CHAPTER 4

Results of Data Analysis

The researcher would present the results of develop Mathematics Curriculum to Promote Learning and Innovation Skills of 21st Century through the Application of Lesson Study and the results of using Mathematics Curriculum. The data analysis was done in two parts, as follows:

Part 1: Development of Mathematics Curriculum to Promote Learning and Innovation Skills of 21st Century through the Application of Lesson Study

Part 2: The results of using Mathematics Curriculum to Promote Learning and Innovation Skills of 21st Century through the Application of Lesson Study

4.1 Development of Mathematics Curriculum to Promote Learning and Innovation Skills of 21st Century through the Application of Lesson Study

This time the researcher had developed a curriculum following Taba's model (1962 cited in Ornstein, C. A. & Hunkins, P. F., 2009) combined with the applying of lesson study approach which consisted of 3 stages; 1) collaboration in research lesson design, 2) collaboration in the research lesson observation, and 3) collaboration in reflection or post-discussion, the researcher applied Lesson Study for each lesson plan. The researcher, working together with other teachers, worked on setting up the learning plan, class observation and reflecting on the effectiveness of learning results after the lesson. After finishing, the researcher will represent the process of developing the curriculum as in Table 4.1

Table 4.1 shows the elements of the curriculum, from the procedure to develop of Mathematics Curriculum to Promote Learning and Innovation Skills of 21st Century through the Application of Lesson Study

Procedure of curriculum development	**Curriculum elements**
1. Diagnosis of school needs	
2. Collaboration in the curriculum design: Plan	
2.1 Define curriculum objectives	• Concept/principle of curriculum • Subject description • Standard of learning • Expectation of learning result/ objective.
2.2 Selection of learning experiences	• Types of learning (Open Approach)
2.3 Selection of contents and 21st century skills performance	• Unit of study/subject of content and time teaching • Student evaluation (frame of behavior indicators/ skills of learning and innovation (4C's))
2.4 Collection of curriculum contents aligned to core standards	• Curriculum structure
3. Collaboration in the curriculum observation : Do	
3.1 Organization of learning activities by using Open Approach and applying Lesson Study for each lesson plan • Collaboration in research lesson design (Plan)	• Lesson Plan (17 plans) • Tools of studying • Documentation of learning

Table 4.1 (cont.)

Procedure of curriculum development	**Curriculum elements**
• Collaboration in the research lesson observation (Do) • Collaboration in reflection or Post-discussion (See)	
4. Collaboration in reflection or Post-discussion on the Curriculum (See)	
4.1 Evaluation of curriculum	-

The details of each procedure following:

4.1.1 Diagnosis of school needs

The researcher is a mathematics teacher at Wiengjedee Wittaya School. The project started with a meeting with the Mathematics Department Chair to interview about problems and the process of organizing mathematics lessons. It was found that thinking skills and actual study time were insufficient, and that the national policies and the school itself were more concerned with teaching on World-class Standard School, and as such the Mathematics and Science subjects were not headed in the direction of being ready to meet international standards.

After that, the researcher continued to meet with the Academic vice Director to aksed more information on the school's policy regarding World-class Standard School which would emphasize the points on students that the school was expecting. The ideas put forth by the Mathematics Department Chair were also confirmed; practical lessons were not clear enough to be considered sufficient as being in World-class Standard School, as they should be used more to develop higher-order thinking skills.

In order to be World-class Standard School, it is imperative to focus on manpower preparation that would prepare teachers for classes of the 21st century. Thus, the researcher has chosen to represent the idea of learning and innovation skills of the 21st Century, as one of the core skills that emphasizes critical thinking and problem solving for students. Students should have

developed communication skills and other skills that are important for the 21st Century. After ongoing discussion about the fundamental issues, the researcher asked the Academic vice Director for permission to have a small group meeting with the school executives on Tuesday 7 May 2013 at 09.30-12.00 hrs. The attendees were the Academic vice Director, Chief of Academics Affairs, Chief of Research and Human Resources Development, Chief of Curriculum and Instruction, Mathematics Department Chair, and the researcher.

At the beginning of the meeting, the researcher presented a method of how to develop the mathematics curriculum to be consistent with the school's policy in World-class standard school standards. After representing the idea, the researcher found that the school executives approved and supported the researcher to prepare the curriculum for the school. Moreover, they suggested that the researcher has a meeting with a group of Mathematics teachers, therefore gaining the support from others teachers for assistance in developing this curriculum.

Figure 4.1Focus group with school executives

4.1.2 Collaboration in the curriculum design: Plan

1) Define curriculum objectives

After discussion with the school executives, they approved and followed researcher's suggestions by holding a meeting with a group of teachers in the department, including Chief of Academics Affairs, Chief of Research and Human Resources Development, Chief of Curriculum and Instruction, Mathematics department Chair, and 8 mathematics teachers, together with the researchers. The researcher first presented the national policy, which requires Thai children's required skills, the 21st Century skills and the school's policy which requires teachers in the mathematics department to have an instruction consistent with the school's policy. The ideas of how to develop the curriculum were presented. These required cooperation from the teaching team on Lesson Study process, in which they would work on three lessons study processes; collaboration in the curriculum design (Plan), collaboration in the curriculum observation (Do), and collaboration in reflection or post-discussion (See) on the curriculum. After that, the researcher discussed with the teaching team about the possibility of working further on this curriculum, some teachers suggested that open approach method is a new way, interesting, and aligned with mathematics subject. For that reason, an open approach lets students have opportunities to have higher-order thinking skills. Another participant suggested that he prefers teachers in the school to have academic learning, sharing together accord with lesson study process. After finished discussion, researcher requested volunteer teachers to join, and result was all teachers were pleased to be part of this curriculum development project (figure 4.2).

Figure4.2 Focus group with mathematics teachers

A group meeting with the school executives was held on Friday 7 July, 2013 at 10:30-12:00 hrs. The attendees were: Academic Vice Director, Chief of Academics Affairs, Chief of Research and Human Resources development, Chief of Curriculum and Instruction, Mathematics department Chair, and the researcher. The researcher presented first the curriculum development process, using (i) a lesson study process, (ii) skills for the 21st Century, (iii) national's policy, (iv) school's policy of expecting the results on students, and (v) an instructional using open approach method. The participants and researcher then discussed further about formulating a set of concept/principle of curriculum, subject description**,** standard of learning, expectation of learning results/ objective that would be consistent with the core curriculum of basic learning standards and the skills of the 21st Century (Table 4.5)

2) Selection of learning experiences

In order to select a particular learning experience, the researcher began by meeting the team on Monday 10 July 2013 from 15:10 -16:00 hrs. The participants were Chief of Academics Affairs, Chief of Research and Human Resources development, Chief of Curriculum and Instruction, Mathematics department chair, eight mathematics teachers, and the researcher; a total of 13 people. The researcher reviewed the method of using a lesson study process for

developing the curriculum together. After that, the researcher presented a sample of a video lesson, showing the open approach taught by Japanese teachers so that they could see the whole picture of a lesson, which empowers students to think, to communicate, and to collaborate. After the video, the researcher handed out sample documents showing the skills of learning and innovation skills; critical thinking and problem solving, creativity and innovation, communication and collaboration.

After discussion with the participants about the video and sample class lesson, the researcher opened up a chance for the teachers to give their opinions about the teaching video. In summary, most of the teachers were of the opinion that open approach was a good teaching style, because it provided a chance for students to participate in sharing, helping each other and gaining more student interested in problem solving and inspiring a sense of self-study, in which the problem situation would be very interesting and also the problem was very realistic and familiar with the student's life. At the end of the discussion, the outcome was to try this method of posing open-ended problems to teach, which follows the concept of Inprasitha (2010), the four steps of which were as follows:

Step 1: Posing an open-ended problem
Step 2: Students' self-learning
Step 3: Whole class discussion and comparison
Step 4: Summarization through connecting of the student's mathematical ideals that emerged in the classroom

3) Selection of contents and 21st century skills performance

1. Selection of contents

In order to select the contents, the participants were Chief of Academics Affairs, Chief of Research and Human Resources Development, Chief of Curriculum and Instruction, Mathematics department chair, eights Mathematics teachers, and the researcher. The number of participants was 13 people. It was the group's consensus that that these skills were consistent with the subject content

of grade 7. For this selection, the teachers suggested that Integers, Powers, and Basics of Geometry could reasonably represent a project in mathematics showing creativity in a mathematics game because it would likely accord with the intention of learners. This was in best consideration of the timing of class lessons as well.

