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Lesson Study: Problem Solving Approaches in Mathematics Education as a Japanese Experience

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Abstract

Lesson study is a scientific activity for Japanese teachers on their meaning. In Japan, research topics for lesson study usually shared through the regular revisions of curriculum and research movement by several societies (Isoda et al.; 2007). As a result of teachers' challenges, several local theories of teaching were shared. 'Problem Solving Approach' has been known as Japanese teaching approach (Stigler & Hiebert; 1999). It is a well known theory of teaching for developing children who learn mathematics by/for themselves in Japan. It includes teaching about learning how to learn. Another important products of lesson study are theories for curriculum, described in teacher's guidebooks as a number of technical terms which are only used by teachers and math-educators for sharing pedagogical content knowledge.

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Keywords: Japanese lesson study; Problem Solving Approach; Pedagogical Content Knowledge; History of lesson study

1. Introduction

Lesson study is a scientific activity for teachers who try to develop their theories for developing and sharing good practices. Product of lesson study is not limited within what each participant learned from the class and the post-class reflective discussion. Each participant reproduces the class with their own developed theories of practice in each of their contexts. On the personal meaning, their theories are just a kind of pedagogical content knowledge, which is working as their local theory on teaching in each of their practices. In the case of Japan, the regular revisions of curriculum supply national research topics for lesson study (Isoda et al.; 2007). As a result of teachers' challenge on the same topic from a school to national level, local theories are integrated into a shared theory of teaching. Teachers' journals and academicians who usually participate in lesson study support this theorization through proposing necessary technical terms for improving practice.

'Problem Solving Approach' has been known as Japanese teaching approach, which was well described by Stigler & Hiebert (1999). It is one shared theory for developing children who learn mathematics by/for themselves in Japan. It includes teaching about learning how to learn, which means how to develop mathematics by/for themselves. It is the consequence of more than one hundred years of lesson study.

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Another important product of lesson study is theories for curriculum, described in teacher's guidebooks as a number of technical terms which are only used by teachers and math-educators for sharing pedagogical content knowledge. For example, in US, Cognitive Guided Instruction Project showed us the evidence of the counting types for addition and subtraction in 1980s. In the case of Japan, counting types and the problem situations were categorized after World War I and before World War II. In 1960s, there was a confrontation on the definition of multiplications between fixing the limitations of dimensions (like Euclid) and going beyond the limitation (like Descartes). Proportional number lines have been introduced to overcome the limitation. Japanese national curriculum clearly enhanced the extension and integration as for the principle of curriculum sequence to develop children for learning mathematics by/for themselves.

Both major achievements are well described at the Special Issues of Journal of Japan Society of Mathematical Education for EARCOME 5 (Isoda & Nakamura; 2010). The origins of technical terms are different depending on each term. For example, various ancient mathematics such as Chinese mathematics and Arabic mathematics used to describe the methods of solutions depending on the problem types. Thus, historically, analyzing the problem type itself used to be a mathematical activity. Distinguish of division between Partitive division (Tobunjyo) and Quotative division (Hoganjyo) related with Japanese Language. On the other hands, the history of problem solving approach is comparatively easy to find the origin.

In this paper, the meaning of products of lesson study is explained and then, the brief history until problem solving approach is illustrated. Using a case of school level lesson study project, the practical theory of teaching for the Problem Solving Approach is explained. It is a sample of lesson study on the problem solving approach.

2. What is lesson study and What are the products of lesson study

2.1 *What is lesson study*

There are various understandings of lesson study. In many of English articles, lesson study is understood as enhancing the school based approach for improvement of teaching as for professional development. In the case of Japan, we have much more contexts of lesson study. Here, the Japanese lesson study is recognized with following features.

