating situations mathematically; 2) employing mathematical concepts, facts, procedures, and reasoning; and 3) interpreting, applying and evaluating mathematical outcomes.

In summary, mathematical literacy is an individual's ability to understand, formulate, apply, and interpret mathematics in various contexts, including reasoning mathematically and using concepts, procedures, facts, solving mathematical problems, using mathematical language to communicate, and connecting mathematics to the real world. Further elaboration on the relationship between process domain of mathematical literacy and the assessment framework is described in Table 1.

Table 1. Correlation between various mathematical processes with fundamental mathematical capabilities (OECD, 2017)

Fundamental mathematical capabilities	Formulating situations mathematically	Employing mathematical concepts, facts, procedures and reasoning	Interpreting, applying and evaluating mathematical outcomes
Communicating	The process of comprehending and understanding statements, questions, tasks, objects or images involves reading, interpreting, and creating a mental representation of the given situation.	Express a resolution by demonstrating the steps taken to achieve it and/or provide a condensed summary of the mathematical outcomes reached during the process.	Create and convey reasoning and justifications within the framework of the issue at hand.
Mathematising	Recognize the fundamental mathematical elements and concepts within a real-world problem, and establish suppositions to facilitate their utilization.	Employ knowledge of the situation to direct or hasten the mathematical problem-solving procedure, such as striving for an appropriate level of precision that aligns with the context.	Comprehend the scope and constraints of a mathematical resolution as a result of the mathematical model utilized.

Fundamental mathematical capabilities	Formulating situations mathematically	Employing mathematical concepts, facts, procedures and reasoning	Interpreting, applying and evaluating mathematical outcomes
Representation	Develop a mathematical depiction of information derived from the real world.	Understand, connect, and apply multiple forms of representations while engaging with a problem.	Decipher mathematical results in diverse formats regarding a situation or purpose; juxtapose or assess two or more representations in connection to a situation.
Reasoning and argument	Elucidate, uphold, or offer a rationale for the chosen or developed representation of a real-life scenario.	Clarify, support, or provide a rationale for the methodologies and techniques employed to derive a mathematical outcome or resolution. Establish connections between pieces of information to arrive at a mathematical solution, formulate generalizations, or construct a multi-step argument.	Contemplate mathematical solutions and produce justifications and arguments that corroborate, contradict, or modify a mathematical resolution to a problem situated within a context.
Devising strategies for solving problems	Choose or create a tactic or approach to reframe contextualized problems mathematically.	Implement efficient and consistent control measures throughout a multi-stage process that leads to a mathematical solution, conclusion, or generalization.	Create and execute a plan to interpret, assess, and confirm the validity of a mathematical resolution to a problem situated within a context.
Using symbolic, formal, and technical language and operations	Utilize suitable variables, symbols, diagrams, and established models to express a real-world problem through symbolic or formal language.	Comprehend and employ formal structures founded on definitions, regulations, and formalized systems, as well as utilize algorithms.	Grasp the connection between the problem's context and the mathematical solution's representation. Utilize this comprehension to aid in the interpretation of the solution within the context and assess the practicality and potential constraints of the solution.
Using mathematical tools	Apply mathematical tools to identify mathematical structures or to illustrate mathematical relationships.	Understand and have the ability to use various tools that can be helpful in carrying out methods and procedures for determining mathematical solutions.	Employ mathematical tools to evaluate the plausibility of a mathematical solution and any constraints or limitations of that solution, taking into account the context of the problem.

The evaluation process for mathematics learning in Indonesia in terms of literacy skills has consistently ranked in the bottom 10 (2009-2018) according to OECD assessing literacy skills based on PISA (Programme International for Student Assessment). The international average score for mathematical literacy is 500 (level 3), while the average score for Indonesian students is 375 (level 1), which is the lowest of the six levels of mathematical literacy established by PISA and the highest level that Indonesian students can achieve is level 3 (Asmara et al., 2019; Wardono et al., 2016), and some students are at level 4 (Edo et al., 2013). Many students know or only memorize mathematical subject matter, but are unable to apply their knowledge to improve their quality of life or, in other words, are less able to solve problems in real life (Pradana et al., 2020; Zulkarnain, 2013). In other words, this very much reflects the level of difficulty or inability of students to construct knowledge about changes in behavior (learning outcomes) or can be referred to as students experiencing cognitive load. Therefore, it is necessary to optimize students' working memory to be able to understand and construct each concept they receive.

