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Integration of Information and Communication Technology in Japanese Mathematics Lessons

―Observations and Teachers' Perspectives―

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日本の数学授業におけるICT活用

― 授業観察と教師の視点 ―

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ABSTRACT

This study explores how schools are established in terms of technological facilities, how teachers perceive integration of information and communication technology（ICT）in mathematics, what ICT tools teachers use, how often technology is integrated in lessons, and what type of constraints teachers face in technologically pioneering countries like Japan. The study was conducted in two schools（an elementary and a junior high school）attached to Hokkaido University of Education, mainly through observations of classroom practices and distribution of questionnaires to teachers. The results revealed that, despite ICT's great potential in enhancing mathematics lessons, actual classroom practice is more challenging than expected due to various constraints. The teacher's attitude and acceptance toward innovations plays a pivotal role in ensuring the success of ICT in education but only once the necessary facilities are well-established. It also indicated the importance of teachers' professional capacity in examining the need for ICT for particular topics and selecting the right tools to create thought-provoking activities that enable learners to think mathematically. ICT definitely has the capacity to stimulate curiosity and interest in young generations to learn mathematics, if necessary facilities are established, and teachers are committed to be continuously innovative.

１．Introduction

１．１．Background of the Study

With the rapid advancement of information and communication technologies（ICT）and modern technologies impacting everyday life, the education sector is witnessing paradigm shifts. The emerging paradigms emphasize that the delivery of education is less about teaching and more about learning [UNESCO Institute for Statistics（hereafter UIS）, 2019]. The rigidity associated with the conventional chalk-and-talk method of delivering education has seen numerous challenges, which are even more amplified by the rapidly changing in-demand skills in a globalizing labor market. Preparing children by equipping them with skills and values required for a 21st-century knowledge-based society has been a global educational policy concern. As many researchers have noted, "ICT in and for education is now seen worldwide as both a necessity and an opportunity" (UIS, 2009, p.13). However, UIS (2009) reported that, despite decades of large investments in ICT to benefit education in Organization for Economic Development and Cooperation countries and its increased use in developing countries, evidence of effective impact is elusive or even debatable.

Japan, one of the most advanced countries and a leader in technological innovations, incorporates technology into every aspect of society. The significance of ICT in education was realized as early as 1985 during the first report of the National Council on Educational Reform (MEXT, 2011). However, technology use in education has been low compared to other fields of society as well as among other industrialized countries (MEXT, 2011; Isoda, 2011). The reasons for slow progress, among others, according to Isoda (2011), is that Japan succeeded in delivering quality education to the children throughout 1990s, the era of no ICT use. The latest ICT-related initiative, "The Vision for ICT in Education-Towards the Creation of a Learning System and Schools Suitable for 21st Century" (2011), is a comprehensive policy on the utilization of ICT in education. The policy aims to develop digital textbooks; provide 1:1 technology; and incorporate digital equipment such as interactive white boards, projectors, epidiascopes, terrestrial digital televisions, and ultrafast network connections.

Bhutan, a country where a ban on television and internet was in effect until 1999, is striving to catch up with the global trends. The Ministry of Education identified ICT as one of the tools to ensure quality education in 21st-century skills and values. Yet the progress of ICT, specifically in education, is minimal despite due to various constraints such as no or low internet connectivity; limited access to hardware, software and digital content; and inferior professional capacity in digital pedagogy. Students' access to computers and the internet is confined to ICT classes (MOE, 2020). The use of ICT as the main tool for teaching and learning is found mostly in colleges and much less in schools since the former have adequate ICT facilities (Kinley et al., 2013). The authors, as teachers in Bhutan, have been fascinated with the establishment of schools in terms of technological facilities, teacher perception of integration of ICT in mathematics, ICT tools used by teachers, the frequency of technology integration in lessons, and the constraints faced by teachers in a technologically pioneering country like Japan.

1．2．Objectives of the Study and Research Questions

The purpose of the study is to understand teachers' perceptions of the usefulness of ICT in mathematics lessons, the frequency at which ICT is integrated, the ICT tools used, and the constraints faced by teachers for ensuring successful integration of technologies. Therefore, the following research questions were formulated to achieve the stated objectives of the study.

1. How do teachers perceive the integration of ICT in Mathematics lessons?
2. What are the facilitating/enabling conditions necessary for successful ICT integration?
3. How often teachers do incorporate ICT in their lesson?
4. What ICT tools are adopted by teachers to enhance students' mathematics learning?
5. Which mathematics content can be best taught with ICT?

2. Literature Review

2. 1. Japan's Approach to Mathematics Teaching

Japan's major reforms in teaching and learning mathematics in the 1970s and 1980s included a shift from traditional teacher-centered instruction to student-centered education that focuses on students' active engagement in mathematical activities (Takahashi, n.d). Stigler & Hiebert's (1999) analysis of eighth grade mathematics classes in Germany, Japan, and the United States through video-taped lessons yielded certain contrasts on what actually goes inside the classrooms of those three countries. The study concluded that the mathematics lessons in Germany and United States are strongly aligned; Japan's lessons are unique especially in terms of how they are structured and delivered by teacher. The Japanese lesson pattern is characterized as "structured problem solving," which follows the sequence of five activities: reviewing the previous lesson, presenting the problem for the day, students working individually or in groups, discussing solution methods, and highlighting and summarizing the major points. The review is a teacher's brief lecture or teacher leading a discussion or student reciting main points of previous lesson. One key problem is presented on which student usually work individually. After the students have worked on the problem, the teacher initiates a prolonged discussion of multiple solutions to a problem, often selecting students to present rather than taking volunteers. The lesson ends with the teacher's brief lecture summarizing the main points and drawing conclusions.

