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A 5E Learning Cycle Approach–Based, Multimedia-Supplemented Instructional Unit for Structured Query Language

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ABSTRACT

With the benefit of multimedia and the learning cycle approach in promoting effective active learning, this paper proposed a learning cycle approach–based, multimedia-supplemented instructional unit for Structured Query Language (SQL) for second-year undergraduate students with the aim of enhancing their basic knowledge of SQL and ability to apply SQL to a database. The students were engaged into the learning unit by using the designed multimedia, were asked to explore SQL syntax errors using a game in the developed instructional multimedia and to share and discuss the cause(s) of the SQL syntax error(s) with the class. They then constructed, practiced, and applied SQL commands, and evaluated their own understanding using the multimedia. Research data were collected through an SQL achievement test, small projects, and a questionnaire. The results showed that the students who participated in this developed instructional unit had better ability to apply SQL to a database compared to other groups of students.

Keywords

Learning cycle approach, Inquiry–based learning, Instruction, Multimedia, SQL, Database

Introduction

A database is a collection of data organized into a structured format defined by metadata. Metadata are data about the data being stored: they define how the data are stored within the database (Sheldon, 2003). Sometimes the data stored in a relation are linked to the data stored in another relation. If one of the relations is modified, the other must be checked and perhaps modified to keep the data consistent. Database query languages provide access to information in a database. Such queries may be composed via menus, command languages, or direct manipulation, but at last appear as Structured Query Language (SQL) queries (Smelcer, 1995).

SQL is today the de facto standard language for relational and object-relational databases (Brass & Goldberg, 2006), and is the most important language used to support the creation and maintenance of a relational database and the management of data within that database (Sheldon, 2003). Because of SQL importance, students would benefit more if the teachers could demonstrate the queries and ill-defined errors present in those queries and allow the students to practice by themselves instead of following an example from a textbook (Rob & Coronel, 2007; Wilton & Colby, 2005).

In recent years, multimedia has afforded an opportunity to implement an active, student-centered instructional approach in which learners can select relevant words and images, organize them into coherent verbal and visual models, and integrate them into a whole conceptual structure (Mayer, 2005). Such an approach can enhance students' learning when appropriate principles are taken into account (Mayer & Moreno, 2003). Multimedia teaching-learning tools are changing the way students from all levels are taught in the educational arena. Multimedia learning tools have also been successfully adopted in related areas such as data communications and networking (Asif, 2003; Elkateeb & Awad, 1999; Yaverbaum & Nadarajan, 1996), operating system concepts (Rias & Zaman, 2008, 2010), multimedia learning (Lahwal, Amaimin, & Al-Ajlan, 2009; Neo & Neo, 2009; Teoh & Neo, 2006), computer algorithms and design patterns (Byrne, Catrambone, & Stasko, 1999; Dukovich & Janzen, 2009), or even merging skills for learning English (Lai, Tsai, & Yu, 2009; Tsai, 2009). Nevertheless, it is not easy to find studies who demonstrate their effectiveness for SQL learning.

Simply implementing multimedia tools in classrooms is not enough. Moreover, teachers should select appropriate ways to used multimedia tools for enhancing students' learning effectively. The 5E learning cycle model, which is one of the learning and teaching approach based on the concept of inquiry-based learning (Renner & Lawson, 1973), is seen as effective active learning, inquiry-based scientific pedagogy, especially in enhancing students' understanding of the nature of the world (Bybee, 2006; Stamp & O'Brien, 2005). The idea of the 5E learning cycle model has been applied to promote students' understanding in several areas such as life science, biology, and physics (Dibley & Parish, 2007; Kaynar, Tekkaya, & Cakiroğlu, 2009; Krall, Straley, Shafer, & Osborn, 2009).

To our knowledge, there is no research concerning the integration of multimedia into the 5E learning cycle–based activities for SQL learning. With the benefit of multimedia tools and the 5E learning cycle model in enhancing students' understanding, in this study, it is a challenge to develop SQL instructional multimedia based on the 5E learning cycle to support second-year undergraduate students' learning.

The 5E learning cycle model–based learning environment

The 5E learning cycle model has five instructional stages, i.e., engagement, exploration, explanation, elaboration, and evaluation (Bybee, 2002, 2006).