Working memory is responsible for processing and following up on information (Baddeley, 2012). Working memory can only hold about seven items or pieces of information at a time (Atkinson & Shiffrin, 1968; Cowan, 2001; Paas & Ayres, 2014) and will fade away within approximately 15 to 30 seconds if not recalled (Cowan, 2001; Paas & Ayres, 2014). When processing information (organizing, differentiating, and comparing), humans can only manage two or three pieces of information simultaneously, depending on the type of processing required (Mayer & Moreno, 2010).

The process of recalling information done by the brain in our students varies depending on their characteristics. There are students who easily understand a concept, but there are also many who have difficulty understanding a concept. The theory that describes the level of difficulty or inability of learners to process and construct knowledge or information received as a result of our learning strategies is known as cognitive load theory (CLT). CLT is the mental effort that must be made in memory to process information received within a certain time frame (Sweller, 2018).

According to van Merriënboer and Sweller (2005), students experience different levels of cognitive load in memory, which can be caused by three sources: intrinsic cognitive load (ICL), extraneous cognitive load (ECL), and germane cognitive load (GCL) (Clarke et al., 2005; Plass et al., 2010). Intrinsic cognitive load depends on the difficulty level of a material. Extraneous cognitive load depends on the presentation of the material. Germane cognitive load is the relevant or advantageous load imposed by teaching methods that lead to better learning outcomes. In learning, the excess cognitive load depends on the difficulty level of the material studied according to intrinsic cognitive load. If the material studied has a high intrinsic cognitive load, then the learning design should be organized in such a way that extraneous cognitive load can be minimized.

CLT-based learning emphasizes the importance of reducing extrinsic cognitive load (i.e., cognitive load unrelated to learning goals) and managing intrinsic cognitive load (i.e., cognitive load related to learning goals). This is achieved through various instructional strategies, such as providing clear explanations, breaking down complex problems into smaller components, and providing examples and practice opportunities. Based on the synthesis of the explanations provided and the analysis, a CLT framework can be obtained, as shown in Table 2.

Table 2. Cognitive load theory matrix

Cognitive load	Indicator
Managing intrinsic cognitive load	a. Material presented gradually b. Students can control the display (media/process) to be learned c. Providing initial apperception/training before discussing the material with step-by-step assistance. d. Presenting material with pictures or narration e. Sequential study

Cognitive load	Indicator
Reducing Extranous cognitive load	a. Eliminating irrelevant material from the main topic b. Removing excessive text in the presentation of learning media c. Presenting images and text simultaneously d. Placing text and graphics on the same screen (media) e. The intonation of the teacher f. Activating and maintaining students' prior knowledge
Increases German cognitive load	a. Learning using words and pictures b. Presenting information based on students' abilities c. Directing student activities that can add to their learning experiences d. Providing feedback in the form of commands, questions, or explanations that can direct students to obtain the required information or material e. Providing opportunities for students to explain information or material in their own language

This is in line with previous studies stating that a CLT-oriented learning process can solve mathematical problems (Damayanti, 2013; Ni'mah et al., 2017). CLT-based learning can be an effective method for improving mathematics literacy in seventh grade students. By optimizing students' learning capacity through the reduction of extraneous cognitive load and the management of intrinsic cognitive load, CLT-based learning can help students to better understand and apply mathematical concepts.

Based on the explanation, it is possible to integrate mathematical literacy within the process domain with three components of CLT. This integration is expected to generate a learning pattern that is anticipated to be one of the solutions for enhancing the mathematical literacy of 7th-grade students.