Shimizu (n.d) explains the role of the teacher in effective problem-solving lessons, as identified by Japanese mathematics teachers. *Hatsumon* is asking a key question to provoke students' thinking at a particular point in a lesson. It includes questions to be asked at the beginning of lesson to promote students' understanding of the problem and during whole-class discussion to establish connections, efficiency, and applicability among the proposed approaches. *Kikan-shido*, which translates to instruction at students' desks, is a purposeful scanning of students' problem solving by the teacher to assess students' progress, suggest hints and direction, and make mental note of students' approaches and sequence them to be featured in whole-class discussion. *Neriage* is "kneading up" or "polishing up" students' ideas during whole-class discussion to develop mathematical concepts. *Matome* is summing up to make final and careful comments on students' work and provide brief review and summary of whole-class discussion.

These teachers' roles are carefully prepared and analyzed during *kyozaikenkyu*, which means instructional materials research (Fujii, 2013). Kyozaikenkyu is "investigating what kind of materials various textbooks use to teach this topic to students, and what research suggests (if anything) about various methods for teaching the topic" (Takahashi, 2006); It refers to the careful analysis of the topic in accordance with the objective(s) of the lesson by analyzing the mathematical connections both among the current and previous topics and anticipating students' approaches to the problem (Shimizu, 1999). Watanabe et al. (2008) describe kyozaikenkyu as a "two-phase" activity. The phases are to first study the existing materials, which are developed as *kyozai* (instructional materials), and then to develop kyozai through an in-depth investigation of the particular subject matter.

2. 2. Benefits and Constraints of ICT Integration

Extensive research emphasizes the strong potentialities of ICT in education, particularly for teaching and learning mathematics (UIS, 2009; Perienen, 2020). According to the UNESCO Institute for Statistics, technologies can improve the teaching/learning process by 1) reforming conventional delivery systems, 2) enhancing the quality of learning achievements, 3) sustaining lifelong learning, and 4) improving institutional management. It further states that the most substantial effects were observed when ICT was used in mathematics, science, and English. Acquisition of knowledge and assimilation and understanding of content, particularly mathematics, improves with effective and appropriate use of technology (Perienen, 2020).

Zakaria and Khalid (2016) reviewed 20studies based in different countries like Malaysia, the United Kingdom, the United States, and others to reveal prominent benefits and constraints of ICT integration in mathematics. The benefits are enhanced interaction among students and knowledge sharing, the generation of higher-level thinking skills, and increased motivation and interest toward the subject, all of which improve student achievement. The common constraints they found are limited teaching time; insufficient training; lack of technical support; limited resources, especially when students are at home; and lack of pedagogical knowledge among teachers. ICT-based activities, such as the use of digital images and video clips to stimulate modeling with 2-D geometry and algebra; the use of 3-D geometry software to develop visualization and modeling in space; and the use of hand-held devices with data-loggers in capturing and analyzing for experimental data, would help make mathematics more exciting, relevant, and challenging to young learners. ICT cannot displace the mathematics teacher but may make him or her more effective in winning the hearts and minds of the next generation (Oldknow, 2008). Iijima (2006) states that mathematical activity can be supported and fostered with ICT for deeper and wider investigation of the problems. However, a computer with a projector in an ordinary room, which remains a one-way presentation despite the presence of technology, may be even more tedious for students than a traditional chalk-and-talk style of teaching. Therefore, the technology integration in mathematics must incorporate interactive presentation.

The progress and success of ICT in education has been slow compared to other fields. UIS (2009) reported that, despite decades of large investments in ICT to benefit education in Organization for Economic Development and Cooperation countries and its increased use in developing countries, evidence of effective impact is elusive or even debatable. A large majority of teachers are aware that the use of technological innovation would enhance teaching and learning but have not fully translated this into real classroom practice, as evidenced by ICT integration being limited to basic procedures like information search through the internet and the use of presentation programs and other applications (Perienen, 2019).

The reason for the lagging progress of ICT use in education is due to various factors associated with the integration of ICT in education, which are often different in different countries depending on advancement level and educational beliefs and values. For the nations in the introductory phase of ICT in education, the focus is on creating an ICT infrastructure and providing access to newer technologies, while nations in further developed phases of ICT use in schooling have different priorities like the management of pedagogical innovation, adaptive and inclusive curriculum, organizational change, sustainable technical support, and continued staff development (UIS, 2009). Ghavifekr et al. (2016) states that in the developing countries, the teachers' lack of technological competence is a main barrier to their acceptance and adoption of ICT, which is no longer a main barrier in developed countries. BECTA (2003) categorized factors affecting successful integration of technologies in education as resource-related factors; factors associated with training, skills, knowledge and computer experience; attitudinal and personality factors; and institutional factors. According to Gebremedhin and Fenta(2015), since educators' attitudes toward technology use is critical for the success of technology use in education, effective professional development, sufficient time, and technical support for teachers are essential. They also argue that the key factor that influences the success of learning is not the availability of technology but the pedagogical design for effective use of ICT. This is in line with Iijima's (2006) statement that many teachers do not use ICT in mathematics teaching in Japan because of the lack of the standards for mathematics teaching with ICT, as using ICT is not a goal in itself but a means for good practice.