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| <p>Process/lesson study cycle: Plan (Preparations), Do (Observations) and See (Discussion and Reflection) activities involving with other teachers.</p> <p>Various Dimensions of Open Classroom: Personal (by master teacher), Whole School, Regional and National lesson study but Systematic.</p> <p>Theme of lesson study: Study Topics and Objective are different. Study Topics such as Developing Mathematical Thinking, Learning for/by themselves in relation to development, reform or improvement. Objective is specified at each class related with curriculum. In the case of Japan, the objective is often described by the sentence 'Through A, students learn/understand/enable to do B' because Japanese curriculum asked teachers to teach learning how-to and achievement as for outcome.</p> <p>Lesson Plan: A format is not fixed, usually developed/improved depending on a study topic of lesson study. Some countries recommend a set of national lesson plans as a part of curriculum, but lesson study is implemented for new challenges and pushes the new format of lesson plan and ways of teaching approach.</p> <p>Teachers' mind: Lesson study is conducted by teachers for developing students in a classroom and making each student developing him/herself, not for researchers who just observe a classroom through their telescopes. Even though researchers participate as for their research, if they do not understand teacher's objectives for developing children, and if they do not work together with them, it is just the activities as a social scientist as an observer. In this sense, lesson study recommends that researchers are teachers who propose improvement of class, as well as teachers are researchers who analyze children's understanding.</p> <p>Results: Lesson study usually considers achievement in relation to study topic and objective. At the same time, aims of lesson study change depending on participants and are not always the same as seen in the following: Model teaching approach, New ideas for traditional approach, Understanding objectives, What students</p> |
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learned before the class, What students learned and could not learn in the class, Teachers' values, Students' values, Professional development, Ideas for the curriculum reform, Theory of mathematics education, and so on.

Sequential experience for sharing the heritage: Lesson study cycle continues beyond the generation. It's usually opened for newcomers and changes experienced bearers. On this context, similar experiences usually are recognized as new experiences with challenges. That is the reason why lesson study develops the learning community.

One of the most sharable products is a description of model approaches. The guidebooks for teaching contents and teaching approaches have been written by teachers. In these twenty years, videos have been used for sharing good approaches by making them more visible (APEC lesson study project 2006: first announcement). In some countries, a model approach sometimes means a teaching manual with the sequence of teacher's questions and children's answers which are expected to be followed by every teacher such as hamburger shops. On the other hand, in the case of lesson study, it is nature of that to work beyond a model because lesson study usually includes a proposal to develop something new in their group based on their own theme of lesson. And usually, new challenges includes some difficulty should be overcome. Thus, on the context of lesson study, a model approach means an illuminating approach and major resources for adapting a model into each teacher's classroom. And sometimes it means an object of improvement for specific aims. On this meaning, lesson study is a reproductive science for teachers.

2.2 *What are the products of lesson study*

There are no limitations on the products of lesson study. On APEC Lesson Study project directed by Isoda, M. & Inprasitha, M. since 2006, it has been engaging in the lesson study to develop good practice on the theme for enhancing Mathematical Thinking (2007), Mathematical Communication (2008), and Assessment (2010). The project aimed to spread lesson study movement for improving teaching practice. Math-educators have been developing lesson study community with elementary school teachers in their economies. On this context, the project asked the specialists the following questions (Figure 1) in relation to how lesson study is productive or influential in participating 19 economies on APEC project (Isoda & Inprasitha; 2008).

| | |
|---|-------|
| Useful for improvement of the quality of mathematics education. | 100 % |
| Influential to other subjects | 93% |
| Used for developing innovative teaching approach. | 93% |
| Used for curriculum improvement. | 80% |
| Used for sharing model teaching approaches. | 80% |
| Used for developing teachers | 80% |
| Used for developing students | 80% |
| Used for developing practical/local theories of Mathematics Education | 53% |

Figure 1: Survey results by the specialists from APEC economies (Isoda & Inprasitha; 2008)

Most of APEC economies have been in the stage for introducing lesson study. On this context, developing theories of mathematics education are still unusual. On the other hand, in some economies such as Japan, teacher cannot recognize the theory of mathematics education without considering their practice. There are researches which have enhancing theories of mathematics education through the practical experiment. Gravemeijer, K. (2007) explained the process to develop the local theory of teaching (Figure 2). This is a case of Netherland to develop local theory based on classroom practice on his research Mathematics in Context. Depending on the research context, the meaning of theory for mathematics education is difference but Figure 2 by Gravemeijer is an illuminating case to show its existence.

