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DEVELOPING METACOGNITIVE SKILLS FOR STUDENTS IN TEACHING MATHEMATICAL ANALYSIS AT HIGH SCHOOL

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THE AUTHOR'S PUBLICATIONS
RELATED TO THE DISSERTATION TOPIC

1. Phi Van Thuy (2015), *Fostering students' competence to mobilize knowledge through teaching math solutions in high schools*, Journal of Education, 363, Volume 1, August, p.44- 48
2. Hoang Xuan Binh, Phi Van Thuy (2016), *Fostering metacognitive skills for students through solving spatial geometry exercises in high school*, Journal of Education, No. 385, Volume 1, July, pp.47-50.
3. Phi Van Thuy (2016), *Metacognitive model in solving mathematical problems*, Journal of Educational Management, No. 8, August, pp.53-58.
4. Hoang Xuan Binh, Phi Van Thuy (2016), *The role of metacognition in teaching Mathematics in high schools*, Journal of Education, special issue, November, pp.236-237, 218.
5. Phi Van Thuy (2017), *Developing students' metacognitive skills in Mathematics classroom*. Anale. Series Informatica. Vol. XV fasc. 1.
6. Phi Van Thuy (2019), *Measures to develop metacognitive skills for students in teaching Mathematical Analysis in high schools*, Vietnam Journal of Educational Sciences. No. 18, June, p. 78-83.
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PART I. INTRODUCTION

1. Reason for choosing the research topic

"Metacognition" or "thinking about thinking" is explained as the ability to monitor, direct, and manage an individual's thought process, especially the cognition of selecting and using problem-solving strategies. Metacognition is self-control of our thought processes while solving problems. Developing metacognitive skills for students in the process of teaching and learning high school mathematics is a new teaching trend that is being paid attention to in many countries in the world today (Thailand, Singapore, USA...). The development of metacognitive skills for students is to help students understand their own thinking process in the process of learning math and the value of learning math.

In Mathematics at high school, Mathematical Analysis is an important content whose subject matters are variable, continuous and infinite in nature. Different from the type of thinking when studying Algebra, which is a "finite" and "discrete" thinking, the thinking when studying Mathematical Analysis is characterized by a "dynamic" and "infinite" type of thinking, which makes the methods and thinking techniques that learners need to use when learning this content also different. It is the difference in the nature of the subject matters, thinking styles, methods and specific techniques when learning Algebra and Mathematical Analysis that creates certain difficulties for teachers and students in the teaching process. The reason is that students are familiar with the subject matters, thinking patterns, and technical methods of Algebra. In Mathematical Analysis, concepts such as limit, continuous function, and derivative are basic and important concepts, and are typical concepts of thought in Mathematical Analysis. These are difficult concepts to teach and understand in the program. In teaching Mathematical Analysis, if students can build by themselves the concepts of a series of numbers with a finite limit, a finite limit of a function, a continuous function at a point, a continuous function on an interval, a segment, the derivative of the function at a point, this will be convenient for the construction of analytic knowledge later. Therefore, Mathematical Analysis has the necessary characteristics, suitable for the development of metacognitive skills for students, and vice versa, to learn well Mathematical Analysis, students need to develop metacognitive skills.

In our country, there are now a number of documents on teaching methods and a number of research works that have mentioned how to adjust the learning process and cognitive acquisition of students in the direction of promoting positivity, creativity and self-control. However, they have not explicitly mentioned about developing metacognitive skills for students, while in the world today, the trend of teaching towards the development of cognitive

abilities for students is actually a new teaching trend. Therefore, we would like to focus our research on clarifying metacognitive skills and ways to develop those metacognitive skills, as well as clarifying the importance of developing these metacognitive skills for students in teaching Mathematical Analysis in high schools. Accordingly, we can identify, develop and propose measures to develop metacognitive skills in teaching mathematics in our country in specific cases.

Stemming from the above reasons, we chose the research topic: ***"Developing metacognitive skills for students in teaching Mathematical Analysis at high school".***

2. Research Aims

Identify metacognitive skills and propose some possible measures to develop students' metacognitive skills in teaching Mathematical Analysis in high schools to contribute to improving teaching and learning efficiency in Mathematical Analysis in High School.

3. Research object and subject

3.1. Research subject

The process of teaching Mathematical Analysis for high school students.

3.2. Research object

Important and relevant metacognitive skills need to be developed for students in teaching Mathematical Analysis in high schools.

4. Scientific hypothesis

If the necessary metacognitive skills are identified and can be developed for students and at the same time develop some suitable and feasible pedagogical measures, it is possible to develop students' metacognitive skills in teaching Mathematical Analysis in high schools, thereby developing students' thinking competence, contributing to improving the quality and effectiveness of teaching Mathematical Analysis in high schools.

5. Research tasks and scope

5.1. Research tasks

1. Study the theoretical basis of metacognitive skills.

2. Study the formation and development of metacognitive skills for students in teaching Mathematical Analysis in high schools. Identify some metacognitive skills necessary to be developed for students in teaching Mathematical Analysis in high schools.

3. Investigate the current situation of teaching Mathematical Analysis in high schools in the direction of developing metacognitive skills for students.

4. Propose some pedagogical measures to develop students' metacognitive skills in teaching Mathematical Analysis in high schools.

5. Conduct pedagogical experiment to test the effectiveness and feasibility of the proposed measures.

5.2. Research scope

Due to the content framework and research time, we only focus on identifying and building pedagogical measures to develop students' metacognitive skills in teaching Mathematical Analysis content at high school.

