CHAPTER 2

Literature Review

A study in development of Mathematics Curriculum to Promote Learning and Innovation Skills of the 21st Century through the Application of Lesson Study, researcher reviewed documents, textbooks, and related researched as follows:

2.1 The 21st Century Skills

- 2.1.1 Conceptual framework of the Partnership for 21st Century Skills
- 2.1.2 Conceptual framework in enGauge 21st Century Skills of NCREL and Metiri Group
- 2.1.3 Learning and Innovation Skills

2.2 Curriculum development to promote the 21st century's learning skills

- 2.2.1 Concept of curriculum development
- 2.2.2 Concept of curriculum development to promote the 21st century's learning skills

2.3 Teacher professional development using lesson study and open approach

- 2.3.1 Lesson study
- 2.3.2 Open approach

2.1 Learning Skills in the 21st Century Skills

We have found that the education in the past century often focused more on core contents than encouraging learners to build up their own knowledge (see figure 2.1). An educational model heavily relied upon contents and content-based assessment. This made the learning processes limited to a classroom. But in the 21st century, the education model has more emphasis on life and social skills (see figure 2.2). Apart from core contents, learners have to learn about life skills, information and communication technology (ITC), thinking skills and gain innovations for learning. Knowledge about the new world in the 21st century is added in the new curriculum in order to make learners understand how the world has changed recently. In so doing, they can live their lives happily in the ever-changing world as well as use ICT devices to connect and communicate with others effectively and efficiently.

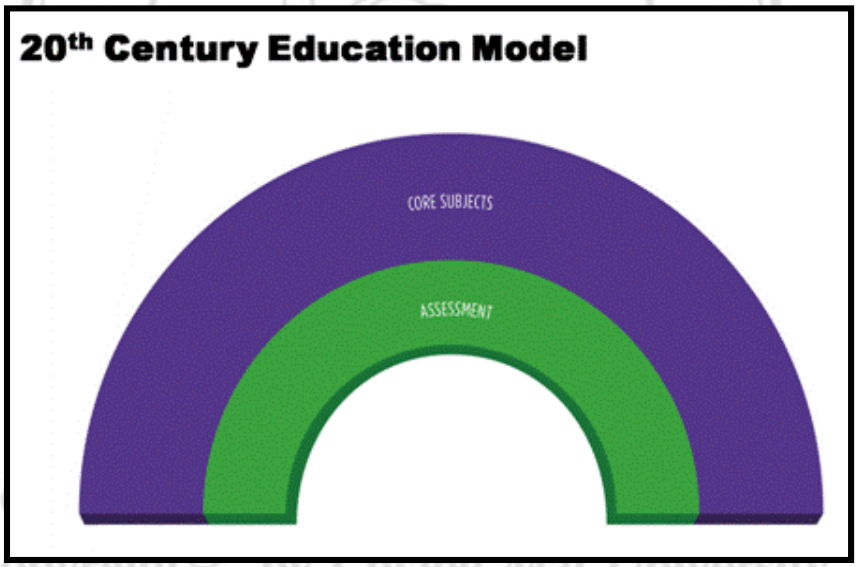


Figure 2.1 20th Century Education Model

In an age where everything has changed rapidly, the success in school may not guarantee a bright employment future. On the contrary, learners who have knowledge plus some skills to handle the ever-changing society and have the ability to adapt themself with ever-new situations have more chance to succeed in life. Therefore, the education in the 21st century should comprise of knowledge in core subjects and the 21st century skills (life skills, learning and innovation skills, ICT skills), whereby these skills are integrated in core subjects. This could make the education even

stronger. Hence, there were many sectors and organizations in the U.S. which collaborated to develop a conceptual framework for educational development. Consequently, several frameworks were introduced by several organizations such as The Partnership for 21st Century Skills, NCREL and Metiri Group, and OECD. Here, I would like to discuss about the first two conceptual frameworks; 1) the Partnership for 21st Century Skills, which is most widely used and 2) enGauge of NCREL and Metiri Group which is used as a learning approach for world-class standard schools in Thailand in order to prepare Thai youths for the international society as detailed below.

2.1.1 Conceptual framework of The Partnership for 21st Century Skills

In 2002, some leaders in business and education joined as an alliance for designing the 21st century skills. They are Apple, the Association for Supervision and Curriculum Development (ASCD), Cisco Systems, Microsoft Corporation, and the National Education Association (NEA) and others. In total the group comprised of 40 organizations. This framework takes emphasis on vital components each learner should have for success in the 21st century. There are 4 vital components, as follows; 1) core subjects and 21st century themes, 2) learning and innovation skills, 3) information, media, and technology skills, and life and career skills as shown in figure 2.2.

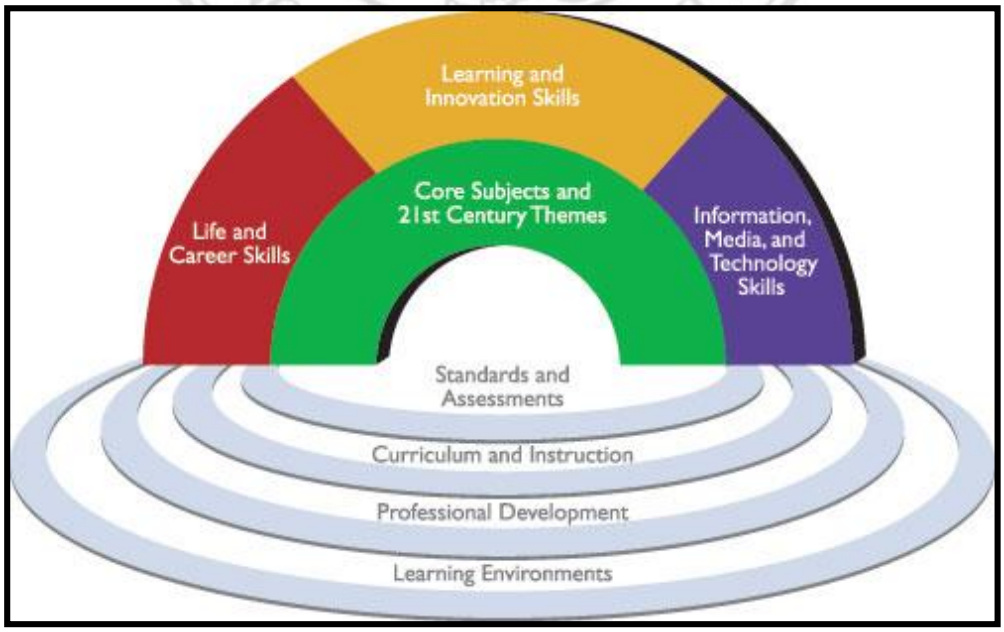


Figure 2.2 shows a conceptual framework for education in the 21st century of The Partnership for 21st Century Skills

Source: The Partnership for 21st Century Skills (2009)

Core Subjects

- English, Reading, and Art of Language Usage
- Economics
- World's Major Languages e.g. English, Chinese, Japanese
- Science
- Art
- Geography
- Mathematics
- Administration
- History

A concept of the 21st century themes

- Global awareness
- Fundamental knowledge on finance, economy, business, and entrepreneurship
- Fundamental knowledge on citizenship
- Fundamental knowledge on health
- Fundamental knowledge on environment

Learning and Innovation Skills

- Critical thinking and problem-solving
- Creative thinking and innovation
- Communication
- Teaming

Information, Media, and Technology Skills

- Fundamental knowledge on information
- Fundamental knowledge on media
- Fundamental knowledge on information and communication technology (ICT)

Life and Career Skills

- Flexibility and adaptability
- Initiative and self-direction
- Social skill and trans-cultural learning
- Productivity and self- awareness
- Leadership and responsibility

Supportive system for education in the 21st century

- Standard and assessment for the 21st century
- Curriculum and pedagogy for the 21st century

- Professional development for the 21st century
- Learning environment for the 21st century

2.1.2 Conceptual framework of enGauge 21st Century Skills of NCREL and Metiri Group

A conceptual framework of enGauge 21st Century Skills adds visual literacy in Digital Age Literacy. In addition, "curiosity", "bravery" and "managing complexity" are also included in the 21st century skills. Therefore, the framework of enGuage focuses more on situational knowledge and skills, rather than an overlapping of contents and curriculum. The enGuage framework puts emphasis on various skills in the digitalized era which are categorized into 4 groups as shown in table 2.1 and the framework in figure 2.3.