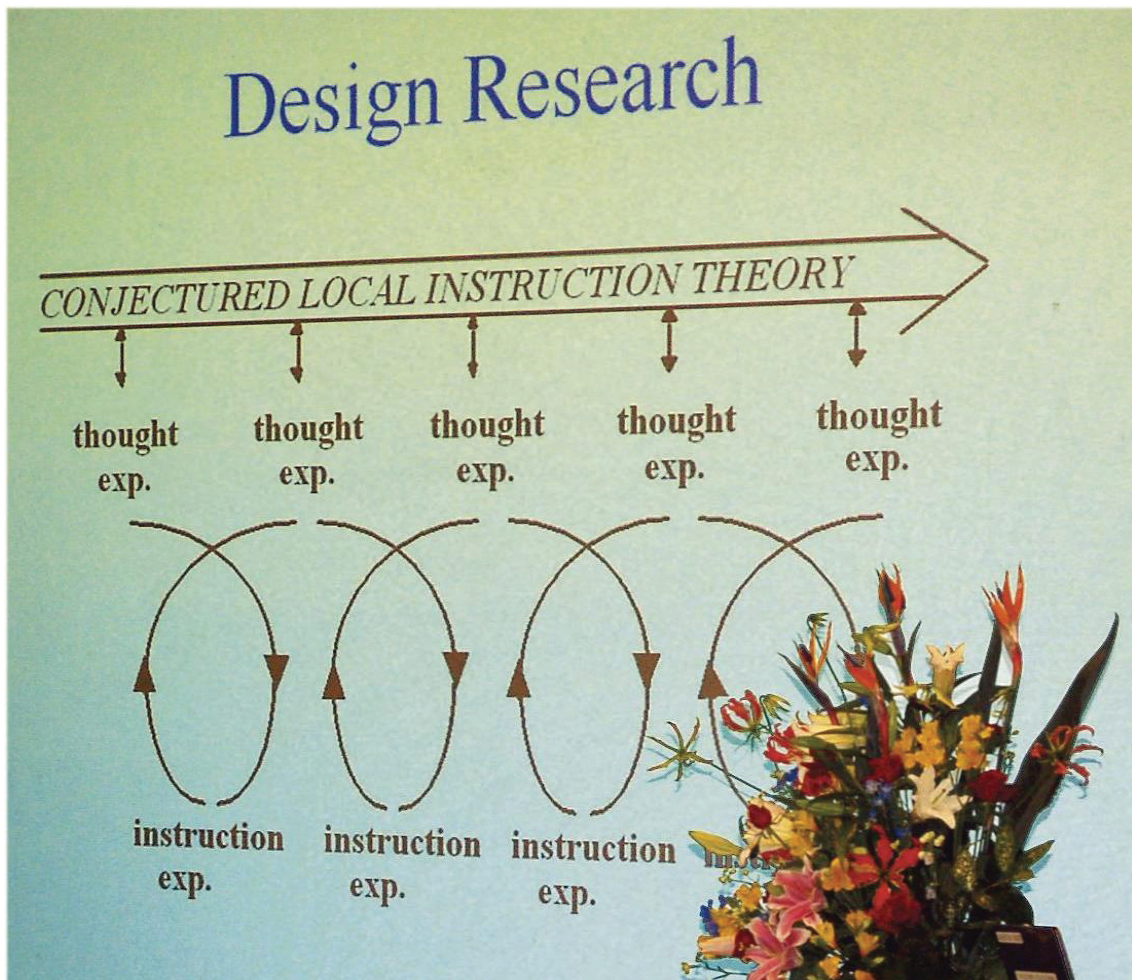


Figure 2: Development of Local Teaching Theory by Gravemeijer, K. (2007)

3. History of Japanese lesson study from the viewpoint of the theme

In the case of Japan, theories of teaching approaches and theories of subject matters or curriculum have been the product of lesson study. This custom is deeply related with that each lesson study is done by the study theme such as special topic of the lesson study. Following Figure 3 shows samples of shared study topics (revised, Nagasaki, E.;2007).

Instead of lecture style, argumentation has been enhanced from the origin of lesson study at Tokyo Normal School (University of Tsukuba) in 1880s. The problem posing by children progressed at the attached school of Nara Women's Higher Normal School (Nara Women's University) in 1920s. Open-ended problems began to be enhanced before World War II. Beyond the occupation after WWII, the approach had been theorized again and again. For developing mathematical thinking, the prototype of this approach was well-known. In 1980s, the approach began to shear. The junior high school textbook based on problem solving approach began to be published in 1980s. A number of teaching guidebooks for explaining how to implement this approach have been published from 1980s. In following sections, some extracts are explained from history.

| Topic of Lesson Study | | |
|-----------------------|--|---------------------------------------|
| 1880s | Pestalozzi Method and Dialog Method (including argumentation between teacher and students) | Not only limited mathematics. |
| 1910s | Mathematics for Life (including problem posing) | Not only limited mathematics. |
| 1930s | Curriculum Integration in Mathematics (including Open-Ended Problems) | From 1900s |
| 1950s | Core curriculum movement based on the social study | Under the occupation after WWII. |
| 1960s | Mathematical Thinking (Japanese way of New Math.) | Related with New Math |
| 1970s | Open-Ended Approach and Problem Solving Approach | For developing Mathematical Thinking. |
| 1980s | Problem Solving | Related with US |

Figure 3: Samples of Lesson Study topics.

