

The Development of Grade 10 Students' Mental Models on Solutions
Through Model-Centered Instruction

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Abstract

This study aimed to construct the mental models of students in the 10th grade in order to attain a higher level of mental models by adopting a model-centered education sequence. This might be accomplished by adopting a model-centered instruction sequence. The research group consisted of 33 students who were all in the tenth grade at one school in the Mahasarakham province of Thailand during the second semester of the academic year 2021. The following instruments were utilized in the course of this research: 1) six different lesson plans, each with its own set of answers, that utilize a model-centered instructional technique, 2) mental model test, 3) students' notebook, and 4) teacher's note. Statistics such as the percentage, the mean, and standard deviation were applied in the process of doing the data analysis. The result revealed that the majority of students have accurate mental representations of scientific models, the adoption of a model-centered education sequence can help students gain more achievement. When it comes to accurately preparing diluted solutions, boiling points of solutions, and freezing points of solutions, the proportions of accurate mental models were 45.5, 51.5, and 48.4 respectively. It has been shown that the percentages of individuals who have entirely incorrect mental models, flawed mental models, incoherent mental models, and those who have no reaction are all on the decline.

Keywords: Mental Models, Solutions, Model-centered Instruction

INTRODUCTION

Chemistry is a subject where most of the content is abstract as it studies the properties of substances and their transformations either at the atomic or molecular level, which are invisible to the naked eye. Therefore, it is difficult to understand and convey the meaning of the chemical phenomena that occur. Chemists often use and create models to describe data, predict events, and contribute to the understanding of chemical changes. Chemists use models to represent ideas or thought structures within the brain or in one's own thoughts that are unique, also known as "mental models" (Greca & Moreira, 2000; Norman, 2014). In interpreting chemical phenomena, chemists often use and build models to describe predictive data and help build an understanding of chemical dynamics (Justi & Gilbert, 2002; Fratiwi et.al., 2020; Ubben & Heusler, 2021). One of the main objectives in chemistry courses is for students to think like scientists (Dukerich, 2015; Onsee & Nuangchalerm, 2019). As well as giving students a thorough understanding of scientific models, students should have mental models that are consistent with scientific models. This can create and use models to predict or explain natural events and phenomena as well as understand the nature of the model. It is the method that scientists use to create and develop scientific knowledge.

Understanding solutions is an important part of introductory chemistry, especially in the laboratory. For example, most chemistry experiments require students to know how to prepare or dilute solutions of known concentration, such as standard solutions (McElroy, 1996; Wang, 2000; Dunnivant et.al., 2002). Dahsah & Coll (2007) also point out that students are often unable to solve problems about the basic concepts involved, such as solvent, solute, solution concentration, solubility, and mole count. There are also other topics, such as the volumes and molecules present in solutions, that are necessary for solving problems, so it is important to understand mental models.

The model-centered instruction sequence (MCIS) was developed by academics at Michigan State University in 2009. The project aims to address problems in traditional teaching and scientific practice. Most students were not involved in scientific activities such as hypothesis-making, observation, and discussion to clearly generate scientific knowledge (Windschitl et.al., 2008; Schwarz et.al., 2009). Learning by using MCIS uses constructivism to develop teaching and learning management (Kim & Kim, 2017; Jantrasee & Kanamuang, 2018; McDonald, 2018). The constructivist theory is the basis for important learning theories and concepts.

The next theory is Modeling Theory, which is the expression of students' thoughts (Gibbons, 2008; Gibbons & Rogers, 2009), when the students themselves are perceived by experiences and phenomena and then create ideas within themselves known as "mental models." Then the model is presented as a symbol representing ideas and understandings based on science called "scientific models" (Hestenes, 2006), and the final theory of learning by using MCIS has evolved from model-based learning or model-based inquiry as a learning process. Modeling the problem-solving process can generate understanding in students by studying phenomena, drawing conclusions, or reasoning with models. If the proposed model is defective or has problems, students will be able to revise (Johnson-Laird, 1983, as cited in Buckley et.al., 2004: 23). MCIS-based teaching and learning has three goals: (1) to allow students to participate in scientific practice; to allow students to discuss or argue about building and reasoning based on a model, (2) to allow students to make hypotheses, practice reasoning and understanding through modeling, and (3) to allow students to create models that are derived from scientific knowledge. And the model can reflect the knowledge and understanding gained from that lesson.