6. Research Methods

6.1. Theoretical research methods

This method is used to study issues related to the topic. Specifically, this method is used to analyze and synthesize philosophical, psychological, and pedagogical perspectives on active teaching, thinking, competence, cognition, and metacognition. Accordingly, there is a theoretical basis for evaluating the results of investigation, research, and application in teaching and learning Mathematics.

6.2. Observation and investigation methods

Conduct observation of teachers teaching and students learning; Use questionnaires, have in-depth discussions with educators, groups of teachers and students about attitudes, motivations for teaching and learning, active teaching methods, and development of thinking and metacognition. Use qualitative and quantitative methods in research; the results of investigations and surveys will be summarized and analyzed specifically as a basis for proposing solutions.

6.3. Pedagogical Experiment

This method is used to test the feasibility and effectiveness of pedagogical measures to develop students' metacognitive skills in teaching Mathematical Analysis in high schools.

6.4. Mathematical statistical methods

This method is used to assess learning outcomes through tests.

7. Contributions of the thesis

7.1. Theoretical contributions

- Systematize, analyze and synthesize concepts, models and research results in the world on metacognition.

- Identify some basic components, characteristics and functions of metacognition and point out the role of metacognition in education in general and in teaching mathematics in particular.

- Study the difference between cognition and metacognition.

- Possibility to form metacognitive skills in teaching Mathematical Analysis. Compatible activities in teaching Mathematical Analysis to develop metacognitive skills.

- Identify the scientific basis for the formation and development of metacognitive skills for students in teaching Mathematical Analysis in high schools.

- Identify some metacognitive skills necessary to be developed for students in teaching Mathematical Analysis in high schools.

7.2. Practical contributions

- Propose pedagogical measures to develop students' metacognitive skills in teaching Mathematical Analysis in high schools, contributing to innovating math teaching methods towards developing metacognitive skills, thus improving teaching and learning efficiency in high schools.

- The thesis is a reference for teachers, students and graduate students majoring in Theory and Methods of Teaching Mathematics.

8. Arguments to be defended

8.1. Establish grounded and reliable bases for metacognitive skills (04 metacognitive skills).

8.2. Some compatible activities to develop students' metacognitive skills in teaching Mathematical Analysis in high schools (04 compatible activities).

8.3. Basic orientation to build and implement measures to develop metacognitive skills (05 orientations).

8.4. Proposed pedagogical measures to develop students' metacognitive skills in teaching Mathematical Analysis in high schools (05 measures).

9. Thesis structure

In addition to the Introduction and Conclusion, the thesis content consists of 3 chapters.

Chapter 1. Theoretical and practical basis

Chapter 2. Some measures to develop students' metacognitive skills in teaching Mathematical Analysis in high schools.

Chapter 3. Pedagogical Experiment

PART 2. RESEARCH RESULTS

Chapter 1
THEORETICAL AND PRACTICAL BASIS

1.1. A historical overview of research on metacognition

1.1.1. International research on metacognition

1.1.1.1. Research on the origin of the concept of metacognition

1.1.1.2. Some studies on metacognition in education

1.1.2. Research on metacognition in education in Vietnam

1.2. Cognition

1.2.1. What is cognition?

1.2.2. The nature of cognition

1.2.4. Cognitive activity

1.2.5. Levels of cognitive processes

1.3. Metacognition

1.3.1. What is metacognition?

In this study, we use J.H.Flavell's definition of metacognition, according to which *metacognition is an individual's understanding related to his/her own*

cognitive processes, products and other factors. It also refers to actively monitoring, adjusting results, and aligning these processes to stay on track towards set goals".

1.3.2. Some models of metacognition

1.3.2.1. Components of metacognition

Although there are different definitions of metacognition and while the descriptions of the components of metacognition by different researchers also differ, most researchers nevertheless believe that metacognition consists of these components: planning; monitoring; adjusting cognitive processes; assessing cognitive processes. Therefore, in this study, we also use Tobias & Everson's research results on the components of metacognition: planning; monitoring; adjusting cognitive processes; assessing cognitive processes.

1.3.2.2. Some models of metacognition

a) The model by J.H. Flavell

b) The model by Ann Brown

c) The model by Tobias & Everson

d) The model by Nelson and Narens

1.3.3. Features and functions of metacognition

1.3.3.1. Features of metacognition

Based on the studies on the characteristics of metacognition, we can point out that the basic and important features of metacognition are:

+ Metacognitive knowledge is relatively stable

+ Metacognitive knowledge can be observed and communicated – spoken out.

+ Metacognitive knowledge can lead to faulty reasoning and incorrect ideas.

+ Metacognitive knowledge comes after cognition

+ Metacognitive control is associated with the cognitive activity of students or others, that is, it depends on the specific situation and task.

+ Metacognitive control is unstable.

+ Metacognitive control is independent of age

+ Metacognitive control is inaccessible and uncommunicable.

Metacognition originates from within the human mind and is associated with mental and spiritual activities and the way one perceives matter. Metacognition is an integral part of information processing and plays an important role in most tasks students perform.

1.3.3.2. Functions of metacognition

After reviewing researches, we believe that metacognition has the following functions: the function of perceiving one's own cognition; the function of planning and selecting strategies; the function of monitoring and regulating cognitive processes; the function of assessing cognitive processes

1.3.4. Some research results on the role of metacognition in learning

1.3.5. The difference between cognition and metacognition

Flavell (1979), in his model assumption of cognition and metacognition, stated that they differ in contents and functions.