- **Engagement phase (E1):** Teachers access students' prior knowledge and help them become engaged in a new concept through the use of short activities that generate enthusiasm and access prior knowledge. The activities should make connections between what students know and can do, expose prior conceptions, and organize students' thinking toward the learning outcomes of the current topic.

- **Exploration phase (E2):** Exploratory experiences provide students with a common set of experiences within which present concepts (i.e., misconceptions), processes, and skills are reflected and conceptual change is facilitated. Students have the opportunity to compare ideas that identify inadequacies of current concepts. Learners are not just passive receptors: they also have the chances to acquire knowledge actively. They may manipulate materials using existing knowledge to generate new ideas, explore questions and possibilities, and execute a preliminary investigation.
- **Explanation phase (E3):** In this phase, there are more interactions between teachers and students. The explanation phase focuses students' attention on a specific aspect of their engagement and exploration experiences and provides opportunities for students to demonstrate their conceptual understanding, process skills, or behaviors. This phase also provides opportunities for teachers to use direct instruction. Learners explain their understanding of the concept. An explanation from the teacher or the curriculum may guide them to modify and enhance their conceptual understanding.

- **Elaboration phase (E4):** Teachers challenge and extend students' conceptual understanding and skills. Through new experiences, students learn to develop broader and deeper understanding and adequate skills, and perhaps acquire additional information. Students apply their understanding of the concept by performing additional activities.

- **Evaluation phase (E5):** The evaluation phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate students' progress toward achieving the learning goals (Bybee, 2002, 2006).

The 5E learning cycle model is a realistic, constructivist method of leading students through a learning sequence in which they become engaged in a topic, explore that topic, are given an explanation for their experiences, elaborate on what they have learned, and are then evaluated (Wilder & Shuttleworth, 2005). The idea of the 5E learning cycle model has been applied to promote students' understanding in several areas. For example, in 2007, Beffa-Negrini, Cohen, Laus, and McLandsborough applied the 5E learning cycle model to a teacher development program in a food safety curriculum. They recruited seventy-one secondary teachers to register for the program, which designed online food-safety training activities rooted in the American National Science Education Standards and the Biological Sciences Curriculum Study. The participants went through 3 modules, each with 15 hours of web-based instruction, interactive discussion, and tools for conducting experiments or for critically evaluating food safety. After analyzing 38 pre-tests and post-tests, they found that the teachers were satisfied with the program and that most of them felt more capable of critically evaluating food safety information on the Internet. By experiencing the 5E instructional strategy on the food safety topic, and by using an inquiry-based approach, these teachers could continue to effectively instruct in this topic. Krall, Straley, Shafer, and Osborn (2009) evaluated a unique series of physical-science, distance-learning courses in a professional development program for middle-school teachers in a rural region. The lesson followed the 5E learning cycle model and incorporated key tenets from conceptual change research. Instruction through active learning, inquiry-based investigations distinguish this program from other distance-learning programs. The results from the pilot study indicated that the 43 teachers' content knowledge was higher for six out of nine temperature and heat concepts. The teachers' views toward the distance-learning medium and the course in general were positive. Gerdprasert et al. (2010) developed a web-based learning unit based on integrating the principles of the mechanism of labor with the 5E learning cycle model. The results showed that supplementing the conventional lecture with the learning unit made learning significantly more effective than the traditional lecture alone and students responded positively toward this learning unit.

The developed multimedia-supplemented instructional unit based on the 5E learning cycle model

Two lessons of the SQL instructional unit were developed: Lesson I—SQL for defining and manipulating data, and the rules related to keys in a relational database—focused on SQL's data definition language (DDL), which relates to creating tables, and on the part of the data manipulation language (DML) that relates to inserting, updating, and deleting data, and integrity rules. Lesson II—SQL for retrieving data—focused on DML statements related to data retrieval. These lesson plans were designed based on Bybee's (2006) 5E learning cycle approach—engagement, exploration, explanation, elaboration, and evaluation. Each lesson was divided into two parts: a two-hour computer laboratory with the use of the developed multimedia tool and a one-hour lecture. These instructional plans provided students with experiences in the computer laboratory before attending the lectures. The overall activities of each lesson were as follows:

Phases/Description	**Objectives**	**Student Activities**
Lesson I: SQL for defining and manipulating data and the rules related to keys in a relational database		
Engagement I (10 mins)	1. To introduce students to SQL commands	Students were engaged into the learning unit by using the designed multimedia animation.
Exploration I (30 mins)	1. To expose students to SQL commands and syntax: defining tables, manipulating data, and integrity rules 2. To predict the output of SQL commands 3. To practice writing SQL commands to generate output 4. To investigate the cause(s) of SQL syntax error(s)	Game investigation: students predicted SQL statements, both the DDLs (create, alter, and drop a table) and the DMLs (insert, update, and delete data from a database). Content investigation: students tried to write SQL commands with the designed multimedia as shown in Figure 1 by using an SQL manual, used the Microsoft Office Access program in a computer laboratory for observing SQL syntax errors, communicated their results with peers, and discussed the results of game and content investigation with the class.
Explanation I (20 mins)	1. To summarize the objectives of DDL commands, and relate DML commands (manipulating data in a database) to integrity rules	The teacher encouraged students to share and discuss the cause(s) of SQL syntax error(s) they faced, summarized the objectives of DDL commands, DML commands (except query commands), and related DML commands to integrity rules. Also students were encouraged to construct the whole SQL command concepts. The teacher taught in-depth

Phases/Description	Objectives	Student Activities
		concepts related to SQL syntax.
Elaboration I (20 mins)	1. To elaborate by applying knowledge to new situations	Students practiced and applied DDL and DML commands by using the multimedia animation and used the Microsoft Office Access program to learn from error message responses. The teacher provided results and additional information on practicing SQL commands.
Evaluation I (10 mins)	1. To evaluate their understanding and perceptions	Encourage students to evaluate their understanding, findings, explanation, and elaboration.
Lesson II: SQL for retrieving data		
Engagement II (10 mins)	1. To introduce students to more SQL commands	Students were engaged into the learning unit by using the designed multimedia animation.
Exploration II (30 mins)	1. To experience data query 2. To predict the output of SQL commands 3. To practice writing SQL commands to generate output 4. To investigate the cause(s) of SQL syntax error(s)	Game investigation: students predicted SQL's DML statements (query commands). Content investigation: students tried to write SQL commands with the designed multimedia animation as shown in Figure 2 by using an SQL manual, used the Microsoft Office Access program in a computer laboratory for observing SQL syntax errors, communicated their results with peers, and discussed the results of game and content investigation with the class.
Explanation II (20 mins)	1. To summarize the objectives of DML (query commands)	The teacher encouraged students to share and discuss the cause(s) of SQL syntax error(s) they faced, and summarized the objectives of DML (query commands). Also students were encouraged to construct the whole SQL command concepts
Elaboration II (20 mins)	1. To elaborate by applying knowledge to new situations	Students practiced and applied DML commands (query commands) by using the multimedia animation and used the Microsoft Office Access program to learn from error message responses. They shared and collected results with peers. The teacher provided results and additional information on practicing SQL commands.
Evaluation II (10 mins)	1. To evaluate their understanding and perceptions	Encourage students to evaluate their understanding, findings, explanation, and elaboration.