3.1 An Origin of lesson study

Japanese lesson study originated in 1872 when the Education code was established and the Normal School (University of Tsukuba) and the Attached Elementary School (Elementary School Attached to the University of Tsukuba) were established at the same time (Isoda et al., 2007). It began from the observation of teaching methods in whole classroom teaching which were firstly introduced in those schools beyond the temple school culture on tutorial teaching methods. People observed the ways of teaching for knowing how-to. Teachers' Canon was published by the Normal School in 1873 which already mentioned the etiquette for entering classroom for observation as for avoiding troubles during observations (Figure 4).

3.2 An Origin of Developing Students thinking and learning by/for themselves

Sometimes, general educators and educational management researchers enhance the function of the professional development on the lesson study but do not concern preparation of subject matter and teaching approaches for improvement. If it does not have the subject and teachers' perspective for developing children, it is not satisfying the meaning of lesson study. The history of lesson study has been described with a new theme and a new approach on lesson study for developing children because the new theme and approach themselves are the aims of study and represent the reform, improvement, or focus of study itself.

The first known lesson study guidebook for teachers in Japan which have these features is 'Reform the Methods of Teaching' (1883: see Figure 5). The lesson study topic was Pestalozzi methodology of teaching approach for whole subjects, but it was not same as the original version in German because it was imported from New York Oswego Normal School and adapted in the Japanese way. In those days, lesson study had been introduced in Japan in a top-down way as well as establishment of the school system with an initiative of the government.

Another important feature of the first guidebook is the establishment of model teaching approach through questioning ('Hatsumon', as we call it today) *for developing students who think by themselves*. For enhancing a dialogue style of classroom communication in whole classroom teaching, the model approach itself was described through the dialogues such as ones of Plato and Confucius. The model dialogues in order to represent the process within a limited number of pages at high cost of publication are a recommended process for enabling teachers to plan their lesson and did not develop for following the protocol to describe social phenomena by current researchers on social science. Teachers' guidebooks in Japan have been keeping the custom of the model dialog because it is much reproductive than the social-science-like protocol. From the viewpoint of teachers who are trying to reproduce

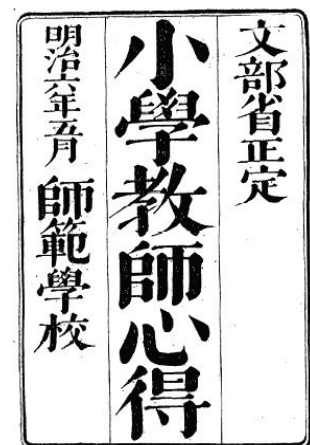


Figure 4: Teacher's Canon (1873)

his approach based on the model approach, model dialogue description style is reasonable because careful protocol as for data only describes the past as the object of interpretation and does not aim for designing new practice.

