

The evolution of Indonesian curriculum: Hypothetical learning trajectory for mastery of mathematical and computational thinking

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ABSTRACT

Some conditions are unconcerned with students believing they are learning mathematics. Students' disinterest increases when the situation is online learning due to the COVID-19 pandemic. In that case, fully online learning reduces students' mathematical and computing abilities. Therefore, this study aims to obtain a hypothetical learning trajectory in mathematics learning in constructing the skills to master mathematical and computational thinking for secondary school students. This study used part of the research development method of validation research which focuses on Hypothetical Learning Trajectory (HLT). The preparation of the HLT focuses on mastering the mathematical and computational thinking skills of junior high school students using teaching materials, learning media, and evaluation instruments on rank number and square roots materials. The subjects in this study were 30 junior high school students in class IX who took mathematics classes. The series of activities and forms of student learning assumptions become one complete trajectory for the purpose of learning achievement. A Hypothetical Learning Trajectory (HLT) was developed based on the findings of an analysis of the activities of the Junior High School Mathematics curriculum suite and PISA 2021, test results, initial observations during the learning process, and interviews with students and teachers. HLT preparation has an impact on creating learning designs that are ready to be continued at the implementation stage in the following class.

INTRODUCTION

A professional mathematics teacher must always be prepared with information knowledge and knowledge about the best learning process taught in class in order to meet the demands of the practice by introducing the latest technology (Charitas & Prahmana, 2015; Guerriero, 2014). Professional teachers can create their own set of learning instruments to help them fulfill their roles and responsibilities (Keiler, 2018). Teachers must adapt their lesson plans to the needs of their students and classes in order for them to be effective in meeting learning objectives (Puspitarini & Hanif, 2019). However, students encountered challenges in adapting to this situation, such as compiling device and assessment assignments (Metin, 2013), selecting digital learning models choosing a learning model digitally (Lodge et al., 2018), and linking device evaluations with learning objectives (Sewagegn, 2020).

Meanwhile, this is a learning experience. This becomes a means of interrelationships and interdependencies between hindering factors (Wong, 2015). As a result, a teacher must constantly update their ability to adapt to the times, choose simple and effective learning strategies, and always

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interact so that understanding conditions students to achieve their learning goals and the implementation of a meaningful learning process (Tanner, 2013). Professional teachers plan meaningful learning activities that focus on how students can develop their thinking and understanding (Bartolini, 2014). Professional teachers achieve the outcomes and experiences they desire for students in the cognitive-emotional domain (Ananda Kumar & Chellamani, 2020; González-Ceballos et al., 2021; Herodotou et al., 2019). Understanding how students learn in a unique and different way (Ilçin et al., 2018) can provide an interesting starting point for students' thinking and understanding to process and develop with methods of capturing material and seriousness in undergoing the learning process.

Teachers can plan a series of activities to help students develop their independent thinking and understanding while providing the detailed guidance that is explicitly required during the learning process (Pinnock, 2021). Furthermore, teachers must understand the fundamental teaching and goals developed in education as a form of moral science pedagogy (Tirri & Toom, 2020). Therefore, teachers must understand, build, and develop students' thinking skills before, during, and after learning (Kooloos et al., 2022; Zhu et al., 2018), as well as present the relationship between learning and teaching (King, 2017). The ability to think mathematically to solve various mathematical problems is an important thinking skill for students to develop (Cresswell & Speelman, 2020; Mustafa et al., 2019). Assuming mathematics employs mathematical techniques, concepts, and processes to express and predict ideas logically and intuitively.