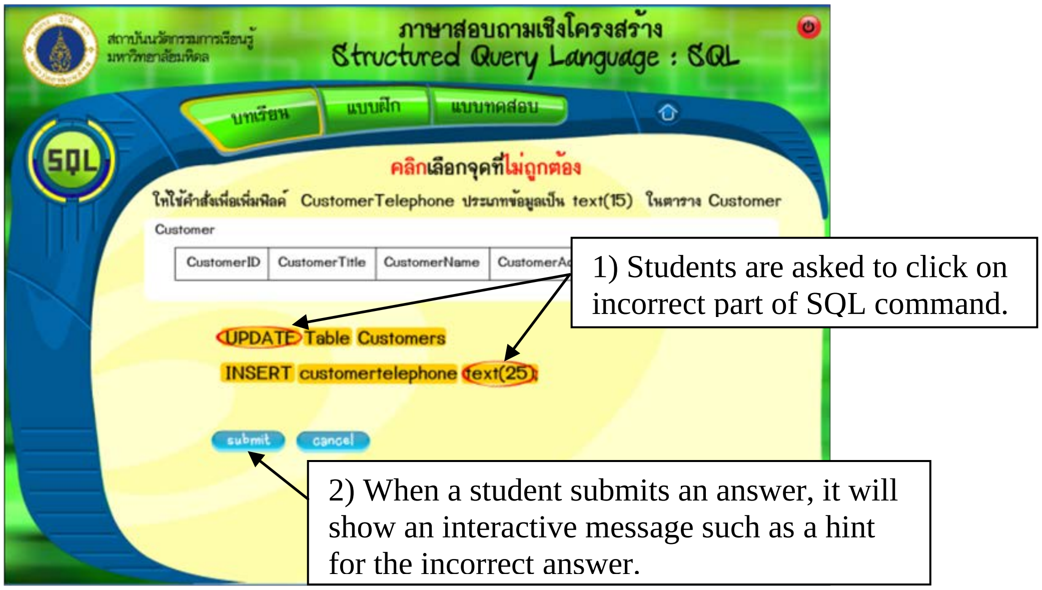

Figure 1. An SQL interactive game that asks the students to find and click on each incorrect part of an SQL statement in the phase Exploration I

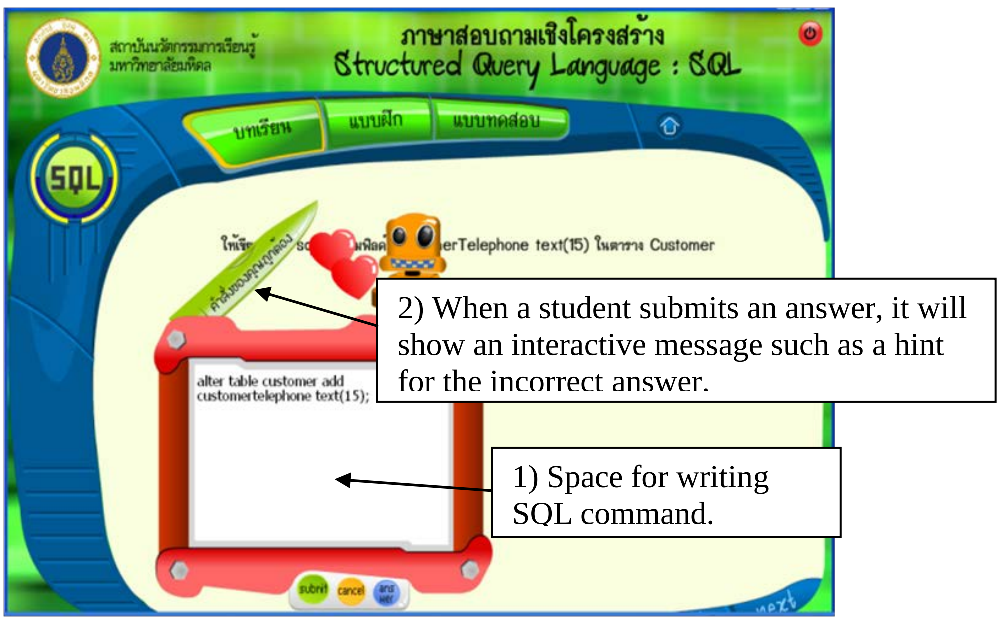

Figure 2. An interactive game for writing SQL commands in the phase Exploration II

The development of the SQL learning unit started from planning the instruction, consulting with the curriculum experts, conducting the pilot study, and revising the draft. The next step was implementation and data collection. Finally, the SQL learning unit was evaluated from all the data.

Research objectives

1. To investigate the students' learning achievement on SQL after participating in the learning unit based on 5E learning cycle model supplemented with interactive multimedia.
2. To investigate the students' learning attitude after participating in the interactive learning unit based on 5E learning cycle model supplemented with interactive multimedia.

Research questions

1. To what extent can the learning unit based on 5E learning cycle model supplemented with interactive multimedia promote undergraduate students' learning achievement on SQL?
2. What is undergraduate students' attitude toward the innovative SQL learning unit based on 5E learning cycle model supplemented with interactive multimedia?

Methods

This study is experimental research. The faculty teacher in the university who teaches SQL did all teaching in this study. Researchers by ourselves constructed the pre- and post-test (open-ended questions), questionnaire, and set criteria of rubric scores for evaluating students' projects. Researchers asked another faculty teacher (who did not teach in this study) to score pre- and post-tests and evaluate students' projects based on the rubric scores. The details of participants and research instruments (i.e., pre-post tests, criteria of rubric scores, and questionnaire) are included in this section.