From related research studies, it was found that Baek et.al., (2011) developed an instructional model using MCIS to study scientific modeling in the subject of evaporation and condensation with 28 grade 5 students; it took 6-8 weeks. It was found that 64% of all students had increased scientific modeling capabilities. This is consistent with the research of Najang (2011), which has studied the effect of MCIS-based teaching and learning management on the ability to create scientific models and concepts on the law of motion and the model of motion. It was discovered that students in the experimental group had significantly higher average scores on the concept of the laws of motion than those in the control group. Bootvisate et.al. (2015) developed a chemistry learning management system according to the MCIS learning management approach on chemical bonding. Chemical bonding before study averaged 45.76%; after study, it averaged 82.95%, with students who passed the 70% consensus criteria after school representing 95.45%. This can be confirmed by Kanamuang & Chantrasee (2018), who studied the scientific modeling process of evaporation using model-based learning management, the study group consisted of 16 secondary school students. The results showed that the students had a moderate level of understanding of the

scientific modeling process in terms of model building and evaluation. The improvement of the model is at a very good level and the aspect of using the model is at a good level.

Therefore, the researcher is interested in developing mental models of solutions by using the MCIS learning management system with Grade 10 students, it can help students create mental models. This will promote a better understanding of the content of the solutions for students. Improving and implementing a model is an important part of the modeling process. Therefore, model-based learning management is appropriate to be used in the management of science learning.

METHOD

Participants

The participants were Grade 10 students, studied in semester 2 of the academic year 2021 at one school in Maharakham Province, Thailand. In the COVID-19 epidemic situation, purposive sampling was used to select 33 students for this study based on classroom limitation.

Research Instrument

The research instrument for this study included a model-centered instruction sequence learning lesson plan on the solutions, a mental model test, a student journal, and a teacher's note. In this study, expert judgments

accept reliable research instruments. Most of the validity and reliability information was provided as qualitative comments.

Lesson plan: Six lesson plans for MCIS received 12 hours in 3 weeks of chemistry instruction. In the first teaching sessions, which lasted four hours, first and second lesson plans were implemented. The second teaching sessions, third and fourth lesson plans were used in four hours. The third teaching sessions, lesson plans fifth and sixth. Each lesson plan was reviewed and corrected by three experts to ensure its appropriateness. Then improve lesson plans with expert guidance to be more complete.

Mental model test: Two items, solutions open-ended tests are used at the end of each teaching sessions. In 1 item, there are 2 parts: Part 1 is a drawing and part 2 is a writing explaining the picture that the student drew. By measuring the composition of grouped responses, a mental model of students (Kuathan, 2011). The constructed test was checked and developed using the index of objective congruence by three experts.

Student journal: It is semi-structured in that students write about the process of obtaining the mental model and their feelings at the end of the activities assigned by the teacher as a work piece. This will allow students to

take notes after every teaching session so that the researcher will be able to use the information obtained to assess and develop learning management in the next teaching sessions.

Teacher's note: It is the researcher's diary, in which the events that occurred during the learning management are recorded in detail as they occurred in class. For collecting data and studying student behavior, including problems and obstacles and a summary of learning activities. The researcher recorded the video to record the behavior. Conversation between researchers and students during learning activities.

