Development and evidence of Student Participatory Class model in Mathematics Education: Through the cases of Junior High Schools and High Schools in Guizhou, China

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Abstract

The student participatory class model in mathematics education was developed to nurture the necessary literacy in mathematics education. To nurture mathematical literacy, Compulsory Linkage, Project Cycle Management for Education, and Micro Presentation are used. Of the basic mathematical academic abilities, the author focused on Logical Thinking, Critical Thinking and Mathematics Expression, and made efforts to solve the issues of mathematical education today through the development of a student participatory class model aimed at the comprehensive nurturing of each skill. So as to verify the efficiency of this class model, a practice class was conducted at the junior high schools and high schools in Guiyang, Guizhou, China. From the results, the mathematical literacy of the junior high school and high school students increased because of the student participatory class model. The efficiency of the student participatory class model was proved and is reported.

Keywords: Mathematics educationt; Mathematical literacy; Junior high schools

I. INTRODUCTION

In 21st century China, the economy rapidly developed in the coastal areas, but the economies in the inland areas were left behind. As a result economic disparity expanded. For this reason, the modernization of science technology was conducted in 1975 as one means of addressing this economic disparity. In order to train superior personnel with this modernization process, mathematics education was regarded as a particularly important element in school education. In the school curriculum reform, development in science technology was attempted by focusing on mathematics education by increasing the number of annual class hours for math. Accordingly the author conducted a research on math teachers in both Japan and China and carried out mathematics teacher's training in Guizhou, China. As a result, it became clear that there is a lack of autonomy in students, an expanded disparity in the capacity and ability for mathematics education, shortage of education budgets, teachers and teaching materials, and insufficient education maintenance. In this report, the student participatory class model was developed with the aim of improving the lack of autonomy in the students and the capacity and skills of the math teachers.

II. THE DEVELOPMENT OF THE STUDENT PARTICIPATORY CLASS MODEL

The skill that should be nurtured in the student participatory class model is logical thinking, critical thinking and mathematical expressions. Logic and imaginative power are regarded as important qualities in mathematical activities not only in the mathematics education of Japan but also in China. For this reason, through the content analysis of the mathematics textbooks of junior high schools and high schools, text books specifically pick up phenomena of everyday life, and the teacher conducts the class by having the students convert the image of the learned content into the context of everyday life phenomena.

As a structural factor to mathematical expressions in the class model, the method of "mathematical communication" cited by Tadao Nakahara (1994) can be considered.

· Realistic Expression (Expressions by actual condition and object)

· Operational Expression (Expressions through the actual operation of teaching tools)

- Pictorial Expression (Expression by pictures and figures)
- Linguistic Expression (Expression utilizing everyday speech)
- Symbolic Expression (Expressions utilizing mathematical symbols)

Realistic Expression is the ability to express mathematical phenomena in the specific everyday phenomena of the learning content. Operational Expression is like drawing a figure using teaching tools, such as a compass or ruler, and drawing specific figures and graphs. Pictorial Expression is to express mathematical phenomenon by utilizing pictures or photographs in the learning content. Linguistic Expression means to express mathematical phenomena by language. Symbolic Expression means to express mathematical phenomena with mathematical symbols.

The author cited Nakahara's definition and defines mathematical expression as "the ability to communicate to others their thoughts utilizing specific objects, figures, tables, graphs, languages, symbols, and numerical formulas considered when mathematically processing the phenomenon." In this research, the development of a class model which nurtures logical thinking, critical thinking and mathematical expression was the first step. As an effective method to nurture these abilities, the following three methods were adopted.

- Compulsory Linkage
- Project Cycle Management (PCM) for Education
- Micro Presentation

An explanation regarding each method will be described in a simple manner as follows. Compulsory Linkage and Micro Presentation are methods developed by Tokuji Hayashi (2002).