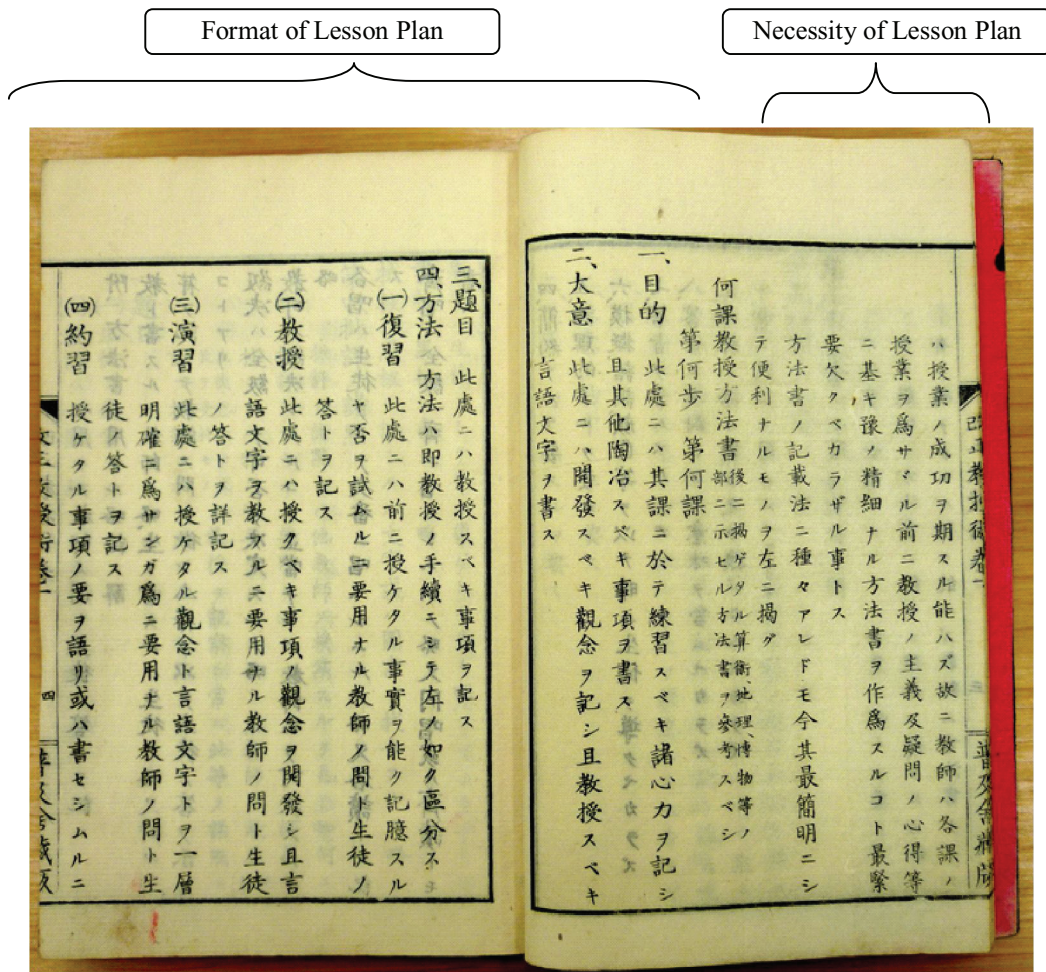


Figure 5: 'Reform the Methods of Teaching' (1883)

3.3 Origins of Problem Solving Approach

In 1910s, Jingo Shimizu was a known case. He wrote a book 'Teaching Elementary School Mathematics through Problem Posing' in Japanese (1924), which explained the innovative teaching approach including a fact that an activity of learning mathematics begins from children's problem posing (Figure 6). In that era, Japanese Teaching Principle, 'Learning by/for Themselves' had been described by teachers and educators who wrote the teachers guidebook for teaching. As seen this example, those samples could be seen as several origins of current problem solving approach.



Figure 6: Problem Posing Approach by Jingo Shimizu (1924)

Japanese Problem Solving Approach, known as the process through ‘posing a problem’, ‘independent solving’, ‘comparison and discussion’, and ‘summary and application’, was known in the US through the comparative study on problem solving in the 80s by Tatsuro Miwa and Jerry Becker. It influenced the world through the TIMSS video study in 90s (Stigler & Hiebert, 1999). Jerry Becker and Shigeru Shimada (1997) explained the approach from the view point of open ended problems. Shimada’s idea itself originated 1940’s. It is a good approach to introduce lesson study in any school (Inprasihta, M.; 2006)

Problem Solving Approaches are one of the shared approaches in Japan and developing such a sharable approach itself is one of the long-term results of lesson study. Lesson study is known in the world with Problem Solving Approach. It may not have been spread if it were only explained by the lesson study cycle. The problem solving approaches combined with lesson study has spread to the world from Japan through the comparative studies and teacher training programs for developing countries from 1980s, the Japan International Cooperation Agency’s projects from 1993 (See, Isoda et al., 2007) and APEC projects from 2006.

4. Local theory for Problem Solving Approach

Each Japanese elementary school usually sets a theme of lesson study project on school level through a year depending on the demands of national reform movements, teachers and school district. Major themes of lesson study projects at elementary schools are Japanese, Mathematics or general topics. General topics are usually related with crossing curriculum topic such as Physical and Mental Health. More than 50 years, improvement of mathematics teaching for better achievement of curriculum has been a major theme of lesson study (Isoda et al; 2007). Especially, in these days, the achievement of Japanese, Mathematics and Science on PISA has been lower due to the 20%

reduced curriculum in 1999, Mathematics and Japanese are two major subjects in Elementary School lesson study project.