Participants

Ninety-five second-year undergraduate students (fifty-two males, forty-three females), aged 18–20, were recruited to participate in this study. They were taught by the same teacher. After learning fundamental database concepts in the database course, all students took a pre-test to ensure whether they had equivalent prior knowledge about the fundamental database concept and they then were randomly divided into three groups, namely a control group (thirty-three students), an experimental group 1 (thirty students), and an experimental group 2 (thirty-two students). The students in the control group (CG) participated in the traditional lecture without interactive multimedia as a supplementary material. The teacher guided them to follow SQL commands step-by-step by the textbook in three-hour lectures without any supporting activities or discussion with their classmates. Those in the experimental group 1 (E1) were given the developed 5E learning cycle model–based learning unit without interactive multimedia as a supplementary material. They participated in the active learning activities based on the 5E learning cycle model and discussed with their classmates and the teacher in three-hour sessions. Those in the experimental group 2 (E2) participated in the developed 5E learning cycle model–based learning unit with the instructional interactive multimedia. They manipulated the animation in the interactive multimedia to engage their prior knowledge before learning SQL and playing the game in interactive multimedia to explore and observe the cause(s) of SQL command error(s) by discussing with their classmates and receiving the guidance from the teacher in three-hour sessions after experiencing learning activities, all participants were assessed by a small project and a post-test on the database system to examine learning achievement in SQL. To measure the students' attitude with the 5E learning cycle model–based learning unit supplemented by the instructional interactive multimedia, a questionnaire was administered after finishing the post-test to the students who followed the developed learning instruction. The complete procedures for experimental designing are shown in Figure 3.

Research instruments

To evaluate undergraduate students' learning achievement on SQL and attitude toward learning activities, we constructed research instruments including (1) pre-post tests, (2) criteria of rubric scores, and (3) a questionnaire. The pre-test was a ten open-ended question test, in which each item scored three points with the aim of testing students' prior knowledge about the fundamental database concept before learning SQL commands. In this test, the KR-20 reliability was .79, indicating that the items were useful.

The post-test was intended to compare the SQL commands knowledge of the three groups of students after taking the different learning activities. The test, different from the pre-test, was a ten open-ended question on two categories: three items on the basic knowledge of SQL and seven items on the ability to apply SQL. In this test, the KR-20 reliability was .75, indicating that the items was useful.

