The Effects of a Technology-Enhanced Inquiry Instructional Model on Students' Understanding of Science in Thailand

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***Abstract*—The study examined the effects of a technology-enhanced inquiry instructional model on students' understanding of science in Thailand. Two sixth-grade classrooms at a medium-sized public school in Bangkok, Thailand were randomly selected for the study - one as the control group and the other as the experimental group. The 34 students in the control group only received the inquiry instructional model, while the 35 students in the experimental group received the technology-enhanced inquiry instructional model. Both groups of students had been taught by the same science teacher for 15 weeks (three periods per week). The results and findings from the study seemed to indicate that both the technology-enhanced inquiry instructional model and the inquiry instructional model significantly improve students' understanding of science. However, it might be claimed that students receiving the technology-enhanced inquiry instructional model gain more than students only receiving the inquiry instructional model. In addition, the technology-enhanced inquiry instructional model seemed to support the assessment during the 5E Model's evaluation stage. Most students appeared to have very good attitudes toward using it in the science classroom suggesting that the technology-enhanced inquiry instructional model motivates students to learn science.**

***Index Terms*—5E model, HubNet discussion tool, inquiry-based science teaching, peer instruction's cycle.**

I. Introduction

The purpose of the study is to examine the effects of a technology-enhanced inquiry instructional model on students' understanding of science in Thailand. Inquiry instructional models are grounded in sound educational theory and have a growing base of research to support their effectiveness and significant impact on science education [1]. Nevertheless, there is a continued need to conduct research on the effectiveness of this model, including how the model with technology enhancement is implemented in the science classroom. In the study, a technology called the classroom communication system was integrated into the inquiry instructional model in the science classroom. The group of students that received this technology-enhanced inquiry instructional model was compared with the other group of students that only received the inquiry instructional model.

In Thailand, the National Education Act 1999 [2] provided a guideline for education by stating that:

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'Education shall be based on the principle that all learners are capable of learning and self-development, and are regarded as being most important. The teaching-learning process shall aim at enabling the learners to develop themselves at their own pace and to the best of their potentiality.'

This guideline, which focuses on student-centred learning and instruction, conforms to the concept of the inquiry instructional model. Also, reform in science education has focused on the demand for integrating technology into teaching and learning. Unfortunately, the actual use of technology in classrooms remains limited although many schools regularly invest in new technology [3], [4]. Technology has only been an isolated subject in the traditional curriculum. Many teachers in other subject areas are not integrating it into their instruction. Thus, technology must have a new role and become an integral part in the curriculum [3], [5].

The Centre for Research and Information Technology and Organizations conducted a large-scale study of more than 4,000 teachers (grade 4-12). The study included a survey related to technology integration into subject areas. The result of the study indicated that only 17 percent of science teachers reported 'frequent computer use' in their respective classrooms [6]. Teachers appear to lack the skills and/or be reluctant to integrate technology into their instruction. There is an urgent call for teachers who are capable of integrating technology into science instruction.

In the study, two main research questions are:

1. Does the technology-enhanced inquiry instructional model improve students' understanding of science in Thailand?
2. What are students' attitudes toward using the technology-enhanced inquiry instructional model in the science classroom?

II. Review of the Literature

An innovative technology, which is maturing and further increasing the likelihood of pervasive adoption, is a classroom communication system. It is becoming commonly available from many vendors such as 'Personal Response System; PRS' from Educue LLC, 'Classroom Performance System; CPS' from eInstruction, 'TI-Navigator' from Texas Instruments, and 'Interactive Presenter' from Dolphin Interactive [7], [8]. This technology can make students' thinking visible and help teachers provide meaningful learning experiences; scaffolding; and tailored instruction to

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meet specific needs of students [9].