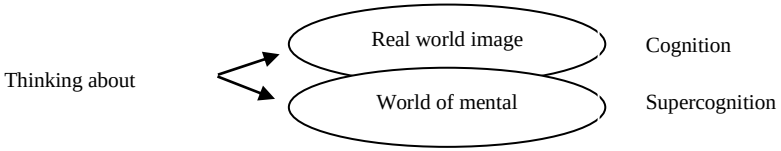

Figure 1.8. Metacognitive and cognitive models

To better understand the above metacognitive and cognitive models and the difference between cognition and metacognition, we illustrate in the following comparison table:

Related problems	**Cognition**	**Metacognition**
Concept	According to *the Dictionary of Psychology: "Cognition is understanding something, acquiring knowledge about something, understanding the laws of certain phenomena and processes"*	Flavell (1976) stated that metacognition is: *"Individual knowledge related to self-perceiving processes, products, and other related factors, including active monitoring, adjusting the results and aligning these processes to always work towards the set goals".*
Contents	Cognition includes objects, people, events, psychological phenomena, skills to deal with these problems and information about the task.	Metacognition includes knowledge, strategies, skills, and cognitive information. It can be said that "metacognition is not derived from reality outside the subject but is associated with mental and spiritual activities, which can include what a person knows about the introspection process, how to perform and how people perceive it" (Hacker, 1998)
Features	***Features of cognition*** According to the point of view of dialectical materialism, human cognition has the following characteristics: + Cognition is the process of human thinking going from the particular to the general, from the phenomenon to the nature; + Cognition follow the principle of going from abstract to concrete; + Cognition is also an abstraction and generalization.	***Features of metacognition*** - Cognition of one's own thinking process. + Monitor and direct cognitive activities + Regulate and operate the cognitive process + Assess cognitive processes
Function	Cognition functions to solve problems and bring about results after solving problems	+ Function of perceving one's own cognition + Function of planning and selecting strategies + Function of monitoring and adjusting cognitive processes

Related problems	Cognition	Metacognition
		+ Function of assessing cognitive processes
The object of the activity	The object of cognitive activity is: + Knowledge and methods + Things and phenomenon + Certain rules and processes	The object of metacognitive activity is: + Choose a problem-solving strategy; + activities to monitor and administer the cognitive process; + activities to compare and adapt the problem-solving process + Evaluate the thinking process in accordance with the law; + Assess the cognitive process according to a scientific logic: Choosing the right methods and premise knowledge to properly solve problems; + Reflect on the way of thinking.
Products	Cognitive products are the results of problem solving such as math learning results, problem solving results.	The product of metacognition is to make the cognitive process more efficient, which indirectly contributes to problem-solving outcomes.
Example	When solving a math problem, students use knowledge and skills to solve that problem	When solving a math problem, students realize that they can't solve the problem; they can stop to think, connect with the knowledge that is related to the problem and choose knowledge and methods to solve that problem.

Although cognition and metacognition have the above differences, cognition and metacognition still have a close and supportive relationship with each other; There is a cognitive process, then there is a metacognitive process and vice versa. Metacognitive process will help the cognitive process better. In other words, metacognition is an activity and takes place in the cognitive process.

1.4. Supercognitive skills

1.4.1. Skills

In this thesis, we conceive that: ***Skill is the ability to effectively perform an action by selecting and applying existing knowledge and experiences to act in accordance with specific conditions.***

1.4.2. Cognitive skills

There are many ways to understand cognitive skills, but all researchers agree that: *Cognitive skills are a set of information processing abilities related to knowledge, attention, memory, choice of solutions, judgmen, reasoning, logic, decision. Skills are abilities used to learn, understand, and integrate information in a meaningful way.*

1.4.3. Metacognitive skill

1.4.3.1. Concept of metacognitive skill

We believe that: ***Metacognitive skill is the ability to monitor, manage and direct cognitive activities; it includes the skills of planning, supervising, processing and assessing cognitive processes.***

1.4.3.2. Some components of metacognitive skills

Although there are different definitions of metacognition, and there are different models of metacognition, domestic and foreign researchers agree that metacognitive skills the skills of planning, supervising, adjusting and assessing cognitive processes. In this study, we also agree with most of the researchers as we think that ***the important component skills of metacognitive skills include the skills of planning, supervising, adjusting and assessing cognitive processes.***

1.4.3.3. Relationship between metacognitive skills and cognitive skills

In our opinion, metacognitive skills and cognitive skills are closely linked and can be relatively distinguished. The activities of metacognitive skills are based on the activities of cognitive skills, and conversely, only when there are cognitive skills, there are metacognitive skills. These two types of skills exist side by side and support each other.

1.4.4. Component skills of metacognitive skills in math learning

1.4.4.1 Planning skills

1.4.4.2. Supervising skills

1.4.4.3. Adjusting skill

1.4.4.4. Assessing skills

1.4.5. The role and meaning of developing metacognitive skills

1.4.6. Effective criteria for developing metacognitive skills

1.5. Developing students' metacognitive skills in teaching Mathematical Analysis in high schools

1.5.1. Features of teaching Mathematical Analysis

1.5.2. Possibility to form metacognitive skills through teaching Mathematical Analysis

Here are some possibilities to form metacognitive skills through teaching Mathematical Analysis

- Possibility to build problem-solving skills

- Possibility to form adaptability skills

- Possibility to develop evaluation skills (look back at the problem solving process)

- Possibility to develop skills of detecting and correcting mistakes

-The Possibility to generalize the problem and expand the problem

- The Possibility to evaluate the problem-solving method and lessons learned to occupy

1.5.3. Compatible activities in teaching Mathematical Analysis to develop metacognitive skills

Metacognitive activity is essential in applying the strategies of metacognitive knowledge to achieve cognitive goals. It enables the regulations and control of cognitive processes (Alexander, Carr, & Schwanen flugel, 1995).