The facts show that the ability to think mathematically is a solution to solving problems (Başaran, 2011; Estebanell Minguell et al., 2017; Kurniasih et al., 2020). Several studies have found that students in Indonesia have low mathematical thinking skills (Sudarwo & Adiansha, 2022; Tanudjaya & Doorman, 2020). Thinking about ordinary mathematics leads to many students who are uninterested in learning mathematics because they believe that thinking about mathematics develops personality (Çelik & Özdemir, 2020). Teachers should therefore investigate students' mathematical thinking skills more thoroughly, focusing on students' thinking processes rather than final results (Tran et al., 2017). Because, so far, the main focus of learning has rarely been the mathematical thinking process, looking at the final results of student score assessments and drawing conclusions about learning success from the final results.

Aside from students, teachers in the field of mathematics education must be able to master good mathematical theory, particularly by thinking mathematically (Kamamia et al., 2014). However, the advancement of computers in mathematics learning requires that teachers prepare themselves to master problem-solving abilities that resemble the structure of computer answers or computational thinking, which has begun to enter the school curriculum (Gadanidis et al., 2017). Computational thinking is an essential ability for students, which has the same basis as the ability to read, write and count (Zhong et al., 2016). Learning using computational thinking as a foundational skill across the school curriculum will enable students to learn abstract, algorithmic and logical thinking and be ready to solve complex, open-ended problems. Mathematics teachers need critical considerations in understanding the two cognitive paradigms, namely mathematical and computational thinking abilities, so that in learning mathematics, teachers and students can master both. As previously stated, some conditions are unconcerned with students believing they are learning mathematics, and so on. Students' disinterest increases when the situation is online learning due to the COVID-19 pandemic (Hafeez et al., 2022; Lavidas et al., 2022). These comprehensive online learning requirements will go into effect in 2020, instilling trust in the Indonesian people (Sutini et al., 2022). Students struggle to study due to limitations in digital devices and internet access used by large groups of students at home (Dhawan, 2020). In that case, fully online learning reduces students' mathematical and computing abilities.

In Indonesia, the facts show that out of 1700 respondents, around 70% complained that there was an internet connection problem when studying from home, and 18% complained that they did not have a digital device (Pradana & Syarifuddin, 2021). The limited condition of digital devices and internet access makes students think things that are worse for the ability to explore. Students are less enthusiastic in learning, so their thinking skills are less honed (Cui & Ng, 2021; Harefa & Sihombing, 2021; Muthuprasad et al., 2021). In 2022, schools in Indonesia will begin to implement complete offline learning or begin to move towards a progressive condition. Students return to face-to-face learning with teachers at school in order to be more flexible in their learning and to control

the learning environment. However, the learning conditions remain constrained, especially those related to reconstructing mathematical and computational thinking skills by the previous two years' complete online understanding. Meanwhile, in the latest curriculum in Indonesia, the government is trying to integrate computational thinking skills into education and fostering mathematical thinking skills due to the loss of learning as an online learning effect. So, this study aims to obtain a hypothetical learning trajectory in mathematics learning in constructing the mastery of mathematical thinking and computing skills of junior high school students based on the initial exposure.

Previous studies on mathematical and computational thinking in mathematics learning has always linked the analysis of students' test results with indicators of second thinking skills. However, there will not be much more research until the design step of the Hypothetical Learning Trajectory (HLT) focuses on students' mathematical and computational thinking abilities from learning mathematics. For this reason, this research aims to design a Hypothetical Learning Trajectory (HLT) based on students' mathematical thinking and computing abilities in mathematics learning. The HLT of both their thinking abilities plays an important role in ensuring that learning achieves its goals by permanently incorporating students' thinking processes as an important factor in mathematics learning. The success of this research is based on the students' thought process. The student's thinking process serves as the foundation for the mathematics learning trajectory, which is student-centered and employs procedural and contextual technology to achieve learning objectives.

