Grade 11 Student’s Mental Model of Fluid and Analytical Thinking in Science Teaching Through Science Technology and Society (STS) Approach

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Abstract. This study reported Grade 11 student’s mental model of fluid and analytical thinking in science teaching through science technology and society (STS) approach. The participants were 38 Grade 11 students in Moeiwadee, Roi-et, Thailand. The teaching and learning about fluid through science technology and society (STS) approach had carried out for 12 hours. The fluid through STS approach was developed based on framework of Yuenyong (2006). Students’ mental model of fluid and analytical thinking were collected during their learning by participant observation, open questionnaire, semi-structured interview, student’ task, analytical thinking test, and journal writing. The findings revealed that students’ mental model of fluid were represented as verbal, equation, drawing. Data were analyzed identify patterns that offer insight into aspects of student understanding and discussed in the scientific concept. The student’s analytical thinking could behave the characteristics for analytical thinking such as thinking for classifying, compare, contrast, reasoning, interpreting, collecting data and decision making. This study will discuss implication of these for science teaching and learning through STS in Thailand.

1. Introduction
In recent world, the knowledge of Science and Technology was an important instrument in preparing young people to be able to live in society with Science and Technology as a foundation. It affected every level of life, both in person, occupation, and socio-culture of every life. Consequently, people could be able to perceive and make decision in social problems occurring from the effect of Science and Technology with knowledge and understanding, participation in society in community level, national level, and global level with full esteem.

For Science instructional management, the students should be focused on knowledge and understanding in boundary, nature, and limitation of Science, components of Science as the content collecting facts, concepts, hypotheses, principles, theories, rules of Science until it could be utilized as well as the technique in searching foe Science Process Knowledge, obtaining understanding and awareness of the importance of Science toward participation in society so that the students would be developed for higher order thinking, problem solving ability, communication and decision making, Scientific attitude. Therefore the teachers had to provide learning facilitated in developing human beings to have characteristics for wide vision, far thinking, love to know, and focusing on process for
the students to develop their analytical thinking, opinion expression, and knowledge search by themselves, as well as participation in thinking and practicing [1]. So, teaching was very important thing in instructional management for developing quality of students.

One approach the Scientist around the world encourage and applied in developing Science instructional in recent time, was Science, Technology, and Society (STS) Approach which was an approach of Science instructional management in context of human’s experience by focusing on situation or problem situation regarding to Science an Technology that truly occurred, and attempt to encourage the students to find answers for that situation. It was the encouragement for students to analyze and apply their approaches and processes in real situation of students’ society [5]. It was supported by Yeunyong (2008) [6] statement that the objective of instructional management based on Science, Technology, and Society (STS) Approach was: the students could be able to have Science concept integrated by themselves with knowledge in Science, Technology, and Society Approach, competency in applying the studied knowledge in daily life, with reasons, analytical thinking, self development, could work with the others well and be good members, responsibility for themselves, community, local, and society.

When the students obtained experience from knowledge management based on Science, Technology, and Society (STS) Approach, they could construct their body of knowledge by themselves from experience they obtained by knowledge management. Each student had different concept model from learning for explaining some things which based on their characteristics including general competency, prior knowledge, motivation and environment, culture, language, and communication [2]. Therefore, if we wanted to know the students body of knowledge constructed from their experience by knowledge management, could be studied from mental model as their representation.

Although there was a policy for instructional reform focusing on developing analytical thinking, it was in limited boundary and didn’t achieve the ultimate goal as wanted. It could be viewed by the findings of assessment 7,273 schools passed the assessment by The Office of Accreditation and Educational Quality Assurance (Mass Organization) 2004, found that the standard of students, Standard 4, only 18.12% of them had analytical thinking ability, synthetic thinking, critical thinking, creative thinking, and vision, as the standard that the students should be improved and developed. It was supported by the second round of assessment of Moeiwadee Pittayakom School in 2007, found that the standard of students, Standard 4, it was in “Fair” level. According to the problems, the researcher was interested in developing the students’ analytical thinking ability since it would help us to know the facts, consider the appropriateness, know fundamental reasons, understand the incidence. Consequently, the facts as basis for applying in making decision for solving problems, assessment, and making decision in various things correctly [3].