2. 3. ICT Tools for Mathematics Teaching

The UNESCO Institute for Statistics defines ICT as "diverse set of technological tools and resources used to transmit, store, create, share or exchange information." The technological tools and resources include hardware, software, internet, live and recorded broadcasting technologies, social media, websites, mobile applications, and so on. This section contains the review of ICT tools, which are of particular relevance to the teaching and learning of mathematics.

Clark-Wilson et al. (2015), in their study "ICT and Mathematics: a guide to learning and teaching mathematics 11-19," state that selecting a small range of tools that have widespread use across the full mathematics curriculum would lead to efficient integration of ICT as the time spent to learn those tools will be adequately repaid. They categorize the tools as 1) whole-class displays, 2) hand-held technology, 3) small programs, 4) programming languages, 5) general purpose software, and 6) mathematics teaching software. The whole-class displays tools are digital data projectors; interactive whiteboards; PCs; overhead projectors; TV/video output; and hand-held technology, including graphing calculators, data-loggers and other palm-tops, and new generation mobile phones, which have great educational potential despite being not specifically designed for that purpose. The small programs are those that are mostly in the form of games and simulations, which are often very useful for addressing particular aspects of the curriculum by using it as resources for stimulus for discussion and thinking. Logo, as not only a geometrical tool but also a useful tool for investigating number patterns and sequences, has the potential to develop an understanding of variables and encourage mathematical communication. General purpose software like Microsoft Office products such as Excel, Word, Internet Explorer, and PowerPoint are not only useful for teachers for their own preparation of materials outside the classroom but also for actual classroom teaching through presentation and linking to online resources. Software specific to teaching mathematics includes Dynamic Geometry Software such as Cabri Geometry and the Geometer's Sketchpad and Computer Algebra System packages like Mathematica, Maple, and Reduce. It is important to bear in mind the hardware and software combinations and keep as much flexibility as possible in the deployment of ICT, as it is the ICT that should be adapted to the needs of mathematics and not otherwise Clark-Wilson et al. (2015).

Digital textbooks are another ICT tool gaining in popularity over the world. For example, the Education Ministry of South Korea announced the Digital Textbook program on March 8, 2007, and California announced a Free Digital Textbook Initiative in 2009 with a focus on high school textbooks (Gould, 2011). Similarly, although the first digital textbook in Japan, which was an electronic copy of a print textbook without dynamic functions, was developed in 2005 by a school textbook company, MEXT proposed deployment of enhanced digital textbooks to all elementary and junior high schools in late 2010 (Taizan et al., 2012). Digital textbooks contain additional contents and free software to utilize the textbook. For instance, digital textbooks in Japan include functions like highlighting the particular parts of text or writing in blank page; showing certain problems in the screen; showing the contents attached to digital textbooks, such as pictures, movies and computer simulations; showing other information by linking to the web contents to digital textbooks; and renewing any information attached to digital textbooks when required (Isoda, 2011). Engbrecht (2018) reviewed literature to study pros and cons of digital textbooks over print textbooks and concluded that there is no absolute best option available. Given students' different learning preferences and due to the differential benefits of two different forms of textbooks, students must be provided with choices between print and digital.

There are varieties of ICT tools; some are designed specifically for education while other can be integrated for educational purpose. However, not all tools available are easily accessible, often due to high costs associated with their integration. Hence, the use of ICT in education is often limited to planning and preparation; record keeping; PowerPoint presentation; and projection of images, videos, and other materials.

2．4．Planning ICT Integration

Despite extensive research emphasizing the benefits of ICT in enhancing the teaching and learning of mathematics, actual classroom integration tend to be more challenging than expected. The teacher as a central actor of integration and his/her acceptance and professional capacity, among other factors, determine the success of ICT integration. The availability of technology in the classroom does not determine the improvement in student outcomes; instead, it is the teacher's decisions on how to integrate ICT that will either improve or hinder student outcomes (Jackson, 2017). Koehler et al. (2014) also state that teachers often lack the knowledge to successfully integrate technology in their teaching, and their attempts tend to be limited in scope, variety, and depth. This section presents the review of literature on different planning models and standards and procedures to be considered for successful integration of ICT in teaching of mathematics.

Koehler et al. (2014) explains a framework called Technological Pedagogical Content Knowledge (TPACK), which describes the kind of knowledge required for effective integration of technology in education. According to this framework, there are three major knowledge components a teacher should possess: content knowledge, pedagogical knowledge, and technology knowledge. The way these three bodies of knowledge interact with, constrain, and affect each other must be understood for effective teaching with ICT. The combination of the three knowledge bodies results in the four components of the TPACK framework: technological content knowledge, pedagogical content knowledge, technological pedagogical knowledge, and TPACK. The framework suggests that the teacher should have an in-depth understanding of each component to coordinate technology, pedagogy, and content for meaningful teaching. There are other similar frameworks, like ICT-related pedagogical content knowledge, which is defined as knowing how to 1) identify topics to be taught with ICT, 2) identify representations for transforming content, 3) identify teaching strategies that were difficult with traditional technology, 4) select ICT tools to support content and teaching strategies, and 5) infuse ICT activities into classrooms. Roblyer's (2006) model of planning of technology integration has five stages: determining relative advantage of ICT integration, deciding objectives and assessment, designing integration strategies, preparing the instructional environment, and evaluating integration strategies. The 5W1H model (Haslaman et al., 2008) emphasizes identifying the integration process by asking questions of what, where, how, when, why, and who.