Roschelle et al. [8] defined a classroom communication system as a combination of networking hardware (computers or hand-held devices) and software to provide displays that show what students are doing, thinking and understanding, and to expand an interaction loop between teacher and students in the classroom. It has been developed to enhance questioning and feedback, to stimulate and oversee the participation of all students, to support discussions of important concepts, and to empower students' thinking. It overcomes one of the greatest obstacles to improving classroom assessment: the collection, management, and analysis of data. It helps the teacher to provide frequent formative assessment to all students. Educators across grade levels and subject matters have frequently found that classroom communication systems enable them to focus on students' prior knowledge, address conceptual understanding, motivate students, and promote group discussion.

Another example of a classroom communication system is the HubNet discussion tool (see Figure 1). It is free software developed by Uri Wilensky and Walter Stroup [10] with funding from the National Science Foundation (NSF). This software is used with networked computers in the classroom to enhance students' learning. It allows teachers to prepare questions in advance or introduce new questions during class. The teachers can collect students' text or numerical responses, and display the whole-class responses in various formats including lists, text, histograms of numerical or letter responses. The teachers can also save the results as web pages and send back to students. In addition, the software offers an anonymous option for students to answer questions.

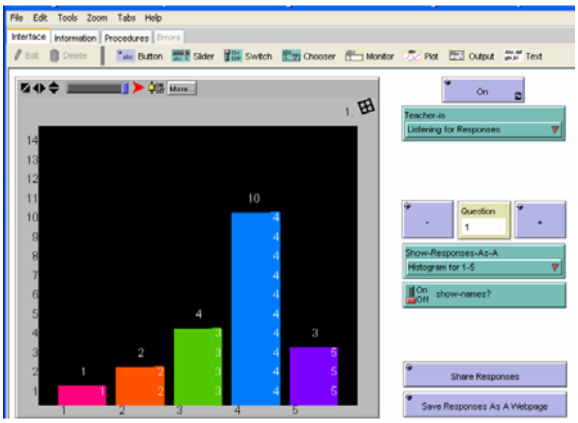

Figure 1. HubNet discussion tool [10]

Classroom communication systems can make a difference. However, all reports to date strongly suggest that teacher implementation, not the technology, is the primary cause of students' improved performance [8]. A model called CATAALYST or 'Classroom Aggregation Technology for Activating and Assessing Learning and Your Students' Thinking' was proposed by Roschelle and his colleagues [8]. Their model addresses an integration of technology with instructional strategy. Three key features of the model are allowing the teacher to more efficiently and effectively (1) introduce an investigative question at the essence of the subject matter, (2) collect student responses immediately and anonymously, and (3) rapidly compile a public, aggregate display (e.g. a histogram) that makes prominent the diversity in the group's ideas without revealing individual contributions.

Most existing studies on classroom communication system seem to focus on teachers' and students' appreciation and attitudes toward using the classroom communication system. Only a few studies concentrate on the impacts on students' understanding such as increased test scores or improved performance. In addition, it appears that none of the studies has appropriately controlled comparisons in which the only difference is the use, or lack of use, of the classroom communication system [11]. These studies suggest the need to further investigate the effects of the classroom communication system on students' understanding with the appropriately controlled comparison [11]. The major goal of the present study is to provide such an investigation to the small body of knowledge already in existence.

III. Research Design and Method

This section describes the study site for the research. It also reveals materials, methods and procedures that were used to collect data to examine the effects of a technology-enhanced inquiry instructional model on students' understanding of science in Thailand. A mixed quantitative research design [12] was selected for the research design. A pretest-posttest control-group design was implemented for the experimental research. A causal-comparative design using questionnaire and classroom observation was employed for the non-experimental research.

A. *Study Site*

The study was conducted at a medium-sized public school in Bangkok, Thailand. The school was established in 1963 with the area of 2.7 acres and serves the students from pre-kindergarten to sixth grade including two classes of special education. Currently, there are 684 students (405 males and 279 females) and 42 teachers. Most students in the school come from lower middle-class and poor families in the urban area and slum of Bangkok. The majority of the parents are blue-collar employees and more than a half of them are single parents. The school was chosen because it could provide the researcher with sufficient resources and adequate facilities to conduct and complete the study. Moreover, the school principal showed a strong support and encouraged teachers in the school to learn new things from the study to improve their teaching and students' learning.