There were 4 units covering 32 teaching hours and had the following topics for each lesson;

Unit1 Integers (4 weeks)		
Integers	1	hr.
Integers on the Number Line	1	hr.
Opposite Numbers	1	hr.
Addition of Integers	2	hrs.
Subtraction of Integers	1	hr.
Multiplication of Integers	2	hrs.
Division of Integers	2	hrs.
Numbers properties	1	hr.
Unit2 Powers (4 weeks)		
Powers form	1	hr.
Exponent	1	hr.
Solution of Powers	1	hr.
Multiplication of Powers ($a^n \cdot a^m = a^{n+m}$ and $(a^n)^m = a^{n \times m}$	3	hrs.
Division of Powers $\frac{a^n}{a^m} = a^{n-m}$	1	hr.
Scientific notation	1	hr.
Powers problem	2	hrs.
Unit3 Basic Geometry (3 weeks)		
Definition of Point, Line, Segment, Ray right angle, acute angle, obtuse angle	1	hr.
Construction of Segment	4	hrs.

Construction of angle and angle's division	3	hrs.
Unit4 Math Project (1 weeks)		
Presentation of Mathematical Game	2	hrs.

2. Identify the 21st century skills performance

To identify 21th Century Skills Performance factors, the researcher organized a meeting on Monday 17th June 2013 from 15.10-16.30. The attendees were: Chief of Curriculum and Instruction, a group of 4 mathematics teachers, and the researcher, for a total of 6 people. The purpose of the meeting was to select the indicators of the skills of learning and innovation (4C's). The researcher began the discussion by connecting the ideas about skills of learning and innovation that were presented at the previous group meeting, which consisted of critical thinking and problem solving, creativity and innovation, communication and collaboration. The researcher distributed a behavioral document concerning the 4C's in more detail, to all teachers. Next, they reviewed a video of the open approach method lesson of Thai teachers and requested their observation on the video and to write about the students' behavior on 4 skills, for each student. Once again, the researcher distributed a document of sample/behavior that showed the skills of learning and innovation and a discussion followed, in order to select the indicators of skills of learning and innovation, This was to become the framework for student's evaluation about 21st century skills performance.

Figure 4.3 Focus group to identify 21th century skills performance (4C's)

The framework for student's evaluation about 21st century skills performance (learning and innovation skills; 4C's) were;

1. Critical thinking and problem solving; C_1
   - 1.1 Verbal and written reasoning
   - 1.2 The propensity to seek reason
   - 1.3 Inquisitiveness in open-ended problem
   - 1.4 Making decision in solving problem
   - 1.5 Interpreting and explaining
   - 1.6 Making another choice and convincing others with appropriate reasons
   - 1.7 Engaging in analyzing each other's answer
   - 1.8 Solving open-ended problem
   - 1.9 Analyzing arguments, claims, or evidence

2. Creativity and Innovation; C_2
   - 2.1 Generating ideas, often by thinking divergently using fluency and originality
   - 2.2 Being tolerant of ambiguity
   - 2.3 Willing to take intellectual risks

2.4 Generating new and varied ideas

2.5 Expressing different ideas

2.6 Generating learning style or tools

3. Communication; C_3

3.1 Rephrasing other's explanation

3.2 Engaging in question and discussion

3.3 Paying attention to others' reasons

3.4 Effectively communicating math concepts orally and in writing

3.5 Selecting appropriate reading strategies for open-ended problems

4. Collaboration; C_4

4.1 Being Able to express math problems with peers and teachers

4.2 Having sense of team work

4.3 Sharing ideas and listening to others' perspectives

4.4 Negotiating to get consent

4) Collection of curriculum contents aligned to core standards

After identifying the 21st century skills performance, the group of teachers discussed the core curriculum 2008 as it applied in the first semester of grade 7 Fundamental Mathematics, to identify the unit of learning name, name of each study plan, learning and teaching method, timing of hours of each topic and correct the structure of the curriculum, which is an adjustment of old curriculum in course levels, to get better results for this curriculum improvement (Table 4.2) effected in terms of aim of position, subject addition, learning and studying, assessment through the processing of curriculum improvement.

Therefore to reach the aim of new purpose, the contents contain 4 units of learning: Integers, Powers, Basics of Geometry, and Math Project, all totaling 32 teaching hours. And Curriculum structure in table 4.3

Table 4.2 Show the concepts of mathematics curriculum.

Topic	Mathematic curriculum (developed)
Aim of Position	Contents + Math skills + the 21st Century Skills
Subject Addition	More integration of contents with situation, contextual surrounding. Subject contents with situation problem approach.
Learning and Studying	Open Approach

Table 4.3 the structure of Mathematics Curriculum to Promote Learning and Innovation Skills of the 21st Century

Unit of lesson	Name of lesson plan	Contents	Learning and innovation skills	Time (hr.)
1.Integers	Investigating Accounts	Integers	C_1, C_4	1
	Negative Integers	- Integers on the Number Line -Opposite Numbers	C_1, C_3	1
	Where am I?	Addition of Integers	C_1, C_2, C_3, C_4	2
	Change the sign	Subtraction of Integers	C_1	1
	Eat and don't eat	Multiplication of Integers	C_1	2
	Divided me!	Division of Integers	C_1	3
	Numbers properties	Numbers properties	C_1	1
2.Powers	I am a power	- Powers form - Exponent	C_3	1

Table 4.3 (cont.)

Unit of lesson	Name of lesson plan	Contents	Learning and innovation skills	Time (hr.)
Powers	Operation of powers	Solution of Powers	C_1	2
	Multiplication property	Multiplication of Powers $a^n \cdot a^m = a^{n+m}$ $(a^n)^m = a^{n\times m}$	C_1, C_3	3
	Division property	Division of Powers $\frac{a^n}{a^m} = a^{n-m}$	C_1	1
	How big am I?	Scientific notation	C_1, C_2	2
	Alien Game	Powers problems	C_1	2
3.Basic Geometry	Yes, I am!	Definition of Point, Line, Segment, Ray, right angle, acute angle, obtuse angle	C_2, C_3, C_4	1
	How to construct (1)?	Construction of Segment	C_2, C_4	4
	How to construct (2)?	Construction of angle and angle's division	C_2, C_4	3
4.Math Project	My project	Presentation of Mathematical Game	C_2, C_3, C_4	2
Total				**32**

C_1- Critical Thinking and Problem Solving, C_2- Creativity and Innovation, C_3- Communication, C_4- Collaboration

4.1.3 Collaboration in the curriculum observation: Do

In this process, the participants consist of the mathematics teachers who observed the lesson plan 1 and 2. After that participants collaboratively reflect upon class completion or discussion after class to adjust some documents or activities before designing others lesson plans (table 4.4). The organization of learning activities using open approach for instruction and the lesson study process to develop each lesson plans, which consists of 3 steps; (1) collaboration in research lesson design, mathematics teacher

teams, as well as the researcher collaboratively design the lesson plans, which follow curriculum structure. The result was 17 lessons which collaborate lesson 1 and 2 from the process before and meeting team on Tuesdays after class was over. This step found that the major focus was on grade 7 teachers collaboratively designing lesson plans. There were 2 teachers from grade 7, 1 teacher from grade 8, and researcher for a total of 4 people (2) collaboration in the research lesson observation, from the meeting, they decided to attend the classes of each teacher's free classes and at least two teachers would collaborate to observe the lesson and only the teachers that were involved in this project. For the main purpose of observation, participants observed the 21st century skills performance of the students and recorded it in the 21st century skills performance observation form. And (3) collaboration in reflection or post-discussion. After reflecting upon class completion or discussion after class they found that in some lessons they could reflect upon class completion immediately, but for most of the classes, several teachers had other commitments, for instance, having the next lesson. Therefore, it was often inconvenient to reflect upon the class immediately upon completion, so the teacher and the researcher arranged to meet every Tuesday, class 9, for the reflection upon class completion, before going on to the next collaboratively designed lesson plans meeting.