The most significant impact of ICT is when it is used to enable pupils to model, explore, analyze, and refine mathematical ideas and reasoning (Clark-Wilson et al. 2015). This is in line with the statement of Gould (2011) that objects that can be manipulated directly are usually easier to understand. Hence, it is important to create good problematic lessons rather than elegant presentations to ensure engagement of students in learning. Ijima

(2006) outlines standards to be considered for meaningful lesson with ICT: 1) Use traditional methods for the main instruction—for example, display images and figures onto a surface like regular smart-board on which you can write for easy annotation of diagrams. 2) Use technology sparingly as the more it is used, the less mathematical thinking. For example, it is ideal to spent 5 minutes for the whole-class presentation, 10-15 minutes for individual/group investigation, and more time for understanding, formulating, hypothesizing, and discussion. 3) Use open approach in many cases.ICT is often very useful to conduct lesson with open-ended questions. 4) Focus on problem quality rather than presentation aesthetics. 5) Teachers should objectively but also affectively and subjectively navigate problem solving smoothly in accordance with students' findings, ideas, suppositions, utterances, and awareness. Therefore, it is necessary to provide teacher with training on knowledge and skills to integrate technology, pedagogy, and content with ICT.

3. Methodology

The study to explore the use of ICT in Japanese mathematics lessons employed both qualitative and quantitative approaches, mainly through lesson observations, questionnaire, and literature analysis. The data collected are interpreted through descriptive analysis.

The classroom practice observation is the main data collection tool adopted, as "teaching is a cultural activity and cultural scripts are learned implicitly, through observation and participation, and not by deliberate study" (Stigler & Hiebert, 1999, p.86). The random lessons ranging from first to eighth grade in Hakodate elementary and junior high schools attached to Hokkaido University of Education (HUE) were observed from March 2021 to December 2021. The main components in observation include ICT facilities in the classroom, ICT tools used during the lesson, description of how teachers used ICT, and students engaged with ICT tools in solving problems presented. The benefits and constraints related to the particular use of ICT tools were also recorded by noting student-teacher and student-student interactions. A total of 17 lessons, 3 video-taped and 14 actual classroom lessons, were observed.

To complement and supplement the data gathered through observations, questionnaires were distributed to three junior high school teachers, though only two teachers responded to the questionnaire. The questionnaire consisted of four sections: demographic information, teacher's perception of integration of ICT, ICT tools adopted by teachers, and content that can be best taught with integration of ICT. The data collected under demographic information were gender, year of experience, classes currently teaching, frequency of ICT use, and their competency level. The teachers' perception on integration of ICT involved reflection on their preference of ICT-integrated lessons over the traditional chalk-and-talk method, perceived benefits and constraints, most important facilitating conditions, and their role for successful ICT-integrated mathematics lessons. The questionnaire also included the section to list all ICT tools they use and to rank the four content strands (number and calculation, figures, relationship between quantities, and utilization of data) in terms of how each of them can best be taught with ICT. The findings were further supported by analyzing literature and official documents.

4. Result and Discussion

4. 1. Sample of Observed Lessons

Lesson observation 16

Class: V Date: 12/14/2021 Topic: Area of Parallelogram

Review of previous lesson (Time: 10:25-10:32)

Teacher displayed several figures on the television screen and asked, "what are these figures?" Students said "parallelogram, rhombus, triangle, trapezoid, …” in chorus. The teacher asked how to find the area of a square and rectangle and recorded student responses on the board.

Presentation of problem

The teacher shared the aim of the lesson on the board: “let us think how to find the area of parallelogram” then displayed the parallelogram on the board and instructed students to open Google Classroom in their PC. Students accessed the same figure in the digital textbook through the link shared by the teacher. The teacher instructed students to think of cutting the portion/s of a parallelogram to form a familiar figure for which they knew the area formula.

Students working individually (Time: 10:32-10:44)

Students worked individually on cutting parts of figures to form a rectangle using dynamic functions of digital textbook. The teacher moved around, observing students’ work, nodding, and reminding students of different formulas but not commenting or explaining directly to students. Figure 1 shows the students working individually on the problem.

Sharing ideas and solutions

The teacher then asked students to move around and share and discuss their work with

Fig. 1 Students working individually on the problem

friends and set 5 minutes on the timer. Students paired or got into small group randomly and took turns demonstrating their work.

Whole-class discussion (Time: 10:50-11:07)

After 5 minutes, the whole-class discussion was initiated by teacher. She called volunteers to share their ideas to the whole-class. Five students shared their work by demonstrating how to change the parallelogram to a rectangle using the figure displayed on the screen from digital textbooks using its dynamic functions. Every time each student explained his/her idea, the teacher asked how many of them have the same work and how many of them have different ideas. Figure 2 shows the images of students presenting multiple solutions to a problem.

