EMTEKA: Journal of Mathematics Education
Volume 6, No. 2, 2025. 834-848
DOI: https://doi.org/10.24127/emteka.v6i1.8670

e-ISSN 2746-5594
p-ISSN 2746-5608

HYPOTHETICAL LEARNING TRAJECTORY COMPUTATIONAL THINKING LEARNING BASED ON *SCRATCH*ROGRAMMING LCM MATERIAL CLASS V

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Received 20 June 2025; Received in revised form 28 August 2025; Accepted 30 September 2025

ABSTRACT

The design of a Hypothetical learning trajectory *plays a crucial role in structuring learning experiences that align with both curriculum goals and students' cognitive development. However, in the context of teaching Least Common Multiple (LCM) at the elementary level, there is a lack of hypothetical learning trajectory models that integrate computational thinking and digital tools. This study aims to develop an hypothetical learning trajectory for teaching LCM using Scratch programming, incorporating the approaches of* tinkering, making, *and* remixing. *The research adopts the* preliminary design *phase of a design research methodology, involving curriculum analysis, literature review, and exploratory interviews with elementary school teachers to identify instructional needs and implementation challenges. Based on this process, a structured hypothetical learning trajectory was developed, consisting of seven sequential learning activities ranging from creative exploration of Scratch features to constructing interactive visual solutions for LCM problems. Each activity includes predicted student responses and Sargeted learning goals. The designed hypothetical learning trajectory not only supports contextual understanding of the LCM concept but also fosters students' computational thinking skills. This trajectory is expected to serve as a practical guide for educators to implement technology-enhanced, student-centered mathematics instruction at the elementary level.*
Keywords*: Computational thhingking; LCM; scratch programming*

ABSTRACT

Desain *Hypothetical Learning Trajectory* (HLT) memiliki peran penting dalam merancang pembelajaran yang terarah dan sesuai dengan karakteristik materi serta kebutuhan siswa. Namun, pada pembelajaran Kelipatan Persekutuan Terkecil (KPK) di sekolah dasar, belum banyak dikembangkan HLT yang terintegrasi dengan pemikiran komputasional dan media digital. Penelitian ini bertujuan mengembangkan desain HLT untuk pembelajaran KPK berbasis pemrograman Scratch dengan pendekatan *tinkering*, *making*, dan *remixing*. Penelitian dilakukan pada tahap *preliminary design* dari metode *design research*, melalui analisis kurikulum, studi literatur, serta wawancara dengan guru untuk mengidentifikasi kebutuhan pembelajaran dan tantangan dalam mengajarkan KPK. Berdasarkan hasil analisis, dikembangkan sebuah desain HLT yang terdiri atas tujuh aktivitas pembelajaran berurutan, mulai dari eksplorasi fitur Scratch hingga penyusunan solusi KPK secara visual dan interaktif. Setiap aktivitas disertai prediksi respon siswa serta tujuan pembelajaran yang ditargetkan. Desain ini tidak hanya memfasilitasi pemahaman konsep KPK secara kontekstual, tetapi juga mendorong perkembangan keterampilan berpikir komputasional. HLT ini diharapkan menjadi acuan praktis bagi guru dalam mengimplementasikan pembelajaran matematika yang inovatif dan berbasis teknologi di sekolah dasar
Keywords*:*Berpikir Komputasional ; KPK; pemrograman scratch

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e-ISSN 2746-5594
p-ISSN 2746-5608

Introduction

Learning in the 21st century requires mastery of skills that transcend mere knowledge, encompassing critical thinking, collaboration, communication, creativity, and innovation commonly referred to as the 4Cs (Hasanah & Haryadi, 2022). In addition, computational thinking has become one of the essential skills that students need to master, especially in the digital technology era. Computational thinking teaches students to think logically, systematically, and creatively in solving problems (Widodo et al., 2023). According to Brennan & Resnick (Budiyanto et al., 2025) this concept encompasses abstraction, decomposition, pattern recognition, and algorithm design, which can be flexibly applied depending on the problem at hand.

Inner wing (Zia et al., 2024) explains that computational thinking involves problem-solving, system design, and understanding human behavior based on fundamental concepts of computer science. Computational thinking is believed to offer solutions that help students think logically, systematically, and structurally. This concept began to gain widespread recognition after it was introduced as a thinking approach that combines problem-solving and design by applying principles of computer science. Brennan dan Resnick dalam (Sadiq dkk., 2024) Three key components are proposed within the computational thinking framework context, practices, and perspectives. Its main pillars consist of abstraction, decomposition, pattern recognition, and algorithm design, which can be flexibly applied according to the specific problems being addressed.