For this step, researcher will represent the example of lesson study process in Investigating Accounts, Unit 1 Integer Numbers. There were 3 steps as follows;

1) Collaboration in research lesson design

In designing lesson plans about Investigating Accounts, Unit Study 1: Integers, first lesson, processing began on Tuesday 18 July 2013 from 15:10-16:30. The attendees were; Mathematic department Chair, Chief of Curriculum and Instruction, Chief of Research and Human Development, Chief of Academics Affairs and 8 Mathematics teachers and the researcher, for a total of 13 people. As a starting point, the researcher let each teacher present their style of teaching, therefore students could understand their

lesson, and create a situation. This could be; if the cost of product is higher than what a student has, using a thermometer, tank excavation, climbing up trees, and using opposite numbers. Each of these situations helps students learn what negative numbers are all about. However, there was still controversy about how could students understand about negative numbers when the teacher is using thermometers and climbing up tree situations, which they found rather paradoxical. So the result was instead to use the situational style of buying-selling for the lesson plans. After that, there was discussion about problem creativity details, whereby students would be able to demonstrate negative numbers, which was divided into 2 types; one was to let the students buy and sell items and allowing the student to create their own account (Debit-Credit). The situation was to have them buy more than they had money in their account, so students would have to make their own negative account (credit) and observe how the student could make their own icon for their account. After students finished recording their account, they would bring it to present in class and teacher would make an observation.

After students had written the problem situation together, such as “Our store wanted to buy the items (for the store) from the shop in Lamphun”, each group went shopping according to the list they created (each group selected 4 stores) and wrote a Debit and Credit account. Each group got 100 baht. “How can the student manage to write their financial account?” For a teaching tool, the teacher used fake bills and divided the students into groups, together there were 7 groups and each one got 210 rather than 100 baht. So again the situation changed as they got more money. The teacher posed questions to the students about problems in buying and selling on students experiences, then presented a new situation and problem that could happen and gave a task for the students to work out, by asking students to create a debit-credit account and they could have their own style on writing it, After they would come and present in class.

For the concept of selection sampling by groups with minus marked and groups without minus marked, some teachers suggested that for the trading products the list should have variety. Some groups got minus and some not. Then they could compare and try to observe students saying the words with minus meanings. For example, “Owing”, “In debt”, and teachers could write down these words (with minus marks) on the whiteboard. Then the class could come to a conclusion. After that, there would be a co-discussion about the lesson, a summary based on different opinions, such as writing negative numbers on the number line, and writing numbers on the number line with opposite numbers. One teacher had the idea to recommend using a mirror to show the opposite numbers. However, someone debated that would make students confused because the concept of differences should be taught in the next lesson, and there might not be enough time to run the activity. Thus, it was concluded that after students did the activity, the researcher (teacher) must summarize as before, using a real situation, how we will write symbols or numbers for “Owing”, “In debt”, first showing, and then teaching how to compare these numbers and write them on the number line. For the next lesson, in terms of learning skills and culture, the teaching team agreed students would be exposed to the skills of critical thinking and collaborative group lesson from the indicator showing focus on student thought and problem solving and collaborative learning with others in problem solving, cooperation and creativity. Moreover, several teachers suggest that they should play the role of the inspector, that is, the researcher announces that when in the class together, the researcher needs all other teachers to help observe students in class that have qualifying behavior.

After that, the teacher team decided on locations for appointment places that they would use for the lesson investigating account, in which timing must be matching, and the agreement came to be decided as the last lesson on Monday.

Figure 4.4 Focus group of Mathematics teachers to collaboration in lesson design

2) Collaboration in the research lesson observation

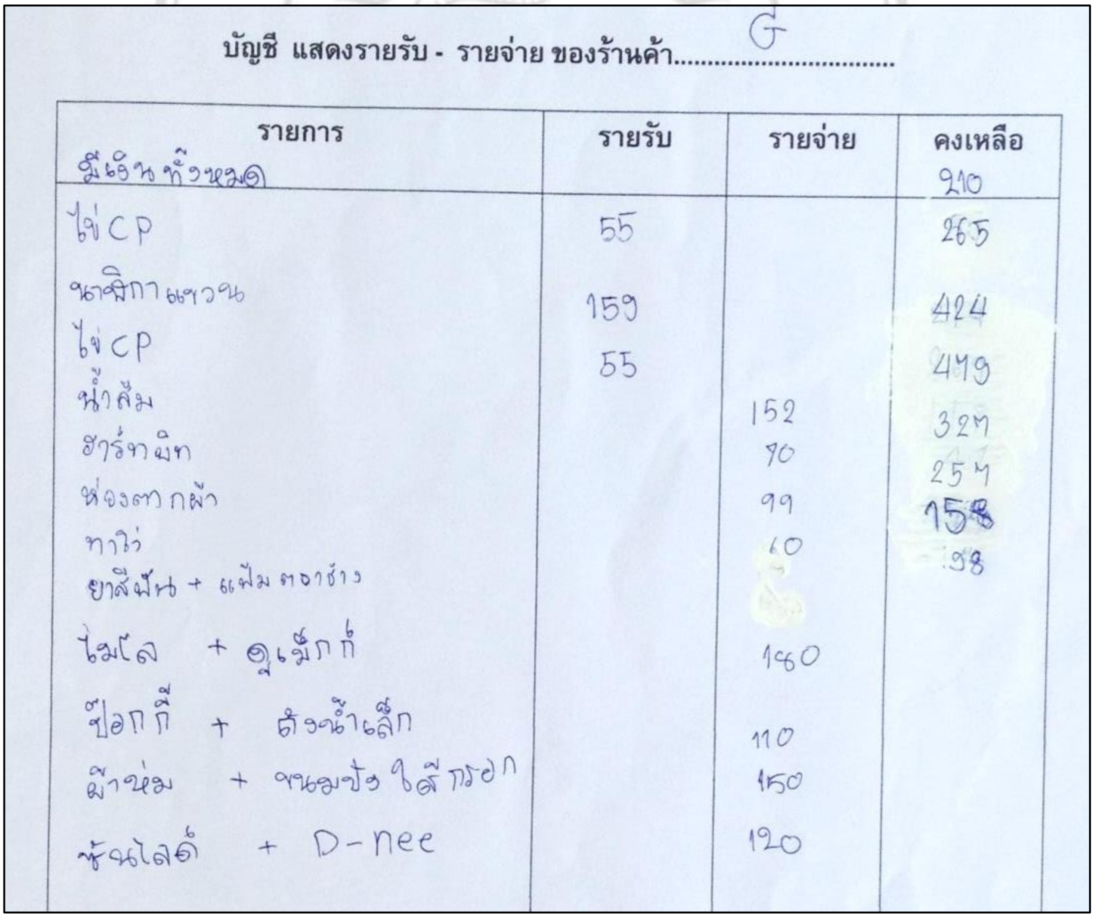
For the lesson 'Investigating Accounts', the researcher presented sample classes that the researcher and teacher teams had planned, which was on Monday 24 July, 2013. For the procedure, a five minute team meeting was held before class started. The observing people were; Chief of Curriculum and Instruction, 6 Mathematics department teachers and the researcher, totaling 8 people. For the observation, the observer will receive the 21st century skills performance observation form; these forms record how the students react and exhibit skills of learning and innovation (4C's). When the research appointed teachers came to observe the students' behaviors and learn what the results were, the student gave substantial attention and interest and collaborated intently on the lesson. The teachers then had a meeting and discussed what they had recorded from their observation; also to find out about the behavior of students in the class, consisting with which indicators they had observed.