So, the researcher was interested in studying the Mental Model and Analytical Thinking in “Fluid” of Grad 5 Students of Moeiwadee Pittayakom School, Roi-et Province, under jurisdiction of Roi-et Educational Service Area 3, by using instruction based on Yuenyong’s (2006) Science, Technology, and Society (STS) Approach. The characteristics of fluid to analyze Mental Model of this study included “Density and pressure of Liquid.”

1.1. The scientific concept of density and pressure of liquid.

Density is a term that refers to a measure of mass per volume. The symbol of density is "\( \rho \)" (rho). It is a Greek symbol. Its SI unit is the kilogram per cubic meter or kg/m\(^3\).

\[
\rho = \frac{m}{v}
\]

Pressure (symbol :\( P \)) is the force per unit area applied in direction perpendicular to the surface of an object.

\[
P = \frac{F}{A}
\]
The pressure exerted by a static fluid depends only upon the depth of the fluid, the density of the fluid, and the acceleration of gravity.

The pressure from the weight of a column of liquid of area A and height h is

\[ P = \rho gh \]

\[ V = hA = \text{volume} \]

\[ \text{weight} = mg \]

**Figure 1.** Pressure of liquid

### 1.2. Science Technology and Society (STS) Approach of Science Learning

The STS Approach of teaching was Science instruction focusing on student centered. Consequently, they viewed that Science and Technology were things around them. They could value in Science on living and be able to apply the studied knowledge for usefulness. As a result, they were more knowledgeable in various issues of Science and Technology affecting on students and whole society. They could use Science process in improving problems, searching for information. They would understand and learn how to adjust their needs with each other. The teaching based on STS Approach didn’t emphasize on students’ knowledge or memorization of concepts while they were searching for information to solve problems and answer questions. They would directly learn various concepts from their work (Myer, 1996 cited in [4]).

Many Scientist Educators constructed and presented instructional management model based on Science, Technology, and Society Approach. It was broadly used in organizing different activities. The STS Approach of instruction based on Yuenyong’s (2006) approach was another using in Thailand (STS Approach) based on Yuenyong’s (2006) approach including 5 stages as follows [8]:

1. **Identification of social issues stage.** This stage is designed to focus student attention and attitudes on learning about energy. The STS instruction has to begin in the realm of society. Instruction will be begun by posing issues related to energy use in society. These questions or problems of social issues need to be solved by citizens. For energy concept, the issued of saving energy and the social problem related generating power should be brought into classroom by various strategies such as informing situation related these issues from posing in newspaper; posing the social questions related these issues for allowing students to participate in public decision-making; seeing social problem by taking field trip.

2. **Identification of potential solutions stage.** Students plan to solve the social problem related to energy use. This stage supports students to concern with the technological aspects for find the possible solutions. Technological aspects are skills to support student decision making. Students need to think of what, why, and how ideas, design, systems, volition of application scientific knowledge work for that social problems. Teaching strategies may be used discussion among students’ group, role-play, brain storming, searching information via internet, and discussion with expert (e.g. engineers or scientists).

3. **Need for knowledge stage.** This stage involves developing scientific knowledge. Social questions and technological knowledge create the need to know some science content. Energy concept was formulated in many strategies to help students to understand the technology and social issues. The strategies, for examples, include reflection reading document provided by teacher, and lecture. To give
feedback students’ understanding about energy concept, the short quiz will be taken after class of this stage.

(4) Decision-making stage. This stage involves student in making a decision on how to use energy knowledge and technology as solution of the social problem. This aspect public rhetoric about energy related technological and societal issues becomes dominated by dichotomies like ‘chances and problem’, ‘advantages and disadvantages’, or uses and abuses’. Student will be given chance to learn to choose between alternatives and in a thoughtful way systematically comparing as many relevant pro’s and con’s as possible. Teaching strategies may be used discussion among students’ group, role-play, and brain storming.