Therefore, the objectives of this research are: integrate component of CLT that is ICL, ECL and GCL with indicators of mathematical literacy in the process domain, which consists of formulating situations mathematically; employing mathematical concepts, facts, procedures, and reasoning; and interpreting, applying, and evaluating mathematical outcomes. And also try to describe Patterns of mathematical literacy process domains of seventh grade students based on the aspect of formulating situations mathematically; employing mathematical concepts, facts, procedures, and reasoning; and interpreting, applying, and evaluating mathematical outcomes according to cognitive load theory.

2. METHOD

This study used design-based research (DBR). DBR is a systematic study of designing, developing, and evaluating educational interventions such as programs, strategies, and learning materials, products, and systems as solutions to solve complex problems in educational practice, with the aim of advancing our knowledge of the characteristics of these interventions and the processes of designing and developing them (Plomp, 2013). Plomp's explanation can be understood that DBR aims to design and develop learning components, whether it be learning strategies, learning materials, or products and systems. These components are designed and developed so that problems faced in the world of education can be solved. Based on this, this study attempted to integrate component CLT (see Table 2) , that is ICL, ECL and GCL with mathematical literacy in the process domain (see Table 1) that is formulating situations mathematically; employing mathematical concepts, facts, procedures, and reasoning; and interpreting, applying, and evaluating mathematical outcomes. The integration of two components results in a learning pattern used as a learning component referred to as Mathematical Literacy Based on Cognitive Load Theory (MLCLT). It is expected that MLCLT will be able to improve the mathematical literacy process of junior high school students.

Design-based research (DBR) is a research method that focuses on the development and evaluation of solutions or innovations in real-world contexts, incorporating a process of analysis, design, evaluation, and revision to achieve satisfactory research outcomes, particularly in the field of education (Anderson & Shattuck, 2012; Armstrong et al., 2020; Barab, 2014; Fowler et al., 2023; Sandoval & Bell, 2004). DBR combines theory and practice to create effective and relevant learning designs or interventions for users. The steps in conducting research using DBR are organized into 4 phases, as described in the research design based on DBR in Figure 1.

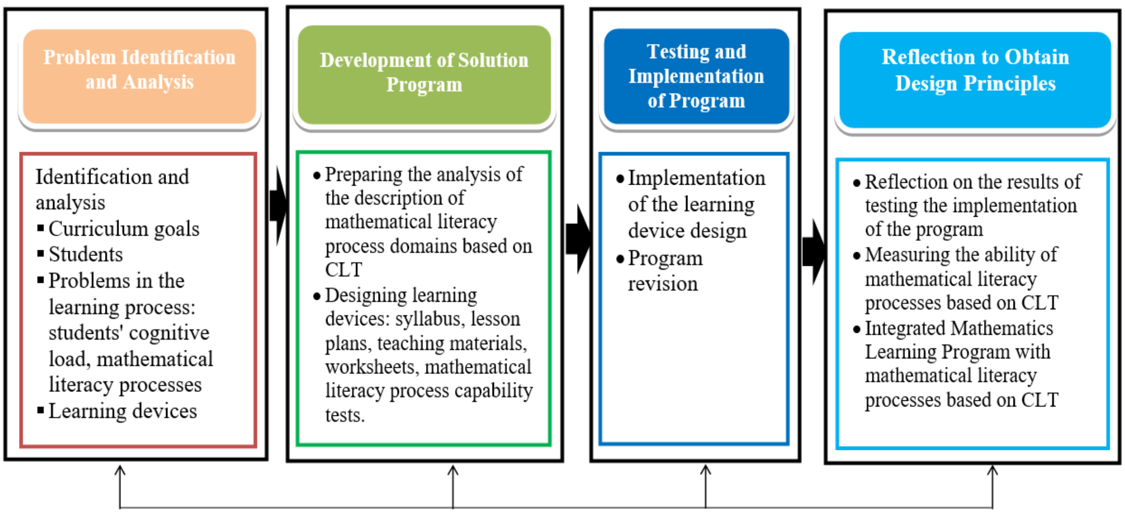

Figure 1. Research design (adapted from Reeves, 2006)