METHODS

This study employs a component of the validation studies research development method that focuses on Hypothetical Learning Trajectories (HLT). Validation studies present a learning trajectory design to develop and describe a theory about the learning process and its implications for creating a learning environment design (Akker et al, 2006). The HLT in this study did not limit teachers to pursuing a single learning goal or initiating a single study path. It must, however, connect learning processes and activities to the development of mathematical and computational thinking skills, as well as student learning patterns. The goal of the teacher in initiating HLT is for the structured hypothesis to be used as a benchmark for creating a learning design capable of developing students', mathematical, and computational thinking skills in learning rank number and square roots materials. Hypothetical Learning Trajectory (HLT) consists of three components: learning objectives, learning activities, and learning processes that anticipate how students' thinking will develop mathematical and computational thinking abilities. To produce the HLT, literature from previous studies was used, accompanied by supporting literature, daily experiences, and discussions between researchers and experienced class IX teachers. This HLT is a form of conclusion from preliminary research to answer the importance of designing learning based on students' mathematical and computational thinking abilities. Figure 1 shows a research scheme showing the steps for preparing HLT based on several conditions that lead to mathematical and computational thinking abilities in mathematics learning.

The research method for developing validation studies uses a phenomenological approach. The phenomenological approach is a way for researchers to understand a particular phenomenon to obtain valid research results according to natural conditions in the field (Teherani et al., 2015) and life experiences (Neubauer et al., 2019). In this study, the phenomenon that occurred was learning mathematics after the Covid-19 pandemic, which continued to prioritize mathematical and computational thinking skills. However, in reality, they experienced difficulties when they returned to learning mathematical concepts because previously, they used whole online learning. The subjects in this study were 30 junior high school students in class IX who took mathematics classes that covered exponent numbers and root forms. The design of HLT in mathematics learning in class IX necessitates the use of the following instruments: PISA 2021's high school mathematics curriculum and mathematics problem solving, test kits to assess students' mathematical and computational thinking skills, observation sheets, and interview sheets.

Data analysis used the following techniques: (1) direct analysis of the junior high school mathematics curriculum and PISA 2021, which aims to determine the need to integrate mathematical and computational thinking skills into junior high school mathematics learning; (2) direct analysis of students' mathematical and computational thinking processes through observation during the learning process and test results; and (3) direct analysis of the results of interviews with teachers