Data collection

Due to the spread of the COVID-19 pandemic, one school from Maharakham province, Thailand has adjusted teaching and learning activities by dividing students into junior and senior high school students and switching between on-site and online classes. Therefore, this research is conducted to collect data in the first and the third teaching sessions, which are online classes, and the second teaching session, which are on-site classes. The researcher divided the data collection into three phases as follows in Figure 1.

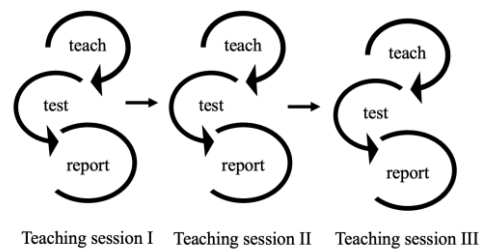


Figure 1. Steps of this research

Teaching session I: The researcher collects data on the mental model problems of grade 10 students by using the developed mental model test to grade the preliminary group of students. Then the researcher proceeded to teach according to the learning management plan using MCIS about% and parts per million, molarity, molality, and mole fractions, amounting to 2 lesson plans for 4 hours. During learning, the researcher observed student behavior using a teacher's note. At the end of the first teaching session, the researcher collects qualitative data: activity sheets and student journals. After that, the researcher collected data by using the mental model test for teaching session I as a subjective examination of 2 items. The researcher used the data obtained from collecting to summarize and report the results. Then bring it back to improve, modify, and develop it for use in the next teaching lesson.

Teaching session II: The researcher improved the activities from the first teaching session to be more

detailed. After that, teach according to the learning management plan using MCIS about preparation of solutions from pure substances and preparation of dilute solutions from concentrated solutions with 2 lesson plans for 4 hours. Then the researcher proceeded similarly to teaching session I, data collected by using the mental model test for teaching session II as a subjective examination of 2 items and used the data obtained from collecting to summarize and report the results.

Teaching session III: The researcher improved the activities from the first teaching session to be more detailed. After that, teach according to the learning management plan using MCIS about properties about the boiling point of solutions and properties about the freezing point of solutions with the

last 2 lesson plans for 4 hours. Then the researcher proceeded similarly to teaching session I and II, collected data by using the mental model test for teaching session III as a subjective examination of 2 items and used the data obtained from collecting to summarize and report the results. The researcher used the evaluation results of all 3 teaching sessions to analyze the results of learning activities to determine whether they were in accordance with the set objectives or not.

Data analysis

The researchers analyzed the data in this study based on the research objectives. Data analyzed by comparing student's answers to the modified criteria from the concept of Kuathan (2011), as shown in Table 1.

Table 1. Mental model grouping criteria from the concept of Kuathan (2011)

Level	Component
Correct Mental Models (CMM)	The pictures of the model drawn by the students are correct, and the students can explain the reasons correctly in accordance with the scientific model.
Incomplete Correct Mental Models (ICMM)	The pictures of the model drawn by the students are correct, and the students can explain the reasons correctly in line with the scientific model for at least 1 element.
Complete Flawed Mental Models (CFMM)	The picture of the model drawn by the students is correct, but the reason used to explain it is not consistent with the scientific model; or the students' model picture is incorrect, but the right reasons for explaining are consistent with the scientific model.
Flawed Mental Models (FMM)	The pictures of the model drawn by the students are incorrect, and the reasoning is not consistent with the scientific model.
Incoherent Mental Models (IMM)	The pictures the students draw is incorrect, and the reasoning is inconsistent with the text or writing. Reasons are described but not explained.
Not Respond (NR)	Students do not answer questions or do not show pictures.

RESULTS AND DISCUSSION

It was found that before teaching using MCIS learning management, all 33 students showed that most students, 33.84%, had a CFMM level, especially the concept of the preparation of solutions from pure substances, Properties about the boiling point of solutions, and Properties about the freezing point of solutions, respectively. Secondly, 26.77% of students had a

FMM level in the concepts of concentration of solution in percent and ppm and molarity, molarity, and mole fraction, respectively as shown in Table 2.