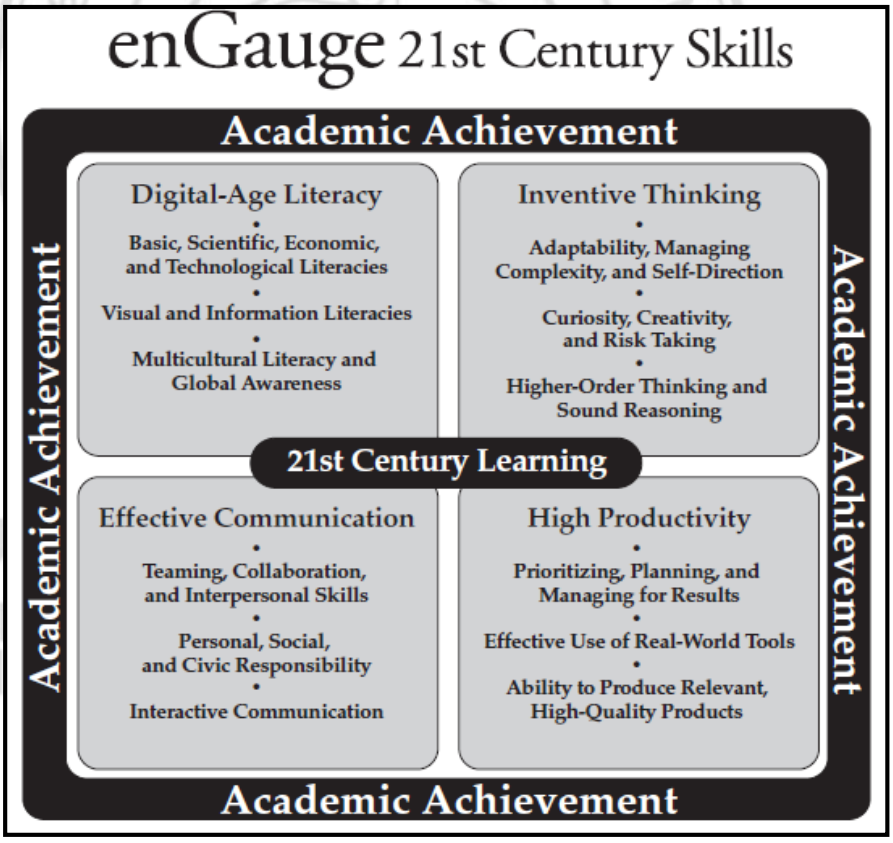


Figure 2.3 shows a conceptual framework for education in the 21st century of enGuage 21st Century Skills

Source: The Metiri Group (2003)

Table 2.1: The 21st Century Skills of enGauge

Digital Age Literacy	**Inventive Thinking**	**Effective Communication**	**Quality and Results**
Fundamental knowledge on Basic, Science, Economics, and Technological Literacies	Adaptability, Managing Complexity, and self-Direction	Teaming, Collaboration and Interpersonal Skills	Prioritization, Planning, and Managing for results
Visual and Information Literacy	Curiosity, Creativity, and Risk Taking	Personal, Social, and Civic Responsibility	Effective use of real-world tools
Multicultural Literacy and Global Awareness	Higher-order Thinking and Sound Reasoning	Interactive Communication	Ability to produce relevant, high-quality products

According to the figure 2.3, the conceptual framework for the 21st century skills comprises of four respects as follows:

1. Digital-Age Literacy

During 1990, the expectation for basic skills was centered on reading, writing, and calculating skills. However, at present learners need additional skills so as to succeed in the 21st century. These additional skills are science and technology, culture, and digital-age literacy which are described in detail below.

Fundamental knowledge: Comprises of proficiency on language (English), and mathematics in daily life for the success in set goals and developing crucial knowledge in the digitalized era.

Knowledge on science: Understanding and knowledge of concepts and scientific methods are crucial for decision-making process in political activities and cultural engagement as well as productivity.

Knowledge on economics: The ability to understand problems in economy, choices, prices, and profits. Be able to analyze economic situations, probe a consequence of change in economic conditions and public policy. Be able to understand and cope with economic situations.

Knowledge of technology: This kind of knowledge is a specific skill for specific works. This implies the ability to use technology effectively to achieve any particular end.

Visual literacy: It is the ability to apprehend messages, use, and select appropriately the technology for making picture and motion media by using higher-order thinking processes and decision-making, communication, and learning skills.

Knowledge on information: The ability to process information via various types of media. Be able to categorize the information, synthesize and use it effectively. And be able to access the information by using communication, electronic technology.

Knowledge on multicultural: The ability to understand similarity and difference in beliefs and values of one and other's cultures.

Global awareness: The awareness and understanding of the relationships between organizations, states, countries, cultural groups, and individuals in this world.

2. Inventive Thinking: This skill is constructed as "life skills" in the digital age, as follows:

Adaptability, managing complexity: The ability to adapt thought and attitude or behavior of individuals for the better future context. Be able to manage objectives, missions, and other diverse inputs while understand the limits of time, raw materials, and systems.

Self-Direction: The ability to set goals for learning and plan for achievement. In this process, time management and independent attempts are important as well as the quality in outcomes and learning assessment.

Curiosity: The yearning to learn or shown enthusiasm in what interested in which leads to further inquiry.

Creativity: Action or process of innovating.

Risk taking: Bravery or admitting mistakes and readiness to face any unsolved problems.

Higher-order thinking and sound reasoning: The intellectual process including comparison, reference, translation, assessment, and synthesis for problem-solving in different situations.

3. Effective Communication: Both researchers and business persons agreed that effective communication is a crucial skill for the success in knowledge-based society. This skill consists of the following aspects:

Teaming and collaboration: The collaboration in working between two persons or more in order to solve problems, create outcomes or learning contents.

Interpersonal interaction skill: The ability to realize and cope with feeling, motif, and behavior of oneself and of other's during the interaction in society.

Personal and civic responsibility: The ability of managing with technology and administration to support the public as well as to protect society, the environment, and democracy.

Interactive communication: The process of exchange in communication via various devices.

4. High productivity: Having high productivity in school is not consistent with real situations in the workplace. High productivity should comprise of the following aspects:

Prioritization, planning, and managing results: The ability to manage set goals of projects or to deal with problems at hand effectively.

Effective use of real-world tools: The ability to use real devices i.e. hardware, software, network, and devices used in information works in the 21st century for communication, collaboration, problem-solving, and task establishment.

Ability to produce relevant, high-quality products: The ability to produce products by using information or raw materials including synthesis of materials for real use in knowledge-based practice.