In the Merdeka Curriculum at the elementary school level, computational thinking is integrated into several subjects, including Mathematics. (Amalia & Annisa, 2022). Through this integration, students are introduced to systematic, logical, and creative ways of thinking in Mathematics learning, especially to support more structured problem-solving skills. The demands of 21st-century education competencies cover various areas, including critical thinking, problem-solving, innovation and creativity, communication, collaboration, as well as the ability to understand, operate, and utilize technology effectively (Halim, 2022). To achieve all of these competencies, the education system must prepare a generation that is ready to face change—starting from elementary school. This is reinforced by the need to educate students in ways that are relevant to a world that increasingly depends on technology (Alifah & Widodo, 2024). In the context of mathematics learning in elementary school, computational thinking plays an important role in strengthening the understanding of abstract concepts (Miftahul Jannah & Miftahul Hayati, 2024).

One of the topics that often presents a challenge for students is the Least Common Multiple (LCM). This topic requires the ability to recognize number patterns, list multiples, and identify the smallest common multiple between two numbers (Sihombing et al., 2025). However, based on observations and field data, many elementary school students still struggle to understand the concept of LCM in depth. In addition, the integration of Scratch programming as a learning medium for mathematics particularly in teaching LCM has not been optimally implemented. These challenges include a lack of systematic lesson planning and the absence of clear guidelines for effectively combining mathematics learning with programming.To answer these challenges, structured and contextual learning design is needed through the preparation of a Hypothetical learning trajectory. hypothetical learning trajectory functions as a conceptual plan that describes learning steps that are in accordance with the material objectives and characteristics of learners (Simon & Tzur in Lestari & Marsigit, 2020). The development of hypothetical learning trajectory has been proven to increase the effectiveness of learning in various fields of study (Rahayu & Wijaya, 2018; Lesmana et al., 2024). However, research examining the development of hypothetical learning trajectory based on Scratch programming specifically for LCM materials in elementary school is still very limited.

In designing computational thinking learning based on Scratch programming that is integrated into mathematics subjects for the Smallest Common Multiples (LCM) material, systematic and structured planning is needed. One of the relevant approaches is the preparation of *the Hypothetical learning trajectory*, which functions to provide an overview of important aspects of learning planning (Lestari & Marsigit, 2020). According to Simon and Tzur (in Lestari & Marsigit, 2020), Hypothetical Learning Trajectory supports educators in designing conceptual learning by choosing activities that are in accordance with the mathematics objectives. hypothetical learning trajectory is likened to a travel plan, where understanding the various possible paths allows educators to determine the best strategies in achieving learning goals. hypothetical learning trajectory is an important reference in the preparation of more effective and contextual learning tools (Saefudin et al., 2023).

The development of Hypothetical learning trajectory has been widely carried out in various fields of study, as shown by Rahayu and Wijaya (2018) in the development of hypothetical learning trajectory for statistical thinking materials, as well as Lesmana et al. (2024) n the design of hypothetical learning trajectory learning to measure the volume of building spaces based on ethnomathematics of Rajapolah crafts. These studies show that systematic and contextual hypothetical learning trajectory design can improve students' understanding. Meanwhile, (Sari *et al.*, 2024) mphasized the importance of preparing hypothetical learning trajectory through steps such as examining students' thinking characteristics, understanding material concepts, reviewing existing curriculum and teaching materials, identifying learning barriers, and estimating students' responses to learning activities. Although many studies have addressed the development of hypothetical learning trajectory in various contexts, there are still few studies that specifically examine the development of hypothetical learning trajectory based on Scratch programming integrated with the mathematics learning of the Smallest Multiple of Communion (LCM) material in elementary schools. Therefore, this study aims to design an initial hypothetical learning trajectory that can be a reference for educators in developing Scratch-based teaching materials for mathematics learning LCM materials in grade V elementary schools in developing the design of Hypothetical learning trajectory learning of the Smallest Common Multiples (LCM) learning which is integrated with scratch-based computational

EMTEKA: Journal of Mathematics Education e-ISSN 2746-5594
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thinking in elementary schools. The approach used involves the concepts of tinkering, making, and remixing to design systematic and contextual learning activities

Research Methods

This study adopts an approach from (Sari et al., 2024) who develop *Hypothetical learning trajectory* on statistical thinking material. The similarity taken lies in the use of design research methods with an emphasis on the stage *preliminary design*, as well as the initial step in the form of needs analysis through interviews and document studies. This study also applies the principles of hypothetical learning trajectory preparation based on the identification of students' thinking characteristics, potential learning difficulties, and analysis of learning materials and contexts, as carried out in the study.