Based on the research design used, data analysis techniques in this study were bersing 4 phases, which are:

a. Identification and analysis of problems

This phase involves various preparations such as curriculum review, analysis of learning processes (research results, articles, and others), analysis of mathematical literacy (in various countries, OECD, TIMSS) as well as analysis of student cognitive load and its instructional design (cognitive load theory). This phase has two stages in its technique, namely: (1) Initial needs analysis when creating new patterns, and (2) Ongoing needs analysis after new patterns have formed. The patterns of mathematical literacy based on cognitive load theory are developed.

b. Development and solution programming

This phase includes analyzing the description of the mathematical literacy process domain based on CLT, and developing learning tools as a product of the program development. This second phase is described in several stages, namely: prototype development stage of MLCLT, MLCLT development stage, and MLCLT modification stage.

c. The testing and implementation of the program

The testing and implementation of the program involve several stages to implement the program and conduct reflection. There are several stages for testing the new patterns that have been developed and refined along with their learning tools. After the new patterns and their learning tools have been developed, the first test is conducted with experts (expert judgment), followed by the first trial or evaluation of the prototype phase. After the evaluation is completed, reflection is carried out. The results of the reflection are used to revise the program to make it more perfect. Then, there is another expert judgment test to categorize the developed patterns.

d. Reflection to get design principles

The final stage is the reflection on the program development and produces the final product which has novelty in the form of new patterns of mathematical literacy processes for ICL, ECL, and GCL domains. There are two reflection steps in this stage. The first one is to reflect on the prototype results, and the second one is the final reflection to see how far the research objectives can be achieved. It also includes the final evaluation and reflection on the new patterns that have been generated.

3. RESULT AND DISCUSSION

3.1. Results

As previously explained, this research develops a learning component aimed at enhancing students' mathematical literacy by integrating the learning components resulting from the integration of mathematical literacy within the process domain (see Table 1), namely Formulating Mathematical Situations; Using Mathematical Concepts, Facts, Procedures, and Reasoning; and Interpreting, Applying, and Evaluating Mathematical Results, along with the indicators from the CLT component (see Table 2), namely ICL, ECL, and GCL. This integration produces a learning pattern that is then translated into a learning product in the form of a learning tool that can be used for instructional activities.

Overall, the learning patterns obtained from the integration of mathematical literacy process domain and cognitive load theory are nine. The resulting patterns, based on the analysis of Table 1 and Table 2, are named Mathematical Literacy Learning based on Cognitive Load Theory (MLCLT). The resulting patterns are transformed into a learning program that is able to improve the mathematical literacy process of junior high school students. The following is an overview of the mathematical literacy process patterns based on cognitive load theory, viewed from the intrinsic cognitive load (ICL) in Table 3.

Table 3. Patterns of mathematical literacy learning reviewed from ICL perspective

Patterns of Learning	Indicator
Formulating Mathematical Situations (I1)	1. Starting with Presenting Context or Productive Questions 2. Using Symbolic Language/Modeling.
Using Mathematical Concepts, Facts,	1. Applying and Designing Strategies 2. Using Mathematical Tools to Solve Problems

Patterns of Learning	Indicator
Procedures, and Reasoning (I2)	3. Applying Facts (Modeling) or Extracting Information to Construct Concepts 4. Making Generalizations 5. Reflecting and Summarizing
Interpreting, Applying, and Evaluating Mathematical Results (I3)	1. Evaluating the Connection between Solutions and Problems 2. Understanding the Level and Limits of Mathematical Concepts and Their Solutions.

We can observe the pattern of the mathematical literacy process in terms of extraneous cognitive load (ECL) in Table 4.

Table 4. Patterns of mathematical literacy learning in terms of ECL

Patterns of Learning	Indicator
Formulating Mathematical Situations (Related to Context) (E1)	1. Starting with Presenting Context 2. Presenting Productive Questions
Using Mathematical Concepts, Facts, Procedures, and Reasoning (Related to Learning Strategies) (E2)	1. Applying and Designing Strategies using Language and Symbols 2. Applying Facts (Modeling) or Extracting Information to Construct Concepts 3. Making Generalizations 4. Reflecting and Summarizing
Interpreting, Applying, and Evaluating Mathematical Results (Related to Learning Media) (E3)	1. Using Learning Videos/ICT 2. Using Worksheets (LKPD)

A new pattern of mathematical literacy process in terms of Germane Cognitive Load (GCL) is observed in Table 5.