As a result, the researcher improved grade 10 students in the FMM, IMM, and NR levels by 26.77%, 6.06%, and 8.17%, respectively, to have a higher level of mental model.

Table 2. Number and percentage of students with a cognitive model after learning by using MCIS

Solutions concept	Number of students (%) (N=33)					
	CMM	ICMM	CFMM	FMM	IMM	NR
Average percentage of students before learning by using MCIS	7.58	14.14	33.84	26.77	11.61	6.06
Percent and parts per million	8 (24.24)	10 (30.30)	11 (33.33)	4 (12.12)	0 (0.00)	0 (0.00)
Molarity, molality, and mole fractions	6 (18.18)	13 (39.39)	4 (12.12)	8 (24.24)	2 (6.06)	0 (0.00)
Average percentage after the 1 st teaching session	21.21	34.84	22.73	18.18	3.03	0.00
Preparation of solutions from pure substances	11 (33.33)	15 (45.45)	4 (12.12)	2 (6.06)	1 (3.03)	0 (0.00)
Preparation of dilute solutions from concentrated solutions	15 (45.45)	10 (30.30)	4 (12.12)	3 (9.09)	1 (3.03)	0 (0.00)
Average percentage after the 2 nd teaching session	39.39	37.88	12.12	7.58	3.03	0.00
Properties about the boiling point of solutions	17 (51.51)	4 (12.12)	6 (18.18)	3 (9.09)	3 (9.09)	0 (0.00)
Properties about the freezing point of solutions	16 (48.48)	8 (24.24)	6 (18.18)	3 (9.09)	0 (0.00)	0 (0.00)
Average percentage after the 3 rd teaching session	50.00	18.18	18.18	9.09	4.55	0.00

The development of a mental model for Grade 10 students by using MCIS learning management in the first teaching session revealed that 34.84% of students had ICMM level. Secondly, 22.73% of students had CFMM level, and 21.21% of students had CMM level. 18.18% of students had FMM level, 3.03% of students had IMM level, and students with NR level were not found.

In the second teaching session, 39.39% of students had CMM level, followed by 37.88% of students with

ICMM level. 12.12% of students had CFMM level. 7.58% of students had IMM level. 3.03% of students had FMM level, and students with NR level were not found.

During the third teaching session, 50.00% of students had CMM level, 18.18% had ICMM level and CFMM level, and 9.09% had FMM level. 4.55% of students had IMM level, and students with NR level were not found (Table 3).

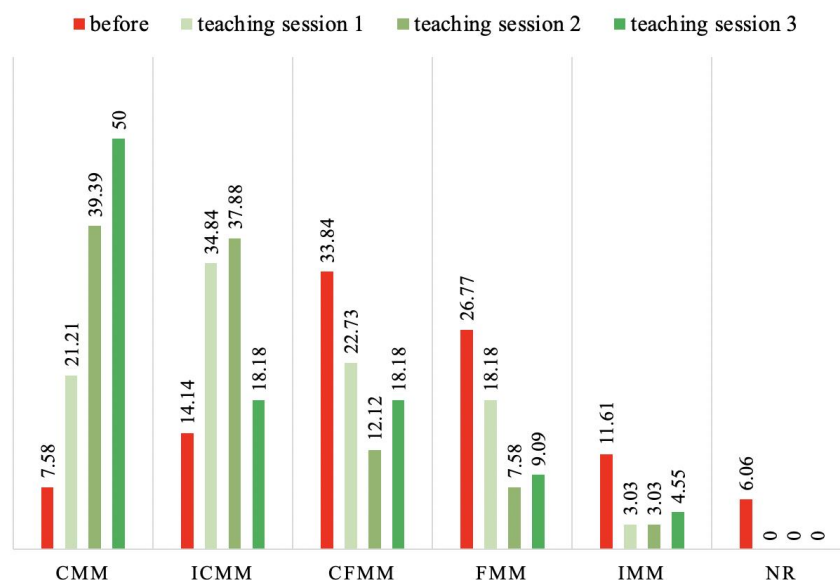


Figure 2. The results of group analysis of students' mental models for 3 teaching sessions