The school includes of four sixth-grade classrooms; three are normal classrooms and one is gifted and talented classroom. Two normal classrooms were randomly selected for the study - one as the control group and the other as the experimental group. The 34 students in the control group were provided only the inquiry instructional model, while the 35 students in the experimental group were provided the technology-enhanced inquiry instructional model. Both groups of students were taught by the same science teacher for the same amount of time. He has more than 30 years of teaching experience and holds a bachelor's degree in education with a science major. He serves as the head of

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science department in the school.

B. Materials

Three main assessment instruments (the subject matter pretest and posttest, the observation rubric, and the attitude questionnaire) were employed to answer the research questions in the study. Also, some hardware and software were utilized. They are described in greater detail in the sub-sections that follow.

1. Subject matter pretest and posttest

The science teacher adopted 30 test items from the school's test bank that conform to the Thai national science content standards for both the pretest and posttest. These items were designed to measure students' understanding of science and were used to compare subject-matter knowledge of students in the control group only receiving the inquiry instructional model with those in the experimental group receiving the technology-enhanced inquiry instructional model. However, the pretest items and the posttest items were not the same in order to keep confidentiality of the posttest that was also a school exam at the end of the semester. But with a careful selection, both the pretest and posttest appeared to have the same level of difficulty. The posttest/school exam scores were also counted in students' grade point averages (GPAs) to make students pay more attention to the test. Additionally, the pretest scores were used as the concomitant variable in the one-way analysis of covariance (ANCOVA) to remove any effects influencing the posttest scores.

2. Observation rubric

The lesson observation rubric adapted from 'Lesson observation rubric' by School of Education Dean's Office, The College of New Jersey [13] was employed to observe the science teacher and students in both groups.

3. Questionnaire

A questionnaire designed to determine students' attitudes toward using the technology-enhanced inquiry instructional model in the science classroom was applied in the study.

4. Hardware and software

In the study, HubNet discussion tool software [10] was installed into 36 networked computers including the teacher's computer. In addition, a projector and a screen were used to display the teacher's questions and the students' responses.

C. Methods

Students in the experimental group had received guidance in how to use HubNet discussion tool [10] with networked computers in the computer laboratory before the study began. The students in the control group did not receive any information about HubNet discussion tool [10]. However, students in both groups were taught the same five units of science by the same science teacher for 15 weeks (three periods per week). These five units of science were plants, animals, life and environment, systems of the human body, and substances. The teacher implemented an inquiry instructional model called the 5E Model [1] as a major instructional strategy. It consists of five stages: engagement, exploration, explanation, elaboration, and evaluation. However, the main emphasis was on the evaluation stage where Peer Instruction's Cycle [14] was incorporated. During this stage, the teacher posed questions on the projector screen and provided time for students to think, then students provided their answers to the teacher and received feedback. Next, students tried to reach agreement with their neighbours and provided their revised answers again for feedback. Finally, the teacher summarized and explained the correct answers. Students in the experimental group sent their answers to the teacher via the classroom communication system. In contrast, students in the control group gave their answers verbally and by showing the number on their fingers.

Three main types of data gathering procedures were also employed in the study – the pretest/posttest procedure, the observation procedure, and the survey procedure.

1. Test procedure

The one-way analysis of variance (ANOVA) and the one-way analysis of covariance (ANCOVA) at alpha level 0.05 were applied to analyze the data from the pretest and the posttest. At the beginning of the study, students in both the control group and experimental group took the pretest. These students took another test at the end of the semester as the posttest.

2. Observation procedure

During the study, the lesson observation rubric was employed in both the control group and experimental group to observe students' learning and the consistency of teaching.

3. Survey procedure

At the end of the study, a questionnaire survey was introduced to students in the experimental group to gather information regarding their attitudes toward using the technology-enhanced inquiry instructional model in the science classroom.