Table 5. Mathematical literacy learning syntax based on cognitive load theory

Learning Syntax	Learning Activities
Mathematization (G1)	1. Identifying problems based on context 2. Analyzing and making assumptions 3. Applying modeling 4. Translating into mathematical language
Application (G2)	1. Applying and designing strategies 2. Applying facts (modeling) or mining information to construct concepts 3. Making generalizations

Learning Syntax	Learning Activities
Meaning-making and Reflection (G3)	1. Reviewing the results of generalization 2. Analyzing whether the conclusions can be relevant to the problem 3. Identifying the suitability of the model used to solve the problem 4. Reflecting and summarizing

A total of 9 patterns were obtained based on the analysis, labeled as I1, I2, I3, E1, E2, E3, G1, G2, and G3. The patterns obtained from the analysis describe the entire learning process by creating a completeness of learning in the form of developing a program.

The generated learning patterns are transformed into learning tools for direct implementation in teaching. The derived patterns include the Learning Steps derived from the GCL-based learning pattern, material management taken from the ICL pattern, and the teaching strategies employed by the teacher derived from the ECL pattern. The subsequent step involves creating a teaching technique guide such as a lesson plan, worksheet, mathematical literacy test instruments (GCL instrument), and a questionnaire assessing the implementation of teaching by teachers (ECL instrument). These technical guides are consolidated into a process book and process usage guidebook. Following this, the learning product is validated by experts. Expert validation is conducted twice: first during the prototype phase and once during the final phase for refining the product.

Overall, the learning program was validated by experts and consisted of two phases according to the research design. The prototype phase received a score of 0.70 in the "good" category, and the final phase received a score of 0.84 in the "very good" category. These scores indicate that the patterns generated are suitable for implementation in the learning process. Overall, the validation score of the development of mathematical literacy process patterns based on cognitive load theory, which we call LMCLT, is described in Figure 2.

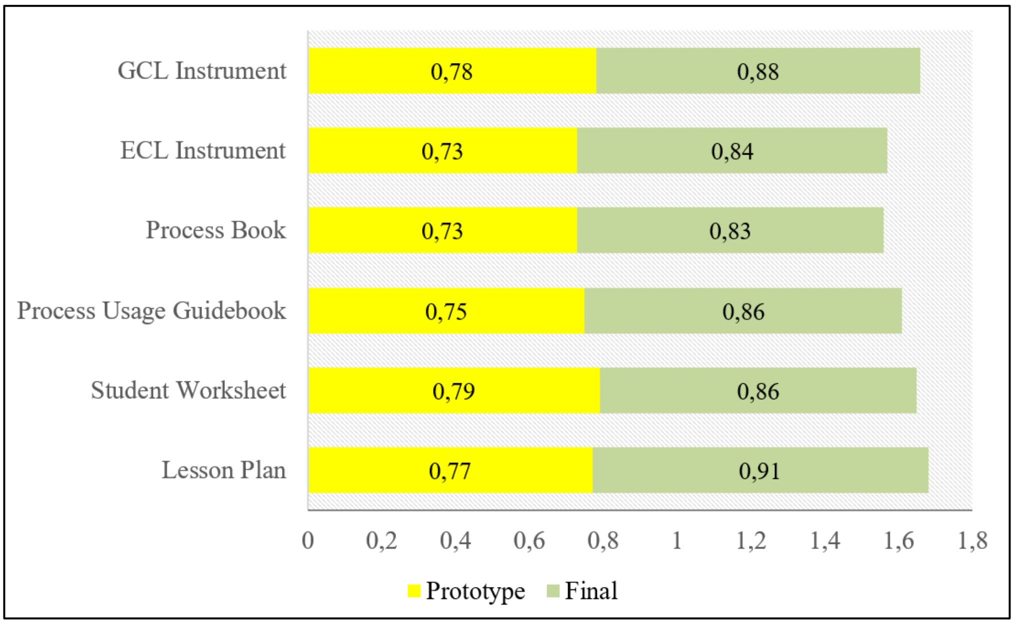

Figure 2. Validation score of the development of mathematical literacy process patterns based on cognitive load theory