Figure 4.5 Participants' collaboration in the research lesson observation in the Investigating Accounts lesson

3) Collaboratively reflect upon class completion

The researcher presented a sample of collaborative reflections upon class completion, based on "Investigating Accounts", in which research had been done, on Tuesday, 25 July 2013 at 15:00-16:30 hrs. The attendees were Mathematics department chair, chief of Curriculum and Instruction, chief of Research and Human Resources Development, and 8 mathematics teachers. Including the researcher, there was a total of 13 people. At the beginning of the meeting, the researcher, who was the teacher in the first reflection, reflected that the lesson plan ran in order according to the open approach style. On the first step, when the Open-Ended problem was presented, students were having so much interest in the problem in creating a solution, it transpired that students forgot to record the account, whether they are doing buying and selling at in which prices and the cost was credit or debit them on the account (when they received cash of 210 baht). This did not

follow through what the researcher had planned, because the teacher of the class had not explained the task properly. From that result, some groups of students were interested only to sell and not buy any product from the group that was selling and that made the students accumulate more plus accounts, not the minus account at all. This meant that students did not understand, or did not listen to the task ‘order’ from the teacher. Consequently, each group had different ideas of recording an account, such as some groups wrote down their account, only what they had received first, then wrote down what they had spent after that (selling more, in order to have more money to go shopping, because they had to shop in 4 stores). That enabled them to have more money, rather than having minus/negative numbers on their account (figure 4.6)


บัญชี แสดงรายรับ - รายจ่าย ของร้านค้า.......G.......

รายการ	รายรับ	รายจ่าย	คงเหลือ
มีเงินทั้งหมด			210
ไข่ CP	55		265
นาฬิกาแหวน	159		424
ไข่ CP	55		479
น้ำส้ม		152	327
ยาร์ทามิก		70	257
ห่อของกผ้า		99	158
ทาไว่		60	98
ยาสีฟัน + แฟ้มตราช้าง			
ไมโล + ตุ๊กตาเห็ก		140	
ป๊อกกี้ + ตัวน้ำเล็ก		110	
ผ้าห่ม + ขนมปังไส้กรอก		150	
ขนมไลด์ + D-nee		120	

Figure 4.6 Example of students’ recording an account

And for some groups, students wrote down minus numbers on their account but later deleted them, because they were scared of losing points on this activity from the teacher (because they thought whoever had the most money on their account would be the winner of the activity). This was because of students trying to earn profit rather than losing their money, so they did not want to spend on buying products. Therefore, this lesson 'activity' took too long and unfortunately that point could not come into the conclusion after the lesson. In the class discussion and collaboration class comparison, only one group presented while the other groups moved on to the next lesson. This was due to coming to the end of the lesson time. Students were thinking about going home and did not listen to what the teacher said in class, rather to wait and have class in the morning. It was the conclusion of the team that students were interested in the activity and collaborating, but the lesson was taken too long.

After that, the researcher allowed the other teachers to reflect on this step: Collaboratively Reflect upon class completion. This consisted of two points, the first is a situation with an interesting problem that positively engages students to be able to contact with learning media, which will take time in the purchasing situation, and the working group size is less. The second is Type 1 students who record incomes – expenses at real purchasing situation (get minus number when expenses more than income, ask teacher how to write) while Type 2 students record and summarize all incomes and all expenses then provide a summary of all income minus expenses.

Regarding the "Activity Statement", it was found that it was not so clear. Students could not understand the activity statement. 'Group of teachers collaboratively reflecting upon class completion about Investigating Account' noted that students were chaotic, not listening to the activity statement, focusing on making profit, and even when the teacher had completed the activity statement, students still didn't understand what they were tasked to do. Another "Observation Point" was that the students who sit at the back of the class will not act according to the activity statement

instructing them of what to complete. One advice given was that the teacher should divide students into groups of fewer numbers of group members. Therefore, students should be more engaged in thought and have discussion opportunity. Or else the students can be divided into two big groups and have a co-teacher with them in the group for being the student's facilitator, but still have the other teacher as the main person for the class and have the activity statement explanation by both teachers. Students could go about their duty for the class activity and do activities as group by group. However still some teacher at the meeting disagreed because the research (main teacher) should only teach the class as one person and other teachers should just collaboratively observe the lesson, after which they then collaboratively reflect upon class completion. So if there is a problem to fix they could suggest that it should be improved in the other group's trial lesson. But due to the fixed timing, there would not be a second chance to try to improve on next class because other classes had taken the lesson already.

After having done this part, the next part was to 'Collaboratively Reflect on Group System Collaboration'. This was done by soliciting teacher recommendations and raising their hand to speak one by one when they had a question. The researcher then elaborated about the problems that that were found on the trial lessons and bring about improvement in the next lesson. The teacher's group continued to discuss styles of 'Collaboratively Observing the Lesson' to benefit that it is good to have it, because they could group brainstorm their thoughts and adjust them together. This is because in actual collaborative design lesson plans, it should work in this direction. And should there be any mistake that appears, then they should bring them up to improve the quality if there were a chance of doing this activity again with other classes. Therefore to make the quality of learning even better, and if the teachers continue to use this process, there may be a new perspective, in order to develop student's behavior on learning, according to collaboratively designed lesson plans that they have planned.

Figure 4.7 Participants' collaboration in reflection or post-discussion after class finished in Investigating Accounts lesson

In the part of 'Reflection upon the 21st century skills performance observation form that the group has been completing, the teachers and researcher collaborated on brainstorming ideas about the Behavior Reflection Form. They came to the conclusion that it is too broad and sometimes the person making the observation could not record the student's behavior, or did not know to record it. This was the first time that a behavior form had been created by the researcher, which according to the idea of skills of learning and innovation (4C's), by following the process of Open Approach there come into consideration 4 elements; Posing open-ended problem, Students' Self-learning, Whole class discussion and comparison, and Summarization through connecting students' mathematical ideas emerged in the classroom. This meant having another set of indicating papers (indicators that are part of the collaboratively designed lesson plans) shown as appendix A. After finishing the class, the observer suggested that the researcher should have another kind of form of observation behavior form, maybe a variation such as an overall observation form that works through the indicators had been selected by the group. Therefore, for the next class, the

researcher created a new behavior observation form by having indicators for each skill on the left column of the form and the behavior that the observer had witnessed in class during the activity written down on the right side of the behavior's observation form shown as appendix B

When doing 'Collaboratively Observe the Lesson' until 14th lesson plan, the group of teachers again created a new behavior observation form. This was because on the whole picture of a student's behavior, it makes a macro view and there is a lack of micro view; on specific points, and on each of step of doing a style of teaching as Open Approach. Therefore they collaboratively remodeled the behavior observation form that shows skills of learning and innovation (4C's). It can be noted that there were 4 steps of teaching style of Open Approach, and space to record the student's behavior that the observer found in class on their observation (appendix B)

From "What the Teachers had collaboratively reflected upon class completion": for each lesson plan it was discovered that the teachers had a clearer perspective view. They were able to give samples of the behavior of the students and meet for discussion about them. When all 17 lesson plans had been completed, the researcher presented the whole picture of the development of the lesson plan and the process of adaptation into class following table 4.4

Table 4.4: Summary of reflections for each lesson plan

Unit of Learning	Name of Lesson Plan	Content	Learning and Innovation Skills		Hours	Results from Reflections
			Pre-teach	Post-teach		
1.Integers	1.Investigating Accounts	Integers	C_1 , C_4	C_1, C_2, C_3, C_4	1	1. Instructions should be explained clearly before starting teaching. 2. Inconsistency of designed problems and learning materials. 3. Activity's instructions were unclear. 4. Students should be divided into smaller groups and rules for group working should be explained. 5. Too much time spent on activity
	2.Negative Numbers	- Integers on the Number Line - Opposite Numbers	C_1, C_3	C_1, C_2, C_3, C_4	1	1. Learning materials should be more virtualized.

Table 4.4 (cont.)

Unit of Learning	Name of Learning Plan	Content	Learning Skills and Innovation		Hours	Results from Reflections
			Pre-teach	Post-teach		
	3. Where am I?	Addition of Integers	C_1, C_2, C_3, C_4	C_1, C_2, C_3, C_4	2	1. Instructions should be clearly informed that the text-symbol was required. 2. Time should be allocated clearly for each sub activity. 3. All 4 learning skills and innovation found.
	4. Change the sign	Subtraction of Integers	C_1	C_1, C_3, C_4	1	1. Students could use representation on a number line, and could write text-symbol in mathematics as expected. 2. Before giving condition of problem, demonstration and example should be given on the white board in order to link with activity pertaining to addition of the integer number. This would be easier to understand. 3. Should be group activity.
	5. Eat and don't eat	Multiplication of Integers	C_1	C_1, C_3, C_4	2	1.Condition of problem should be changed to find out the relation to the relation in mathematical form by giving meanings of symbol (+) as eat and (-) as don't eat.