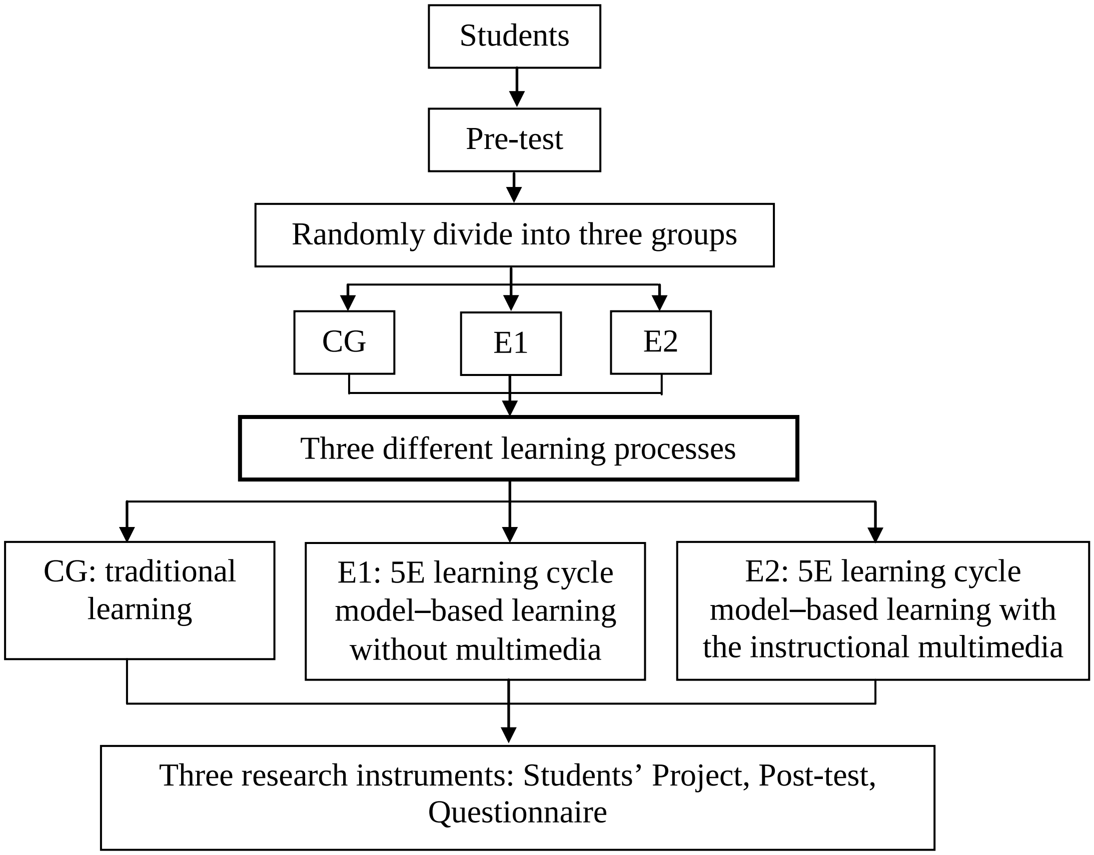

Figure 3. Work flow of experimental design of the second study

The criteria of rubric scores were carefully set for evaluating students' ability to apply SQL-related database concepts on students' project after experiencing the learning activities. The rubric score consisted of five criteria: (1) database design; (2) framework of database system; (3) user interface design; (4) data preparation; and (5) applying SQL, where 0–1.5 represents "beginning", 1.51–2.50 represents "developing", 2.51–3.50 represents "accomplished", and 3.51–4.00 represents "exemplary" as shown in Table 1.

The questionnaire was administered to the students in three groups after finishing the instructional process. The questionnaire was employed to investigate students' attitude toward the learning activities using a 5-point Likert scale, where 1 represents "strongly disagree", 2 represents "disagree", 3 represents "uncertain", 4 represents "agree", and 5 represents "strongly agree." The Cronbach's alpha of this questionnaire was .87, implying that this questionnaire is reliable.

Table 1. Scoring rubric for analyzing students' projects

Criterion	**Descriptions**			
	4 (Exemplary)	**3 (Accomplished)**	**2 (Developing)**	**1 (Beginning)**
1. Database design	Designed database cover 5 conditions: 1. Remove data redundancy 2. Setting primary key 3. Setting foreign key 4. Setting relationship 5. Determine appropriate attribute in each table	Designed database defined cover 4 conditions from all 5 conditions	Designed database defined cover 3 conditions from all 5 conditions	Designed database defined cover 2 conditions from all 5 conditions

Criterion	Descriptions			
	4 (Exemplary)	3 (Accomplished)	2 (Developing)	1 (Beginning)
2. Scope of application system	Scope of designed application cover 4 conditions: 1. Completely scope 2. Simulate the real system 3. Complexity of system 4. Useful system	Scope of designed application defined cover 3 conditions from all 4 conditions	Scope of designed application defined cover 2 conditions from all 4 conditions	Scope of designed application defined cover only one condition
3. User interface	Designed user interface cover 5 conditions: 1. User friendly 2. Appropriate to use 3. Well fineness designed page 4. Designed data access system 5. Accuracy of data displaying in interface	Designed user interface defined cover 4 conditions from all 5 conditions	Designed user interface defined cover 3 conditions from all 5 conditions	Designed user interface defined cover 2 conditions from all 5 conditions
4. Data preparation for system testing	Data preparation cover 4 conditions: 1. Fundamental data 2. Operational data 3. Completely data 4. Reasonable data	Data preparation defined cover 3 conditions from all 4 conditions	Data preparation defined cover 2 conditions from all 4 conditions	Data preparation defined cover only one condition
5. Applying SQL command in application	Applying SQL command cover 4 conditions: 1. Updating data 2. Querying from one table 3. Querying from more than one table 4. Querying by condition	Applying SQL command defined cover 3 conditions from all 4 conditions	Applying SQL command defined cover 2 conditions from all 4 conditions	Applying SQL command defined cover only one condition

Results

In this study, the results from the pre-test, the post-test, the small projects, and the questionnaire were analyzed to find out whether the developed learning unit helped enhance learning achievement.