A. Compulsory Linkage

Compulsory Linkage is a method for nurturing logical thinking skills as well as class design skills that stress linearity. Between the pre-established starting point (target group/participants) and the end point (the goal), association are made while incorporating vocabulary connected with the aspect in question (schema), and thereby

refining the presentation composition. The incorporated vocabulary considers the target groups' readiness (preparedness/prior education), and provides participants with the ability to acquire new skills and knowledge until their goal is attained. Compulsory Linkage, unlike existing Image Mapping, features the fact that the establishment of a goal results in the participants converging the temporarily expanded thought. Applying this method during presentation planning takes note of the target group or index, considers the target groups' background and prior knowledge, as well as the matter in concern, and aims to nurture their planning ability to logically assemble the new schema for communicating the information.

B. PCM for Education

PCM for Education is a method of problem analysis that utilizes a visual logic tree structure. Furthermore, the process of creating a logic tree structure aims to nurture the ability to think critically while mutually enhancing discussion. Logic trees, representative of diagrammed thought tools, organize the causal relationships of items (cause–effect) and help to clarify the structure of complex problems. In these instances, the logic tree structure can establish an evaluation index for objective measurements of the goal or the valuation standard for denoting the accomplishment of the goal for this particular index. This approach makes it possible to critically consider the causal relationship between cause–effect while preventing omission or one-sidedness during discussion.

C. Micro-presentation

Micro-presentation is a method for nurturing expressional and communicative skills. In our class model, students conduct micro-presentations based on the contents created through the Compulsory Linkage method. In the micro-presentations, both listeners and presenters (students) mutually evaluate the presentation while considering "verbal, nonverbal, media use, comprehension, interest, and degree of staying." The aim of this activity is to nurture communicative and expressional skills.

The author of this paper has noted the abilities beyond basic mathematical skills such as logical thinking, critical thinking, and mathematical expression. In addition, I have devised a solution for the issues of modern mathematics education by developing a student participatory class model that aims to comprehensively nurture their individual abilities.

I have hypothesized that the students will acquire an aptitude for mathematics education challenges such as "problem solving, conceptualization/logic, explanation/ expression, and logical judgment" by fostering the above-mentioned logical thinking, critical thinking, and mathematical expression skills. Therefore, the hypothesis posited by the author will be verified through the development of a student participatory class model whereby the Compulsory Linkage, PCM for Education, and Micro-presentation methods can be comprehensively administered. Fig. 1 below illustrates the image of the math-related student participatory class model envisioned by the author.

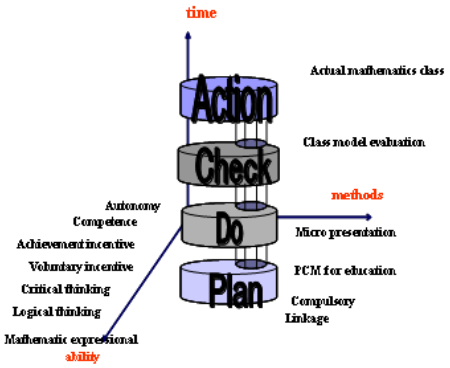

Figure 1. Math-related Student Participatory Class Model

Here, the author have not established an arrangement for listing behaviors/abilities with regard to the seven behaviors/abilities listed for literacy in Fig. 1, but I have simply ordered these from autonomy to mathematical expression subjectively. However, even with regard to my method of listing, I would like to study the arrangement or connectedness of each particular behavior/ability in the future.

I. APPLYING THE STUDENT PARTICIPATORY CLASS MODEL IN GUIZHOU, CHINA (GUIYANG CITY)

A. Application 1 of the Student Participatory Class Model at the Guiyang City Junior High and High School.

1) Purpose: Apply the student participatory class model in mathematics classes at the Qinghua School and verify the significance of the model.

Method/Contents: This application of the student participatory class model utilized the Compulsory Linkage method to nurture logical thinking. In addition, the Micro-presentation method was used to nurture critical thinking and mathematical expression.