3.2. Discussion

This discussion aims to answer three research objectives, which are. The learning patterns developed for the aspect of formulating mathematical situations based on cognitive load theory result in 3 patterns named mathematization patterns (performed at the beginning of learning), each pattern to manage intrinsic cognitive load (I1), reduce extraneous cognitive load (E1), and increase germane cognitive load (G1). The mathematization pattern developed to manage intrinsic cognitive load (ICL) is included in the lesson plan in the aperception to improve students' mathematical literacy processes because one characteristic of intrinsic cognitive load depends on the difficulty level of a material and is not influenced by external factors (Cooper, 1998; de Jong, 2010; Sweller & Chandler, 1994), but with good presentation techniques that do not complicate students' understanding, and starting from simple to complex material, the intrinsic cognitive load can be managed (van Merriënboer & Sweller, 2005).

Aperception as an initial activity in a learning process aims to stimulate motivation and focus students' attention to actively participate in the learning process because the activity links new information to relevant concepts for a person's cognitive structure as a process (Wantika, 2017). The management of ICL in aperception is carried out by coordinating productive questions, starting from general and known questions to questions that stimulate students to think further about the material to be discussed.

Based on empirical tests, there is a difference in students' understanding of the material between students who learn using the MLCLT mathematization pattern and those who do not. This indicates that the indicators of effective mathematization patterns are stored in aperception to measure students' ability to receive and process information (ICL) because aperception is an important activity that can determine the success of the next learning stage (Anggraeni, 2009). Observational data for teachers show that what teachers do to effectively manage students' ICL, which can be stated by providing aperception, leads to better student understanding of the material (Prasetyaningtyas, 2019; Sunita & Nardus, 2018).

The mathematization pattern developed to reduce extraneous cognitive load (ECL) because ECL is caused by instructional material, depends on material presentation, is related to schema formation and automation but can be altered by instructional interventions (van Merriënboer & Sweller, 2005). In the learning process, it is the teacher's intonation arrangement in delivering productive questions and presenting relevant contexts with productive questions. ECL is observed through questionnaires and interviews. Statements in the questionnaire refer to the learning process steps carried out by teachers (Sweller, 2018). Based on data analysis, the context greatly helps students in understanding a material, but most students from three schools agree that the context presented for the concept of understanding, type, and nature of the triangle material is easy to understand. As for the concept of area and perimeter of the triangle, it is somewhat difficult to understand, but when understood, it is easy to apply in answering questions about the area and perimeter of the triangle.

Based on the results of the questionnaire analysis, mathematical formalization is quite effective in reducing students' ECL (extraneous cognitive load), as it allows students to focus on improving their understanding of a subject. The use of real-world contexts in learning, provided through aperception, makes the concepts or topics studied more meaningful to students (Nuraida & Putri, 2020). This can improve their understanding by constructing knowledge and applying it to problem-solving (Kamsurya & Masnia, 2021; Klančar et al., 2021), leading to long-term memory retention. According to the questionnaire, the most effective context for reducing ECL is the topics of parallelograms and kites, as students quickly understand the given context and can identify information, allowing them to move on to the next concept. The initial context of learning can positively influence the learning process, making it more enjoyable and improving students' understanding of mathematical concepts (Kamsurya & Masnia, 2021). On the other hand, the most difficult context to understand and progress to the next activity is the topic of triangles, but once students understand it, the optimization of triangle concept comprehension for definitions, types, properties, and area and perimeter of triangles is better.

The mathematical formalization pattern produced to improve GCL (germane cognitive load) is used as a syntax of learning and involves several activities: identifying problems based on context, analyzing and making assumptions, applying modeling, and translating into mathematical language. These activities are intended to improve student learning outcomes, specifically in terms of improving their mathematical literacy. With the learning activities detailed in mathematical formalization, students can experience and understand the benefits of mathematics in daily life. When the activities begin by presenting a context or productive question, the context is presented through a real-world situation that is formulated abstractly (I1, E1) and then presented with intonation that is easy for students to understand (E1). The process of conveying a context is then identified and organized by previous mathematical knowledge that has been constructed to produce a complete concept/topic that is easy to understand for a long time (G1). Therefore, mathematization can be understood as a simple process of modeling phenomena mathematically, or in other words, problems that arise from the real world are brought into a mathematical context to be solved, and then the solution is returned to its original context.