(5) Socialization stage. Students need to act as people who are a part of society by reporting their proposal for solving problem. Student might exhibit their solution in public by produce a poster, a newspaper article or a plan, present science project.

2. Methodology

The research design of this study was Qualitative Research emphasizing on interpretative paradigm for studying the Mental Model and analytical thinking of Grade 11 Students studying Science titled “density and liquid pressure” based on Science, Technology, and Society (STS) Approach.

2.1 The Target Group
31 Grade 11 Students, Moeiwadee Pittayakom School, Moeiwadee District, Roi- et Province, during the first semester, 2009 school year.

2.2 Data Collection
The researcher collected data by using 8 Science Knowledge Management Plans based on Science, Technology, and Society (STS) Approach titled “fluid” with the target group, total duration of 16 hours, during the first semester of 2009 school year. Students’ conceptual model of fluid and analytical thinking were collected during their learning by participant observation, open questionnaire, semi-structured interview, student’ task, analytical thinking question, and journal writing.

2.2.1 Preparation for Students before teaching. The researcher oriented the students by informing the Expected Learning Objectives , learning and teaching activity management based on Science, Technology, and Society (STS) Approach by using Yuenyong’s (2006) STS Approach for their understanding whereas the open questionnaire making in “density and fluid pressure” asking their conceptual model and analytical thinking question before learning .

2.2.2 Learning and Teaching Implementation
The target group was taught by using 3 Science Knowledge Management Plans titled “density and fluid pressure” by the researcher, and instructional model based on Yuenyong’s (2006) Science, Technology, and Society (STS) Approach, duration in implementing the instructional activities for 6 hours.

(1) Identification of social issues stage: The teachers presented the news issue of “Dam Bursts in Indonesia, Killing Dozens in Flood”. Then, the students were asked for setting questions they interested in the news of dam bursts in Indonesia, that be able to get answers by applying knowledge in Density and Pressure in liquid.

(2) Identification of potential solutions stage: The teachers and students collaborated in grouping the questions with nearly the same kind which could be find common answer. Then, they were assigned into groups to brainstorm their thought and guidelines in finding for the answers.

(3) Need for knowledge stage : The students explored, searched for Density, Pressure in Fluid, relationship between Pressure, Depth, and Density of liquid, the force of water on the water gate or dam, the teacher suggested supplemented knowledge in calculating quantity, by assigning each group of students to study the construction of dam outside their class schedule by studying from the officers
who took care of Wangnong reservoir, Moeiwadee District, civil officers in Sub-district Administrative Organization, or scholars in constructing weir in community.

(4) Decision-making stag: The students each group brainstormed the construction technique of dam.

(5) Socialization stage: The students proposed their ideas they designed for constructing dam in their classroom. The teachers and classmates expressed their opinion and provided additional suggestions.

2.2.3 After Learning and Teaching
When the knowledge management process was ended, the researcher analyzed students’ mental model and analytical thinking findings from participant observation, open questionnaire, semi-structured interview, student’ task, analytical thinking question , and journal writing Questionnaire of decision making, Interview Form and Observation Form, Worksheet.

3. The Findings and Discussion
This research was Interpretive Paradigm focusing on explaining Mental Model and analytical thinking in “density and Pressure” of students before and after instructional management based on Science, Technology, and Society Approach. The students had to respond the open ended questionnaire. Then, all students’ answers were read for viewing overall view in concept of fluid titled” Density and Pressure. The data were analyzed by grouping the students’ concepts and analytical thinking. The findings would be presented as follows:

3.1 Mental Model in ‘Density and Pressure.”

3.1.1 Mental Model “Density”. When the students were asked that: “If the cylinder shape iron, with its amass 1,000 kilograms, dropping into the sea, do you think that the iron would be sunk or floated in the sea water?”

If the same lump of iron was built the boat, then it was dropped into the sea again, do you think that it would be sunk or floated in the sea water?  Why does it happen?