IV. Results and Findings

To answer the first question whether or not the technology-enhanced inquiry instructional model improves students' understanding of science in Thailand, the posttest scores of students in the control group and those in the experimental group were compared and analyzed using both the one-way analysis of variance (ANOVA) and the one-way analysis of covariance (ANCOVA) at alpha level 0.05 (the pretest scores of students in both groups were also applied as the concomitant variable in the one-way ANCOVA). Furthermore, the pretest scores of students in the control group and those in the experimental group were compared and analyzed using the one-way ANOVA at alpha level 0.05 to check the validity of the random sampling process and confirm that students in both groups came from the same population.

The results from both the one-way ANOVA and the one-way ANCOVA showed that there is no significant difference at alpha level 0.05 between the mean of posttest scores of the control group and that of the experimental group. In addition, the one-way ANOVA result revealed that there is no significant difference at alpha level 0.05 between the mean of pretest scores in the control group and that in the experimental group. Nevertheless, the results from the one-way ANOVA suggested that there is a significant difference at alpha level 0.05 between the mean of pretest scores and the mean of posttest scores in both the control group and experimental group. The pretest and posttest means of both groups and their gains are displayed in Table 1.

Table 1. Pretest/posttest means and gains

	Pretest means (Total of 30)	Posttest means (Total of 30)	Gains (%)	P Value
Control group	12.74	17.59	4.85 (38.07 %)	< 0.05
Experimental group	11.97	17.53	5.56 (46.45 %)	< 0.05

To gather additional data about the first question about whether or not the technology-enhanced inquiry instructional model improves students' understanding of science in Thailand, the lesson observation rubric was also applied in both the control group and experimental group to observe students' learning and the consistency of teaching.

The findings from the lesson observation rubric indicated that the lessons for both the control group and experimental group showed content competence and had clear objectives with appropriate choice from the teacher. Each lesson also applied for all students in both groups and had a beginning related to lesson objectives that is valid in capturing students' attention. Moreover, transitions were smooth and logical. The teacher used transitions within the lesson as learning opportunities. He was also good in maximizing instructional time and encouraging student autonomy in the distribution and use of materials. He successfully used questioning techniques to gauge and deepen students' understanding. During the observations, it was obvious what he was assessing and how it was measured to let him know whether all students had learned. In addition, he listened carefully to students' ideas and contributions. Student to student listening was facilitated by him as well. He reacted to students' ideas with flexibility, respect, and humour. He also acknowledged individual differences in student behaviours with respect. He closed the lesson by encouraging student reflection about what was learned, and then provided connection to the upcoming lesson. Furthermore, he was competent in maintaining positive and appropriate classroom control. Students in both groups were interested and curious in his lessons.

However, based on observations, the teacher was able to utilize materials and technology to support the assessment during the evaluation stage of the BSCS's 5E Model in the experimental group more potentially when he implemented the technology-enhanced inquiry instructional model. HubNet discussion tool [10], the software used in the technology-enhanced inquiry instructional model, was able to overcome one of the greatest obstacles to improving classroom assessment: the collection, management, and analysis of data. It also offered anonymity for students to answer questions without the worry of peer influence and humiliation. As a result, the assessment for the experimental group appeared to be more student-friendly than that for the control group.

To answer the second question about students' attitudes toward using the technology-enhanced inquiry instructional model in the science classroom, a questionnaire survey was administered at the end of the study to 35 students (24 male students and 11 female students) in the experimental group to gather information regarding their attitudes toward using the technology-enhanced inquiry instructional model in the science classroom. There are five levels of agreement in the Likert scale questionnaire: 5 is strongly agree; 4 is agree; 3 is neutral; 2 is disagree; and 1 is strongly disagree. The findings from the survey are exhibited in Table 2.

Additionally, some students provided comments on the strengths and weaknesses of HubNet discussion tool [10], the software implemented in the technology-enhanced inquiry instructional model. For the strengths of the tool, some students explained that it is a fashionable technology that is fun and easy to use. In addition, it has an anonymous option for them to answer questions more comfortably and motivates them to learn. Some students felt that they could learn more subjects via this tool. For the weaknesses of the tool, some students expressed that they could be distracted by other things on the computer such as games and websites since the tool must be operated on the network computers which can also access to the Internet. Therefore, it is possible for them to play games or surf some of their favourite websites on the Internet while they are using this tool. Furthermore, some students criticized the tool's malfunctions that happened sometimes while they were logging on or sending their answers simultaneously.