Table 4.4 (cont.)

Unit of Learning	Name of Learning Plan	Content	Learning Skills and Innovation		Hours	Results from Reflections
			Pre-teach	Post-teach		
	6. Divided me!	Division of Integers	C_1	C_1, C_3, C_4	3	1. Students could summarize the principle of division of the integer number as expected.
	7. Number properties	Number properties	C_1	C_1, C_2, C_3, C_4	1	1. Students should be asked to find out the relation in the form of identification and inverse. 2. Summary on the white board should be more systematized, such as dividing the board for the summaries of addition and multiplication.
2.Powers	8. I am a power	-Power form - Exponent	C_3	C_1, C_2, C_3, C_4	1	1. Students could show ideas as expected. 2. Questions should be given in order to make a conclusion of a lesson in which students could respond person by person to assure that they understood the lesson.
	9. Operation of powers	Solution of Powers	C_1	C_1, C_3, C_4	2	1. The problems given were so easy that students could solve in a short time and made them inactive. 2. Students should be asked to present ideas in front of the class.

Table 4.4 (cont.)

Unit of Learning	Name of Learning Plan	Content	Learning Skills and Innovation		Hours	Results from Reflections
			Pre-teach	Post-teach		
	10. Multiplication property	Multiplication of Powers by $a^n \cdot a^m = a^{n+m}$ $(a^n)^m = a^{n \times m}$	C_1, C_3	C_1, C_3, C_4	3	1. Done with activity that helped students to understand form and background of the multiplication of exponents and led them to the conclusion $(a^n)^m = a^{n \times m}$.
	11. Division property	Division of Powers by $\frac{a^n}{a^m} = a^{n-m}$	C_1	C_1, C_3, C_4	1	1. Students could show ideas and found out the relation of form as expected. 2. Summary of the multiplication of exponents should be provided on the white board.
	12. How big am I?	Scientific notation	C_1, C_2	C_1, C_3, C_4	2	1. Contents on basic Mathematics should be re-arranged and added more so as to avoid the duplication of contents. 2. Students should be asked to summarize the scientific notation so as to compare with cases that have many numbers and less numbers.

Table 4.4 (cont.)

Unit of Learning	Name of Learning Plan	Content	Learning Skills and Innovation		Hours	Results from Reflections
			Pre-teach	Post-teach		
	13. Alien Game	Powers problems	C_1	C_1, C_2, C_3, C_4	2	1. Criteria should be added more to the problems provided. 2. Students should be chosen randomly to show up and summarize the lesson one by one.
3. Basic Geometry	14. Yes, I am!	Definition of Point, Line, Segment, Ray right angle, acute angle, obtuse angle	C_2, C_3, C_4	C_1, C_2, C_3, C_4	1	1. Students could categorize characteristics of geometry as expected. 2. Learning materials should be bigger and clearer. .

Table 4.4 (cont.)

Unit of Learning	Name of Learning Plan	Content	Learning Skills and Innovation		Hours	Results from Reflections
			Pre-teach	Post-teach		
	15. How to construct (1)?	Construction of Segment	C_2, C_4	C_1, C_2, C_3, C_4	4	1. The problems given facilitated students to practice thinking process and teaming very well. 2. Students had different ideas beyond the expectation. 3. Teacher should write different ideas found in the class on the white board after the group discussion.
	16. How to construct (2)?	Construction of angle and angle's division	C_2, C_4	C_1, C_2, C_3, C_4	3	1. Students showed different ideas as expected, but the sequences of making were different from the expectation of teacher. 2. Should be more exercises.
4. Exploring Math	17. Math Project	Presentation of mathematical games	C_2, C_3, C_4	C_1, C_2, C_3, C_4	2	1.Students should be asked to get their friends joining the game in order to assure that their friends understood what they presented.
				Total	**32**	

4.1.4 Collaboration in Reflection or Post-discussion on the Curriculum

Curriculum Evaluation

Focus group, to evaluate the overview of the curriculum after finishing the research, was held on Tuesday 1st of October 2013 at 14.00-15.00. Participants in the meeting were the Academic vice Director, Chief of Academics Affairs, Chief of Research and Human Resources development, Chief of Curriculum and Instruction, Mathematics Department Chair, 8 Mathematics teachers, and the researcher, totaling 14 persons.

1) Curriculum Evaluation from Co-Developers

Researcher presented a videotape, an overview of the collaboratively developed curriculum in order to review all of the activities conducted together. These were; collaboration in lesson design, collaboration in classroom observation, and collaboration in reflection. After that, teachers were asked to give reflections regarding details in each part of the curriculum, as well as overall perspective of the curriculum as follows.

1. Concept/principle of the curriculum, course description, learning standards, expected learning results/course objectives

Concept/principle of the curriculum was set to conform to the school's needs. With regard to the school's policy towards the curriculum development for internationality, these were learning management in Mathematics to promote higher-order thinking skills along with subject content. In case of course description, it would cover everything students should learn conforming to Basic Education Core Curriculum B.E. 2551 (A.D. 2008) for Mathematics. Exercises and tasks were collated to help students integrate all knowledge they have learnt and then presented to peers and their teacher. In respect of learning standards, it should be aligned with Basic Education Core Curriculum B.E. 2551 (A.D. 2008) for Mathematics as well as expectation/objectives of learning results. It was significant to promote students to have learning skills and innovation including an emphasis on systematic thinking and respect for each other in a group.

2. Features of learning activity

Learning management using open approach is the way to stimulate students to be active all the time, which is different from the previous approach. Advantages of this approach are; students have self-learning process, the knowledge is long-lived, students have more chance to discuss among peers in the class, students can practice teaming skills, which requires respect for each other and then they build up good relationships at the end of the semester. However, time is a disadvantage of this approach. Some lessons may take more than 1 period, while among a big group of students; it may not take all to solve the problems. By the way, when they are divided into a smaller group (3-4 people) they had developed communication skills through talking, discussing, exchanging with peers.

3. Unit of lesson/topic of content and time for teaching

There are 4 units of learning which are appropriate and consistent with time to be spent on learning management in each semester. In a plan of periods spent in each topic, it should be consistent with time duration of the course. However, in practice, some lessons might spend longer than specified because of several reasons and summarization of a lesson may then have to be done in the next period. On the contrary, some lessons may take shorter than specified, because the school's activity schedule is ever-changing. The lesson then could not be completed.

4. Evaluation of Skills

The evaluation in this curriculum is to evaluate learning skills and innovation. Teachers worked collaboratively to discuss and set indicators from watching videotapes. The evaluation in accordance with the specified indicators is sometimes limited because some behaviors of students may fit into more than one indicator. If it is possible, the indicators should be revised by using clearer terms to distinguish indicators from each other.

5. Structure of the Curriculum

Structure of the curriculum may be changed in the way to reduce the number of lessons and give more time for each lesson. It is because, in practice, one period is inadequate. Therefore, the structure should be flexible in time. For example lesson no.1 “Investigating Accounts” and lesson no.2 “Negative Numbers” should be merged to 1 lesson and extend the time to 2 hours.

6. Lesson Plan

Focus group was held to make a plan for activity in each period. Questions, expectations, student’s ideas, and learning materials were nearly complete because these relied on co-working regarding questions and expected responses from students, or how to set a question. All 17 lessons have been done by this process, yet these should be revised in parts of expected ideas or some questions that students did not understand, e.g. lesson “Eat and don’t eat”. Writing pattern for the learning plan was very new where the student’s ideas were included in order to help the teacher to expect the answers of students.

7.Learning Materials

Learning materials were good because they were both diverse and interesting. Worksheets helped them to practice thinking skills. Learning materials that students could touch helped them in the self-learning process. The class was then more colorful because they were not only listening to the teacher.