From the two conceptual frameworks, researcher analyzed and concluded that in general the two frameworks are consistent (see figure 2.4) in aspects of effective communication, and high productivity. These are crucial skills for life and work. Having interpersonal interaction skills will lead to good social skills, flexible in living as well as adaptable to changes. Inventive thinking is similar to learning and innovation skills which focuses on promotion of higher-order thinking, critical thinking for innovative creations. Additionally, fundamental knowledge in the digital age could link information, media, and technological skills which are crucial for the 21st century's education.

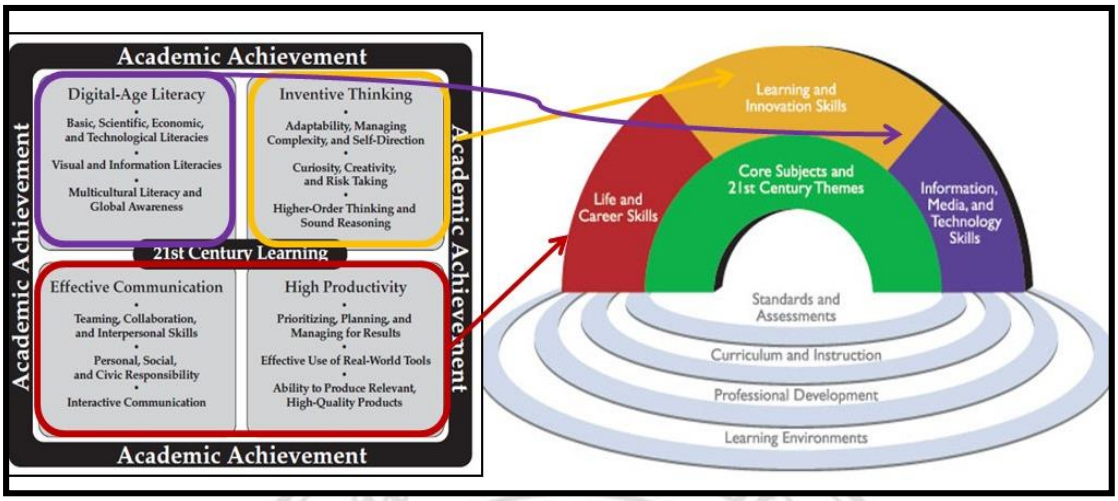


Figure 2.4 shows the consistency of enGuage 21st Century Skills and The Partnership for 21st Century Skills

Pedagogy for learners in order to gain skills of the 21st century, teachers are very important as facilitating and encouraging them to gain the kind of skills as much as they can. Teachers therefore should improve their competency for educational development so that learners can learn and develop. The world is changing and has grown more complicated. Learning and innovation skills have become crucial, basic skills that all students should have.

2.1.3 Learning and Innovation Skills

The learning and innovation skills are at the top of the Knowledge-and-Skills Rainbow (in figure 2.2) which is at the heart of skills for living in the 21st century. Learning how to learn or learning skills, and learning skills for the betterment (innovation) comprise of the following aspects (Panich, 2012):

1) Critical thinking & Problem-Solving

- Students are able to use reason, think rationally in various methods such as inductive and deductive depending on situation.

- Students are able to use systematic thinking and are able to analyze how minor factors relate to each other and lead to a consequence in a whole picture.

- Students are able to think critically and make a decision as follows; are able to analyze and evaluate based on information, arguments, assertions, and beliefs; are able to compare and evaluate main ideas including synthesizing and linking between information and arguments. Moreover, they are able to interpret information and conclude it on a basis of analysis, and are able to think in critical reflection for respects of learning and methods.
- Students are able to solve challenges problems by practicing unfamiliar problems. Various kinds of issues, both conventional and unconventional, are provided as well. They are able to raise questions that help them to have a clearer understanding from different dimensions and figure out a better solution.

2) Creativity and Innovation

- Students are able to think in different perspectives, and are able to create an alternative point of view. This could be either a modified or a newly created one. Additionally, students should join in the processes of making understanding, improving, analyzing, and evaluating the perspective of each other in order to understand the creative thinking process.
-Students are able to develop for innovation by taking action using their creativity.

3) Communication

- Students are able to organize their ideas and articulate clearly. Moreover, they are able to communicate via various channels; verbal, written, and non-verbal (e.g. body language).
- Students have efficient listening skills gained from the ability to apprehend meaning, knowledge, value, attitude, and concentrate while listening.
- Students are able to communicate for various results such as to inform, to order, to persuade and to induce.

- Students are able to communicate for results within various situations including a situation that multi-lingual communication is required.

4) Collaboration

- Students are able to work in groups very well and respect diversity within a group.
- Students have flexibility and are able to devise a compromise acceptable for a collective goal.
- Students have responsibility for group's work and value other's role and functions.

These learning and innovation skills accord with the policy of Education Ministry for youth development in the 21st century. The policy aims to add up morality, loving for Thainess, critical and creative thinking skills, technological skill, teaming and ability to live peacefully with others and the global society to all students (Ministry of Education, 2008).

Related Researches on Learning and Innovation Skills

Moylan (2008) in a study "Learning by Project: Developing Essential 21st Century Skills Using Student Team Projects" finds that "7-Cs" are essential: Critical thinking and problem-solving, Creativity and innovation, Collaboration, teamwork and leadership, Cross-cultural understanding, Communications and information fluency, Computing and ICT fluency, and Career and learning self-reliance are the skills that students gain from project-based learning activities. "Project Learning" has been identified as a key methodology for filling this gap between current student learning and developing their necessary knowledge and skills essential for success in the 21st Century. Multiple proposals to improve student performance in science, engineering, technology and mathematics use Project Learning as a construct for student engagement.

Clark (2008) shows in his study focusing on two elements of the Partnership for 21st Century Skills: using 21st century technology tools and creating the 21st century context for learning. The population for this study is all PK-12 West Virginia teachers. The study finds that West Virginia teachers frequently use few 21st century technology tools, seldom use the 21st century technology tools to create the 21st century context for learning, and identified supports and barriers that enable or prohibit their use of technology.

Bell's (2010)Project-Based Learning for the 21st Century: Skills for the Future reveals that Project-Based Learning (PBL) is an innovative approach to learning that teaches a multitude of strategies critical for success in the twenty-first century. Students drive their own learning through inquiry, as well as work collaboratively to research and create projects that reflect their knowledge. From gleaning new, viable technology skills, to becoming proficient communicators and honing advanced problem-solving skills.

Lombardi (2007) studies about Authentic Learning for the 21st Century focuses on real-world, complex problems and their solutions, using role-playing exercises, problem-based activities, case studies, and participation in virtual communities of practice. The research finds that learning-by-doing is generally considered the most effective way to learn. The internet and a variety of emerging communication, visualization, and simulation technologies now make it possible to offer students authentic learning experiences ranging from experimentation to real-world problem-solving.

Kaur (2013) indicates that nurture collaboration and effective communication in the 21st Century skills lies in two main areas. The first is crafting suitable tasks for use in lessons and the second is facilitating discourse that engages students in active deliberations of the work they are doing, reflecting on what they are doing and interacting with their peers while doing it. The learners worked collaboratively with their peers, articulating their thoughts and making sense of their own ideas as well as synthesizing others' ideas.