Table 2. Mean scores for all students and by gender of students' attitudes toward using the technology-enhanced inquiry instructional model in the science classroom

Items	Means (Total of 5)		
	Male	Female	All
Simple and easy to use (in terms of technology)	4.54	5.00	4.69
Increasing subject interest	4.21	4.36	4.26
Supporting class participation	4.58	4.73	4.63
Enhancing subject understanding	4.33	4.09	4.26
Improving environment for teaching and learning	4.29	4.64	4.40
Increasing teacher insight into student difficulties	4.29	4.55	4.37
Supporting collaborative learning	4.42	4.27	4.37
Suitable for this class	4.54	4.55	4.54
Necessary for this class every time	4.50	4.27	4.43
Prefer this model of teaching and learning	4.67	4.91	4.74

V. Discussion and Implications

The results from the one-way ANOVA suggested that there is a significant difference at alpha level 0.05 between the mean of pretest scores and the mean of posttest scores in both the control group and experimental group. These results would seem to indicate that both students only receiving the inquiry instructional model and students receiving the technology-enhanced inquiry instructional model significantly improve their understanding of science. The average gain of students' scores in the experimental group was 5.56 or 46.45 %, while the average gain of students' scores in the control group was 4.85 or 38.07 %. The gain difference between the experimental group and the control group was more than 8 %. Thus, it might be claimed that students receiving the technology-enhanced inquiry instructional model gain more than students only receiving the inquiry instructional model.

Analysis of the data from the one-way ANOVA suggested that there is no significant difference between the mean of pretest scores in the control group and that in the experimental group at alpha level 0.05. This implies that students in both groups came from the same population and therefore supports the assertion of validity of the random sampling process.

The results from both the one-way analysis of variance (ANOVA) and the one-way analysis of covariance (ANCOVA) showed that there is no significant difference at alpha level 0.05 between the mean of posttest scores in the control group and that in the experimental group. In other words, the posttest scores of students only receiving the inquiry instructional model and the posttest scores of students receiving the technology-enhanced inquiry instructional model are not statistically different. These results seemed to indicate that technology enhancement does not have any impacts on students' test scores when compared to students receiving the inquiry instructional model alone. This supports the study of Mazur [14] who stated that the success of his instruction is independent of the technology, but seems to refute the result of Bullock et al. [15] and Nicol [16] who found that the implementation of the technology can improve student performance on exams. However, they compared the student performance between the traditional instruction and the technology-enhanced modified instruction. More research needs to be done with appropriately controlled comparisons in which the only difference is the use, or lack of use, of the technology [11].

The finding from the lesson observation rubric data was especially valuable. It indicated that the teacher was able to utilize materials and technology to support the assessment during the evaluation stage of the BSCS's 5E Model in the experimental group more potentially when he implemented the technology-enhanced inquiry instructional model. HubNet discussion tool [10], the software used in the technology-enhanced inquiry instructional model, was able to overcome one of the greatest obstacles to improving classroom assessment: the collection, management, and analysis of data. It also offered anonymity for students to answer questions without the worry of peer influence and humiliation. As a result, the assessment for the experimental group appeared to be more student-friendly than that for the control group. This suggests that the technology-enhanced inquiry instructional model supports the assessment during the evaluation stage and, therefore has some implications for educators.

The review of the literature indicated a number of studies suggesting that formative assessment through feedback can create significant learning gains and facilitate conceptual changes, but it is important to note that long delays in feedback can lead to fluctuations and inefficiencies in the learning process. Without immediate feedback, misconceptions can become somewhat fixed in the student's memory and remain uncorrected. A study from the Institute for the Promotion of Teaching Science and Technology [17] in Thailand also revealed that science teachers implementing the BSCS's 5E Model in their class rarely assess students during the evaluation stage. To solve these problems and support good assessment practice in science classes, educators should integrate the technology-enhanced inquiry instructional model into teacher education programs for pre-service science teachers and professional development for science teachers.