· Period of Implementation「March 2008.」

· Location and Time of Implementation

· 「Qinghua School, a single 45-minute class.」

· Persons Implementing the Study「Author」

· Collaborator「Yamaguchi University Professor Hayashi Tokuji, Guizhou University Professor Zhang Chongde, Yuan Guangwei (Translator)

· Target Group「49 first-year students at the Qinghua School.」

· Other「Seven mathematics teachers at the Qinghua School. 」

a) Nurturing Logical Thinking: The author first presented an example of the Compulsory Linkage method and then explained the relationship and relatedness of the vocabulary from the compulsory linkage sheet posted on the blackboard. Approximately 10 minutes after presenting the compulsory linkage sheet, the participants were instructed to create their own compulsory linkage sheets that included as many vocabulary words that they could associate as possible. For this particular study, the initial keyword was provided as “rocket” and the final word as “potato.”

After another 10 minutes, participants were instructed to exchange notebooks with the students sitting next to them and then explain the contents of their writings. The students who had completed their compulsory linkage sheets were then instructed to write their responses on the simili paper posted on the blackboard.

Two students are then nominated. These two students investigate the number of terms present while the compulsory linkage sheets are being drawn up on the simili paper. These two are guided to check the relatedness and consistency of the associated words from the “initial word” to the “final word” based on their own compulsory linkage sheet, and to determine whether they are logically written. From this explanation, each student corrects and examines the compulsory individual linkage sheet they each drew.

b) Nurturing Critical Thinking and Mathematical Expression Skills: The listeners (the pairs of students) mutually discussed the method of presentation and the contents of their micro-presentations based on the compulsory linkage sheets created by each of them. After the discussion, they exchanged their compulsory linkage sheets and mutually evaluated the information. This study of the content of one another's compulsory linkage sheets and presentation method nurtures critical thinking and mathematical expression in the students.

3) Result: According to a term-number survey of the compulsory linkage sheets, five students provided 10–15 terms, 19 students provided 16–20 terms, 22 students provided 21–25 terms, 3 students provided 26–30 terms, but none of the students provided more than 31 terms. To show the students the results of the term-number survey, a bar graph was presented on the blackboard. At that time, those students with 30 or more terms were praised for having superior abilities. Next, the students who wished to present their compulsory linkage sheets were instructed to raise their hands. At that time, approximately half of the students wrote their compulsory linkage information on the simili paper posted on the blackboard.

Many of the students enthusiastically created their compulsory linkage sheets and after completing the task, two students were nominated to deliver micro-presentations in succession. Subsequently, each student received comments on their presentation methods and skills as well as their technique and method of explaining the contents in an accessible manner.

The contents presented by these students are noted below.

Students performed their micro-presentations for approximately three minutes. The presenting students efficiently transferred the information from their compulsory linkage sheets in their notebooks onto the simili paper posted on the blackboard. These students also showed great attentiveness/interest during the presentation and toward the creation of the compulsory linkage sheets.

These students created four routes in their compulsory linkage sheets. The terms found in the presenting students' compulsory linkage sheets totaled 18 words. A consistency in the associated words' connections was observed.

a) Logical Thinking Ability: After analyzing the students' compulsory linkage sheets, it was observed that the majority used terms associated with the initial keyword of

"rocket" and the final keyword of "potato" with relatedness and consistency. It appeared that students performed divergent thinking when listing associated words after the initial keyword. However, midway through the process, students began thinking in a convergent manner when connecting the terms to the final keyword. Many of the term included a clear causal relationship and the students acquired the ability for logical thinking during the course of this study. Furthermore, the terms of those students deemed to have unclear relatedness were reviewed and confirmed after their micro-presentations. In sum, it can be understood this particular effort nurtured logical thinking in a majority of the students.