Anchalee Toekool (2008) studies the behavior and ability to think critically of grade 7 students who learned by problem-based approach integrated with discussion and problem-solving approach. The study reveals that the critical thinking behavior of students in post-test average score is higher than pre-test average score which is in middle level. With regard to each area, the critical thinking behavior is significantly higher in post-test average score. Students who learned by the problem-based approach integrated with discussion and problem-solving approach have high average score for the critical thinking behavior. It is higher than the pre-test average score, which is in the must improve level. Every step of critical thinking skills always has higher post-test scores and students also have high satisfaction.

2.2 Curriculum Development to promote the 21st Century Skills

2.1.1 Concepts for Curriculum Development

Curriculum development is very important for pedagogy which should be designed to fit well with the ever-changing society. George J. Posner introduces concepts for the curriculum development in his study "Analyzing the Curriculum" in 1992. From his work, 5 concepts are postulated as follows; traditional, experiential, structure of the disciplines, behavioral, and cognitive. Each concept has its distinct focus, and has its own philosophers/thinkers as follows:

Concept of traditional believes that education is crucial for cultural inheritance. A curriculum should promote intellectual skills for learners. Moreover, textbooks should be focused on accurate information. Main function of schools is to pass down knowledge and contents to the new generation. Philosophers/thinkers in this approach are such as William Torrey Harris (1897), E.D. Hirsch, Jr. (1987).

Concept of experiential believes that learners' experiences are crucial. A curriculum should be considered in a wider range, not confined to school and classroom. Schools should provide learning process that fits to or relates to learners' experiences. Moreover, a curriculum could be possibly amended and re-organized at all times in order to achieve the best results toward experiential

development of each learner. Philosophers/thinkers in this approach are such as Hobbes, Descartes, John Locke (1913) and John Dewey

Concept of structure of the disciplines believes that a curriculum should be focused on structure of the disciplines where each discipline has its own inquiring process which is not only of that scientific process. Therefore, managing discipline should be in subsequent order as well as in-depth, comprehensive, and widened in accordance with learners' experiences. Philosopher/thinker in this approach is such as Jerome Bruner (1960).

Concept of behavioral believes that a curriculum should not be focused only on contents but also on how learners apply these contents in real situations. Therefore, managing curriculum should put emphasis on what and how learners have learned. Furthermore, learning behavior and approach used for assessing and analyzing the behavior should be taken into account. Philosophers/thinkers in this approach are such as Frankin Bobbitt (1924), Ralph W. Tyler, Robert Mager and Fred Keller.

Concept of cognitive believes that learning is not just data receiving but includes the ability to connect data or knowledge with knowledge in other fields. There will be more than knowing what to perform but also knowing when and how to react in different situations. A curriculum then should be focused on practicing in thinking process where learners can construct their own knowledge. Philosophers/thinkers in this approach are such as Jean Piaget, Noam Chomsky, and David Ausubel.

The concepts discussed above provide pathways for educational specialists and curriculum developers to develop the curriculum which promotes learners' adaptability in different contexts. The curriculum development is then considered by educational specialists/curriculum developers in many respects as described below.

1) Meaning of Curriculum Development

Auraiwan Hanwong (2008) suggests that the curriculum development is processes for planning and developing learning experiences longs for changes in learners. These processes are; determinng learning objectives for a newly designed curriculum, selecting and managing learning experieces for learners, selecting learning materials, and implementing and evaluating a curriculum.

Panattha Soradeth (2010) states that the curriculum development means improving and amending of a curriculum longs for the advancement of leaners. The curriculum development should focus on curriculum aims, goals, and objectives so as to achieve the set ends.

Sakonlawat Suthamanee (2008) suggests that the curriculum development means improving the existing curriculum into a better one or arranging a new curriculum with the integration of the known curriculum as its basis, inclusion of fresh materials for learners, and maintenance of familiar terms with curriculum development within the curriculum development jargons, such as curriculum designing and curriculum organizing.

The above mentioned definitions of curriculum development was improving curriculum under curriculum users that consits of curriculum design, objectives establishment, creating learning management guideline and tools for evaluation.

2) Models for Curriculum Development

Allan C. Ornstein and Francis P. Hunkins (2009) introduce an approach for the curriculum development in their work “Curriculum; Foundations, Principles, and Issues”. Leigh Chiarelott also discusses about vital conditions for the curriculum development in his work “Curriculum in Context” (2006).

I borrow their ideas as well as discuss about other interesing ideas and approaches pertaining to the curriculum development in recent decades as follows:

1. Tyler's curriculum development model

Ralph W. Tyler provides the rationale for curriculum developers to set goals for a curriculum to be created. In order to do this, developers must answer the following questions;

1) What are the goals/objectives of the education of school?

2) How the school manages learning experiences in order to achieve these ends?

3) How the school manages these learning experiences for the effective pedagogy?

4) How to assess the effectiveness of these learning experiences?

These 4 questions are crucial for the curriculum developers so as to form frameworks for the curriculum development. They can make a choice in accordant with the particular context. Allan C. Ornstein and Francis P. Hunkins borrowed this idea and developed the Tylers' model as shown in figure 2.5.

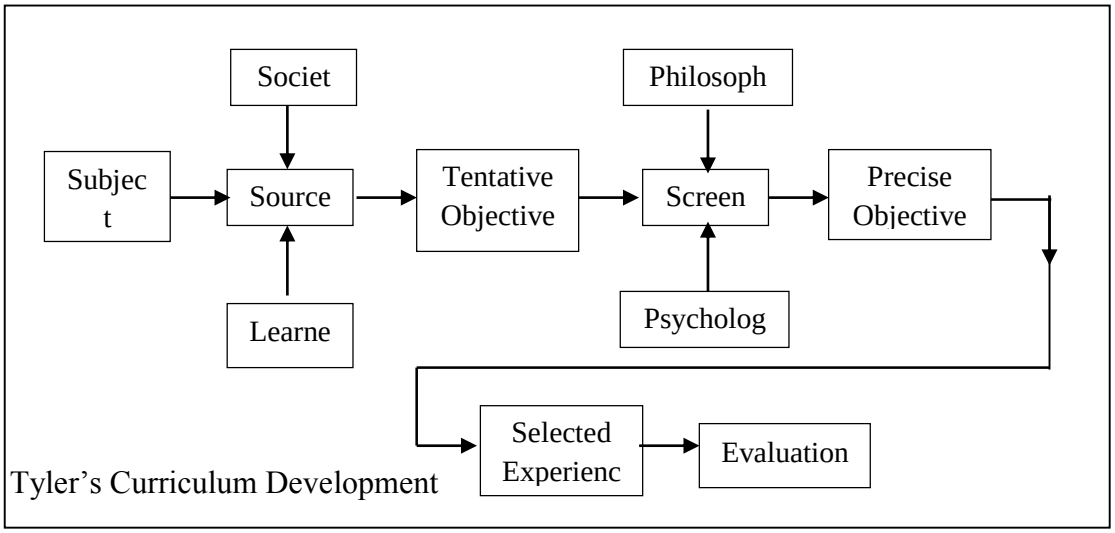


Figure 2.5 shows Tyler's model for curriculum development

From this model, the curriculum development could be done by the following steps:

Step 1 Formulation of objectives: This could be tentative describing three main dimensions; social, learners, and contents. Then scrutinize

them in areas of educational philosophy, learning psychology in order to make clearer, concise learning objectives.

Step 2 Selecting learning experiences: Select learning experiences that lead to the learning objectives.

Step 3: Assessment: In order to consider the level of achievement the selected learning experiences can reach.