Review and summary

The teacher shared with the class that though

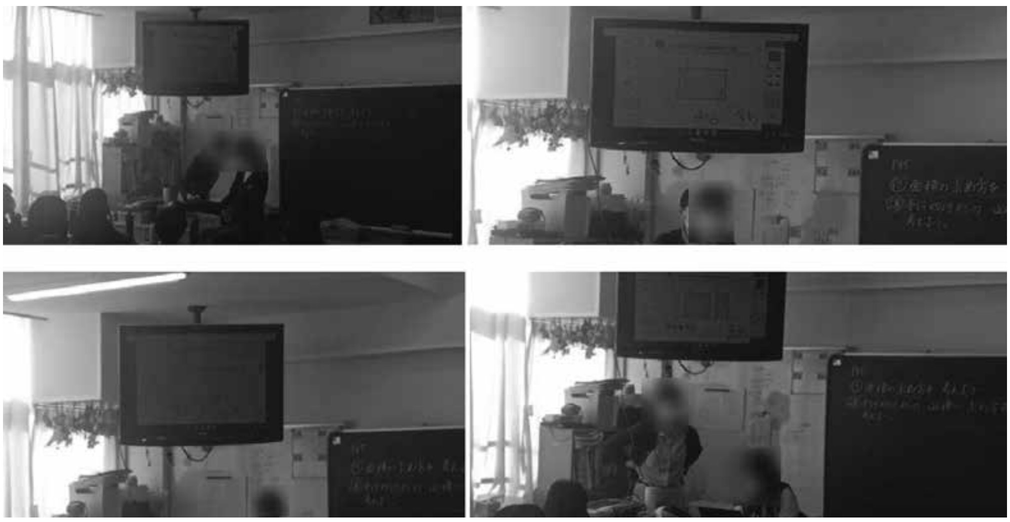

Fig. 2 Whole-class discussion of multiple solutions by students

students presented different solutions, "the idea is same, what is the common idea?"

The students changed the parallelogram to a rectangle.

The teacher wrote the concept of the lesson on the board, and students copied. Students explored and learned that the area of a parallelogram can be found by changing it to a rectangle.

4．2．General Mathematics Lessons

The mathematics lesson in Japan categorized by Stigler and Hiebert (1999) as "structured problem solving" involves five steps: review of the previous lesson, presentation of the problem, individual/group work, whole-class discussion, and review/summary.

The observation of lessons focused on capturing the type of activities, instructions, roles played by teacher and students, and time spent in each stage of problem solving lessons. Almost all lessons observed followed the same procedures, although approaches to each problem solving lesson stage varied slightly in terms of type of materials used, types of activities conducted, time spent in each stage, and so on. Figure 3 shows the brief summary of the activities conducted in each stage of regular lessons.

The lesson typically begins by students and teacher bowing to each other in unison on command/signal from the student monitor of the class. The students then settle, while teacher readies himself/herself to officially begin the lesson. The "reviewing of previous lesson" is done by conducting any one or more of the following: asking set of questions, students repeatedly reciting the main concepts, solving problem not completed during previous lesson, making comments and feedback on previous concepts, or discussing solutions to students' home assignment. The lesson continues with the teacher "presenting problem" for the day. The problem is either presented by writing the goal on the chalkboard, displaying a problem from textbook on the television screen, distributing worksheets to students, displaying problems and images/pictures printed on charts, explaining background of problem through PowerPoint presentation or sharing the problem as digital content to be assessed by students on their respective PCs. The review of previous lesson and presentation of problem together take around 5-10 minutes. The presentation of