On this context, more than 30 teaching guidebooks for elementary school mathematics are published, every year, as for explaining theories of teaching. Here, for explaining designing strategy of class on Problem Solving Approach and showing the meaning from the improvement of children’s performance, the teachers’ guidebook titled ‘Designing Problem Solving Class with the Basic Standards for Teaching Given by Check Sheets’ by Isoda et al. (2009), is explained because it is currently known as one of the best-sellers in this area (the 1st printing was sold out within two months). Many of guidebooks written by math-educators were adopted to develop check sheets. A characteristic feature of this book is that it is written as the result of school level lesson study project and described for novice teachers who do not know well how to teach mathematics, even if they might have several years of experience. It also published in Spanish (Isoda & Olfos; 2009).

In Japan, problem solving approaches are shared to develop children’s ability to think and learn by themselves. For knowing their achievement, there are two sets of national assessment problems. First type focuses on understanding and skills and second type focuses on mathematical thinking including mathematical argumentation. Both tests problems are developed on the national curriculum standards and the problems of the second type are deeply related with problems solving approach itself.

4.1 *Checking List for Implementing Problem Solving Approach*

This book by Isoda et al. (2009) has checking lists (Figure 7 as for a sample) as for explaining and sharing this school’s local theory of problem solving approach.

| Problem Posing | Self-Evaluation |
|--|------------------------|
| 1. The lesson sets tasks that can be solved in a variety of different ways by applying previously learned knowledge, and presents the content to be learned. | 4 3 2 1 |
| 2. The lesson planned with tasks (problem given by teacher) and problems (problematic from students), and promotes problem (problematic) awareness. | 4 3 2 1 |
| 3. The teacher expected methods and solutions before. | 4 3 2 1 |
| Independent Solving | |
| 1. The children can recall and apply what they have already learned. | 4 3 2 1 |
| 2. The children’s ideas are predicted before. | 4 3 2 1 |
| 3. Inappropriate solutions are predicted, and advice and hints are prepared for them before. | 4 3 2 1 |
| 4. The teacher, walking around, observes and helps children to insure that children use mathematical representation to solve the problems. | 4 3 2 1 |
| 5. Notebook are written and taken in a manner such that they will be helpful for presentation as well. | 4 3 2 1 |
| Comparison and Discussion | |
| 1. Steps (Validity, Compare, Similarity and Generalization or Selection) are planned for comparative discussion. | 4 3 2 1 |
| 2. The ideas to be taken up are presented in an order that is planned before. | 4 3 2 1 |
| 3. The method for writing presentation sheets is planned in advance and directions are provided. | 4 3 2 1 |
| 4. In addition to develop the ability to explain, children are also fostered with the ability to listen and the ability to question. | 4 3 2 1 |
| 5. When ideas are brought together (generalized), it is important to experience them by themselves. | 4 3 2 1 |
| 6. The reorganization or integration of ideas proceeds smoothly from the presentation and communication of children. | 4 3 2 1 |
| Summary | |
| 1. Activities are incorporated that let children experience for themselves the merits of the ideas and procedures that are generalized. | 4 3 2 1 |

| | | | | |
|---|---|---|---|---|
| 2. The summary matches the aims and problems (problematic) of this lesson. | 4 | 3 | 2 | 1 |
| 3. It is recognized that both correct and incorrect answers (to the task) have something good in the foundation of their ideas. | 4 | 3 | 2 | 1 |
| 4. Children are made to experience the joy and wonder of learning. | 4 | 3 | 2 | 1 |

Figure 7: Lesson Planning Checklist: Self-Evaluation
 [4: Achieved; 1: Not Achieved] (Isoda, 2009; Isoda & Olfos, 2009)

Behind of this list, there is a local theory of problem solving approach. For example, the difference of problem (task) and problematic (problem) is a key because problematic is necessary for children leaning by/for themselves, and it is also related with the objective of the lesson. Without the problematic, any collect answerers are good answerers. In various kinds of answerers, children can discuss which answerers are appropriate. On the other hand, when the school began to use the checking lists on their project, most teachers did not understand the meaning of each checking list, because in the case of this school most of teachers do not know how to teach mathematics well, even if they have a chance to see other teacher’s problem solving approach. After conducting school-level lesson study project for a year and half, through having lesson study once a month in each grade, the teachers well understood the meaning of check lists and developed high achievement.

4.2 The Achievement of the Lesson Study Project on Math by the School using various checking lists

After the one and half year mathematics lesson study project in Ozone Elementary School through using checking lists for mathematics, children’s achievement improved as follows (Isoda et al.; 2009).