Through research on the components of metacognitive skills, we found that compatible activities in teaching Mathematical Analysis to develop metacognitive skills include the following 04 activities:

- Problem-defining activity, which is revealed through the following activities:

+ activities of identifying and stating problems:

+ activities of identifying and analyzing information:

+ activities of detecting contradictions and obstacles and ways to overcome them

+ activities of dividing the problem into smaller problems to solve (a thinking manipulation: analysis and synthesis).

+ activities of associating and mobilizing premise knowledge.

+ activities of abstracting: remove unnecessary components for thinking (Ex: Definition of function limit, Limit of function of the form $\frac{0}{\infty}; \frac{L}{0}, (L \neq 0)$*)*

- activities of choosing a problem-solving method,

+ activities of mobilizing methodological knowledge

+ activities of determining how to solve the problem:

- activities of adjusting the cognitive process: this activity is conducted through some of the following activities:

+ activities of contrasting, comparison and modulation (Compare the limit of a series and limit of a function; Compare arithmetic progressions and geometric progression*)*

+ activities of transforming language

+ activities of familiarization

+ activities of detecting and correcting mistakes

- activities of assessing cognitive processes: this activity is conducted through some of the following activities:

+ activity of looking back on the cognitive process

+ activities of studying the solutions

+ activities of generalizing and expanding related problems

+ activities of mathematizing practical problems (using derivatives to calculate acceleration and velocity of objects)

In short, when students are trained in the above activities, it means that students are trained in thinking operations such as analysis - synthesis; compare - contrast; generalization - abstraction; predict - estimate; thus, forming metacognitive skills for students.

1.6. The current situation of developing metacognitive skills for students in teaching Mathematical Analysis in high schools

1.6.1. Situation survey

1.6.1.1. Survey purpose

1.6.1.2. Reasons for choosing the survey sample and characteristics of the survey sample

1.6.1.3. Participants and time of survey

1.6.1.4. Survey contents

1.6.1.5. Survey methods

1.6.1.6. Survey results

1.6.2. Analyze the causes of the current situation

In summary, in order to develop students' metacognitive skills in teaching Mathematical Analysis, teachers must have an understanding of metacognition, metacognitive skills and measures to develop those metacognitive skills. Accordingly, teachers create a knowledge chain to build a series of sample problems to reinforce and deepen concepts, theorems and solutions. On the other hand, special attention should be paid to building a series of problems so that students can develop metacognitive skills. In addition, a scale is needed to assess the change in metacognitive skills of each student after students are trained in metacognitive skills.

1.7. Conclusion of chapter 1

Metacognition is a concept that was explicitly introduced by scientists in the 70s of the twentieth century, although up to now there have been many different studies on it and the researchers have also provided interpretations of different concepts, basically, the content of this concept is relatively consistent. Most of the research works on it agree that *metacognition is a higher level of cognition, a process by which students monitor and adjust their thinking to bring about greater efficiency in problem solving.*

In Chapter 1 of the thesis, the following specific issues were studied:

i) The researcher has reviewed important domestic and international studies on metacognition, the role and significance of metacognition. At the same time, this literature review helps us see the number of studies on metacognition in the world as well as in Vietnam.

ii) The researcher has given his own concept of metacognition, which is the basis for the thesis research, identified the characteristics of as well as pointed out the functions of metacognition; distinguished the difference between cognition and metacognition; and pointed out the relationship between cognition and metacognition to serve as a basis for distinguishing cognitive activities in the process of solving problems.

iii) The thesis has identified the basic components of metacognitive skills, including: planning; monitoring, adjusting, and evaluating cognitive processes, which form the basis for skills identification. At the same time, the thesis has identified compatible activities to practice skills, which serves as the foundation for proposing measures to practice skills in Chapter 2.

iv) The thesis has investigated the current situation and some causes leading to the current situation of developing cognitive skills for students in teaching Mathematics in high schools in our country today.

Chapter 2
SOME MEASURES TO DEVELOP METACOGNITIVE SKILLS FOR STUDENTS IN TEACHING MATHEMATICAL ANALYSIS IN HIGH SCHOOL

In Chapter 1, we have clarified the theoretical and practical basis of the concept of metacognitive skills. From those theoretical and practical bases, chapter 2 of the thesis will study and develop some measures to develop metacognitive skills for students in teaching Mathematical Analysis in high schools.

2.1. Orientation for building and implementing pedagogical measures

2.1.1. Orientation 1

Pedagogical measures must be consistent with the renovation of the overall general education program and should closely follow the current requirements of teaching methods, and at the same time, the measures must be feasible and contribute to improving the quality of teaching and learning Mathematical Analysis in high school.

2.1.2. Orientation 2

Create conditions for students to practice skills of monitoring, adjusting and evaluating thinking operations and how to develop these skills for students through the problem-solving process.

2.1.3. Orientation 3

Teachers present problems that require students to plan (before solving the problem), detect and correct mistakes (during problem solving) and evaluate (after solving problems).

2.1.4. Orientation 4

Organize for students to explore, discover many different solutions to a problem and check the appropriateness and rationality of each solution. Encourage students to actively think, control and adjust thinking operations in the process of associating and mobilizing pre-requisite knowledge and methodological knowledge to solve specific problems. At the same time, encourage students to create and expand related problems.