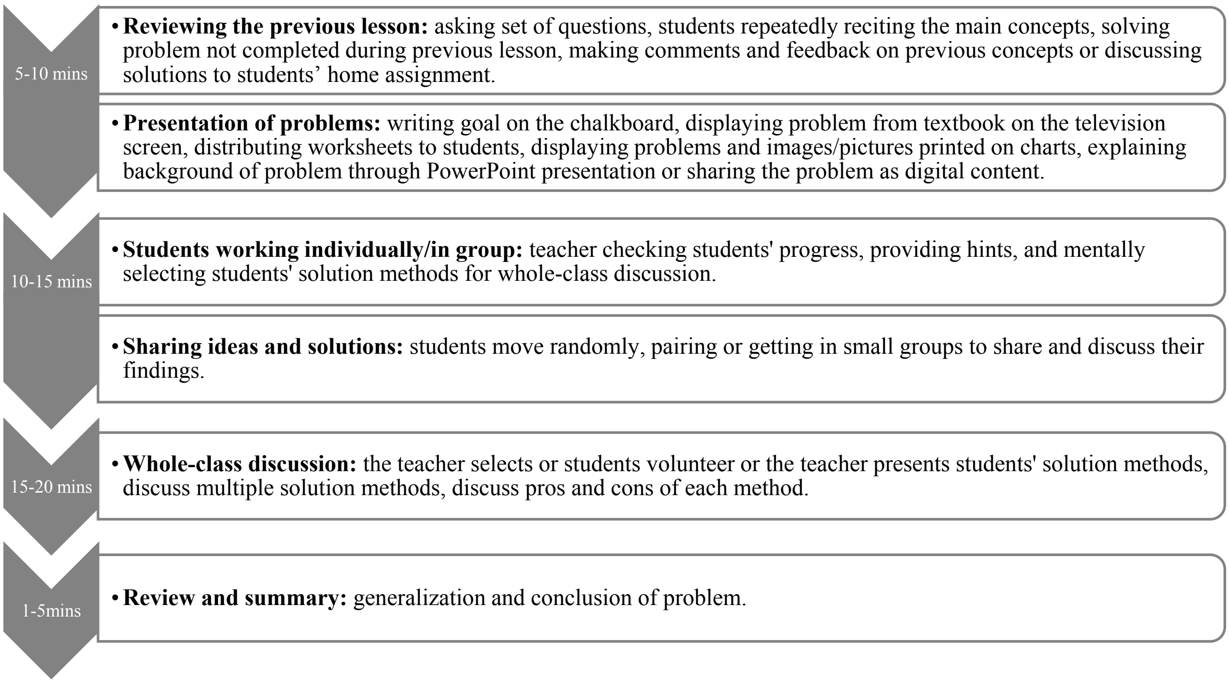

Fig. 3 Activities conducted during each stage of the lesson

problem by teacher is followed by "students working individually or in groups," which often lasts for around 10-15 minutes. However, students rarely work in groups without struggling to solve problem individually first. The teacher moves around the class observing students' progress, often commenting on students' work and providing feedback and hints if necessary but never providing direct solutions during this stage. This teacher movement is considered critical as it is time during which the teacher makes mental note of selecting students and order carefully to present during whole-class discussion to ensure meaningful lesson. After students work individually, they are given about 5 minutes to circulate, sharing their ideas and solutions before whole-class discussion of different solution methods. The teacher then initiates the "whole-class discussion," which lasts around15-20 minutes. The teacher often calls students to present their solutions in the order he/she mentally noted during individual or group work stage. The variety of solutions methods to a single problem are presented, pros and cons of each method are discussed, and students select their preferred methods. Interestingly, some of the wrong solution methods are also selected to be presented to clear students' misconception. The lesson ends with the teacher reviewing and summarizing the main points, often writing generalizations or conclusion of the problem.

It is observed that during the review of previous lessons, presentation of the problem, and review and summary, the teacher played a central role for about 6-15 minutes of the 45-minute lesson, and individual/group work, whole-class discussion, and the stage where mathematical ideas, skills, and concepts were developed took majority of the time. We can conclude that mathematics lessons in Japan are student-centered, where students themselves struggle to construct mathematical ideas and concepts with careful guidance and facilitation by teacher.

4．3．ICT Integration in Lessons: A Review of Lesson Observations

A total of 17 lessons (3 video-taped and 14 in-class lessons) ranging from first to eighth grade were observed in Hakodate elementary and junior high schools attached to HUE. The observations focused on identifying use of ICT in the lessons by recording the types and implementation of tools. The benefits and constraints related to particular use of ICT during the lessons were also noted. From the total of 17 lessons observed, the ICT integration was seen in 7 lessons, meaning 41.2% of the lessons were ICT-integrated. Table 1 shows the summary of lessons observed.

The latest ICT-related initiative, "The Vision for ICT in Education-Towards the Creation of a Learning System and Schools Suitable for 21st Century" (2011), aims to develop digital textbooks, provide 1:1 technology, and increased the presence of digital equipment such as interactive white boards, projectors, epidiascopes, terrestrial digital televisions, and ultrafast network connectivity. As stated in the vision, the elementary and junior high schools observed are providing every student with a computing device. Tablets are provided to students until third grade and PCs (Chromebooks) to students in fourth grade and above. The classrooms in observed schools are set up with televisions, overhead projectors, and digital data projectors mounted in the ceiling. The schools were also equipped with large printers for creating teaching materials on charts. The schools have cloud-based school management systems with a high-speed communications network to ensure higher efficiency in grading and other administrative work. Both teachers and students have access to digital textbooks, which contains additional content, free software, and various functions such as showing movies and pictures, simulations, drawings and picture enlargement, and other information by linking to the web contents to teach the textbook effectively. However, unlike in other industrialized countries, the use of smart interactive whiteboard and hand-held tools like graphical calculators, data-loggers, and so on were not seen.

As reflected in Table 1, the use of ICT in the lessons was mainly to display problems, information, tables, figures and images, and PowerPoint presentation and to review lessons through comments and feedback using a Google spreadsheet. Google Classroom was also widely used as a discussion forum to share comments and review lessons and to post worksheets and solutions by teachers and students. Google Classroom as an alternative classroom, reduced

Table 1. Summary of the lessons observed

Lesson Number	Grade	Topic	Use of ICT	Benefits	Constraints
1	VI	Fraction division	No	-	-
2	II	Triangle and Quadrangle	No	-	-
3		Large numbers	No	-	-
4	V	Volume and proportion	Displaying questions, tables, and figures.	Reducing time for teacher writing on the board and dedicating it to individual thinking and in-depth discussion.	
5	IV	Measurement of angles	Google Classroom for discussing learning and problems of previous lesson, displaying the figures.	Collaboration among students, evaluation of each student's learning	
6	V	Decimal multiplication	No	-	-
7	IV	Measuring angles	No	-	-
8	I	subtraction	No	-	-
9	II	Order of Calculation	No	-	-
10	I	Addition	No	-	-
11	VI	Ordering (number of events/ combination)	PowerPoint presentation of problems with images and description, writing review and comments on the lesson discussed using Google sheet.	More time for discussion and learning, motivation, and curiosity through images and description, instant comments, feedback and discussion.	Ensuring classroom management and individual student's attention and engagement.
12	VIII	Angles and parallel lines	No	-	-
13	VIII	Using the conditions for congruence to make a proof	Recapitulation of previous lesson by sharing students' ideas on website, displaying the figures and problems, whole-class discussion through displaying students' responses.	Opportunity for all to express, instant evaluation, clear and symmetric diagram and figures, more time for individual work and discussion of concepts.	Technical skills problems with few students.
14	VIII	Unit revision (Geometry)	Displaying students' responses, posting of notes, worksheets and solution in Google Classroom.	Learning from students' work, reducing place and time barrier.	
15	II	Multiplication	Displaying multiplication table and textbook contents.	One reference for all, reduced teacher's task during the lesson.	
16	V	Area of parallelogram	Displaying figures on television, posting problem by sharing the link of digital textbook in Google Classroom, dynamic functions of digital textbook to manipulate figure in their PC, PC and television to present their solutions.	Experiencing the mathematical facts, quicker and easier than manual drawing or cutting of figure, more time to explore varieties of methods, Instant display and demonstration of students' solutions	Students' knowledge and skills of using functions of digital textbook, Lack of note taking for future reference
17	III	Fraction	No	-	-