Most of the students, 34.84%, had ICMM level. When considering the second teaching session, most students, 39.39%, had CMM level. In the third teaching session, 50.00% of the students had CMM, which increased from the first and second teaching sessions. When considering sub-concepts, it was found that most of the students had CMM level

consistent with scientific models when learning by using the MCIS, particularly on the sub-concept of preparing diluted solutions from concentrated solutions (45.45%), properties about the boiling point of solutions (51.51%), and properties about the freezing point of solutions (48.48%). CFMM, FMM, IMM, and NR levels were reduced. The

idea of the solution after the three sessions showed that teaching by using MCIS helped the students have a mental model of the solution that was more consistent with the scientific model.

The first teaching session is an online classroom lesson through the Microsoft Team platform. Most students, 34.84%, had ICMM level, followed by 22.73% of students with CFMM level. The 21.21% of students had CMM level, 18.18% of students had FMM level, 3.03% of students had IMM level, and students with NR level were not found. Which can develop higher-level students' mental models compared to their pre-learning results. This is because of the learning activities using the MCIS learning management system, a learning activity that allows students to practice modeling by using, improving, and evaluating their own models. This includes learning from discussions and exchanging models based on classmates' opinions. This is supported by Bootvisate et.al. (2015), an organizing learning activity using MCIS learning management allowed students to discuss and exchange ideas. Learning to accept other people's opinions and getting to do more activities together will result in students understanding and remembering the content well.

This may be due to the organization of learning activities. It is a

teaching that focuses on the practice of creating, using, evaluating, and improving scientific models using MCIS learning management. related to hypothesis, observation, discussion, creating scientific knowledge, and the use of scientific discourse. It relies on speaking or writing related to thinking systems and reasoning in scientific explanations (Baek et.al., 2011; Kim et.al., 2016; Majid & Prahani, 2017). The concept of something being self-created is complete. This will affect the level of grouping of mental models (Barlow et.al., 2017). The researcher solved the problem by using questions to encourage students in groups to discuss the given information. This will lead to constant improvement and verification of the completeness of the data used to describe the student model. This allows students to create meaning on their own, or knowledge is created in the student's mind because of the process of creation and being constantly tested (Bodner et al., 2001, as cited in Hrepic, 2004).

The second teaching session is on-site classroom instruction for improving and developing learning activities using the MCIS learning management system from the first teaching session. It was found that most students, 39.39%, had CMM level, followed by 37.88% of students with ICMM level, and 12.12% of students with CFMM level. 7.58% of

students had FMM level. 3.03% of students had an IMM level, which did not show NR level, which could indicate a higher mental model in students compared to the results after the first teaching session. The students have a discussion and an exchange of ideas, jointly reviewing and improving their own mental models. The researcher uses questions to encourage groups of students to help each other examine data or models, including using models to explain why students' answers should be completer and more accurate.

However, there were students with FMM and IMM level of, on average, 10.61%. The students did not have a mental model and did not explain the solution preparation process. It only has to calculate the amount of pure substance used in the preparation and the concentration of the dilute solution to be prepared, but it is not correct because the students still do not understand the origin of the equation or formula, only remembering it but not knowing how to use it (Batlolona & Souisa, 2020). This is consistent with the research of Niaz (1995), who said that most students will try to use formulas to solve problems, but when using the formula, it still can't solve the problem. Students do not understand the concept or do not have one in that area, which is consistent with the research of Stavy (1990), found that

some students are confused about the concepts of solute and solvent in the concept of solution states in the solid and liquid states. The confusing concept affects the students' problem solving. As a result, the students were still at the FMM and IMM levels. The researcher therefore took up the problem in the second teaching session to improve and develop in the third teaching session.