2.1.5. Orientation 5

Allow students to discuss their thoughts on how to solve a problem quickly and efficiently, and explain the different methods they have used to solve the problem.

2.2. Some pedagogical measures to develop students' metacognitive skills in teaching Mathematical Analysis in high schools

2.2.1. Measure 1: Develop planning skills for students in the process of learning mathematics Mathematical Analysis through activities of associating and mobilizing knowledge

Purpose of the measure

The purpose of this measure is to develop planning skills for students (which is one of the metacognitive skills) through activities of associating and mobilizing premise knowledge, methodological knowledge, experiences and students' own strengths and potentials, thereby forming planning skills for students in the process of learning Mathematical Analysis in high school.

Scientific basis of the measure

According to G. Polya *"The process of solving a problem is like the process of building a house, first gathering the necessary materials and then structuring the discrete materials into a whole according to a design pattern already envisioned"*. Usually, before embarking on solving a specific problem, the solver has accumulated a lot of knowledge, but at this time, which knowledge to use is often not clearly stated in the problem. However, G.Polya also asserted that *"No matter what our problem is, we can be confident that in order to solve that problem, we must apply the knowledge we have learned"*.

In the process of solving a particular problem, of course, it is not necessary to mobilize all the knowledge that the solver has collected and accumulated in advance. What knowledge should be mobilized and what relationships should be considered depends on *the selective ability* of math learners. Math learners have accumulated such knowledge in memory, so now they can draw out and apply it appropriately to solve problems. G. Polya refer to such selective recall of knowledge as *mobilization*.

In summary, in order to develop planning skills for students, it is necessary for students to have activities to associate and mobilize known knowledge and methods to find a solution and at the same time, students will make a plan to solve that problem.

How to implement the measure

To develop planning skills for students in the process of learning Mathematical Analysis through activities of associating and mobilizing knowledge, the teacher raise some problems related to the process of learning Mathematical Analysis and ask students to perform the following activities:

- Problem-defining activity: what is the problem to be solved, what is given in the problem?
- Divide the problem to be solved into smaller ones.
- Identify key problems, obstacles and advantages

- Associate and mobilize knowledge, methodological knowledge and experience related to the problem to be solved

- activities of selecting knowledge and methods to solve problems

- Compare and adjust to find the right way to solve the problem

After students define the problem and mobilize knowledge to find a way to solve the problem, the teacher asks the students to make a plan to solve that problem, through which the students can practice problem-solving planning skills.

2.2.2. Measure 2: Develop monitoring and adjusting skills for students through activities of analyzing, detecting and correcting mistakes in the process of learning Mathematical Analysis.

Purpose of the measure

The purpose of this measure is to develop monitoring and adjusting skills for students through activities such as analysis, criticism, review and comparison in order to detect errors and unreasonableness as well as obstacles and gaps in knowledge, reasoning, and suitability and optimization... in the learning process of students.

Scientific basis of the measure

According to G. Polya, one of the steps to take in the process of solving a problem is to look back at the solution: “try to perfect the small and large parts of the solution, and finally find a way to perfect the whole solution, make the solution intuitively correct", "check carefully the method you have followed, try to get the main part of it and apply it to another problem". This is a necessary and useful step that in fact few students do it.

The reality shows that many students solve problems incorrectly, but they do not know they are wrong because they are very weak in detecting and correcting mistakes in the process of solving a problem. This is clearly shown in the survey results of students' math learning (see the test results of 30 students). Therefore, it is very necessary to develop students’ skills of monitoring, self-detection and correction of mistakes. In order to detect mistakes in the process of solving problems, students must first have knowledge and methods of solving problems, then check each step of the solution.

In short, wrong thinking at the beginning will lead to the wrong end result of the thinking process. This wastes students' time, effort and intelligence. Therefore, in the process of learning math, early detection of errors will help them promptly adjust, supplement and correct mistakes, which has a very important meaning for the results of the math problems.

How to implement the measure

In order to develop students’ skills of monitoring and adjustment through activities of analyzing, detecting and correcting mistakes in the process of learning Mathematical Analysis, teachers give problems so that when students solve that problem, often make mistakes. Accordingly,

students have the chance to practice monitoring and adjustment skills in the problem-solving process.

Teacher asks students to do the following activities:

- Identify problems to be solved, key issues, difficulties and contradictions.
- Teacher asks students to solve the problem
- Review the problem solving process
- Teacher asks students to perform activities such as comparing, contrasting, detecting mistakes and adjusting, supplementing and correcting mistakes.
- Identify the cause of the error
- Detect mistakes (how to detect mistakes)
- How to correct mistakes and overcome difficulties and obstacles.

Accordingly, students' skills of monitoring and adjusting cognitive processes have been improved.

In short, through organizing for students to detect and correct mistakes in the problem-solving process - the cognitive process, students can develop the skills of monitoring and adjusting the cognitive process.

2.2.3. Measure 3: Develop monitoring and adjusting skills for students by enabling students to actively speak out their thoughts related to the problem to be solved and clarify those thoughts.

Purpose of the measure

The purpose of this measure is to develop monitoring and adjusting skills for students in the learning process by creating conditions for students to actively speak out their thoughts related to the problem to be solved such as: difficulties, obstacles, advantages or insights about the problem they are dealing with, as well as suggestions for ideas, solutions and explanations of the bases that lead to those thoughts, thereby, helping students to deeply understand the problems they need to solve. Accordingly, students can develop their monitoring and adjustment skills in the cognitive process.