This approach is not only used as a conceptual reference, but also adapted technically in the design of this research procedure. For example, the interview instrument and document analysis format were developed based on a similar structure to previous research, but adapted to the material of the Smallest Common Multiple (LCM) and the context of Scratch programming integration. Thus, this study combines best practices from previous studies and adapts them contextually to produce hypothetical learning trajectory that is relevant and applicable in mathematics learning at the primary school level(Khairani, et al., 2025).

This research is limited to the stage *preliminary design* and adopt an approach similar to that taken by (Siahaan et al., 2021) which applies it to the material of linear equations. This initial stage focuses on the preparation of hypothetical learning trajectory that is useful as a reference for educators in designing learning tools. The design of hypothetical learning trajectory involves the analysis of students' thinking characteristics, the study of material concepts, curriculum, teaching materials, learning barriers, as well as didactic aspects and possible student responses. In the context of this study, the researcher used interviews, documentation studies, and literature studies to analyze the needs before designing hypothetical learning trajectory on the material for measuring the volume of building spaces based on ethnomathematics of Rajapolah crafts. The data obtained was analyzed using the Miles and Huberman model which includes data reduction, data presentation, and conclusion drawing (Sugiyono, 2022).

Results and Discussion

Analysis Before Design

At the analysis and exploration stage, problem identification was carried out by observation and interviews in several elementary schools. It was found that the learning of computational thinking that is integrated into mathematics subjects is still limited. In fact, in the Merdeka curriculum, computational thinking has been integrated with mathematics subjects (Pramudhita et al., 2022) Teaching materials for computational thinking are still limited, but at SDN 1 Sindnagkasih there have been scratch programming extracurricular activities but have not been integrated with the subject. Based on the problems found, it shows the potential to develop computational thinking teaching materials based on scratch that are integrated with the mathematics subject of the LCM material. This condition makes clear the need for innovative teaching materials that are able to integrate mathematics with computational thinking skills (Putra et al., 2023).

In the development of computational thinking learning based on Scratch programming, the availability of adequate learning facilities is a very important supporting factor. Observations of several elementary schools show that facilities such as Wi-Fi networks, projectors, and computer devices are available, but have not been optimized for their use in mathematics learning. According to (Rahmania & Hudri, 2024) The success of technology integration in learning is not only dependent on the availability of hardware, but also greatly influenced by the readiness, perception, and attitude of teachers and students towards technology. This condition opens up strategic opportunities to develop Scratch-based teaching materials that are able to incorporate informatics into mathematics materials.

Research (Supriatin & Putra, 2023) shows that the effective use of Scratch can improve students' computational thinking skills, particularly in understanding algorithmic concepts and problem solving. Moreover (Romadoni et al., 2023) reinforcing that the integration of computational thinking in mathematics learning not only develops analytical and logical skills, but also encourages students' creativity. By utilizing the available technology facilities and the readiness of teachers and students, the development of Scratch-based teaching materials has the potential to enrich the mathematics learning process to be more interactive, interesting, and in line with 21st century competencies.

Desain *Hypothetical Learning Trajectory*

In the design and construction stages, researchers use *Hypothetical learning trajectory*) as a basis for designing learning activities. This is in line with research (Syabrina et al., 2022) hypothetical learning trajectory is designed to be able to describe the learning sequence that suits the needs of students. hypothetical learning trajectory allows researchers to design learning paths that estimate how students' understanding develops along with the given activity (Syarifah et al., 2023).

At the development stage, the researcher used *Hypothetical Learning Trajectory* as the basis for designing computational thinking learning based on the scratch of LCM material. According to Lesmana., et al (2024) Activities in the design *of hypothetical learning trajectory* are designed to help guide the learning flow systematically and predict the hypothesis of students' thinking, starting from the concrete initial stages to reaching understanding Based on the results of the analysis, the researcher then compiled a *Hypothetical Learning Trajectory* framework consisting of:

a) Learning objectives
b) Scratch-based computational thinking learning activities integrated into mathematics LCM materials
c) Hypothesis of the learning process of students

In its design, the researcher adopts a computational thinking learning approach based on *the Pedagogical Framework* (CTPF) which includes three important elements, namely:

a) Tinkering: Tinkering with a simple script

DOI: https://doi.org/10.24127/emteka.v6i1.8670
e-ISSN 2746-5594
p-ISSN 2746-5608

b) Making: Building more complex projects with algorithmic logic
c) Remixing: Developing or adapting an existing project to expand functions and concepts.