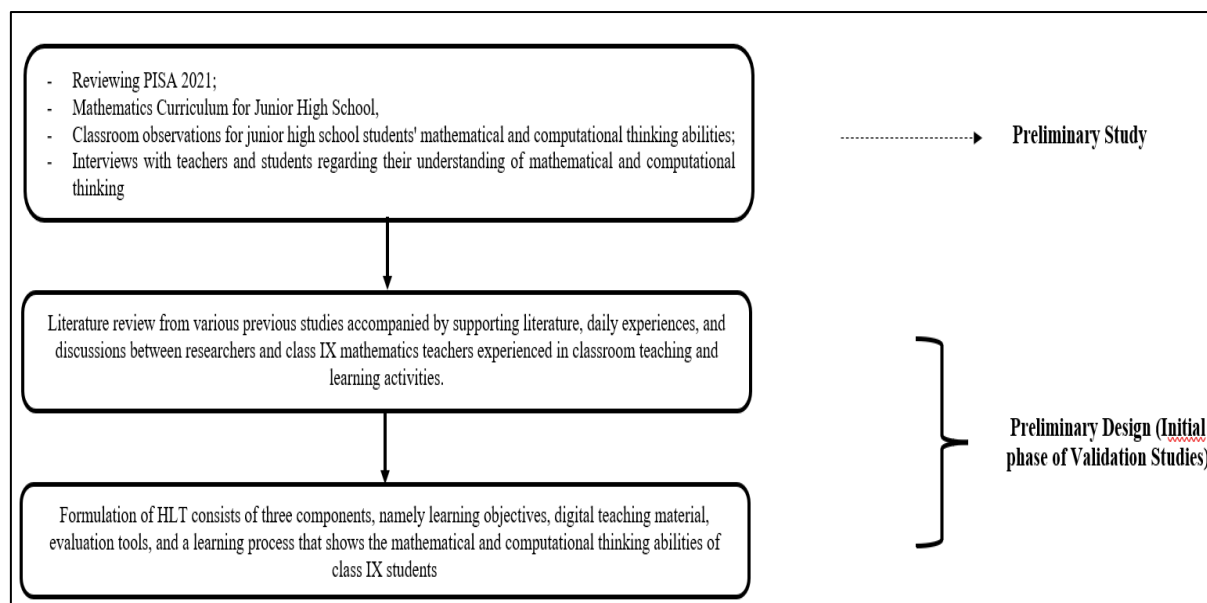


Figure 1. Research flow

and students to emphasize the initial conditions of students' mastery of these two thinking skills. The design of this study describes learning activities using textbooks, media, and evaluation tools based on mathematical and computational thinking abilities in the matter of numbers and roots to achieve learning objectives. To achieve learning objectives, learning activities employ textbooks, media, and evaluation tools based on mathematical and computational thinking in theory rank number and square roots. For structured activities, education must adapt to the composition of the material and the series of activities in the classroom. The development of specific ideas for learning activities is dependent on the teacher's hypothesis about the development of mathematical thinking skills, computational thinking in mathematics learning, and student learning styles, where this hypothesis is the development of the students' most recent and current curriculum conditions.

Meanwhile, when forming suspicions about the learning process in the classroom, teachers must predict the development of students; mathematical and computational thinking skills in class as well as understand the possible strategies of students that emerge as learning activities progress. As a result, teachers must observe students' reactions at each stage, which leads to educational objectives. The teacher who best understands the characteristics of the students in the class must develop the ability of students to master teaching materials and media using rank number and square roots theory. The purpose of this analysis of the junior high school mathematics curriculum and PISA 2021 is to determine the importance of mathematical and computational thinking skills in high school mathematics learning. Meanwhile, observation and testing activities provide information and an overview of students' initial mathematical and computational thinking power observed during the learning process. The interviews for students and teachers, on the other hand, emphasized the importance of students' completeness to second thinking skills.

FINDINGS

The Hypothetical Learning Trajectory (HLT) on the Rank Number and Square Root Materials are based on curriculum analysis and PISA 2021, as well as the results of the mathematical and computational thinking ability pretest, early mathematics learning observations, and interviews with students and teachers. The goal of implementing the curriculum for junior high school students is for them to be able to solve problems that arise from mathematics materials. The curriculum also aims to teach students how to apply mathematical concepts to real-world problems, as well as how to recognize patterns and use them to guess and generalize (conclusions). The curriculum also requires students to collect, process, interpret, and present observational data in the form of tables, diagrams, and graphs, as well as to exhibit thorough, systematic, and procedural behavior. The advantage of the curriculum is that it places students as the primary actors in learning and regulates material delivery

based on student needs and level of mastery. The curriculum's excellence positions students as actors in education, and delivery theory is organized based on the conditions and status of students' completeness.

Temporarily, the conclusion from the 2021 PISA assessment, namely combining thought processes mathematics and computing for the first time, necessitates both thought processes that play a significant role in Indonesian learning. PISA is conducted every three years to assess the abilities of students in the 15-year-old category who are in junior high school. Students must understand mathematical and computational thinking in order to explore ideas and methods for solving high-level mathematical problems. In mathematics, complex problems are the combination of complex thinking and various strategies for solving mathematical problems that require systematic, conceptual, procedural, algorithmic, and innovative thinking.

The pretest results revealed that students lacked understanding of the theory's prerequisite concepts and had difficulty expressing initial ideas for problem solutions at the start of the observation. Students have difficulty finding solutions to pretest questions and are confused about expressing initial ideas in solving the problems contained in the questions. Students tend to work on the issues with limited experience learning mathematics material. The mathematical thinking ability of students is still limited to specialization indicators, such as solving math problems by looking at previous examples. Table 1 shows a complete analysis of the pretest results of the research subjects' mathematical and computational thinking skills.