Scientific basis of the measure

The method of speaking out loud their thoughts will help students develop thinking ability. Metacognitive developing strategic programs emphasize the importance of stimulating students to explain and justify their thoughts (eg, Zimmerman, 1998; Zimmerman & Kitsantas, 1999). King (1992) studied the use of guiding questions to help students express what they are thinking and where they are thinking. Bandura (1997) and Zimmerman used social models to promote students' ability to articulate personal goals for learning. Studies suggest that students do not self-explain their thoughts during the learning process unless they are encouraged to do so.

Explanation is the process of clarifying and making more complete the problem one is solving. Some studies show that students understand more when they explain their thoughts about it. Furthermore, self-explanation is often less

effective when explanations are requested by others, because it requires them to actively think about and mobilize their existing knowledge.

In short, by creating conditions for students to actively and boldly speak out their thoughts related to the problem being solved and clearly explain those thoughts. This contributes to developing students' skills of supervision and adjustment in the problem-solving process.

How to implement the measure

In order to develop monitoring and adjusting skills for students by creating conditions for students to actively speak out their thoughts related to the problem to be solved and clearly explain those thoughts, the teacher gives problems related to the process of learning Mathematical Analysis. Then, the teacher asks the students to do the following activities:

- Divide the class into groups and ask students in the group to discuss their ideas together. The teacher plays the role of an organizer, guide and referee, while the student plays a central role in problem solving.

- Teacher asks each group and each student to do the following activities:

+ Investigate the problem and then speak out their thoughts about the difficulties, obstacles, advantages in the process of finding a way to solve the problem posed to create conditions for students to actively speak out their thoughts related to the problem to be solved and clearly explain those thoughts.

2.2.4. Measure 4: Develop students' skills of assessing cognitive processes through developing students' habit of looking back at the problem solving process

Purpose of the measure

The purpose of this measure is to help students form the habit of looking back at the problem solving process. Thereby, it not only helps students detect and correct mistakes in the process of solving problems in a timely manner, but also systematically gain knowledge, learn lessons for the next problem-solving and understand the meaning of the problem. Accordingly, students have been trained to evaluate cognitive processes.

Scientific basis of the measure

G. Polya argues that "…no problem is final. There is always something left to think about". This statement has shown the prominence in the pedagogical thought of G. Polya at the stage of looking back at the problem: "Focus on finding more optimal solutions and exploiting and developing problems creatively". Focusing on finding more optimal solutions or developing problems more creatively can only happen when learners re-evaluate their own thinking processes.

How to implement the measure

In order to develop students' skills of evaluating cognitive processes through developing students' habit of reviewing the problem-solving process in

teaching Mathematical Analysis, teachers need to lead students to perform the following operations:

- Guide students to evaluate their problem solving process based on the requirement to solve.

- The teacher guides the students to look back at the problem-solving process by converting it into questions. These questions are asked by students themselves or students ask students or teachers ask students, specifically as follows:

+ Are the results correct?

+ Are the steps to solve the problem correct?

+ Are the transformation steps correct?

+ Have you considered all the cases yet?

+ Is the argument rigorous?

+ Is the presentation scientific and reasonable?

+ What causes difficulties and deadlocks?

+ What is the cause of the error?

+ Is this solution optimal? Is there any other better solution?

+ Is the time schedule when implementing reasonable?

+ What is the meaning of the problem?

+ What are the lessons learned after solving the problem?

+ How effective and quality is the problem solving?

+ What is the problem associated with this problem

+ What is the problem extension and practical relevance of this problem?

2.2.5. Measure 5: Organize teaching to encourage students practice and control thinking operations in activities of mathematicized practical situations

Purpose of the measure:

The purpose of this measure is to help students control thinking operations through applying mathematical knowledge to solve practical problems. In order to apply knowledge into practice, students must have thinking manipulations and control thinking operations such as contrasting, comparing, analyzing and adjusting in the process of converting real-world problems into familiar problems (mathematicalization of practical situations). Thereby, students are trained to control thinking manipulation skills. In addition, it also clarifies the important role of developing students' skills of applying mathematical knowledge to solve some problems with practical content, and at the same time understanding the effects of the problem.

Scientific basis of the measure:

We have known that the first mathematical knowledge of mankind about arithmetic, geometry, trigonometry, etc., were born from the need of practice. Numbers arose and evolved from the need for counting and calculation; geometry arose in Egypt from the need to measure the land...

With the purpose of helping students realize that mathematics is very close to the surrounding life, absolutely very practical and the acquisition of math knowledge at the school is not only for exams but it is also an effective tool which helps them solve problems and situations from simple to complex in real life. This is one of the ways to foster metacognitive skills for students.

How to implement the measure

Teachers give problems related to real situations and related to mathematics (practical problems) such as: Measurement, calculation, drawing, economic, production, engineering problems for students to solve.

Teachers organize and guide students to practice controlling thinking operations to convert practical problems into familiar problems through the following activities:

+ Choose knowledge and methods to solve problems

+ What are the conflicts that need to be resolved?

+ Can the problem be broken down into small problems that are easy to solve?

+ Predict, estimate possible solutions and results

+ Analyze and synthesize knowledge, lessons learned after solving problems

+ Compare and contrast with previous knowledge, methods and and solved problems.

+ Evaluate and expand related and practical problems

+ Review to understand important relationships

+ Stop to check understanding

2.3. Conclusion of chapter 2

Metacognition or "thinking about thinking" refers to the cognition of cognition and the ability to control a person's thought processes, especially the ability to control, choose, and use problem-solving strategies. Proposing measures and organize teaching to develop these skills for students is very necessary to help students develop the competence of planning, monitoring, adjusting, and evaluating in their cognitive processes.