place and time barrier, supported collaborative learning among students, and helped teachers assess students' learning and evaluate the quality of lesson conducted. The engagement of students in mathematical activity involving ICT such as dynamic software, simulations, videos etc. were limited and the use of digital textbook and its dynamic functions were rare. The contents of digital textbooks published by six textbook publishing companies are the same as their print copy but enhanced with additional features. Hence, the printed textbooks have topics identified to be taught with digital contents.

Despite the use of ICT being limited to displaying textbooks contents, images and figures, PowerPoint presentations, and Google Classroom as a discussion forum, numerous advantages were observed. For example, when the teacher displays tables, figures, and images related to the problem, the time for a teacher's writing/drawing on the board is reduced, dedicating it to individual thinking and in-depth discussion. The figures displayed are usually clear and symmetric compared to manual drawing on the board, which reduces students' confusion and misconceptions. When the problems are presented using PowerPoint with interesting pictures and funny descriptions, students ready themselves with higher motivation and curiosity to do problem, which would aid in deeper understanding and longer retention of the concepts. The use of digital content and its dynamic functions to manipulate figures allowed students to see, feel, and touch mathematics, encouraging experiential learning. Google Classroom as discussion forum through exchange of comments, feedback, and reviews on lessons taught deeper collaborative learning among students. Teachers are also able to evaluate students' learning and the success of the lesson conducted through students' feedbacks. However, ICT-integrated lessons are constrained by a difficulty ensuring positive classroom management and individual students' attention and engagement, especially when students were allowed to use their PC in classrooms established with a high-speed communications network. The other constraints include technical skills problem for a few students, like knowledge and skills of using functions of digital textbook and limited opportunity to write, draw, and take notes for future reference.

4．4．ICT in Mathematics Lessons: Teachers' Viewpoints

The teachers' view on the use of ICT in the mathematics classroom were ascertained through distribution of questionnaire to three mathematics teachers of a junior high school attached to HUE, of which only two teachers responded. Both the participants were male teachers, one having seven and the other sixteen years of teaching experience. The questionnaire aimed to determine their perception in terms of enabling conditions necessary for integration of ICT in mathematics classroom, the benefits and constraints of ICT integration, and the ICT tools adopted and identify the contents that can be best taught with integration of ICT.

The teachers were competent in integrating ICT, as they rated themselves as either highly or moderately competent and integrated ICT in most or every lessons. They preferred ICT-integrated lessons over traditional chalk-and-talk methods of lesson delivery, justifying that ICT has become necessity for current education system, especially for developing the ability to use information efficiently in this rapidly advancing digital era. When students get an opportunity to interact with technologies during daily lessons, they not only learn about information technologies but also about using available tools effectively by themselves beyond the classroom to further explore and deepen the understanding on a particular topic. There are also new tools that help teach a number of contents efficiently compared to the traditional method. Despite a preference for ICT-integrated lessons, teachers are well aware that not all topics can be best taught with ICT, indicating the importance of a teacher's capacity in selecting the right content with right tools.

"Structured problem solving," in which students struggle to construct mathematical concepts by working individually on problem/s and sharing multiple solutions through prolonged discussion, is the student-centered lesson delivery method well-established in Japan and gaining the world's attention. This strategy was well grounded long before the era of ICT use in the lessons and proved successful through international comparative studies like TIMSS and Programme for International Student Assessment. Therefore, teachers were asked if incorporating ICT in lessons supported and enhanced structured problem solving strategy of teaching mathematics. Teachers agreed that the use of ICT enhanced structured problem solving methods by 1) creating an easy forum to share, discuss, and reflect; 2) freeing up time for individual thinking; and 3) creating deeper understanding of problem through dynamic contents. The social media applications and other educational applications like Google Classroom serve as alternative classrooms to extend discussions of lessons beyond regular lesson time and classroom. Teachers and students in Japan use Google Classroom to reflect on lessons taught through students writing comments and review. The reviews and comments are often displayed for whole-class discussions and clarifications either at the beginning or end of the lesson. This helped students deepen their understanding and teachers to evaluate students' learning and success of the lesson conducted. When teachers display problems, figures, table values, etc. on the screen, it is evident less time is taken for explanation compared to manual writing and drawing on the board, hence dedicating more time for students to think and explore multiple solutions to a problem. The dynamic contents can help students explore concepts through changing values, varying figures, observing the pattern and relations, and so on.