The test results did not demonstrate high levels of procedural activity and understanding when solving math problems. Some students are still fixated on the process of writing answers to the examples. They haven't figured out why the steps they wrote in their answer have such a formula. When students work on different questions, for example, the initial concept of the answer is that students only know and write the elements contained in the questions. Conceptual students have not yet reached the activity of understanding the relationship between concepts and procedures in providing answer arguments for this understanding. In terms of the case's computational thinking ability, mathematics demonstrates that a student was unable to arrange answers systematically. Previously, the teacher had introduced a utilization application that could assist them in developing computational thinking skills through structured coding. The teacher introduces an interesting first application for students to learn, complete with colorful and simple programming, so that students can learn coding in a fun way and demonstrate their procedural thinking skills. The students were finally able to compose the code after several examples of coding provided by the teacher. However, the teacher gave a special number ranking case at the time, and an obstacle arose in cracking the coding, so the students brutally found the final result.

Only about 19% of students can maximize their mathematical and computational thinking skills according to indicators and explore them while still focusing on building knowledge and seriousness in learning mathematics. While the rest still have not maximized their thinking skills due to learning barriers. Figure 2 shows the results of the pretest analysis based on mathematical and computational thinking skills.

The discussion began with the teacher demonstrating that the students had an alarming condition following the online learning skills phase. A simple example: the teacher continues to make it difficult for students to deliver material on time and explore students' thinking at that time. Online learning undermines outcomes; investigate them. Students who are the subject of study have two years of online learning and one semester of limited offline understanding, so teacher complaints about the process of constructing their knowledge are common. Despite the fact that the teacher stated that all of the online learning instruments required by students were already available, such as online learning platforms, learning videos, online learning evaluations, and assignments collected via internet facilities. Furthermore, the teacher complained that when students began learning with the offline system, they had to repeat basic concepts that they should have mastered in elementary school. The repetition of these initial concepts becomes an impediment to rapidly developing mathematical. Repetition results in the teacher's ability to focus on complete theory with limited time and resources, as well as the ability to build on the student learning experience. As a result, the teacher ultimately disregards complex mathematical solving skills or those related to higher order thinking skills. Teachers place a greater emphasis on solving all mathematical theories using simple procedural problems.

Table 1.
Pretest Results of Students' Mathematical and Computational Thinking Skills

Students' Mathematical Thinking Skills		Students' Computational Thinking Skills	
Indicator	Analysis Results	Indicator	Analysis Results
Specializing	Students can identify problems by writing down all the information in the questions and answering questions according to the learning experience. Students try to write answers to problems by looking at examples with the same answer pattern.	Decomposition	Students can identify problems in the questions, but to determine the right solution, they still need guidance from the teacher, so it is impossible to formulate a solution independently.
Generalizing	Students still have difficulty expressing their initial ideas when answering questions independently, so they always ask for directions from the teacher. For this reason, in this section, the teacher has not been able to explore students' abilities because, in the process, they still depend on the teacher.	Pattern Recognition	Students struggle to write systematic mathematical patterns and cannot obtain solutions according to interrelated material concepts. Teachers still need to explore student learning experiences so that students can formulate problem-solving clearly.
Conjecturing	Students have difficulty writing down conjectures for solving problems in questions because they have not been able to predict between the information in the questions and their relation to the idea of writing answers.	Abstraction	Students are still focused on solving routine problems because the learning experience has not yet explored complex problem-solving abilities. For this reason, when concerns enter non-routine cases, students cannot solve similar issues based on their previous experience.
Convincing	Students cannot convince themselves to state that their answers are correct because doubts have arisen from the beginning of writing the answer idea.	Algorithm	Students have not written down problem-solving systematically. Based on the student's answers, some steps involved in applying the concept that should have been there were missing. So that the dominant students do not believe their answers are correct.