The design of the *Hypothetetical Learning Trajectory* of computational thinking learning based on the scratch of LCM material, is as follows

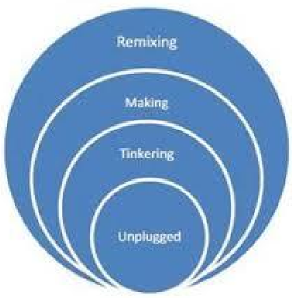
1. Learning objectives

The learning objectives in this hypothetical learning trajectory refer to the Learning Outcomes in Phase C of the number element. In informational learning, it refers to the elements of computational thinking and programming algorithms From these learning outcomes, the learning objectives contained in the hypothetical learning trajectory can be formulated, namely: 1) After participating in learning, students are expected to be able to complete the number pattern of multiples correctly, 2) Through number pattern exercises, coding multiples of a number using the Scratch application correctly, 3) Students categorize numbers based on the multiples of the common through the correct analysis of the list of numbers, 4) Students create a simple program to find the multiples of the common using Scratch correctly, 5) The participants categorize the numbers to determine the Least Common Multiple (LCM) of two numbers correctly, 6) The participants make a project to find the LCM of two numbers using Scratch correctly, 7) The students develop a multiples project of numbers using Scratch by adding creative features appropriately.

2. Learning Activities

Learning activities are designed based on learning objectives that have been formulated beforehand. Some things that must be considered before designing learning activities are that teachers should already understand the concept of computational thinking, as well as understand the operation of the learning media that will be used in this learning, namely Scratch.

Kotsopoulos and al dalam (Dickson dkk., 2022) formulates four frameworks that describe pedagogy (teaching methods) in developing students' computational thinking skills called *Computational Thinking Pedagogical Framework* (CTPF). The four frameworks are illustrated in Figure 1.



Figutre 1. *Four pedagogical experiences*

Figure 1 describe at scractch *activities are usually implemented without computer activities, while* tinkering, making, *and* remixing *activities* can be implemented without using computer activities. Referring to Kotsopoulus' theory, the four pedagogical experiences above do not have to appear in order so that in this learning students will be involved in three activities that utilize computers as

e-ISSN 2746-5594
p-ISSN 2746-5608

one of the learning media. The three computing activities that will be carried out are explained as follows.

The procedure of the defense step that describes the stages of using computational thinking teaching materials based on scratch programming that is integrated into the LCM field are:

Tinkering

a) Learners Complete the pattern of multiples found in the table
b) Students carry out activities to find multiples of numbers with the number of numbers to be displayed using scratch
c) Students draw the blocks that have been made by changing the number that will be determined by the multiples and the number of multiples that will be displayed
d) Students do exercises on the activity of finding multiples of numbers

Making

a) Learners categorize the number of common multiples with the number table
b) Students make a project to find the number of common multiples of three numbers Knowing the common multiples
c) Creating programming finds the common multiples of two numbers by copying an already provided programming script

Remixing

a) Students identify the number of LCM
b) Students make a project to find the number of LCM according to the stages that have been provided
c) Students work on exercises on teaching materials
d) Developing a multi-number project using scratch

The procedure or stages of learning scratch-based computational thinking in LCM material are described in the learning flow scheme, which is illustrated in figure 2.