Teachers pointed out various benefits of using ICT in mathematics lessons such as ease of sharing ideas, deepening the understanding of problem, reduced preparation time and printing cost, ease of storing learning history, better visual aids, and improved teaching-learning materials. However, they regarded well-established ICT facilities as the most important enabling conditions for successful integration of ICT. This is in line with Isoda's (2011) statement that any country could use innovative technologies effectively and meaningfully if time for infrastructure development is considered. When teachers were asked about constraints related to ICT integration, they perceived that taking more time for ICT-integrated lessons is a major challenge. It may be interpreted in two ways as either preparing or actual classroom practice. The availability of technology in the classroom does not determine the improved student outcomes, but it is the teacher's decisions on how to integrate ICT into the mathematics classroom that will either improve or hinder student outcomes (Jackson, 2017). According to this statement, despite the availability of a wide range of tools and numerous readymade materials, teachers must do in-depth and careful analysis of content, pedagogy, and technology to best suit students' learning. If technologies needed for particular content, students' technical skills, materials to be used and instructions to be provided are not examined carefully during the planning, actual classroom practice time would be meaningless.

Conducting kyozaikenkyu to encourage students to look and think mathematically by creating learner-centered and thought-provoking lessons is the most important role ascertained by teachers. Kyozaikenkyu as comprehended from the various available literatures (Takahashi, 2006; Shimizu, 1999; Watanabe, et al, 2008) is the careful analysis of topic in accordance with objectives by conducting in-depth study of instructional materials available and investigating new materials for potential enhancement of the concept, anticipating students' approaches to the problem. Teachers also conduct school-level professional development programs such as training for students on technological tools at the beginning of the school year (e.g., the use of Chromebook and iPad), exchange of ICT lesson practices through exchange of plans and observations, and restricting or removing non-academic sites that can be accessed. The ICT tools mostly used by teachers include Google Sheets, Documents, Slides, Jamboard, GeoGebra, and Meet and iPads.

Teachers ranked the four content strands of junior high school mathematics curriculum in terms of how best each strand can be taught with ICT as shown in Table 2. From the average rank, we can conclude that topics related to figures are most suitable to be taught using ICT, and number- and calculation-related contents are least favorable for ICT integrations.

5. Consideration

The main data collection tool employed for this study was lesson observations, and results were interpreted and elaborated through descriptive analysis, hence the findings may contain the author's views. Further, the result may not be generalized to the trend in the whole of Japan since the study includes observation of lessons in only two schools and responses to the questionnaire from only two mathematics teachers. However, according to Stigler and Hiebert (1999), teaching is a cultural activity learned through informal observation and participation over a long period of time, and lessons within a country follow distinct patterns as they are designed and taught by teachers who share the same cultural scripts. Also, since Japan is a country with homogenous cultural and linguistic traditions (JICA, 2004) and follows common and centralized MEXT-approved curriculum, the study findings may reflect similar trends of Japanese mathematics lessons.

The classrooms observed had updated equipment, and teachers believed that ICT can enhance mathematics lessons and preferred ICT-integrated lessons over traditional chalk-and-talk methods. However, only 41.2% of the total lessons observed used ICT in actual classroom teaching as opposed to their response that they integrate ICT in either most or every lessons. The uses of ICT were to display problems, information, figures and images, PowerPoint presentation and to review lessons through comments and feedbacks using spreadsheet and Google Classroom. The engagement of students in mathematical activity involving ICT such as dynamic software, simulations, videos etc. were limited, and the use of digital textbook and its dynamic functions were rarely observed. The factors affecting success of ICT integration, such as ICT facilities, teachers' professional competency, teachers' perceived benefits, lack of technical support, etc., do not seem to constraint teachers in observed schools as they responded that taking more time for ICT-integrated lessons is a constraint. The educators in Japan succeeded in delivering quality education to the children

Table 2. Teachers' rank of how each content strand can best be taught with ICT

Content Strands	Rank (T1)	Rank (T2)	Average Rank	Examples
1. Numbers and Calculations	4	4	4	Sharing through Jamboard, using flashcards for calculation problems, etc.
2. Figures	2	1	1.5	Actual measurement of the use of similar figures (measurement applications), figure creation through using GeoGebra applications, etc.
3. Relationships Between Quantities	3	2	2.5	Graph creation using GeoGebra applications.
4. Utilization of Data	1	3	2	Creating histograms (frequency distribution tables) in a spreadsheet, analyzing data using spreadsheet.

throughout 1990s, the era of no ICT use (Isoda, 2011). Technology integration requires a new perspective, and things like teachers' beliefs, willingness, and commitment may account for the slow progress of ICT in education compared to other fields and also other industrialized countries.

6. Conclusion

The study could see no differences in the procedures of lesson flow between ICT-integrated and traditional lessons, as mathematical concepts are constructed by following the procedures of well-established "structured problem solving" strategy of lesson delivery. The only notable differences between the two lessons are on tools and materials used to present problem and solutions and the forum used to think, share, and discuss ideas. Despite the great potential of ICT innovations in enhancing mathematics teaching and learning, the meaningful classroom practice seems to be a challenge as not all topics can be best taught with ICT and not all the same tools can teach all topics, indicating the importance of a teacher's capacity to select the right content with the right tools. The question of whether ICT is integrated in a lesson is not important, but creating learner-centered and thought-provoking lessons to encourage students to look and think mathematically is. However, there must be a continuous effort and commitment from educators to stimulate motivation among young generations to create curiosity and interest in experiencing mathematical facts and their applications in the world around us. This can definitely be achieved by innovating lessons with technologies as Oldknow (2008) states that ICT may not be able to displace the mathematics teacher, but it can make him or her more effective in winning the hearts and minds of the next generation of students.

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