Mathematization is an effort to connect informal mathematical knowledge that is stimulated from real-world problem contexts to formal mathematical knowledge. Contextual problems are described by students using informal language such as symbols that students have discovered themselves and have not yet used formal mathematical symbols. The informal mathematical language used by students is then developed into formal mathematical language. This process bridges the gap from informal mathematical knowledge to formal mathematical knowledge. Subsequently, students build formal mathematical knowledge through the use of mathematical symbols and algorithms. The problem-solving process occurs in line with the development of new formal mathematical knowledge. Furthermore, the formal mathematical language is translated and reinterpreted in the context of the real world (NCTM, 2000). The process of mathematization can be simplified as a process of mathematizing the context or translating a context into mathematical concepts. The process of mathematization occurs when the context can be imagined by students and allows students to understand and work within the context using the knowledge and experience they already have (Kamsurya & Masnia, 2021).

The main focus of GCL is to look at schema construction and subsequent automation as the main goal of learning (Cooper, 1998). Schema construction involves processes such as interpreting, exemplifying, classifying, concluding, distinguishing, and organizing (Mayer & Moreno, 2003). Therefore, the learning design should try to stimulate and guide students to be involved in schema construction and automation, in this way it is attempted to improve GCL. Empirical test results show that there are differences in students' literacy processes before and after treatment, both in the prototype and final phases. Based on triangulation, it can be concluded that the resulting mathematization pattern is effective because with the introduction at the beginning of the learning activity, which is filled with giving context and productive questions that are suitable for real-world problems, students can think and use the real-world problem to translate it into a mathematical problem which we then seek a solution to. The mathematization pattern carried out during the learning process can cause some students to have good communication skills (Laamena & Laurens, 2021).

The learning patterns developed for the aspect of employing mathematical concepts, facts, procedures, and reasoning based on cognitive load theory resulted in 3 patterns named as application patterns, each consisting of one pattern for ICL (I2), ECL (E2), and GCL (G2). The application patterns generated for managing ICL, reducing ECL are included in the lesson plan and student worksheet. The generated application patterns are related to the implementation and design of learning strategies, such as using mathematical tools to solve problems, applying facts (modeling) or exploring information to construct concepts to manage ICL. Learning strategies are the teacher's tactics to effectively, efficiently, and optimize the function and interaction between students and learning components in a learning activity to achieve learning and teaching objectives. The learning strategy used in this study refers to the indicators of the application pattern.

The learning steps to manage ICL and reduce ECL are by using student worksheets as a tool. The context in the student worksheet is related to the material to be discussed and consistent with what has been discussed during the introduction, the images displayed are always accompanied by relevant explanations and using language that is easy to understand for 7th-grade students. The steps for working on the student worksheet are arranged starting from the easiest to the most difficult, starting from the known to the unknown, so it is effective for managing ICL and reducing ECL. The application pattern generated to increase germane cognitive load (GCL) is used as syntax for learning activities and has several details, namely: applying and designing strategies; applying facts (modeling) or exploring information to construct concepts; and making generalizations. The learning steps/syntax as a guide for students to solve problems (a guide for working on student worksheets).

The application pattern aims to improve learning skills to understand a concept, in this way, it allows teachers to carry out learning with an approach and strategy according to the speed and learning style of each student. When learning pays attention to the components of cognitive load theory, it is possible to increase and effectively manage cognitive load in students. For example, the study by Nuryadi and Khuzaini (2017) describes how good the quality of mathematics learning devices produced based on CLT. One way to manage ICL in learning is through tools, for example, the use of multimedia assistance so that it can effectively reduce ECL and increase GCL for linear program material (Damayanti, 2013; Safiah et al., 2023).