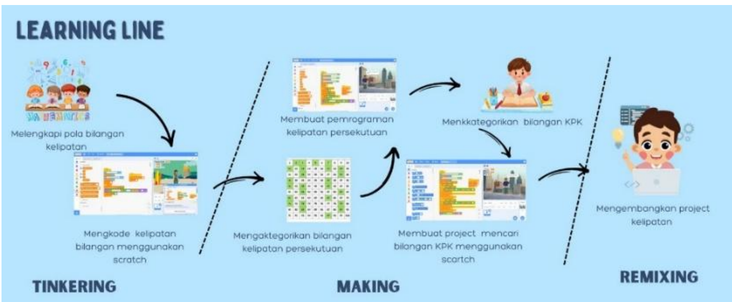


Figure. 2 *Learning line*

Figure 2 descsribe learning procedures or stages in the scheme are arranged based on the theory presented by Brennan & Resnick dalam (Budiyanto et al., 2025), explaining that programming-based learning can develop *computational thinking* through three main dimensions, namely concept, practiceand Perspective. Dimension concept includes an understanding of programming elements such as sequence (*sequence*), repetition (*loops*), and the variables used to troubleshoot.

e-ISSN 2746-5594
p-ISSN 2746-5608

Dimension practice includes trial and error skills (*tinkering*), test (*debugging*), as well as developing ideas gradually (*iterating*). While the dimensions Perspective encourage students to see themselves as makers (*Author*) technology and utilize programming to express ideas.

The learning procedure or stages are formed based on the theory presented by Brennan & Resnck in (Budiyanto et al., 2025) which explains the aspects of the computational thinking component which are explained as follows

Table .1 Computational Thinking Aspects

CT Concept	*CT Practices*	*Prespective CT*
- ***Sequences*** - ***Loops*** - ***Parallelism*** - ***Events*** - ***Conditional*** - ***Operators*** - ***Data***	- *Being incremental and iterative* - *Testing and debugging* - *Reusing and remixing* - *Abstracting and modularizing*	- *Expressing* - *Connecting* - *Questioning*

The following table 1 presents the aspects of computational thinking—concepts, practices, and perspectives—based on Brennan & Resnick's framework, and their relevance to mathematics learning.The combination of CPTF (*Computational Pedagogical Farework*) and computational thinking aspects produces a formulation of activities for flat wake learning and computational thinking. The following is an overview of the activities that will be included in the teaching materials in accordance with Brennan & Resnick's theory in table 2.

Table 2 Combination of aspects and activities of computational thinking

Aspects of Computational Thinking	**Activity Type Used**
Sequences	Students perform algorithmic sequences according to the resulting objectives, for example for a project to find Multiples, students will add forward blocks first then add event blocks and so on until the algorithm sequence that is compiled is able to produce the expected commands
Loops	Students do repetitions during scratch programming activities. Students will do repetition by utilizing existing blocks, for example, *repeat*
Events	Students specify an event to run a programming script, for example, students will use blocks When the flag is clicked to run a LCM programming script,
Being Incremental and interative	Students compile each block one by one until forming a LCM programming script

EMTEKA: Journal of Mathematics Education e-ISSN 2746-5594
Volume 6, No. 2, 2025. 834-848 p-ISSN 2746-5608
DOI: https://doi.org/10.24127/emteka.v6i1.8670

Testing and debugging	Students will check if the script has been compiled. Students will observe whether the script runs according to the expected command or not, if it is, students will look for errors that cause the script not to run as expected
Reusing and Remixing	Students will reprocess numbers to find LCM with their own creativity by changing the number input so that it produces different number results
Abstracting and modularizing	Students will be asked to create two different numbers to determine the Smallest Common Multiple (LCM)
Expresing	During the activity, students will express their creative ideas through an arrangement of programming blocks. Students are also facilitated with modules on LCM number search activities so that they can better express their ideas to produce LCM number search codes
Connecting	During the Compiling Blocks activity, students will try to connect one block to another in order to create a programming script
Questioning	During programming activities, students will certainly ask how something can be poured into a programming script

Table . 2 Combinations of Aspects and activities of computational thinking, the application of computational thinking aspects in Scratch-based mathematics learning allows learners to build conceptual understanding through interactive and technology-based exploration. Aspects such as *sequences*, *loops*and *Events* train students to think systematically in compiling the algorithmic steps needed to solve mathematical problems, in this case looking for the Smallest Common Multiple (LCM). Through this activity, students learn that programming is not just about putting together blocks, but also involves logical sequences and the proper arrangement of events, as explained by (Ayuni et al., 2024) that computational thinking helps students develop logical and procedural thinking skills in the context of problem solving.

The activities such as *being incremental and iterative*, *testing and debugging*and *reusing and remixing* Provide space for learners to iterate, evaluate, and redevelop their projects. This encourages the creation of a trial and error mindset that is very important in the project-based learning process. In this context, students not only focus on the final result, but also on the process of achieving those results. According to (M. Gunawan Supiarmo et al., 2022), this process strengthens the ability to think reflexively and perseverance in the face of mistakes, which are an essential part of computational thinking.