2. Taba's model for curriculum development

Hilda Taba (1962) is a curriculum developer who believes in teacher's significant role in the curriculum development. Her model is called a Grassroots approach developed from users of Bottom up approach which is different from Tyler's model. Though the Tyler's model is developed from curriculum developers and uses Top-down strategy, curriculum compositions are consistent with Taba's model in areas of objectives, subject contents, pedagogical process, and assessment. In this model of development, it can be started from any point depending on skills and interest of each developer. Once it gets started, it must be followed by seven developing processes as described below (Wongyai, 2008).

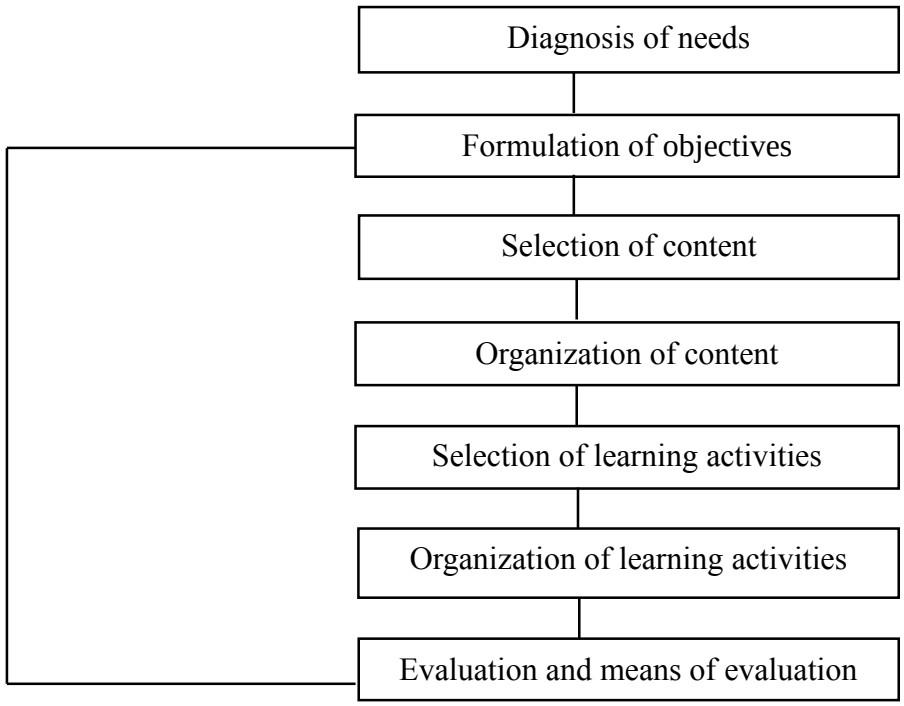


Figure 2.6 shows Taba's model for curriculum development

Figure 2.6 is described by the following steps:

Step 1 Diagnosis of needs: Curriculum developers diagnose needs of learners and society as well as formulate aims/objectives of a curriculum based on the diagnosis of needs.

Step 2 Formulation of objectives: after the diagnosis of needs of learners and society, curriculum developers will formulate aims/objectives of a curriculum based on the diagnosis of needs.

Step 3 Selection of content: Contents are selected in accordant with the set aims/objectives.

Step 4 Organization of content: Curriculum developers organize the contents conforming to nature, competency, and interests of learners.

Step 5 Selection of learning activities: Curriculum developers select various learning styles based on learners' learning levels and make sure that learners are engaged in the contents learning.

Step 6 Organization of learning activities: Curriculum developers organize the sequence of learning activities while regarding learner's conceptual development and differences between learners.

Step 7 Evaluation and means of evaluation: An evaluation to assess in what level the learning activities and experiences provided reaches the set aims/objectives includes an assessment of means for the evaluation.

3. Backward Design for Curriculum Development

Grant Wiggins and Jay Mctighe (1998) suggest a model called "Backward Design" for the curriculum development. This model takes the four vital questions from Tyler's model and then revises it into 3 respects as follows; outcomes, assessment, and learning experience.

They state that the curriculum development should be started from the last step. In other words, it should be focused on outcomes or expected learning standard while an assessment will be considered at the beginning of the developing process.

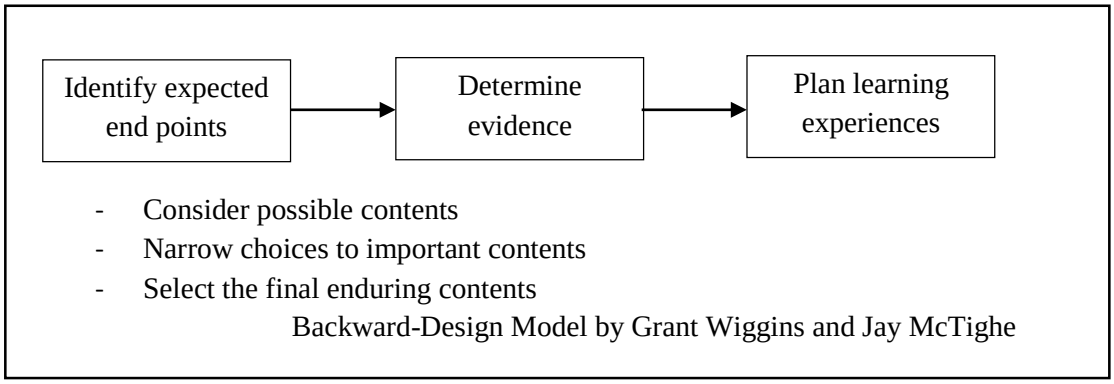


Figure 2.7 shows Backward Design for curriculum development

3. Kerr's model for curriculum development

John F. Kerr introduces a model called Operational Model the aims of which come from three major sources as follows:

1) Level of development, needs, and interests of learners

2) State of problem and needs of society that learners are facing with.

3) Nature of subject contents and learning styles

Step 1 Selection and prioritization of goals: Bloom's model for categorization of educational objectives is taken into account. From Bloom, educational objectives are categorized into 3 domains as follows: affective, cognitive, and psychomotor. This makes the categorizing process much clearer.

Step 2 Learning experience management: This should be consistent with objectives and selected contents. Additionally, other components should be taken into consideration such as readiness of learners, differences between learners, relationships between teacher and learners, and teaching approach.

Step 3 Evaluation: This is a process of data collection for making a decision on the curriculum development. This process consists of various means such as test and interview. Kerr uses arrows to link between components in the model to assert that every single component is absolutely related.

4. Lewy's model for curriculum development

Arich Lewy describes about processes and important steps for the curriculum development. Lewy's model for the curriculum development consists of 3 essential steps; preparation of a proposal, preparation of learning materials, and operation.

1) Step for preparation of a proposal is divided into 3 minor steps as follows; formulating objectives, selecting subject contents, and selecting learning activities.

2) Step for preparation of learning materials is divided into 4 minor steps as follows; creating learning materials, selecting learning materials used for each subject, conducting a try-out for the newly created materials, and revising and amending the learning materials.

3) Step for operation is divided into 6 minor steps as follows; preparing for administration, training for teachers, improving teaching system, coordinating with academic section, controlling the quality, and revising.

2.2.2 Concept of curriculum development to promote the 21st century skills

According to concepts of the curriculum development, meanings and models described above, researcher would like to develop a curriculum using Taba's model which focuses on teacher's role and engagement in the developing process. The curriculum is developed by using Bottom-up strategy which accords with the context of Wiengjedee Wittaya School whose organizational culture gives priority to participatory development of teacher profession.