The third teaching session is an online classroom lesson. When improving and developing learning activities using MCIS learning management from the second teaching session, it was found that most students, 50.00%, had CMM level, followed by 18.18% of students with ICMM level. 18.18% of students had CFMM level. 9.09% of students had FMM level, 4.55% of students had IMM level, and NR level was not found. which was able to develop a higher level of students' mental models compared to the results after the second teaching session. Which was able to develop a higher level of students' mental models compared to the results after the second teaching. self-assessment, peer-assessment in small groups, and more class discussions. The researcher asked all students to ask each other questions, using their grades as motivation for questioning or discussion in groups and in class, so that students who still incomplete models had could finish

them. However, when considering the level of the mental model in the third teaching session and the previous teachings, it was found that the mental model level of students in the third teaching session was at ICMM level and CFMM level with 18.18 each, which is the same, which in theory should not have the same average number of students. The number of students with ICMM level should be on average higher than those with CFMM level, but this was not the case in this study. This may be due to the fact that in the third teaching session, this is the content that was learned about the properties of solutions, which is not continuous from the first and second teaching sessions. As a result, many students took only broad properties to answer questions, and many wrote only the properties of solutes. It is not possible to determine why the boiling point of a solution increases or why the freezing point of a solution decreases.

Therefore, both levels of the mental model had the same average percentage of students. It is shown that a person builds a model or conceptual model based on prior knowledge, through which individuals can assimilate or accept new information (Wang, 2007). The generated mental model will be used and tested in new situations (Gentner & Stevens, 2014). The person will continue to consider the mental model for a period.

As a result of the last two teaching sessions, students' mental models improved because they were constantly creating and applying new situations, and the use of teaching materials was important in learning (Baumfalk et.al., 2019; Chanserm et.al., 2019). Giving students a more complete model of thinking is even more important. According to Sangpradit (2015) research, using technology-based media such as models, images, videos, or animations that show students pictures and clearly explain to be concrete will help students develop a more complete mental model.

From the research results, learning by using MCIS led to the development of a mental model in grade 10 students because it was a learning management system that students were part of or participated in scientific practice. Participate in modeling practice and let students reflect on their knowledge as they practice. Students learn how to acquire scientific knowledge through scientific activities involving hypotheses, observation, and discussion (Baek et.al., 2011; Savard, 2014; Samon & Levy, 2020), and students actively participate in hands-on learning with self-control. Building self-knowledge and social interaction with classmates will enable students to build better mental models. The study focuses on the application of a learning management system known as

MCIS and its influence on the formation of mental models in grade 10 students. According to the information presented in the passage, students have the opportunity to gain scientific knowledge, reflect on their prior knowledge, and actively participate in hands-on learning when they take part in scientific practice and modeling activities. When it comes to the process of developing efficient mental models, it also places an emphasis on the significance of having self-control, having knowledge of oneself, and engaging in social contact with peers.

The significance of the role of MCIS in encouraging the growth of a mental model is one of the most important takeaways from this chapter. It would appear that the utilization of a learning management system that incorporates modeling exercise has a beneficial effect on the capacity of students to develop mental models. Students are given a framework for learning and developing scientific knowledge when they actively participate in scientific activities that entail making hypotheses, conducting observations, and engaging in debate about those observations (Suja et.al., 2017; Sinchai & Wutchana, 2018; Wardah & Wiyarsi, 2020). This method goes beyond merely reading about scientific principles in textbooks by getting students involved in applying

those concepts in real-world settings. The significance of introspection is brought up as yet another issue that cannot be overlooked in this reading. When students participate in scientific practice, they are afforded the chance to reflect on the information and comprehension they have gained along the process (Squire, 2019). They are able to detect gaps in their comprehension, clarify by misunderstandings, and expand on their knowledge as a result of this reflective process.

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