The application pattern focuses on learning strategies/steps that are carried out to find solutions to mathematical problems. Based on triangulation, it is concluded that the application pattern is effective because this pattern has learning steps that can produce many alternative mathematical solutions to problems that have been expressed in the mathematical pattern. The application pattern carried out during the learning process can improve mathematical literacy processes in the mathematizing, representation, reasoning and argument, devising strategies for solving problems, using symbolic, formal, and technical language and operation, as well as using mathematical tools indicators.

The learning patterns developed for interpreting, applying, and evaluating mathematical outcomes based on cognitive load theory result in three patterns named reflection patterns, one pattern for ICL (I3), ECL (E3), and GCL (G3). The resulting reflection patterns are transformed into learning devices in the form of lesson plans and worksheets. The reflection patterns formed for interpreting, applying, and evaluating mathematical outcomes have two indicators: evaluating the relationship between solutions and problems, and understanding the level and limit of mathematical concepts and their solutions. In the learning process to manage ICL and reduce ECL, discussions are accompanied by pictures. The pictures presented in the reflection patterns are aided by Geogebra.

With the Geogebra program, abstract mathematical objects can be visualized and manipulated quickly and efficiently. The data shows that learning using the Geogebra application is very helpful for students to understand a concept so that it can be stored in long-term memory. This is in line with several studies that mention that learning using Geogebra can improve learning outcomes because it can facilitate the learning of a concept (Afrilianto et al., 2022; Tamur et al., 2023; Zetriuslita et al., 2020; Zetriuslita et al., 2021). The learning media for the prototype phase use ICT to facilitate learning, while the final phase uses Geogebra as its tool. The highest questionnaire score for the use of Geogebra as a learning medium, based on data analyzed for the triangle material, is 99.27% of students say that Geogebra is very helpful for clarifying material for understanding, types, and properties of triangles, because Geogebra can be used to demonstrate or visualize mathematical concepts and is a tool for constructing these concepts, and can improve motivation to understand mathematical material, especially geometry and algebra (Bernard & Sunaryo, 2020). With the Geogebra program, abstract mathematical objects can be visualized and manipulated quickly and efficiently (Zetriuslita et al., 2020). The developed patterns are very suitable and expected to provide an experience for students by involving or engaging students in the learning process. This involvement is expected to occur mentally and physically so that learning is more student-centered through student interactions with other students or with teachers, the environment, and even other sources (Minarni & Napitupulu, 2020; Nasution et al., 2021; Praekhaow et al., 2021).

The reflection pattern for improving GCL is used as the syntax of learning activities and has several details: rechecking the generalization results; analyzing whether the conclusions are relevant to the problem; identifying the suitability of the model used to solve the problem; and reflecting and summarizing. The reflection pattern carried out during the learning process can improve mathematical literacy processes in the indicators of devising strategies for solving problems, using symbolic, formal, and technical language and operations, and using mathematical tools.

4. CONCLUSION

Based on the research results, patterns of mathematical literacy process domains were found using CLT. The process of mathematical literacy for formulating mathematical situations using mathematical patterns was described. This process was conducted during the aperception phase of the learning activity, where the learning activity was filled with productive contexts and questions related to real-life problems. This enabled students to think and use real-life problems to create mathematical problems, which could then be solved. As a result, some students were able to develop good communication skills, which is an indicator of the mathematical literacy process.

For the aspect of employing mathematical concepts, facts, procedures, and reasoning, the pattern of application was observed, and an improvement in the process of mathematical literacy was seen for indicators such as mathematizing, representation, reasoning, argument, devising strategies for solving problems, using symbolic, formal, and technical language and operation, as well as using mathematical tools.

Conversely, the identified pattern for the aspect of interpreting, applying, and evaluating mathematical outcomes was referred to as "reflection." Under this pattern, students were accustomed to having markers of the mathematical literacy process, including developing strategies for problem-solving, using formal, technical, and symbolic language and operations, and utilizing mathematical tools. As a result, students were capable of generating genuine solutions to real-world problems by applying their knowledge acquired through the process of studying mathematics.

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