The analysis of findings from the students’ responses. According to the students’ answers, the responded that if the hollow round cylinder shape of iron with its amass 1,000 kilograms, dropping into the sea, they thought that it would be sunk in the sea water. Besides, if the same lump of iron is built for the boat and dropped into the sea again, they think that the iron built for the boat would be float in the sea. The model of concepts in “Density” could be grouped into 3 groups including: Science Concept, Physics Concept, and Object Shape Concept as follows:

Mental Model of student, Group 1: Scientific Concept. For the concepts from the students’ answer explaining the sinking of iron or floating of the boat including concept of density as the examples of following answers:

“because of its hollow round cylinder shape was more than density of sea water as well as the density of boat is less than the sea. So, the boat could be floated above the water.” (Suwat)

“because the density of the hollow round cylinder is more than the density of water. But, its area acted on water is les, So, it is sunk in the water. The boat is floated because it had the area acted on surface of water more, and inside of the boat if shallow. So, its density is less than water.” (Tewarit)

“The lump of iron is sunk because its mass and density were more than water. If it is built for the boat, although its weight is much, its shape and form would include the width, length, depth. So, the water couldn’t be inside. As a result, the boat is floated.” (Anon)
According to the answers and reasons of this group of students, found that they had their concepts the same as Science Concept. The researcher thought that this students group understood concepts of this topic very well since they had knowledge by instructional activity management in schools as well as the content they had already studied from Secondary School.

Mental Model of student, Group2: Force Concept. According to the answers of students in this group, there were explanations of answer by explaining The Force in Physics, which was the expression of the understanding in Science Concept relating to sinking and floating of object. The researcher interpreted that the students had Physics Concept by providing their reasons for the Force and Pressure because they had studied in Grad 10 in “Force and Movement”. Then, they might apply the knowledge of Force connecting and explaining the phenomenon that would occur as: if the object and water had gravity force, the object would be sunk. But, if the water and object had impulsion force, the object wouldn’t be sunk. The molecule of water would hold together by molecular force, as the students’ following answers:

“because when the same lump of iron is built as a boat and dropped into the sea, the molecule of water would hold with each other. So, the liquid wouldn’t separate from each other. Therefore, the iron built as a boat wouldn’t be sunk.” (Prisna)

“when the limp of iron which isn’t built, it is only a kind of object. When it is dropped into water, this lump of iron would be sunk. But, it is built as a boat, this lump of iron would be floated because there is pressure on boat. So, the boat is floated.” (Wipawan)

Mental Model of student, Group 3: Shape of Object concept. According to the answers of student in this group, there were explanation of shape of object affecting object to be sunk or float. So, the researcher interpreted that the students had experience by observing the shape of object with good balance, the object had to be flat with square. If the good balanced object was put into the water, the object would have balance the same as when it was put on general ground. The students didn’t have concept of changing of volume of object, when the object changed its shape, its volume would also be changed. Consequently, the lump of iron had the same weight as 1,00 tons. When it was built as a boat, the volume of this object would increase, its density would decrease. As a result, the boat would be floated as the following answers:

“because the boat has its surface area more and is shallow, not hollow as the piece of iron before it is built as a boat. The iron is flat, so it could be floated” (Supapon).

“the boat is floated because for building boat, we couldn’t built as a circle. We have to build it as a square shape. If we build it as a square, the iron would have more balance than when it is a round shape. When the iron is a round shape, it doesn’t have a balance.” (Laddwan)

“because the iron that would be built as a boat, it has to be shaped. Then, the iron would be floated.” (Supachai)

3.1.2 Mental Model in “Pressure of Liquid” When the students were asked that “the diver explored the variety of fish living in 7 meters depth, the first person dived to survey freshwater fish. The second one dived to survey sea fish. Do you think that the pressure of water acted on two divers would be equal? Why? Explain.