In Figure 8, Children’s mathematical thinking ability which is a key for leaning by/for themselves is improved. It shows that achievement of children in the 5th grade improved by 15 points in mathematical thinking test compared with the average of the whole prefecture. Figure 9 implies that the achievement of school-level mathematics lesson study during one and half year is not only limited to the improvement of children’s mathematics achievement, but also influenced positively other subjects such as Japanese, Science and Social Studies. It means that the lesson study efforts on the teaching approach in mathematics through using checking lists may influence other subject of teaching. Indeed, in Ozone Elementary School, a teacher teaches almost all subjects. Children’s awareness of empowerment in mathematics led to improvement of their interests of learning and developed their wish to study.

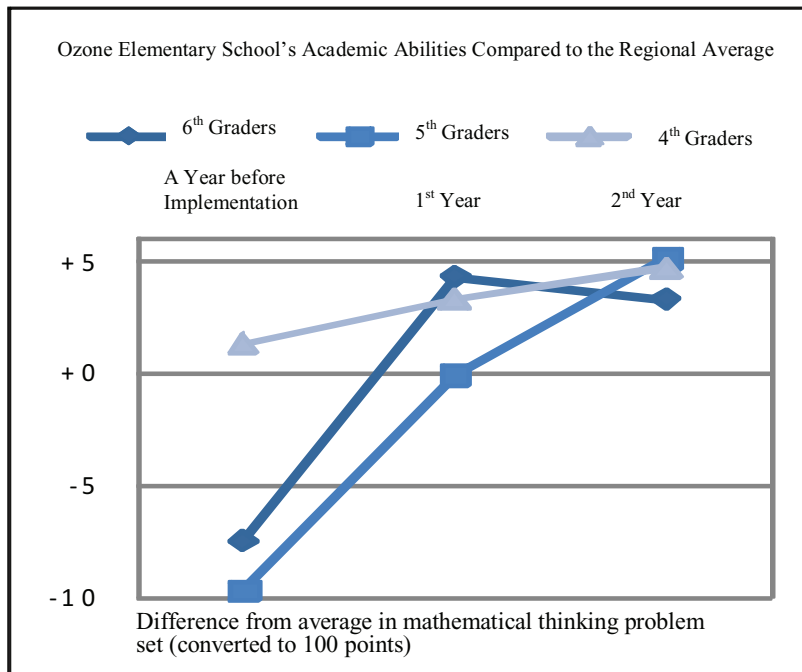


Figure 8: Ozone Elementary School’s Academic Abilities Compared to the Regional Average

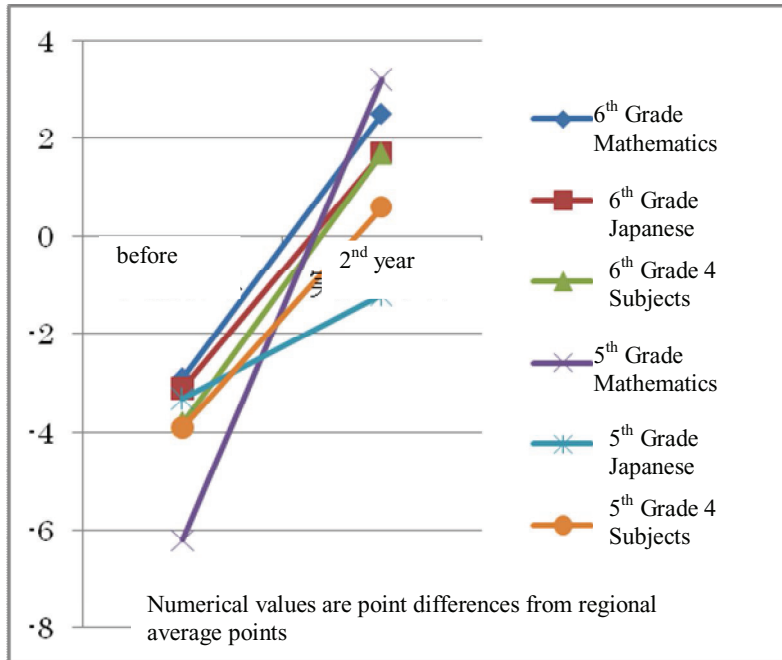


Figure 9: Ozone Elementary School’s Academic Abilities Compared to the Regional Average