The findings from the questionnaire survey administered to participating students showed that the majority agreed or strongly agreed that the technology-enhanced inquiry instructional model:

- Is simple and easy to use (in terms of technology)
- Increases subject interest
- Supports class participation
- Enhances subject understanding
- Improves environment for teaching and learning
- Increases teacher insight into student difficulties
- Supports collaborative learning
- Is suitable for their science classroom
- Is necessary to be implemented every time in their science classroom

In addition, most students preferred the technology-enhanced inquiry instructional model rather than the typical BSCS's 5E Model usually used by their teacher. They seemed to have very good attitudes toward using the technology-enhanced inquiry instructional model in the science classroom suggesting that the technology-enhanced inquiry instructional model motivates students to learn science. Some of these findings were also reported by Bransford et al. [18], Dufresne et al. [19], MacGeorge et al. [20], Penuel et al. [21], and Roschelle et al. [22].

Given these findings, policy makers and administrators might consider more systematic and widespread professional development for teachers in the use of the technology-enhanced inquiry instructional model. However, more research needs to be conducted to determine on what kinds of technology and inquiry instructional models are the most effective. This will ensure that the technology-enhanced inquiry instructional model can continue to be improved.

There are some limitations in the study that should be considered. First, it is quite difficult for most schools in Thailand to allocate time for students to use the school's computers in subject areas other than computer science. The integration of technology across the curriculum requires strong commitment from the school principal and a good collaboration between the computer science teachers and the teachers in other subject areas. As a result, it took a large amount of time to find the school for the study and confined the site selection process to be very specific, so there could be a school effect. Much more research in various schools is necessary. In addition, the study took place in Thailand. It can contribute to the body of research, but many more studies need to be done to expand the research globally.

Secondly, the inquiry instructional model implemented in the study was new to the participating teacher since Peer Instruction's Cycle [14] was incorporated into the evaluation stage of the typical BSCS's 5E Model he usually used. The participating teacher also had no experience about HubNet discussion tool [10], the software used in the technology-enhanced inquiry instructional model. Moreover, he had only a little time to practice these new things due to a large workload. Thus, he might feel little hesitant and that could have impacted the outcomes of the study. Additional studies are needed where more time is provided to teachers to master these prior to their implementation.

Thirdly, HubNet discussion tool [10], the software used in the study, had a few technical problems. It required higher speed of RAM (Random Access Memory) on the teacher's computer when more student computers were added into the network. At this time, it is still unknown what the appropriate RAM speed for the number of student computers or the maximum number of student computers that can be added into the network at any RAM speed. In addition, the networked computers occasionally did not work properly when students were all simultaneously logging on or sending their responses via the software. These technology problems distracted both the students and the teacher from the subject being taught. The implication for this is clear, since the technology problems may have affected the results of the study. Much more research needs to be done with a variety of software and hardware.

The study suggests several implications for both science teachers and school administrators. For science teachers, first, they should consider implementing the inquiry instructional model with or without technology enhancement in their class in an effort to improve students' understanding of science. However, the technology-enhanced inquiry instructional model appeared to be a better alternative since it seemed to support assessment and motivate students to learn science.

Secondly, since some students commented in the questionnaire survey that they could be distracted by other things on the computer such as games and websites, science teachers should work closely with technicians to uninstall any games on the school's computers and block the Internet access when it is not needed for their class. This could help students concentrate more on learning.

For school administrators, they should be concerned about the problem of limited computer access in subject areas other than computer science and allocate more computers and/or time for students in other subject areas. They should also consider providing teachers with adequate professional development, time and incentives to encourage them to integrate inquiry and technology appropriately into their instruction.

Further research is needed to broaden the study and to examine the consistency of the results. Students in various countries, grade levels, socio-economic levels and ability groups, as well as teachers with various skill levels and experiences, could be included in future studies. Besides, due to the limit of computer access and technology problems in the study, other types of classroom communication systems such as hand-held devices and other software could be selected for future research.

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