b) Critical Thinking Ability: Students were asked to mutually evaluate the contents of the compulsory linkage sheets 10 minutes after creating them. As a result, I witnessed many instances in which the students could effectively express and exchange their opinions and thoughts, after listening to the partner's opinions and thoughts. When the students (the listeners) were asked by the author for their opinions and whether they were for or against the presentation's contents, many students were able to respond, listen to their partner's opinions and thoughts, and state their own opinions and thoughts from the presenting student's standpoint.

c) Mathematic Expressional Ability: The author offered advice for each micro-presentation especially with regard to language, e.g., speed of speech, gestures, eye contact, voice volume. Based on their reactions, the majority of the students involved in the student participatory class acquired points to note for expression/communication skills and methods to enhance their future presentations. Furthermore, the author established an evaluation level to assess the student participatory class model by following Kirkpatrick's four-level course evaluation model. According to Hayashi, Kirkpatrick's course evaluation model has been verified up to the third level through a student participation training model, which was designed to improve communication in the school administration, including the principle, vice principle, etc. in the Yamaguchi Prefecture. For our student participatory class model, I decided to apply the first two levels of Kirkpatrick's four-level course evaluation. Table I displays the evaluations of the student participatory class model.

TABLE I. EVALUATION OF THE STUDENT PARTICIPATORY CLASS MODEL

Evaluation Level 1	Student's level of satisfaction (was the content satisfying to the students?)
Evaluation Level 2	Student's level of understanding (were the students able to acquire the particular skill?)
Evaluation Level 3	Change in student behavior (could the students apply the skills acquired in class?)
Evaluation Level 4	Level of contribution toward the creation of a school system

This application of this study occurred during a single 45-minute class period in May 2008 and it involved a target group of 52 first-year students from Qinghua School. The topic of the study was "vector planes" and the Qinghua School mathematics teaching staff administered the lessons. The author analyzed the verbal communication between the teachers and their students and the communication was analyzed in three-second intervals for the 45-minute class held during the first period. In addition, verbal communication analysis was carried out to analyze the dialog between the students and teachers during the mathematics classes to examine the students' initiatives in proactive learning.

It is believed that the students were able to nurture proactivity, critical/logical thinking and mathematical expression through the student participatory class. Furthermore, during the research discussions between the author and teachers, one teacher commented that the Compulsory Linkage method was an effective teaching technique that nurtured critical and logical thinking abilities in the students. The teacher also stated that it enabled the students to become more attentive and interested in the material.

B. Application II of the Student Participatory Class Model at the Guiyang City Junior High and High School

Purpose: To apply the student participatory class model inmathematics classes at Qingyan School and verify the significance of the model.

Method/Contents: Qingyan School, located approximately 90 kilometers from

Guizhou University, is a public junior high and high school situated in the mountainous

region of the Huaxi District, a suburb of Guiyang City. The entire school encompasses approximately 1,000 students and 100 teachers. The account of the implementation of the student participatory class is mentioned below, with Table II denoting the content of the survey carried out at Qingyan School.

TABLE II. SURVEY METHOD AND APPLICATION PERIOD FOR SURVEYS, ETC.

Survey Method	Before the Model Class	After the Model Class
Observation of Mathematics Class	March 2008	May 2008
Mathematics Teacher Questionnaire Survey	March 2008	May 2008
Student Questionnaire Survey	January 2008	June 2008
Student Participatory Application Class	Mid-March 2008	
Student Questionnaire Survey regarding Target Attainment	Mid-March 2008	
Teacher Training Questionnaire Survey	Mid-May 2008	

· Period of Application「March 2008」

· Location and Time of Application「Qingyan High School, a single 45-minute class period」

· Persons Administering the Application「Writer」

· Collaborator「Yamaguchi University Professor Hayashi Tokuji, Guizhou University Professor Zhang Chongde, Yuan Guangwei (Translator)」

· Target Group「50 first-year students from Qingyan School」

・ Other「10 Qingyan School mathematics teachers observed the class. 」

Result: While several students created their compulsory

linkage sheets on the simili paper, a term-number survey showed that 5 students provided 10–15 terms, 32 students provided 16–20 terms, 8 students provided 21–25 terms, 5 students provided 26–30 terms, but none of the students provided more than 31 terms. The students' term numbers were shown on the blackboard as a bar graph. Those students with 26 or more items were praised for having superior abilities. Furthermore, the students were enthusiastically engaged and all of them completed their compulsory linkage sheets with significant attentiveness and interest.