After the collaboration in reflection process, the researcher asked teachers to evaluate the whole curriculum. We found that 12 out of 14 participants (85.71%) agreed that the curriculum created by their collaboration was suitable and had potential lead students to the development of thinking skills, critical thinking, and ability to solve problems. Students could solve unseen or unfamiliar problems in various ways. They also had creative thinking, communication skills; speaking, listening, writing, and collaboration skills which included teamwork, flexibility and accommodation to achieve the set goal. Nonetheless, the curriculum had some limitations such as high time consumption in decreasing each lesson plan and it was suggested that we reduce

the number of lesson plans and combine the overlapped or related contents into one learning unit.

Regarding attitudes of participants in processes of the curriculum development, we found that teachers had a positive attitude towards the collaborations in planning, observation, reflection, and academic discussion. They exchanged and learned from each other. It made them feel confident to learn from experiences of peers in the same profession, and it was the first step for the collaboration in school's curriculum development. Moreover, we found that students had a chance to practice the learning process through the open approach. They were active and excited all the time in the class. They practiced how to present their ideas out loud where higher-order thinking skills were emphasized.

After finished with all processes of curriculum development, researcher summarizes revision of the curriculum after the application of lesson study approach as described in table 4.5.

Table 4.5 shows revision of the curriculum after the Application of Lesson Study process

List	Elements of the Curriculum	Collaborative Curriculum	Revision after the Application of Lesson Study Process
1.	Curriculum's concept and principle	Learning in the 21st century is about learning about life living in society. Moreover, not only learning from academic programs, but to continue adapting what students have learned to apply into their lives continuously and to apply effectively and creatively from what they have learned, improving the skills of thinking, the skills of knowledge in technology, and even more about the details of the new world that is ever changing in the 21st century. Significantly, in the year 2018, Thailand is moving toward to ACE spot. Subsequently, the Ministry of Education has a critical need to develop Thai people, especially the characteristics of Thai students that will be entering the ACE group, in the requirements of having 4 fundamental skills (Ministry of Education,2011); the ability of problem solving using peaceful methods, ability in working together with other people, ability to	

Table 4.5 (Cont.)

List	Elements of the Curriculum	Collaborative Curriculum	Revision after the Application of Lesson Study Process
		combine the skills of technical knowledge with creativity, which is consistent with Learning and Innovation Skills, and also aligned with the Partnership of 21st Century Skills, in which the focus is on Critical thinking and problem solving, Creativity and innovation skills, Communication and Collaboration or 4C's. Wiengjedee Wittaya School is under Secondary Educational Area District Office 35. In order to become a developing International curriculum as a World-class standard school, the school must follow their policy control. Expectations of mathematics lessons emphasize higher-order thinking skills together with knowledge, by organizing classes at an international level of preparation. The results, therefore, would be students entering the ACE group as students of the 21st century, with strong skills.	None

Table 4.5 (Cont.)

List	Elements of the Curriculum	Collaborative Curriculum	Revision after the Application of Lesson Study Process
		To organize learning, the "Open Approach" to learning, a Japanese concept, which expands on problem solving, can be used. It is a tool used to develop knowledge and the comprehension skills of learners. There are 4 elements involved; (i) posing open-ended problems, (ii) student self-learning, (iii) whole class discussion and (iv) comparison and summarization through connecting students' emergent mathematical ideas in the classroom. Thereby; the style of having classes set up using an "Open Approach" will consist of group discussions, gaining diverse ideas from students and developing skills of thinking through group sharing and proper advice from the teacher. In addition, having an "Open Approach" class style is gaining more interest in student classes, as having mathematics communication which emphasizes points of critical thinking skills in	

Table 4.5 (Cont.)

List	Elements of the Curriculum	Collaborative Curriculum	Revision after the Application of Lesson Study Process
		mathematic thought. It is also consistent with the Core Curriculum 2551, and empowers learners to have more collaboration. Hence; it helps them to live in the 21st century.	
2.	Subject description	The objectives of the subject are to teach the concepts of meaning and number operation, for instance, Integers (positive integers, zero, negative integers) Number properties, and the meaning and the processing of Powers. To write a number in scientific notation, Basic Geometry's properties such as linear, segment, parallel line, ray and angle. To construct segment , make in half of segment, angle degree with 45°, 60°, 90°,120°, 135° and doing math projects by connecting concepts of mathematics that have been learned. Using mathematics processing, students can show the sample mathematics method of addition, subtraction,	None

Table 4.5 (Cont.)

List	Elements of the Curriculum	Collaborative Curriculum	Revision after the Application of Lesson Study Process
		multiplication and division of Integers, solving problem of addition, subtraction, multiplication and division of Integers, comparison of positive integers, negative integers and zero, explaining about number properties and explaining the meaning of Powers , indicating of Powers in case of an integers with the integers base. Showing methods of calculation in multiple Powers and writing a number in scientific notation. Explaining Basic Geometry properties, telling the characteristics of points, linear, segments, parallel lines, rays and angles. Build segment and make in half of linear to create degrees of 45, 60, 90, 120, and 135 degrees, having creativity expressed and represented their idea. Thereupon, to ruly develop a learner's potential, and in order to have the learning skills of the 21st Century, students must have Critical thinking and problem solving, Creativity and innovation,and Communication and Collaboration with others.	

Table 4.5 (Cont.)

List	Elements of the Curriculum	Collaborative Curriculum	Revision after the Application of Lesson Study Process
3.	Standard learning	Basic Education Core Curriculum B.E. 2551 (A.D. 2008) for Mathematics	None
4.	Expectation results / Curriculum purposes	1.Academic knowledge 1.1Knowledge and understanding about whole numbers 1.2 Knowledge and understanding about integer numbers 1.3 Knowledge and understanding about geometry fundamentals 2) Skills of learning and innovation of 21st century concepts 2.1 Critical Thinking and Problem Solving 2.2 Creativity and Innovation 2.3 Communication 2.4 Collaboration 3) Attitude and Values Students are most concerned with critical thinking systems, open-mindedness and response to new ideas, interest and seeking knowledge, cooperation in class, having a good attitude toward the study of.	None

Table 4.5 (Cont.)

List	Elements of the Curriculum	Collaborative Curriculum	Revision after the Application of Lesson Study Process
		mathematics subject, effective listening and paying respect to the ideas of other people in the group and sharing with friends in class	
5.	Features of learning activity	Learning activity by using Open Approach which follows the concept of Inprasitha (2010), the four steps of which are as follows: Step 1: Posing an Open-ended Problem Step 2: Students' Self-learning Step 3: Whole class discussion and Comparison Step 4: Summarization through Connecting of the Student's Mathematical Ideals that Emerged in the Classroom	None
6.	Unit of lesson/topic of content and time for teaching	There are 4 units covering 32 hours and one topic for each lesson following; **Unit1** Integers (4 weeks) Integers 1 hr. Integers on the Number Line 1 hr. Opposite Numbers 1 hr. Addition of Integers 2 hrs	There are 4 units 32 hours and have topic for each lesson following; **Unit1** Integers (4 weeks) Investigating Accounts 1 hr. Negative Numbers 1 hr. Where am I? 2 hrs. Change the sign 1 hr

Table 4.5 (Cont.)

List	Elements of the Curriculum	Collaborative Curriculum			Revision after the Application of Lesson Study Process		
		Subtraction of Integers	1	hr.			
		Multiplication of Integers	2	hrs.	Eat and don't eat	2	hrs.
		Division of Integers	2	hrs.	Divided me!	3	hrs.
		Numbers properties	1	hr.	Numbers properties	1	hr.
		Unit2 Powers (4 weeks)			**Unit2** Powers (4 weeks)		
		Power forms	1	hr.	I am a power	1	hr.
		Exponents	1	hr.	Operation of powers	2	hrs.
		Solution of Powers	1	hr.	Multiplication property	3	hrs.
		Multiplication of Powers ($a^n \cdot a^m = a^{n+m}$	3		Division property	1	hr.
		hrs.			How big am I?	2	hrs.
		and $(a^n)^m = a^{n\times m}$			Alien Game	2	hrs.
		Division of Powers $\frac{a^n}{a^m} = a^{n-m}$	1	hr.			
		Scientific notation	1	hr.			
		Powers problems	2	hrs.			
					Unit3 Basic Geometry (3 weeks)		
		Unit3 Basic Geometry (3 weeks)			Yes, I am!	1	hr.
		Definition of Point, Line, Segment, Ray	1	hr.	How to construct (1)?	4	hrs.
		right angle, acute angle, obtuse angle			How to construct (2)?	3	hrs.
		Construction of Segment	4	hrs.			
		Construction of angle and	3	hrs.			

		angle's division	

Table 4.5 (Cont.)