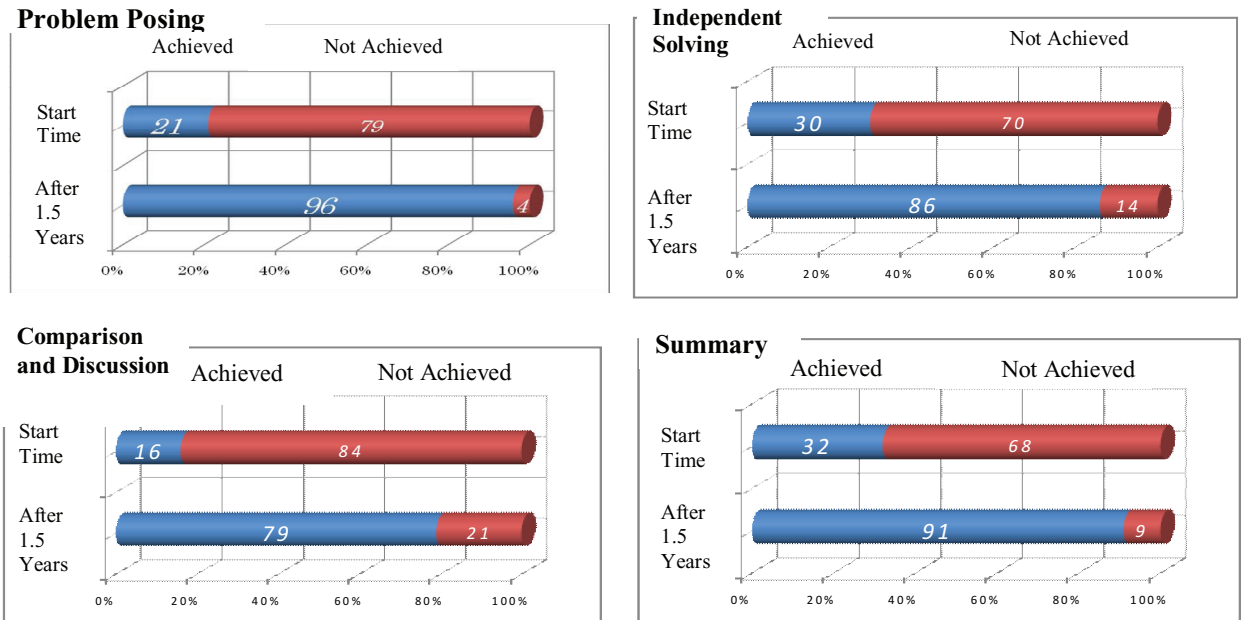


Figure 10: Improvements of Teacher Instruction by Lesson Study with Checklist

The achievement is the result of lesson study through using the checklists in the school. For improvement of classroom teaching, it is important that teachers and children share objectives. For sharing objectives, behind theories such as for Problem Solving Approach and the theory of curriculum had been learned in the process of lesson study. Ozone Elementary School developed Lesson Planning Checklist base on the theory of problem solving approach (Isoda et al. ; 2009), Children Learning How to Learn Checklist, and Lesson Plan Checklist, and also more checklists such as the way or blackboard planning were used (Isoda; 2009) and improved on Isoda and Olfos (2009) for Latin America. They provide opportunities for children to check by themselves for reflecting on what should be improved.

Figure 10 is the result of the self-evaluations by teachers on the lesson planning checklist in order to verify their instruction method and the problem solving approach have been appropriate or not. Figure 10 compares the achievement at start time with that of 1.5 years later. At the beginning of this research (1.5 years before the lesson study open school), teachers were not sure of the meanings of the words listed on the lesson planning checklist. By taking on the challenge of this project throughout the entire school for one and a half years, the teachers gained confidence in their instruction method. Through the improvement of teachers' teaching practices through the school lesson study project in only one and half years, teachers teaching methods are improved and then, children's achievement are improved beyond mathematics. It was the result of collaborative lesson studies by Ozone Elementary School teachers.

5. Final Remarks

This paper illustrated the historical development of Japanese lesson study in the case of mathematics and explained the theories of mathematics education have been developed on this history. For explaining a case of developed local theories, this paper briefly illustrated the case of Ozone Elementary School, school based approach.

The achievement of Ozone Elementary School is just a case of the school level lesson study on Problem Solving Approach. As a number of lesson study activities are done by schools and they are develop their local theories of their Problem Solving Approach for their schools. Those theories are teachers' theories developed by teachers with support of researchers or supervisors to improve their daily practice. Shared Japanese Theory of Problem Solving Approach and theory of curriculum are well described at the Special Issues of Journal of Japan Society of Mathematical Education for EARCOME 5 (Isoda & Nakamura; 2010).

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