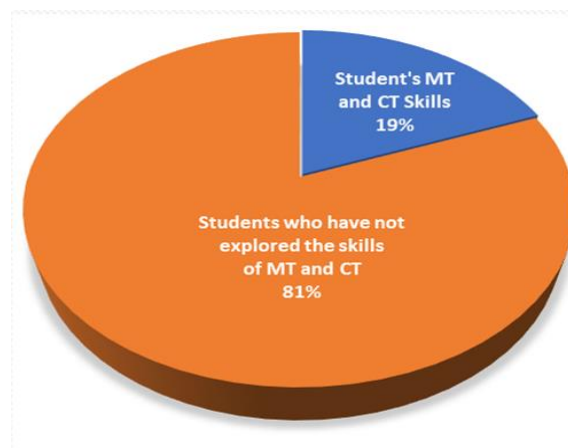


Figure 2. Results of pre-test analysis of students based on mathematical and computational thinking ability

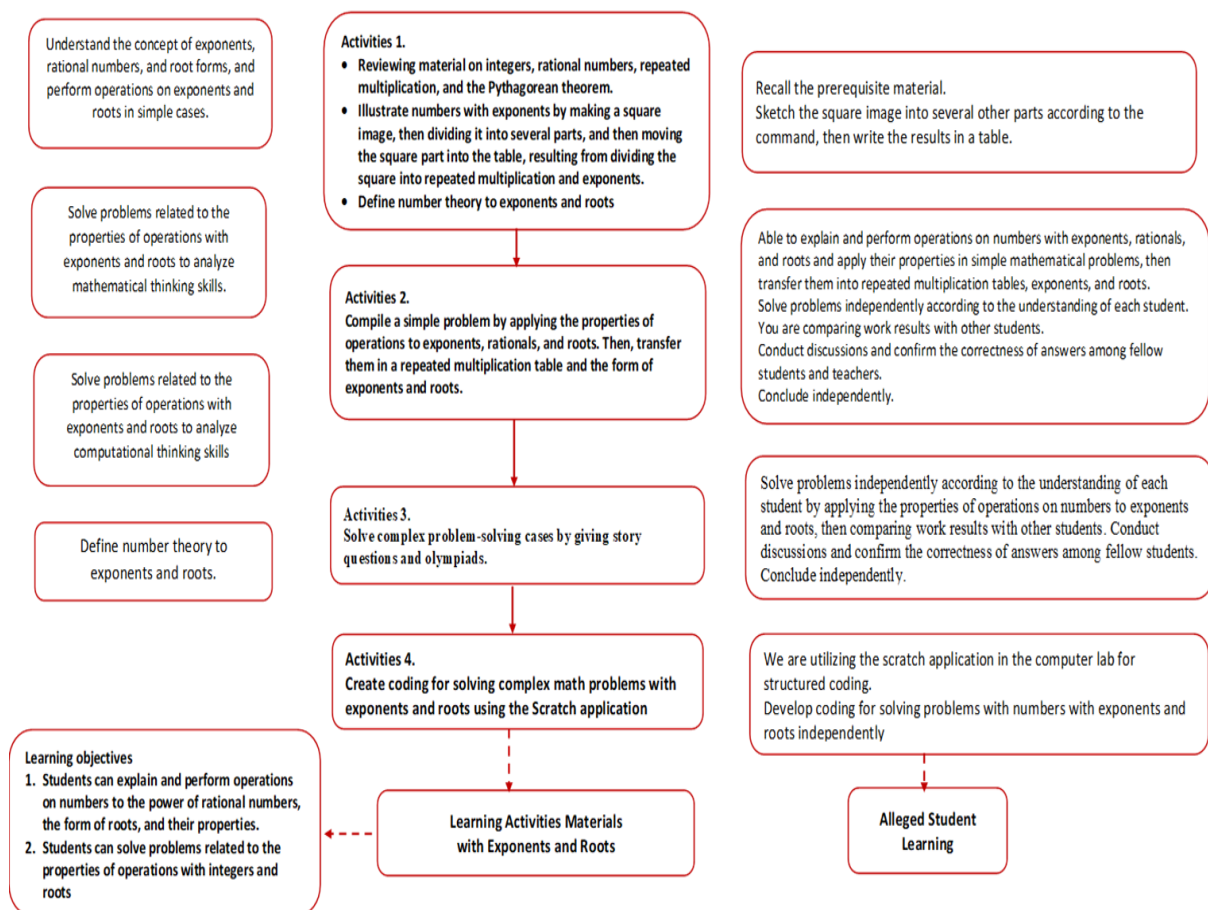


Figure 3. Hypothetical learning trajectory for learning rank number and square roots

A Hypothetical Learning Trajectory (HLT) was developed based on the findings of an analysis of the activities of the Junior High School Mathematics curriculum suite and PISA 2021, test results, initial observations during the learning process, and interviews with students and teachers. As illustrated in Figure 3, HLT consists of learning materials for rank number and square roots. The flow of activities is organized by displaying the teacher's activities during learning and guessing activities to achieve the learning objectives in their entirety. The activity flow includes media and assignments to support the development of mathematical and computational thinking skills, as well as their

development while taking into account junior high students' ability to understand mathematical concepts

DISCUSSION

The study of mathematics learning innovation in compiling hypothetical learning trajectories in teaching rank number and square roots to junior high school students for mastery of mathematical and computational thinking skills. This learning innovation is part of the evolution of education which has begun to integrate computational thinking in mathematics learning which is the main agenda of the new curriculum in Indonesia. For this reason, a teacher needs to change his learning paradigm through changes in the preparation of a validated hypothetical learning trajectory that combines mathematical and computational thinking abilities in the junior high school mathematics curriculum. A Hypothetical Learning Trajectory has been developed based on a series of learning processes: guesswork learning for goal attainment learning. The prepared HLT is presented in a variety of formats that prioritize gradual intervention, beginning with a review of theoretical prerequisites, grant materials, and structured assignments ranging from simple to complex that are accompanied by supporting media for mastering students' mathematical and computational thinking skills. Pressing buttons in online applications can help them develop coding skills as well as cognitive trigger areas that will allow them to think systematically and patterned.

In general, students are more comfortable with face-to-face learning conditions because they are free to ask questions and want to review prerequisite material so that new material is easier to understand (Almahasees et al., 2021). Students continue to focus on the teacher's examples and questions, so their thinking skills remain purely procedural, lacking the innovation and creativity required to generate related ideas using mathematical concepts and connecting them to previous experiences. Several meetings with the offline learning system yielded some interesting results; where was the progress? Students are able to express their creative ideas when solving mathematical problems. However, limitations in understanding theoretical prerequisite concepts impede the development of mathematical thinking and calculating skills.

Students gave a good response during the learning process during the observation phase, but only because they studied the online system for too long, so their learning motivation actually decreased. Because they do not interact and discuss with teachers and classmates, they reduce students' enthusiasm for online review (Almendingen et al., 2021; Meşe et al., 2021). Simultaneously, the process of learning mathematics continues with an increasing level of understanding and evaluation of diverse concepts that necessitate creativity and bright ideas from students who are still developing. As a result, teachers must quickly understand current students in order to develop learning models that accommodate students' thinking skills. Because students have a tremendous capacity to learn, teachers must establish strong relationships with them (Biney, 2018). Furthermore, in order to support the learning process, teachers and students must share the same viewpoint (Dayagbil et al., 2021).