In summary, chapter 2 of the thesis has studied the following issues:

- The thesis has pointed out directions for building pedagogical measures, and based on these orientations, we have built 05 pedagogical measures to develop metacognitive skills for students.

- The thesis has developed 05 suitable and feasible pedagogical measures. In each measure, the purpose, scientific basis of the measure and how to implement the measure were clearly stated. This has helped teachers and students know what skills to be developed as well as what pedagogical measures to be taken. Accordingly, it helps the teaching process of Mathematical Analysis to be much more effective.

- The thesis has built a system of methods to implement pedagogical measures through specific activities in each example.

- The thesis has helped teachers and students know how to teach and learn theorems, concepts, rules and model exercises suitable for students.

- The thesis has built a system of diverse and rich Mathematical Analysis exercises, suitable for the proposed measures and suitable for each individual of high school students in different regions across the country.

- With 05 orientations to build measures and 05 specific pedagogical measures to develop students' skills, chapter 2 will serve as the basis for chapter 03 of the thesis to conduct pedagogical experiment y to test the feasibility and effectiveness of the proposed measures.

Chapter 3
PEDAGOGICAL EXPERIMENTS

3.1. Purpose, requirements, and content of pedagogical experiments

3.1.1. Purpose

Pedagogical experiment aims to test the scientific hypothesis of the thesis through teaching practice; test the student's change in thinking control and adjustment in the problem solving process; thereby, examining the feasibility of measures to develop metacognitive skills in teaching Mathematical Analysis in high schools.

3.1.2. Requirements

Pedagogical experiments must ensure the objectivity of the experiments and be suitable for students, close to the actual teaching situation in many different regions.

3.1.3. Pedagogical experimental contents

Conduct 3 pedagogical experiments on 3 measures, in 12 teaching periods

Measure 1: Develop planning skills for students in the process of learning Mathematical Analysis through activities of associating and mobilizing knowledge (4 periods).

Measure 4: Develop students' skills of assessing cognitive processes through developing students' habit of looking back at the problem solving process (4 periods).

Measure 5: Organize teaching to encourage students practice and control thinking operations in activities of mathematicized practical situations (4 periods).

The specific contents of the experimental periods are presented in the appendix.

3.2. Experimental hypothesis, methods to organize experiments and methods to choose experimental participants

3.2.1. Experimental hypothesis

If the experiment meets the requirements and gives feasible results of pedagogical measures, it will contribute to improving the quality of teaching Mathematical Analysis in high schools.

3.2.2. How to organize the experiment?

3.2.3. How to choose experimental participants?

3.3. Time, participants, process and method of evaluating the pedagogical experiment

3.3.1. Pedagogical experiment time

- Round 1: From November 2018 to December 2018
- Round 2: From March 2019 to May 2019.

3.3.2. Participants of the pedagogical experiment

The thesis conducted pedagogical experiments at 5 high schools in different provinces, namely: Dong Nai province and Da Nang city.

- Le Hong Phong High School, Bien Hoa City, Dong Nai Province
- Long Thanh High School, Long Thanh District, Dong Nai Province
- Tran Bien High School, Bien Hoa City, Dong Nai Province
- Nguyen Trai High School, Bien Hoa City, Dong Nai Province
- Thai Phien High School, Da Nang city

The experimental classes and the control classes have relatively equal knowledge levels and equivalent learning outcomes. The teachers participating in teaching in the experimental class and the control class all have bachelor's and master's degrees with rich teaching experience.

List of experimental classes and control classes in pedagogical experiment round 1:

High School	Number of students/class		Teachers
Le Hong Phong	Experimental class with 37 students	12	Nguyen Thi Yen
	Control class with 39 students	12	Vu Thi Ngat
Long Thanh	Experimental class with 41 students	12	Nguyen Duc Nang
	Control class with 37 students	12	
Tran Bien	Experimental class with 41 students	12	Luu Anh Duc
	Control class with 38 students	12	
Nguyen Trai	Experimental class with 39 students	12	Dinh Van Trung
	Control class with 42 students	12	Huynh Ngoc Thuy
Thai Phien	Experimental class with 37 students	12	Dang Cong Vinh
	Control class with 43 students	12	

There were 394 students in total, in which, 195 students were in the experimental group and 199 students were in the control group and 07 experimental teachers.

Các nhóm lớp thực nghiệm, nhóm lớp đối chứng khi thực nghiệm sư phạm vòng 2:

List of experimental classes and control classes in pedagogical experiment round 2:

High School	Number of students/class		Teachers
Le Hong Phong	Experimental class with 38 students	12	Nguyen Thi Yen
	Control class with 39 students	12	Vu Thi Ngat
Long Thanh	Experimental class with 41 students	12	Nguyen Duc Nang
	Control class with 38 students	12	
Tran Bien	Experimental class with 41 students	12	Luu Anh Duc
	Control class with 38 students	12	
Nguyen Trai	Experimental class with 39 students	12	Dinh Van Trung
	Control class with 42 students	12	Huynh Ngoc Thuy
Thai Phien	Experimental class with 38 students	12	Dang Cong Vinh
	Control class with 41 students	12	

There were 395 students in total, in which, 197 students were in the experimental group and 199 students were in the control group and 07 experimental teachers.

3.3.3. The process of organizing pedagogical experiments

3.3.4. Methods of evaluating pedagogical experimental results

**** Evaluation contents***

Evaluate the feasibility and effectiveness of measures to develop metacognitive skills for students in teaching Mathematical Analysis in high schools.