2.3 Teacher professional development using Lesson Study and Open Approach

2.3.1 Lesson Study

1) Meaning of Lesson Study

Lesson study has been used for more than a century in Japan (Takahashi, 2013). It is a translation of the Japanese term "jugyokenkyu". The term "jugyokenkyu" is a combination of two words "jugyo" (classroom) and "kenkyu**"** (study or research). Lesson study thus literally means classroom study or research. But in truly Japanese culture, when teachers want to teach students by using the lesson study approach, they will participate in a well-designed program. The program comprises of discussion on lesson plan and co-working in classroom observation. This lesson plan is called "kenkyujugyo" which is a reverse of "jugyokenkyu" *lit* . means study or research on lesson. Specifically, lesson in Japanese means the object of one's study. Lesson study is a study follows steps of an attempt to achieve research aims where teachers are willing to work together. For example, in order to make understanding on how to promote student to be an independently self-directed learner.

Many educational specialists interpret the lesson study in many dimensions as follows:

Stigler and Hiebert (1999) (cited in Ming Fai Pang & Ference Marton (2003) state that the lesson study approach is a vital factor entails the success of Japanese students in international mathematics competitions. Apart from the success of students themselves, Yoshida (2004) points out that it is a popular guideline for teacher professional development in Japan. In other words, it is a means to have teachers collaborate considering contents, teaching, and problem-solving approach that leads to the improvement of mathematics education. This is consistent with Rebecca R. Perry and Catherine C. Lewis (2008) who suggest that the lesson study is a cycle of teaching development and a collaboration of teachers who aim at constant growing of students' learning process.

In Thailand, Suladda Loifah and Maitree Inprasitha state that the lesson study is a school-based teacher training. It is used as a guideline for Japanese teachers since at the beginning of teaching profession. The main characteristics of this approach are lesson research conducted by teachers who join in group discussion from time to time and create learning materials. Afterward, they conduct a try-out of the planned lesson and learning materials in real situation where other teachers are present as observers and commentators. Comments and suggestions from them are collected for the next revision. This is apparently the most effective process for improving mathematics teaching in classroom because it is based on the real practice.

Narumon Inprasitha (2009) defines the lesson study as a means for innovative development of teaching profession conducted by teachers in school themselves. Teachers work together at least in the following activities; developing learning process, conducting and observing the learning process, reflecting a lesson, and summarizing effects and results of each teacher. The lesson study is the innovation for teacher professional development that benefits both students and teachers simultaneously.

From the meanings of lesson study described above, I conclude that the lesson study is the innovation for teacher professional development accomplished by promoting co-working process. The process consists of group discussion, reflection in every single step and promoting the culture of sharing and exchanging among teachers in a school.

2) Steps for Lesson Study

Maitree Inprasitha (et al.) states that in Japan, the lesson study for teacher professional development is used in many different ways depends upon the particular context of school. However, they share some common steps as follows: (Stigler & Hiebert, 1999).

Step 1 Defining the problem: This approach is focusing on problem-based strategy. Defining the problem motivates and formulates a framework for teachers. Firstly, the problem could be a general one such

as how to make student interested in mathematics or a specific one like how to develop an understanding of students in ratio's addition (unequal denominator). In general, the problems selected are often from practices in classrooms which affected learners' learning process or pertaining to a policy given by national agency.

Step 2 Planning the lesson: When the objectives are formulated or selected by a group of teachers, they will arrange a meeting for discussion and planning the lesson. Objectives of planning the lesson are not only to obtain a well-planned lesson but also to develop knowledge and understanding on the planning strategy among teachers. At the beginning stage, the plan would be presented to all teachers in a school meeting for comments and suggestions for the next revision. This stage would take a month or several months before it is used in a real classroom.

Step 3 Instruction: The process of practice using a planned lesson in a real classroom. Schedule and teacher are set beforehand. Specifically a teacher must be the one who engaged in every planning step. At steps of introduction and teaching, the rest of teachers would be present for observation, take note in every significant finding and prepare feedback for the next revision.

Step 4 Evaluating the lesson and reflecting its results: After finish the instruction, a group of teachers would evaluate and reflect on the planned lesson used in real situation. Generally, a teacher who performed the instruction would be the first one in the process. The evaluation emphasizes on in what degree it could reach the objectives as well as the obstacles impede the success. Additionally, the reflection should be focused on the planned lesson rather than the teacher who performs the instruction. Ultimately, all members are responsible for effects and results from this planned lesson. In other words, this is a process to critique and reflect on their own invention for the next revision.

Step 5 Revising the lesson: This is a process of revising a planned lesson. The revision is based on findings from the observation and reflection. This may lead to the revision of learning materials, learning activities, questions given in each step or other. It is quite often that the revision is resulted from the misunderstanding of students found during the instruction.

Step 6 Instruction of the Revised Lesson: After the process of revision, the revised lesson would be put into practice again. The teacher could be the former or a new one within the group. All of teachers in school are invited to observe this instruction.

Step 7 Evaluating and reflecting: In this process, all teachers in school will perform the evaluation and reflection. The specialists from outside would probably be invited to take part in. It is similar to the first evaluation; the teacher who performs the instruction should be the first one. The process of evaluation and reflection benefits learners' learning process. Additionally, this provides an opportunity to reflect all the problems found as a result of the planning process especially in areas of theory and concept. This includes the benefits from learning by doing in instruction, lesson planning, and practice in a real classroom.

Step 8 Sharing the results: Although this is a case study in one lesson, curricula of basic education in Japan are mostly alike. Findings and results of the study are fruitful for teachers all over the country who teach in the same subject and in the same level. Therefore with the great support, the study's findings and results are publicized widely in forms of articles and presentations in every level of conference held every year.

In this study, researcher used the lesson study approach in 2 respects; curriculum development in overall perspective, and process of invention and instruction suggested by Inprasitha (2010) as shown in figure 2.8. The process consists of the following steps; collaboration in research

lesson design (Plan), collaboration in research lesson observation (Do), and collaboration in reflection or post-discussion (See). This process is further discussed in detail in chapter 3.

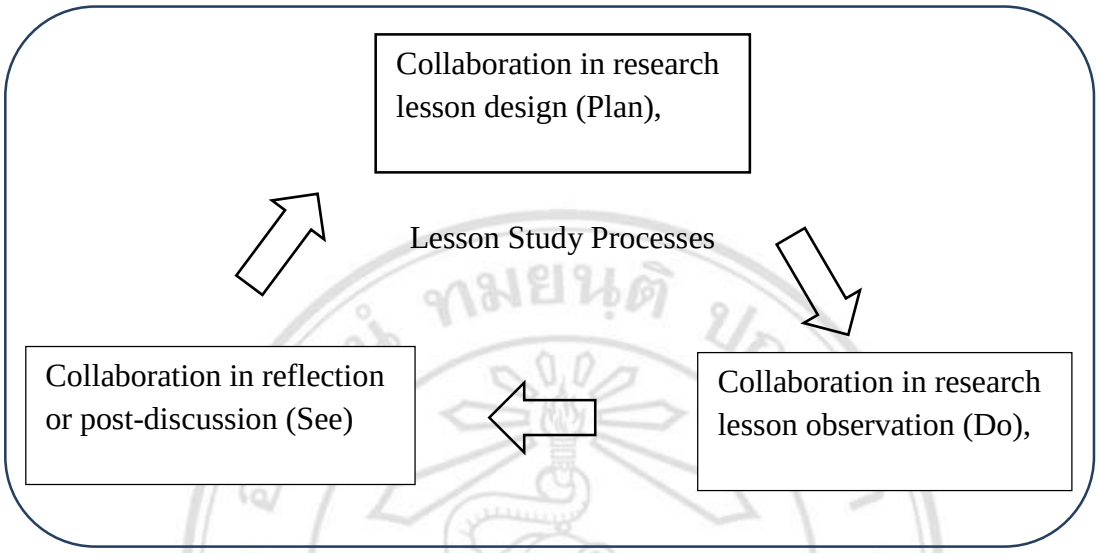


Figure 2.8 shows Lesson Study process

Researches on Lesson Study

Narumon Inprasitha (2009) studies the lesson study approach as an innovation for teacher-student development. The study reveals that by using the lesson study approach for teacher professional development, teachers' attitude change in respects of self-learning management, roles and attitude toward students. For students, they gain learning and thinking skills while studying Thai language as well as gaining positive attitude toward the study of Thai language. With regard to crucial factors entail the success of using the lesson study for teacher professional development, these are support from executives and unit of command in school, collaboration with external specialists, awareness of changes in students and teachers, trust in potentiality of the lesson study approach, co-working experience of teachers participated in the lesson study process, and approach for learning management.