Orientation to students during learning enables a mathematics teacher to be creative and innovative, as well as creative in arranging a learning trajectory based on students' abilities. The results of the curriculum analysis give mathematics teachers the freedom to create learning tools based on thinking skills. Structured design aims to go deeper into mathematical concepts and stimulate student activity by conveying opinions and natural ideas from students' thinking. Learning instruments can assist in the development of hypothetical learning trajectories that focus on students in order to achieve relevant mathematics learning objectives. Because mathematics is at the heart of what computers must do, they require existing learning instruments and media that incorporate knowledge of the theories and technologies that students are familiar with in order to solve problems in mathematics based on structure. Problem-solving strategies for mathematical problems can help students grow their cognitive effectively through manipulation and honest expression in conveying unique ideas. To solve mathematical problems, computational thinking indicators such as decomposition, pattern recognition, abstraction, and design algorithms are required. Setting aside class time to investigate how computational thinking relates to mathematics will help students improve their logic and problem-solving skills. As a result, mathematical and computational thinking become necessary for research and development, so that students become learners who can solve

mathematical problems independently using a pattern of thought and creativity because they master various mathematical theories.

One crucial mathematics theory for junior high school students in Indonesia is rank numbers and square roots. As a result of the material, various case-solving problems range from simple to complex. Aside from the material rank number and square root, some concepts, such as operation rank number and square roots and properties, become prerequisites for mathematics theory. A teacher must develop learning objectives tailored to students' conditions in the classroom. Teachers must build task instruments that can construct knowledge for students from the experience of studying mathematics in previous theories and relate it to the theory of numbers, powers, and roots of forms, in addition to setting learning objectives. During observation, students were comfortable learning by presenting problems in stages. Students need longer study time to achieve mathematical and computational thinking skills, which are complex problem-solving abilities. Still, they are consistent and continuously providing problems with gradual difficulty levels. In this section, the teacher must consistently and patiently provide appropriate treatment during the student learning process.

During learning, students are very enthusiastic about asking the teacher to repeat the initial concept and inquire about the prerequisite theory of the power of rank number and square roots. Even though the questions are still simple, they always seek guidance from the teacher when working on them. They have no ideas in the answer sheet when they reach the stage of giving complex math problems and the teacher has not given advice. They expressed their dissatisfaction with their inability to solve the problems. When the teacher provides examples of related questions, the students are able to concentrate solely on the sample questions. As a result, the learning trajectory hypothesis based on learning outcomes depicts a picture of teacher mastery of the class, while also accommodating students' mathematical and computational thinking abilities in order to meet learning objectives. The teacher must first prioritize the delivery of prerequisite material in order for students to master these two thinking skills. Before explaining the material, the teacher must compile a list of prerequisite materials ranging from numbers to powers and root forms. Then, refresh the problem solving for the prerequisite material, ranging from simple to complex problems, so that students can construct their understanding, making it easier for students to accumulate new knowledge. The preparation of learning designs became the primary goal after passing the initial data analysis stage by understanding the characteristics of student learning, the stage of understanding concepts and materials, the ability to complete evaluations, and interest in mastering learning media. Mastery of mathematical and computational thinking skills becomes easier to integrate into learning in schools, particularly in the classroom, by providing learning media and problem-solving-based evaluations that are arranged from simple to complex with the help of the construction of student learning experiences. As a result, an excellent hypothetical learning trajectory in mathematics learning is a learning trajectory plan that becomes a strong link between teachers and students to develop mathematical and computational thinking skills.

CONCLUSIONS

Preparing a Hypothetical Learning Trajectory that synergizes with the latest mathematics curriculum requires innovation and evolution in learning. Hypothetical Learning Trajectory (HLT) caters to students' mathematical and computational thinking skills by describing the presentation of mathematical concepts from rank number and square roots theory that are organized from prerequisite concepts to delivery properties and number operations. HLT is formed as a result of an overall analysis of learning, which prioritizes all observations and discussions with teachers and students.

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Authors' contributions

SF: main idea, conceptualization, data collection, write the initial manuscript, TH: methodology, validation, review the manuscript, EN: data analysis and refine the final manuscript.

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