List	Elements of the Curriculum	Collaborative Curriculum	Revision after the Application of Lesson Study Process
		Unit4 Math Project (1 week) Presentation of Math Game 2 hrs.	**Unit4** Exploring Math (1 week) Math Project 2 hrs.
7.	Evaluation of Skills	The framework for student's evaluation about 21st Century Skills Performance (Learning and Innovation Skills; 4C's) were; 1. Critical Thinking and Problem Solving; C_1 1.1 Verbal and written reasoning 1.2 The propensity to seek reason 1.3 Inquisitiveness in open-ended problems 1.4 Making decisions in solving problems 1.5 Interpreting and explaining 1.6 Making another choice and convincing others with appropriate reasons 1.7 Engaging in analyzing each other's answers 1.8 Solving open-ended problems 1.9 Analyzing arguments, claims, or evidence	None (Change the form after revised lesson shown as Appendix B)

Table 4.5 (Cont.)

List	Elements of the Curriculum	Collaborative Curriculum	Revision after the Application of Lesson Study Process
		2. Creativity and Innovaion; C_2 2.1 Generating ideas, often by thinking divergently using fluency and originality 2.2 Being tolerant of ambiguity 2.3 Willing to take intellectual risks 2.4 Generating new and varied ideas 2.5 Expressing different ideas 2.6 Generating learning style or tools 3. Communication; C_3 3.1 Rephrasing other's explanations 3.2 Engaging in questions and discussion 3.3 Paying attention to others' reasons 3.4 Effectively communicating Math concepts orally and in writing 3.5 Selecting appropriate reading strategies for open-ended problems	

Table 4.5 (Cont.)

List	Elements of the Curriculum	Collaborative Curriculum	Revision after the Application of Lesson Study Process
		4. Collaboration; C_4 4.1 Being able to express Math problems with peers and teachers 4.2 Having sense of teamwork 4.3 Sharing ideas and listening to others' perspectives 4.4 Negotiating to get consent (The form shown as Appendix B)	
8.	Curriculum structure	Table 4.3	Adjust/add Learning and Innovation Skills (4C's) shown as table 4.4
9.	Learning Materials	- Sheet on state of problem - Worksheet/brochure/bank notes (fake) in topic "Investigating Account" - Material: looking glass on topic in topic "Negative Numbers" - PowerPoint Slide in topic "Where am I?" -Materials for activity in topic "Where am I?"	-Change state of problems in some activities as in table 4.4. - Materials are as media number line instead of the mirror in "Negative Numbers"

able 4.5 (Cont.)

List	Elements of the Curriculum	Collaborative Curriculum	Revision after the Application of Lesson Study Process
		- Materials for word cards activity in topic “Number properties” - PowerPoint Slide PowerPoint in topic “I am a Power” - PowerPoint Slide in topic “Eat and Don’t Eat” - PowerPoint Slide in topic “How Big am I?” - Online learning material in topic “Alien Game” - Activity materials: word cards in topic “Yes, I am!” - Electronic teaching board for teaching in topic “How to construct (1) & (2) ”	- Adjust size of materials for word cards activity “Yes, I am!” To be bigger and clearer.
10.	Learning sheets	- Learning sheets 3 units	None

4.2 Part. 2: The results of using Mathematics Curriculum to Promote Learning and Innovation Skills of 21st Century through the Application of Lesson Study.

Conducting this research, the researcher organized a total of 17 lessons in 32 hours. Research presents results of the implication of Mathematics curriculum to promote learning skills and innovation of the 21st century (4C's) which consist of 1) Critical Thinking and Problem Solving (C_1), 2) Creativity and Innovation (C_2), 3) Communication (C_3), and 4) Collaboration (C_4). The data is analyzed and described wholly in table 4.6 below.

Table 4.6 Shows behaviors of students which were in accordance with the indicators of learning skills and innovation in 17 lessons.

lesson plans	Critical Thinking and Problem Solving									Creativity and Inovation						Communication					Collaboration			
	A1	A2	A3	A4	A5	A6	A7	A8	A9	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	D1	D2	D3	D4
1			✓	✓		✓					✓			✓	✓		✓				✓	✓	✓	✓
2		✓	✓											✓			✓	✓					✓	
3		✓	✓			✓		✓		✓			✓	✓	✓		✓				✓	✓	✓	✓
4								✓									✓						✓	
5								✓															✓	
6								✓											✓				✓	
7		✓	✓				✓				✓	✓				✓	✓		✓		✓		✓	
8			✓				✓					✓							✓		✓		✓	
9				✓												✓							✓	
10				✓													✓				✓			
11				✓													✓				✓			
12		✓	✓														✓						✓	
13							✓								✓				✓		✓			
14			✓				✓				✓				✓			✓	✓		✓	✓	✓	✓
15			✓	✓		✓		✓		✓	✓		✓	✓				✓	✓		✓	✓	✓	
16		✓		✓	✓										✓		✓				✓		✓	
17	✓									✓			✓	✓		✓	✓		✓		✓	✓	✓	

C_1 consists of indicatorsA1-A9 C_2 consists of indicatorsB1-B6 C_3 consists of indicators C1-C5

C_4 consists of indicators D1-D4 (as described in detail in table 4.8)

From table 4.7, the researcher found that students had shown all 4 learning skills and innovation of the 21st century. Most of behaviors in 4 skills which students had shown were 1) Critical Thinking and Problem Solving; students had curiosity in the problems provided. They were able to make a decision to solve

the problems and tried to give explanations. 2) Creativity and Innovation; students showed ideas which were different to their previous ones as well as being different to others. This includes the ability to create their own ways/devices of learning. 3) Communication; students participated in discussing sessions among peers in groups/classes. They had the ability to write or communicate with others. 4) Collaboration; students tried to show and explain their ideas to each other, peer to peer, student to teacher. They also exchanged their ideas and listened to each other. In this respect, the researcher analyzed behaviors of students which were in accordance with the indicators of learning skills and innovation of the 21st century (4C's) as well as the approaches the teacher used to arouse these behaviors in table 4.7

Table 4.7 Summarization of Students Behaviors accordance with the indicators of learning skills and innovation of the 21st century (4C's)

Indicator	Students Behaviors	Encouraging Process from the Teacher
1. Critical Thinking and Problem Solving		
A1: Verbal and Written Reasoning	-Students use explanations -Students give examples, such as an example of the advantages of the game	Using proper questioning to encouraging students to explain how they got the examples
A2: The Propensity to Seek Reason	-Students give examples from their ideas -Students use pictures, messages and symbols to explain -Students use information from other people, such as peers and teachers . Example: Students attempted to write down their ideas and figured out how to get the answer.	-Encouraging students with question without judging right or wrong - Allow students to use technology such as tablet, internet phone and computer to search for more information

Table 4.7 (cont.)

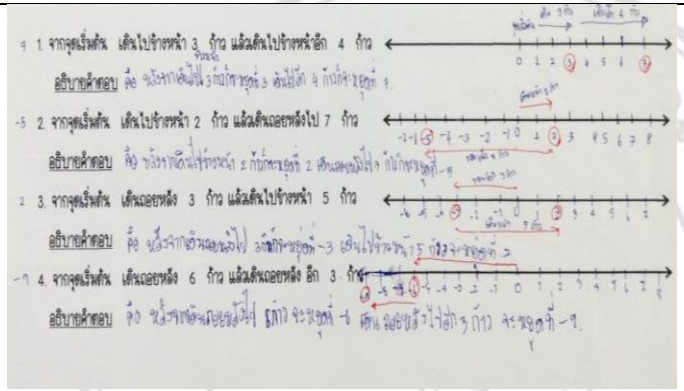
Indicator	Students Behaviors	Encouraging Process from the Teacher
		
A3: Inquisitiveness in Open-ended Problem	-Students show enthusiasm via the presentation -Students show excitement and want to do the experiment -Students discuss with friends about the activity and ask questions	-Using example of real life situations -Using variety of equipment to present to students
A4: Making Decision in Solving Problem	-Students working together came up with the conclusion of how to solve problems -Students able to work by themselves without help	-Group activity with assigned responsibility role for each student from the teacher -Encouragng students to use new ideas to solve the problems

Table 4.7 (cont.)