In addition, aspects such as *abstracting and modularizing*, *expressing*, *connecting*, and *questioning* encourage students to express creative ideas, develop modular solutions, and develop a deeper understanding of mathematical concepts. They not only connect one block to another technically, but also establish a logical connection between mathematical concepts and their programming implementation. Thus, this activity creates an active, exploratory learning environment and facilitates the reinforcement of concepts through high-level thinking skills, as also affirmed by Wing in stating that computational thinking is a fundamental approach in the way we think and solve problems

The following schema illustrates an example of a series of computational thinking learning activities using scratch programming that is compiled based on the learners' learning flow in Figure 3.

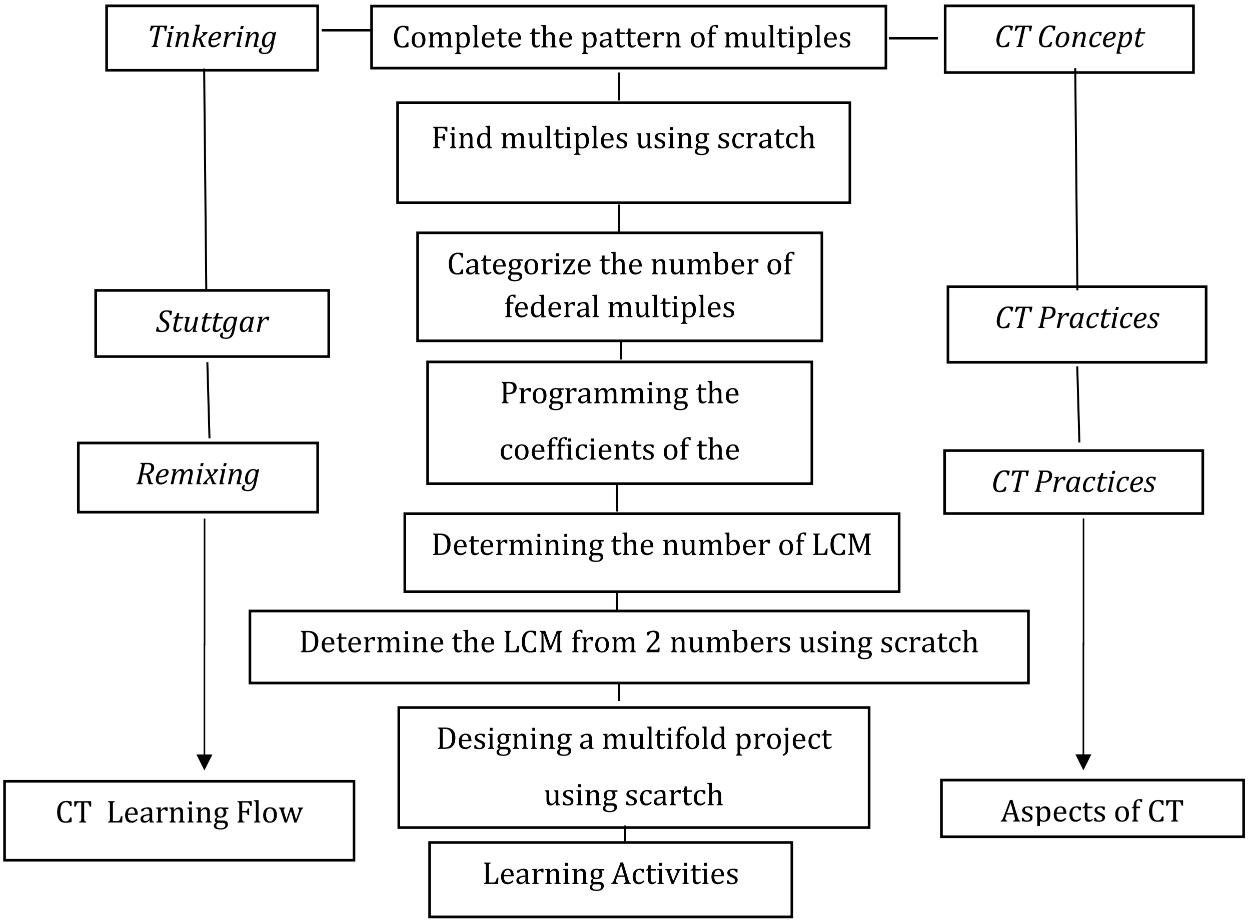


Figure 3.Learning Flow Scheme

The scheme in Figure 3 illustrates the learning flow of students in developing computational thinking skills through Scratch programming. This flow is systematically structured to facilitate the learning stages from the introduction of basic concepts, exploration of Scratch features, simple project design, to problem solving through logic and algorithms.