According to the questionnaire regarding target attainment evaluation noted in the educational instruction plan, many students answered "acceptable" for all of the target attainment contents.

The students who created compulsory linkage sheets created five routes and each student's presentation lasted approximately four minutes. The total number of terms found in the students' compulsory linkage sheets was 29, and a general consistency in term connections was found for the majority of students. A portion of the students' expressions were seen as redundant.

An analysis of the students' compulsory linkage sheets revealed that of the 50 sheets created by the students, the relationship of each term in 48 of the sheets showed relatedness, consistency, and a causal relationship. According to these results, the application and the creation of the compulsory linkage sheets nurtured logical thinking for almost all of the students.

We attempted to promote exchange between the students by having them exchange compulsory linkage sheets and explain the contents in their own words. As a result, the students were able to listen to what their partners were saying, take the position of their partners, and express their own thoughts and opinions. Through this activity, it is assumed that critical thinking skills were nurtured in the students. The author then commented on presentation skills, such as gestures, eye contact, voice volume, and had each of the students perform micro-presentations. During this time, students made an effort to increase their individual skills by observing the successive presentations of their fellow students. Furthermore, the students were able to nurture expression/communication skills through this effort.

According to the findings, the introduction of the student participatory class model helped improve the environment from a teacher-leading class to a student-participatory environment.

IV. SUMMARY OF THE CLASS APPLICATION AT THE GUIYANG CITY JUNIOR HIGH AND HIGH SCHOOL

A summary of the application using a student participatory class model is noted below:

Analysis results of the Qinghua School student compulsory linkage sheets revealed that a majority of students performed divergent thinking when listing the associated words related to the initial keyword. However, midway through the process, students began performing convergent thinking when connecting the terms to the final keyword. It can be understood that many of the terms included causal relationships and the Compulsory Linkage method nurtured the students' logical thinking abilities.

Furthermore, the micro-presentations also contributed to nurturing the students' logical thinking abilities. Many of the students were able to effectively exchange their opinions and thoughts with their partners while giving consideration to the partner's views, as well as answer any pertinent questions posed by the author.

Moreover, it can be understood that the students' presentations enhanced their presentation skills such as word usage, speed of speech, gestures, eye contact, and voice volume. According to our findings, the majority of students involved in the student participatory class acquired important points to note for expression/communication skills and methods to enhance their future presentations.

Furthermore, as a result of the Qingyan School Students' compulsory linkage sheet analysis, it can be understood that a majority of the students showed significant attention/interest in the creation of their individual compulsory linkage sheets. In addition, the process was able to contribute to the nurturing of logical thinking abilities.

Furthermore, students were able to listen and effectively state their own thoughts and opinions from the partner's standpoint throughout the micro-presentations. This effort by the students also nurtured their critical thinking abilities.

Furthermore, according to the analysis of the dialog between the teachers and their students, from the time before the author observed the class to after the application of the student participatory class, the change in the teacher–student relationship showed significant improvement, as classes became more oriented towards proactive studying by the students rather than teacher-led courses, in both high schools in Qinghua and Qingyan.

Based on the results, it can be concluded that the student participatory class model was able to effectively enhance the students' autonomy, which was the primary goal of the student participatory class model. In addition, it was observed that the teachers' explanations to their students had become courteous and forthcoming, and the students' utterances and problem-solving activities had become copious.

V. CHALLENGES OF THE FUTURE

I would like to put our student participatory class model into practice in Japan to enhance the model according to the results of this activity. Furthermore, to improve the mathematics teachers' teaching methods, I would like to develop a curriculum model that utilizes the above class model.

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