Indicator	Students Behaviors	Encouraging Process from the Teacher
A5: Interpreting and Explaining	-Translated message and symbols and made conclusions from them -Give examples	-Lesson plan starts from easy level to more difficult level to motivate students -Using questions that point out the difference and the similarity
A6: Making Another Choice and Convincing Others with Appropriate Reasons	-Created different ways and proper ideas -Using example to persuade classroom	Encouraging students to use new ideas, be creative and share ideas with class
A7: Engaging in Analyzing Each Other's Answer	-Classroom presentation with shared opinions -Debated the results and problems	-Classroom presentation, individually and group -Encouraging students for discussion among class without judging right or wrong -Make conclusion together with the whole class before the end of class

Table 4.7 (cont.)

Indicator	Students Behaviors	Encouraging Process from the Teacher
A8: Solving Open-ended Problem	-Students able to do by themselves -Students can answer the questions properly	Teacher use activity in real life situations
2.Creativity and Innovation		
B1: Generating ideas, Often by Thinking Divergently and Using Fluency and Originality	-Students came out with different ideas	- Encouraging students to create different ideas -Encouraging students to share and discuss ideas with other groups and try to come up with different idea from other groups
B2: Being Tolerant of Ambiguity	-Students try to solve problems by themselves first or with group members -Students didn't give up trying to solve problems	-Evaluated ideas without judging right or wrong -Enough preparation time for students -Encouraging students to discuss with friends

Table 4.7 (cont.)

Indicator	Students Behaviors	Encouraging Process from the Teacher
		- Allow students to use technology such as tablet, internet phone and computer to search for more information
B3: Willing to Take Intellectual Risks	-Students confident to show their ideas to class to try to solve problems	-Teacher courage students to give opinions and respect other people opinions - Create system for students when they want to show their opinions by putting their hand up
B4: Generating New and Variety ideas	-Experimenting with different ways to solve problems -Create different ways of thinking from other groups Example: In order to make a straight line as long as required, students had 2 ways as follows: Way 1- Expand the dividers as wide as required.	-Provide proper media and equipment for students to try -Use open ended instructions so students can create by themselves

Table 4.7 (cont.)

Indicator	Students Behaviors	Encouraging Process from the Teacher
	- Make marks on paper by using a pin punch leg. -Draw a straight line by using a ruler to link one point to the other as marked.  <u>Way 2</u> - Expand the dividers as wide as required. -Make marks on paper by using a pin punch leg, then place a ruler on the marks. - Draw a straight line linking the two marked points .	

Table 4.7 (cont.)

Indicator	Students Behaviors	Encouraging Process from the Teacher
B5: Expressing Different Ideas	-Use different ways to explain their ideas -Use symbols and new ways of explanations - Create different ideas from their friends Example: Students had different ideas on how to record income and expense. These can be grouped into 2 main ideas as follows: Group 1: Students recorded income and expense once sell and buy activities occurred (it was in deficit when they spent more than the income. They asked teacher how to record it) Group 2 : Students recorded all of the income firstly, followed by the expense. They summed up all of the income and then subtracted it with all of the expense. "Summed up the income and then subtracted it from the expense" "Added up all money they had with the income and then subtracted it from the expense".	-Teacher creates a situation that has several ways to solve -Encourage students to create way to solve problems before guiding them -Create group activities to motivate students to share their ideas with members of the group

Table 4.7 (cont.)

Indicator	Students Behaviors	Encouraging Process from the Teacher
	- Students presented the idea to conduct an activity *"Eiffel Opposite"* which was different from other groups, i.e. generally the game was similar to "*Throwing dices*". Comp ete in counting, representing by cartoon figures, the first one to reach the top would be the winner. They also used pins attached to the cartoon figures, so that it could be stuck in the tower.  	

Table 4.7 (cont.)

Indicator	Students Behaviors	Encouraging Process from the Teacher
B6: Generating Learning Style or Tools	-Students try to solve problems by themselves and or with group -Use medias or equipment in real life to help solve problems	-Motivate students to create equipment to solve problems by themselves
3.Communication		
C1: Rephrasing Other's Explanation	-Using example with the explanations	-Motivate students to discuss how each student come up with the answer
C2: Engaging in Questions and Discussion	- Group discussion -Every student had the opportunity to show their opinion Example: In order to write the walking trail, students as a group discussed amongst, themselves, giving explanations and suggestions. For example, "from the starting point walked	-Teacher create activities motivate students to give their opinions

Table 4.7 (cont.)

Indicator	Students Behaviors	Encouraging Process from the Teacher
	Forward 3 steps and then marked with a number, then walk 4 more steps, counted to 4 and marked with number 7". Or should arrow-marks be drawn by sequential order or in over and below?"	
C3: Paying Attention to Others' Reasons	-Students pay good attention in class while others present	- Peer evaluation technique
C4: Effectively Communicating Math Concepts Orally and in Writing	- Give out examples with messages, symbols and pictures -Use simple words to explain and explain step by step Example: Teacher asked students randomly to explain why they thought the mathematical text they got was rightly matched with the English fields they chose (before having a whole-class discussion). Students who had been chosen could explain and helped their peers understand, for example *"2+(3+1)=(2+3)+1* was the *Associative* because at the first	-Teacher randomly choose a student to explain in their own language -Questions in the worksheet encourages students to explain their answers

Table 4.7 (cont.)

Indicator	Students Behaviors	Encouraging Process from the Teacher
	time on the left 3 and 1 were in the same group, while 2 and 3 on the right were in the same group.	
C5: Selecting Appropriate Reading Strategies for Open-ended Problems	NA	-
4. Collaboration		
D1: Being Able to Express Mathematical Problems with Peers and Teachers	-Students work together to get answers -Students have discussion about the answers Example: - In recording income and expense, found that there were many ways to do it. For example, write it one by one, what was actually gained and spent or write all the income, firstly followed by the expense. Members in a group discussed in order to find out the mutual agreement.	-Teacher motivate students for discussion about class -Using real life situation that involves each student to motivate them to solve

Table 4.7 (cont.)

Indicator	Students Behaviors	Encouraging Process from the Teacher
	- Students tried to discuss among themselves, e.g. in walking along the direction as specified in the activity, students sent their representatives, one from each group. The reason was that the distance they took would be equal, but some students disagreed because the lanes provided were already equal so it did not matter who took which lane. -In a process of analysis in a group, each member had tried to present one idea to convince others. For example, in a topic *The Sun*, one student presented that it might relate to the Sun. The Sun has its own light and could spread out like….it might be the ray.	the problems

Table 4.7 (cont.)

Indicator	Students Behaviors	Encouraging Process from the Teacher
D2: Having Sense of Team Work	-Students share responsibility in the group -Students always engaging group work	-Teachers created activities that made students work together -Worksheet have part that student have to determine their responsibility in the group
D3: Sharing Ideas and Listening to Others' Perspectives	-Analyzing how to get answer -Students help their peers who still don't understand Example: Working as groups, students could exchange ideas and listened to each other's opinions, e.g. in *"108 IQ Game"* (group of all male students) which was previously played only in a book. It was a game that players had to find out the answers by calculation as required. Idea of the game was interesting but the game itself was not. Peers in a group then suggested changing the form in order to make it more interesting.	-Teacher should encourage students to help each other before asking the teacher

Table 4.7 (cont.)

Indicator	Students Behaviors	Encouraging Process from the Teacher
	-In case of writing direction in a worksheet, students, in many groups, asked their peers about how to write it as well as the answers their peers had. They compared it with others, if it was different from their peers they would ask the ways and ideas their peers used.	
D4: Negotiating to Get Consent	-Students learn to be open minded to other opinions -Students learn to exchange their opinion and respect others' opinions	-Create situations that motivate students to work together