The analysis of findings from the students’ responses. According to the students’ answers, the researcher interpreted the model for understanding in “Pressure in Liquid” for 3 groups including: Science Concept, Concept Model of Process based on Depth, and Academic Concept Model as follows:
Mental Model of students, Group 1: Scientific Concept. The researcher interpreted the students’ answers that the had Science Concept in “Force in Fluid”, the pressure in any point in static fluid, would be vary to the depth and density of liquid when the temperature is stable, and in static liquid at any point with the same depth, the pressure would always be equal. If the students could correctly answer the question and explain as: Although both of divers would dive at the same depth, the pressure of water acted on them wouldn’t be equal since beside the depth, the pressure was based on density of liquid as the following answers:

“not be equal, the sea level has more pressure than fresh water. The force acted on the divers is different. The diver surveys freshwater fish would have less pressure than the diver surveying sea fish because the sea water has more density than fresh water.” (Nawarat)

“not be equal because although the divers equally dive 7 meter depth, it doesn’t mean that the pressure acts upon them would be equal which could be compared with the following examples: floated egg, sunk egg, when the egg is dropped into water, it appears that the egg would be sunk. When we add salt into water, the salt would be dissolved, the dropped egg would be floated because of different density levels.” (Prisna)

Mental Model of students, Group 2: Concept of Pressure based on Depth. According to the answers of students in this group, found that they had concept in “Pressure in Liquid only some Part,” The students’ answers were that the pressure of water acted on both divers would be equal since both of them dived into the same depth of water as following answers:

“be equal, both surveyors dive into the same depth. As a result, the pressure on both of them isn’t equal since the sea water has more density than fresh water, and the pressure isn’t based on the density of water. But, it is based on the depth of water.” (Titima)

Mental Model of students, Group 3: Academic Concept. The students in this group could answer that even the two dicers dived into the same depth of water. But, the pressure acted on both of them wasn’t equal. The students in this group explained the differences between some kinds of substances in sea water and fresh water: sea water tasted salty. So, they gave reasons that the concentration of some substances in sea water was more than in fresh water. The researcher interpreted the answers of students in this group that the students had academic concept because their explanation in concentration of substance as the following answers:

“I think that the pressure of water acted on both divers is different. The diver in sea water would have more density than in fresh water since the sea water has more density. Consequently, its density is more. But, if the sea water is very salty, the object of man would be floated without swimming” (Anon)

“not be equal because the sea water has many substances. These substances would have reaction on the diver. But, the fresh water even it has the same pressure, different kinds of substance and mineral are not equal to the sea, As a result, the sea water has more pressure than fresh water.” (Patpan)

“not be equal since the fresh water has pressure, the sea water has more pressure because it includes salt in it. Each kind of water would have different pressures. Besides, the divers dive into 7 meters depth, the pressure would act on the explorers. If the sea water, it has more pressure because the concentration of salt is more than the fresh water.” (Kanyarat)

3.2 The study of students’ analytical thinking
The data collected from situation of questions measuring the students’ analytical thinking before knowledge management based on Science Approach, Technology, and Society Approach, were analyzed and interpreted according to the measurement of analytical thinking of Luaen Saiyod and Ankaan Saiyod (1996) as follows:

**Analytical Thinking, Aspect 1: Significant Analysis.** Question from situations measuring analytical thinking ability in analysis of aspect 1 including: What is the main idea of this topic?

According to the students’ answers, found that they could diagnose by searching for main idea or thesis statement from the read statement only by some students who used their skill in classifying situations into sub-topic which was early understood and explained in details as following answers:

‘the body of Titanium Ship had an accident crashing with the huge iceberg. As a result, the water flowed into it and other cabins. So, the ship was wrecked. There were many people were killed by this incidence.’ (Supaopon)

“the titanium ship was wrecked in the sea because of the careless of the captain causing the tragedy.” (Mongkontip)

“the titanium ship crashed with huge iceberg until its body was broken and the sea water flowing the ship. So, the ship was wrecked and there were many losses.” (Tipawan)

But, most of students couldn’t be able to classify the incidences into parts to be easily understood as well as explain its details as the examples of following answers:

“Luxurious and biggest titanium ship in the world crashed with a huge iceberg” (Rampai)

“for this tragedy caused Pooyai Lee and Mrs Ma to death” (Rachada)

“the size of iceberg under the ocean” (Kanyarat)

**Analytical Thinking in Aspect 2: An Analysis for relation.** Question from situations measuring the analytical thinking in aspects 2, What caused Titanium ship be wrecked?