**** Methods of evaluating pedagogical experimental results***

To evaluate the above contents, we use the following tools:

a) Written test:

b) Questionnaires for students:

c) Observations in the classroom:

d) Interview:

e) Asking questions:

f) Mathematical statistics:

3.4. Pedagogical experimental process

3.4.1. Pedagogical experiment round 1

a) Analyze the quality of students before conducting pedagogical experiments (round 1)

To conduct experimental sample selection, we required students to take quality tests and analyze the test results. We selected 2 groups of experimental and control classes with similar results, including 394 students of grade 12 (in which 195 students belonged to 5 groups of experimental classes and 199 students belonged to 5 groups of control classes) of the following 5 high schools:

- Le Hong Phong High School, Bien Hoa City, Dong Nai Province
- Long Thanh High School, Long Thanh District, Dong Nai Province
- Tran Bien High School, Bien Hoa City, Dong Nai Province
- Nguyen Trai High School, Bien Hoa City, Dong Nai Province
- Thai Phien High School, Da Nang city

b) Contents of pedagogical experiment round 1

Analyze the results of the experimental group as follows:

Step 1: Observe students learning in the classroom to assess the process of acquiring knowledge of students.

Step 2: Organize two written tests for students in the experimental group and the control group after the teacher has finished teaching measures to develop students' metacognitive skills in teaching Mathematical Analysis.

Step 3: Organize the distribution of questionnaires to teachers and students; Interviewing teachers and students after pedagogical experimental lessons.

c) Results of the pedagogical experiment - round 1

Qualitative results:

Quantitative results:

3.4.2. Pedagogical experiment round 2

After the first round of the pedagogical experiment, the researcher learned from experience and adjusted the limitations of the measures to ensure higher feasibility. The researcher followed the same steps as in the first round of the pedagogical experiment on the experimental and control groups, but on a larger scale at 5 high schools:

- Le Hong Phong High School, Bien Hoa City, Dong Nai Province
- Long Thanh High School, Long Thanh District, Dong Nai Province
- Tran Bien High School, Bien Hoa City, Dong Nai Province
- Nguyen Trai High School, Bien Hoa City, Dong Nai Province
- Thai Phien High School, Da Nang city.

a) Analyzing the quality of students before conducting the pedagogical experiment (round 2)

To accomplish the experimental sample selection, we required students to take quality tests and analyze the test results. We selected 2 groups of experimental and control classes with similar results, including 395 students of grade 12 (in which 197 students belonged to 5 groups of experimental classes and 198 students belonged to 5 groups of control classes) of the 5 high schools.

b) Contents of the pedagogical experiment - round 2

c) Results of the pedagogical experiment - round 2

Qualitative results:

Quantitative results:

3.6. Conclusion of chapter 3

Through pedagogical experiments, it shows that the role of the measures is very important in student learning. This is clearly shown in the fact that a student whose metacognitive skills are developed has a better ability to plan, monitor, regulate and evaluate cognitive processes than other students. On the other hand, the experiment results show that these skills help students better understand their thinking process in the problem-solving process, hence making students active, creative, positive, interested and passionate about learning. Accordingly, student learning outcomes have improved significantly.

In summary, chapter 3 of the thesis has studied the following issues:

The pedagogical experiment took place over a long time, in many rounds and on many students in many different schools, so it is highly feasible.

Pedagogical experiments have verified the following specific issues:

The identification and construction of some of the above skills are consistent between theory and practice.

Students's skills in learning Mathematical Analysis in high school have an important role in helping students improve academic performance.

The measures to develop skills for students in teaching Mathematical Analysis given in the thesis are completely appropriate and feasible.

The above measures show that these skills can be developed for students.

The learning results of students whose skills are developed are significantly improved, especially the ability to monitor, adjust and evaluate cognitive processes; thereby, helping students' thinking ability as well as self-control and self-study ability are significantly improved.

However, in the experimental process, it also shows that students still have many difficulties when learning Mathematical Analysis. For example, they are weak in detecting problems, selecting problem-solving methods, mobilizing relevant knowledge, controlling and adjusting. For teachers, there are also some difficulties such as lack of time to design lessons and teach in class, lack of equipment and conditions to apply measures to develop skills for students.

PART III. CONCLUSION

The thesis has studied the following issues:

1. Theoretical issues

- Study cognitive theories, skills, metacognitive skills.
- Investigate the current situation of developing metacognitive skills for students in teaching Mathematical Analysis in high schools
- Identify some necessary metacognitive skills that can be developed for students in teaching Mathematical Analysis in high schools
- Research systematically and identify scientific arguments on the formation and development of some metacognitive skills for students in teaching Mathematical Analysis in high schools.
- Design a number of compatible activities to develop students' skills in teaching Mathematical Analysis in high schools

2. Practical issues

- Identify and propose measures to develop metacognitive skills for students in teaching Mathematical Analysis in high schools.
- Conduct pedagogical experiment to test the feasibility and effectiveness of the proposed measures.

Based on the results of the study, it can be concluded that:

i) Metacognition has been described as one's own cognition of knowledge and cognitive ability to understand, control, and manipulate one's own cognitive processes. To learn most effectively, students should not only understand existing strategies, but also be able to devise and choose and use new strategies. In addition, students must be able to plan, monitor, regulate, and evaluate cognitive processes. Students with good skills can supervise and direct their own problem-solving processes and many other processes.

ii) Metacognitive skills are the manifestation of metacognition in activities. Metacognitive skills are important and can be formed for students in the process of teaching Mathematical Analysis in high schools in particular and in Mathematics in general.