Fernandez (2005) found that the lesson study creates a magnificent learning environment for teachers as much as those who employ reforming classroom which gives opportunities for students to learn.

However, although students learn a lot from working on the tasks, nevertheless a teacher who can push, solidify, and sometimes redirect their thinking is critical. Similarly, the teachers described here could have benefited from having a "teacher of teachers" help them make the most out of their lesson study work. However, the idea of introducing to the lesson study experience individuals who fill a teaching role sounds simpler than what is actually entailed in having this involvement lead to productive ends. To have an impact, these individuals will need to know not only how to identify, and perhaps help engineer, opportunities to learn during lesson study but also how to help teachers take advantage of these opportunities.

Marsigit (2007) observes mathematics teaching in the period of the year 2001-2003, results of the initiated of lesson studies are significantly indicated that there are improvements of the practice of secondary mathematics teaching learning processes in term of teaching methodology, teacher competencies, students achievements, alternative evaluation, teaching learning recourses and syllabus. However, in term of the longer term for teacher development program, the result of initiated Lesson Studies can be perceived as merely a starting point. There are still many things to be done in order that mathematics teachers develop their professional development.

Jensamut Saengpun and Maitree Inprasitha (2011) analyze Lesson Study in mathematics in Thailand based on the Cultural-Historical Activity Theory. The results showed that Lesson Study in mathematics in the Thai project school has followings the related components of the activity system: subject (teacher), object (student, problem-solving teaching approach), tools (Open Approach, mathematics contents and Japanese mathematics textbooks), rules (rules for practices in Lesson Study processes and Open Class), community (teacher network, supervisors, experts from university) and division of labor (small sub-groups for making lesson plans, school coordinators, internship program, school

board and local educational service office's supporting). The finding suggested the activity system aims to improve professional learning and skills and student's achievement as outcome.

Lim and Kor (2013) indicated that Lesson Study emphasizes collaborative learning and reflective thinking might provide a supportive platform for teachers to grow professionally and to meet the two challenges; mathematical thinking and solving real word problems. The research found that five mathematics teachers were amazed with the performance of their pupils that they could pose creative problems and engaged so intensely in solving real life problems. Furthermore, collaborative learning and reflective practices that provide by Lesson Study as a professional development platform, teachers are ready for any innovative change.

2.3.2 Learning Management Using Open Approach

1) Meaning of Open Approach

Open approach is a means for learning-teaching management which had been used for the first time in mathematics class in Japan. This approach is widely used later on in many countries includes Thailand. Maitree Inprasitha, director of research center for mathematics education of Khon Khaen University, introduces this approach in Thailand in for the first time in June 2002 (Narumon Inprasitha, 2008). The open approach focuses on the learning management that provides multiple answers possible for one question as well as providing various methodologies to get the answers. This is thus unlike open-ended approach which focuses only on the multiple answers for one question (Maitree Inprasitha, 2004)

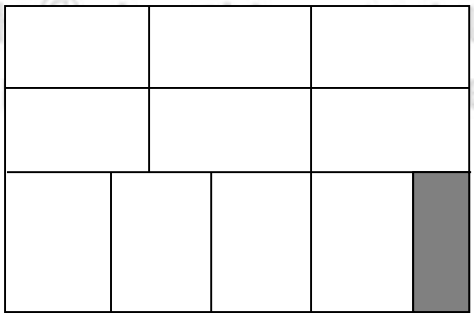
2) Types of Open-ended Questions

Questions or problems used in the open-ended approach are unseen, non-routine. According to the meaning of the open approach described above, we can group the open-ended questions into 3 categories as follows: 1) process is open, 2) end products are open, and 3) ways to develop are open. These three categories of open-ended questions are discussed in detail below.

1. Open Approach: Narumon Inprasitha (2009) suggests that the open approach is a process encouraging students to think about multiple methodologies in problem-solving process. They are independent to think and use any methodology depends on their experiences and prior knowledge. Maitree Inprasitha (2004) suggests that this kind of questions or problems could be resolved by many different ways and most of the mathematics questions are mostly open-ended like these. Nevertheless, what is interesting is that in general the mathematics questions in schools are often focused on one answer for one question, and not pay attention on problem-solving process. An example of the open-ended question is:

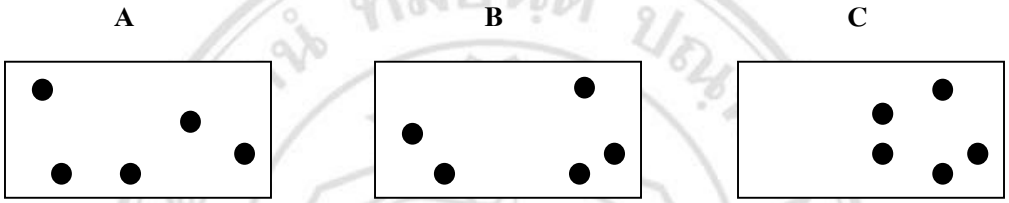
37 students want to make a birthday card for their teacher. In a meeting they agreed to do it together. They want to make a small card (the length is 15 cm. and the width is 10 cm.) cut from a big cardboard (the length is 45 cm. and the width is 35 cm.). The question is how many small cards they can make from this big cardboard?

For this question, students can solve by drawing small cards in the big cardboard as shown in a figure below. Or they can use a calculation of $(35\times 45)\div(15\times 10)$ and the answer of which is 10.5, or by using ratio calculation of $(7\times 9)\div(3\times 2)$.



The multiple methodologies to solve this question facilitate students to learn in accordance with their competency, interest, based on group discussion that could improve their solving-problem process.

2. Open-ended Answers: This kind of open-ended questions has multiple answers possible or open-ended answers. Shimida and her colleague develop a model of this kind of questions. Additionally in Europe, Christensen and Walter (cited in Maitree Inprasitha, 2004) study about the importance of inquiry-based questions which are similar to the questions with open-ended answers. An example of the open-ended questions whose answers are open-ended is a well-known "marble question".



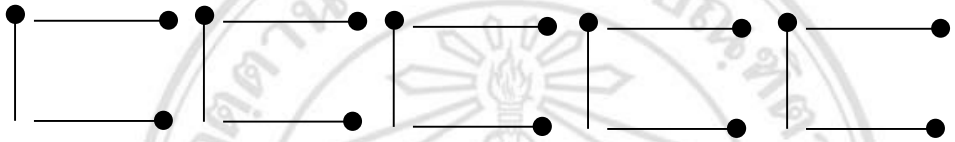
Three figures show positions on the ground of marbles thrown by three students A, B, C respectively. In this game, the one who makes the least spreading marbles is the winner. From the figure, the spread of marbles from figure A to C would be easy to understand if we use numbers to consider the degree of spread. Students please consider from various possibilities how to determine the degree of spread in as much as possible. After that, please explain of the best way you choose how and why.