The analytical thinking to find relationship of different major parts that How did it related together? such as relationship between cause and effect. According to the students’ answers, found that only some students could relate relationship of information in order to analyze cause and effect as the following answers:

“because it was the captain’s careless since he thought that it could pass this huge iceberg. But, it wasn’t the case, there was a very huge iceberg under the ship. So, the body of it crashed with the iceberg. Consequently, the ship was wrecked.”

But, found that most of students couldn’t cause and effect by using skill in associating relationship of different information in situations.

“the crash of Titanium ship with the iceberg.” (Nawarat)

“the body of ship was crashed with the huge iceberg.” (Natapong)

‘because the body of ship was crashed with a hige iceberg under water.” (Kamonrat)
Analytical Thinking in Aspect 3: An Analysis for Principle. Question, this incidence could cause any experiences. Did the students think that the sailors could be able to apply this incidence to prevent the accident on the wreck ship according to crashing with iceberg? How?

The analytical thinking for finding principles was based on ability to summarize or find the main idea from situations, and apply knowledge from the situation in conjecturing, expanding, and applying to the future evidence. The students summarized, integrating experience from the passage, and concluded principle in applying the lessons as the students’ following answers”

“planning in advance would make us safe, without danger. The captain’s careless and no planning until there were losses were received as a motto. The lesson could be applied since it caused the sailors’ lesson for warning them that the should make plan before starting their journey which would be benefit for themselves and other as well.” (Sasiton)

“critical thinking, observing, problem solving, should be applied so that we could have critical thinking with more careful in solving problems.” (Kamonrat)

“We shouldn’t be careless on our lives. But, we should be conscious throughout the time and able to apply lessons from this situation for preventing accident of ship wreck from crash with the iceberg since we should have consciousness and make good decision because every life is valuable. So, we ought to be thoughtful and critical thinkers by considering real principles.” (Jakrish)

“the weather condition and route should be investigated before stating journey. In addition, they should follow the rule or cancel the schedule when they knew that there is an incidence which they couldn’t sail from the radio warning for danger from the station on the shore. The lesson of this incidence should be applied for preventing an accident of ship wreck by crashing an iceberg by designing ship with endurance. The accident should be prevented and warning for their crews.” (Supapon)

“should be careful, conscious, and careful. This lesson should be used because we would be careful and not be careless.” (Napapon)

According to the answers and interpretation from the analysis of Analytical Thinking in 3 aspects including: the analytical thinking for importance, analytical thinking for finding relationship, and analytical thinking for principles, found that each student had different analytical thinking abilities. Most of them still lacked of analytical thinking in classification skill, grouping skill, associating skill, concluding skill, and application skill which might be because each of them had different characteristics regarding to their competency, experience, or knowledge background. They were not trained or practiced before. As a result, they showed different analytical thinking abilities.

4. The Findings and Discussion
According to the study of model of concept and analytical thinking ability in “Fluid” of Grad 11 Students before managing the instruction based on Yuenyong’s (2006) Science, Technology, and Society Approach, found that:

The model of concept of Density of students could be classified into 3 groups. The Scientific Concept, Force Concept, and Shape of Object Concept. Moreover, the concept of Pressure in Fluid could be classified into 3 groups: Scientific Concept, Concept of Pressure based on Depth, and Academic Concept.

The analytical thinking ability could be classified into 3 groups including: the analytical thinking in the importance, analytical thinking for finding relationship, and analytical thinking for finding the
principle, found that each student had different analytical thinking ability. Most of them still lacked of analytical thinking skill including the classification skill, grouping skill, summarizing skill, and application skill.

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