3. Hypothesis of Student Learning Process

After determining the learning activity, the next step is to develop a hypothesis of the student's actions or reactions to each stage of learning that has been prepared beforehand. The hypothesis of the learning process in learning Scratch programming capital is as follows:

a) Completing the Multiple Number Pattern

Students generally already know the pattern of multiples from previous learning, but it is possible that some students still have difficulty recognizing patterns quickly because they only memorize without understanding the relationship between numbers. Understanding these basic concepts is an important foundation before moving on to the programming stage (Stuart et al., 2023)

b) Determining Multiples of Numbers Using Scratch

In this stage, learners will copy and modify Scratch scripts from teaching materials as part of the tinkering and debugging process. Some students may have trouble finding blocks or structuring them correctly, but with exploration and practice, they will get used to recognizing color-based code structures and categories (Supriadi, 2024).

c) Categorizing the Number of Federal Multiples

Students are expected to write down a list of multiples of two numbers and then look for the same number, but mistakes can occur because they do not understand the concept of multiplication or just guess. This stage is important in practicing logical and systematic thinking skills before creating a script.

d) Creating Programming to Find Multiple Federations

Students begin to construct scripts using modulus and variable operators to find common multiples. It's possible that errors occur in the use of blocks or program logic, but this is part of the debugging process that encourages students to think computationally actively (Supiarmo et al., 2021) .

e) Determining the Number of LCM Manually

Students will write a list of multiples of two numbers to find the LCM. A common challenge that may arise is an error in writing multiples or an error in choosing the smallest common multiple. This activity supports the strengthening of the skills of systematically comparing patterns Determining the LCM Using Scratch (Normaya et al., 2024).

Students create a Scratch program to find LCM with the help of loop logic and modulus operators. Some students may have difficulty understanding how the algorithm works, but this exercise is very effective in strengthening understanding of mathematical concepts and programming (Chaerunnisa & Bernard, 2021).

f) Developing Multiples Projects Using Scratch

At this stage, learners are encouraged to create a self-contained Scratch project by combining previously learned code. Remixing and making activities encourage creativity, although some students may experience confusion in designing project ideas and structuring blocks correctly (Maola & Irianto, 2023)

This study provides an overview of the learning flow of the Smallest Common Multiples (LCM) material that is structured and contextual through the development of Scratch-based *Hypothetical learning trajectory*. The set of activities allowed students to visually explore multiples of numbers, predict patterns, and find LCM through interactive simulations. Possibilities that can occur in learning, such as students' difficulty distinguishing multiples per number and limitations in reading number patterns, have been mapped and anticipated through predictions of student responses and alternative teacher interventions.

This hypothetical learning trajectory is compiled based on field findings, curriculum analysis, and computational thinking studies, and validated by mathematics education experts. This study reinforces previous studies as carried out by (Syarifah et al., 2023) and (Irma & Nada, 2024) which emphasizes the importance of hypothetical learning trajectory learning design to provide a hypothetical overview of learners' learning. The contribution of this research lies in the provision of a learning design that not only directs the learning process, but also maps the dynamics of student interaction, the possibility of misconception, and opportunities to strengthen concepts through visual and exploratory approaches.

Conclusion and Suggestion

Based on the results of the research, a *hypothetical learning trajectory* hypothetical learning trajectory design was obtained for learning the Smallest Common Multiples (LCM) material based on Scratch programming with *a tinkering*, *making*, and *remixing* approach. The design includes seven learning activities designed to range from creative exploration of technology to understanding formal math concepts in the classroom. Through this activity, students are directed to understand the concept of LCM in a more contextual and interactive way using Scratch. It is hoped that this hypothetical learning trajectory design can be a reference for educators in implementing programming-based LCM learning,

The suggestion in this study is that after knowing the results of the *hypothetical learning trajectory* design for Scratch-based LCM learning with a tinkering, making, and remixing approach, the researcher can then proceed to the *teaching experiment* and *retrospective analysis* stage to test the effectiveness of such designs in the context of real learning. Thus, the results of this study can make a more comprehensive contribution to the development of computational thinking learning based on scarcth programming

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