In order to solve this problem, some students may find that "area measurement of the polycube" is an appropriate way to determine the degree of spread. Some may think about "measurement of the length of the overall straight line", or some other students may think that "measurement of radius of the smallest circle at the center of spreading marbles" is the best way. All of the possibilities always have both strong and weak points; teacher should provide them the both so as to figure out the answer for the general case amongst other proposed possibilities.

3. Guideline for Developing the Open-ended Question: After the problem is resolved by students, they can develop to a new question by

changing a condition or a component of the former one. This is called "from problem to problem" approach. (Takeuchi & Sawada,1984 cited in Maitree Inprasitha, 2004), and it is a guideline for developing the open-ended questions as well. An example of the open-ended questions is "math stick problem" used in a comparative study of problem-solving in mathematics in U.S.A. and Japan.

Make a quadrate by math sticks as a figure shown below, if we want to make 8 quadrates how many math sticks are used?



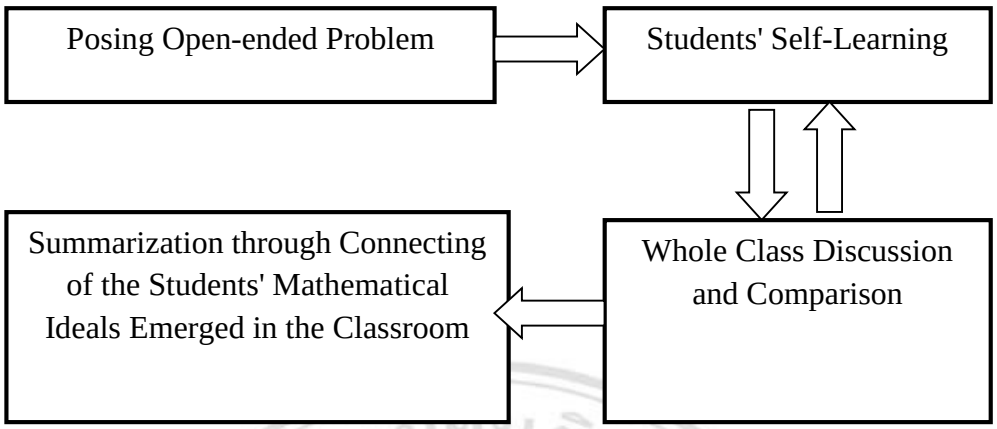
1) Student please writes down a way to solve this problem as well as the answer. 2) Student please creates your own questions similar to the above but in diverse versions as much as you can without showing how to get the answers.

3) Student please selects the best of your question, marks it and describes why you think that it is.

Students may develop the questions by changing the numbers of quadrates or some of them may change a condition from quadrate to triangle or to rhombus. Some others may develop a question asking about the numbers of quadrates when the numbers of math sticks are prior determined. From this approach, students would enjoy with their own thoughts to create the questions. Additionally, from a comparison with peers, they can further discuss about the structure of mathematical questions and generality of the proposed ways to resolve the questions.

3) Steps for Open Approach

Inprasitha (2010) suggests that there are 4 steps for Open Approach (see figure 2.9) as follows:



Source; Inprasitha (2010)

Figure 2.9 shows steps of Open Approach

1) Posing Open-ended Problem

2) Students' Self-Learning

3) Whole Class Discussion and Comparison

4) Summarization through Connecting of the Students' Mathematical Ideals Emerged in the Classroom)

4) Related Researches on Evaluation of Students' Responses

Evaluation of students' responses in the open-ended teaching approach does not focus only on gaining the right answer, but also focuses on promotion of mathematical thinking process and creativity of the students. The evaluation of students' responses can be considered by the following criteria.

Fluency: How many possibilities or ways to resolve the questions proposed by each student

- Flexibility: How much the difference of mathematical conceptions used by each student

-Originality: A degree of originality or initiative of each student.

-Elegance: A degree of clarity and intelligibility in presentation of each student

These criteria should be considered both in qualitative and quantitative especially for the first two criteria. Teacher can evaluate by counting the numbers of possibilities proposed by each student.

Related Researches on Open Approach

Tanya Kasaroon (2006) in her research "a study of teachers' value towards mathematics teaching using the open-ended approach" reveals that value is a vital factor influencing or affecting behavior, role, teaching practice, and activity management in classroom of teacher during both training and practicing stages. Moreover, the value of teachers who took part in the training and brought the open-ended teaching approach into practice was different compared with two teachers who used the open-ended approach in classrooms (case study). A group of trained teachers are still concerned about results rather than learning process. Moreover, they paid attention on other tasks more than teaching, lacked of trust in innovation, and focused more on schedule rather than contents required.

Pichao Aong-anurak (2009) studies about roles of teachers who use the open-ended teaching approach to promote mathematical thinking of students finds that teachers who used the open-ended teaching approach had a significant role in the promotion of mathematical thinking of students. The approach could be categorized in the following respects; teacher's creation, observation in students' problem-solving process, giving an opportunity to discuss with peers and teacher, and summarizing it together.

Sampan Thinwiangthong, Maitree Inprasitha and Suladda Loifah (2012) analyze and develope Small-group Mathematical Communication (SMC) as Mathematical Learning Process (MLP) of the seventh grade for the school year 2008-2010 by adapting the Lesson Study and Open Approach. The research findings found that the students had SMC in mathematics classroom adapting Lesson Study and Open Approach. The students learned mathematics more meaningfully by themselves based on sharing mathematical ideas in order to create the shared meaning and leading to shared goal. They participated in SMC regularly. As a result, they developed a "habit of mind" which was led to a sustainable Mathematical Learning Process.

Ariya Suriyon, Maitree Inprasitha and Kiat Sangaroon (2013) indicated that contextual factors in the open approach-based mathematics classroom affect the development of students' metacognitive strategies in which the teacher has planned learning management related to learning unit structures and focused on instructional activities allowing students "to create knowledge from learning how to solve problems by themselves". In addition, the study demonstrates that the teacher and students have different roles in each teaching step.

Wipaporn Suttiamporna, Suladda Loifah, Maitree Inprasitha and Nongkhran Sasomb (2012) compares the subject matter appeared on traditional Thai Textbooks and Japanese textbooks and analyzes how extension and integration sequence on Japanese textbooks evokes students' mathematics creativity. The results shown that extension and integration sequence is an appropriate subject matter to generate lesson for problem-solving classroom. The sequence of lesson leads students to excitement, curiosity, confidence and intimacy in Mathematics that are powerful effects of mathematical creativity. Students can produce the different and various ways to solve problems that indicate their divergent thinking.

From above, the curriculum development is needed in order to serve the national policy and can be brought into effect by the collaboration of staffs in school. In this study, researcher would like to design a mathematics curriculum which conforms to the 21st century's learning and innovation skills. This curriculum focuses on learning and innovation skills or 4C's as described above. Researcher employed the open approach for implementation. This is the urgent need for the country in order to prepare the youths for the upcoming ASEAN community. Then, this mathematics curriculum is based on the collaboration of teachers in school and additionally the lesson study approach is also used as a guideline for developing the curriculum. The proposed conceptual framework of this study can be schematized as follows:

Conceptual Framework