Students' achievement

The pre-test aimed to examine the prior knowledge of the control and the two experimental groups while the post-test explored how the three groups were affected by the treatments in terms of students' basic and applied knowledge of SQL after the implementation of the developed learning units. Table 2 shows that there was no significant difference in the average pre-test scores of CG (2.70 ± 3.56), E1 (3.42 ± 3.72), and E2 (4.52 ± 1.98). The results suggested that the three groups of the students had similar prior knowledge regarding SQL. However, for the average post-test scores, the score of E2 (19.44 ± 6.04) was significantly higher than those of E1 (12.17 ± 8.27) and CG (7.75 ± 4.58).

Table 2. One-way analyses of variance (ANOVA) for the pre-test and post-test results

Pre-test	**Group**	**Number of students**	**Average score**	**Standard deviation**	***F(2, 92)***	**Post hoc test (Scheffe)**
Overall (Total Score: 30)	(a)	33	2.70	3.56	2.697	-
	(b)	30	3.42	3.72		-
	(c)	32	4.52	1.98		-
Post-test						
Overall (Total Score: 30)	(a)	33	7.75	4.58	27.394	(c) > (a)*
	(b)	30	12.17	8.27		(c) > (b)*
	(c)	32	19.44	6.04		(b) > (a)*

$^{*}p < .05$

(a) Control group CG: traditional learning; (b) Experimental group E_1: 5E learning cycle model–based learning without interactive multimedia; (c) Experimental group E_2: 5E learning cycle model–based learning with the instructional interactive multimedia.

Moreover, Table 3 shows that, regarding basic knowledge of SQL, there were significant differences in the average post-test scores between E2 and E1, E2 and CG, and E1 and CG. Similar results were found for the ability to apply SQL. These results suggested that the SQL learning unit based on the 5E learning cycle model supplemented with the interactive multimedia is more helpful than other learning units for students in learning SQL.

Table 3. One-way analyses of variance (ANOVA) for the post-test results of the three groups regarding basic knowledge of SQL and ability to apply SQL

Category	**Group**	**Number of students**	**Average score**	**Standard deviation**	***F(2, 92)***	**Post hoc test (Scheffe)**
Basic knowledge of SQL (Total Score: 10)	(a)	33	4.55	1.68	28.304	(c) > (a)*
	(b)	30	5.64	1.97		(c) > (b)*
	(c)	32	7.69	1.45		(b) > (a)*
Ability to apply SQL (Total Score: 20)	(a)	33	3.21	3.58	21.576	(c) > (a)*
	(b)	30	6.53	6.71		(c) > (b)*
	(c)	32	11.75	5.21		(b) > (a)*

$^{*}p < .05$

(a) Control group CG: traditional learning; (b) Experimental group E_1: 5E learning cycle model–based learning without interactive multimedia; (c) Experimental group E_2: 5E learning cycle model–based learning with the instructional interactive multimedia.

Results of students' small projects

Table 4 shows the overall student-project results. Students' projects in the experimental group 2 (E2) regarding the database design, the framework of the database system, the user interface design, and the data preparation were exemplary. Moreover, they were exemplary in applying SQL commands to update and query data from multiple tables, and in querying data by using correct conditions. The projects in the experimental group 1 (E1) were exemplary in the framework of database system and in applying SQL. As a comparison, students' projects in the control group were only exemplary in the framework area. These results confirmed that our innovative learning unit was able to promote students' understanding of SQL, particularly in applying SQL to develop small projects.

Table 4. The overall rubric scores of students' projects

Criteria (Total scores: 20)	**Results of students' projects**		
	(a)	**(b)**	**(c)**
Database design (4)	Accomplished	Accomplished	Exemplary
Framework of database system (4)	Exemplary	Exemplary	Exemplary

Criteria (Total scores: 20)	Results of students' projects		
	(a)	(b)	(c)
User interface design (4)	Accomplished	Accomplished	Exemplary
Data preparation for system testing (4)	Accomplished	Accomplished	Exemplary
Applying SQL (4)	Accomplished	Exemplary	Exemplary

(a) Control group CG: traditional learning; (b) Experimental group E_1: 5E learning cycle model–based learning without interactive multimedia; (c) Experimental group E_2: 5E learning cycle model–based learning with the instructional interactive multimedia.

Students' attitude: Results of the questionnaire

The questionnaire was employed to investigate students' attitude after experiencing the learning activities. As shown in Table 5, the students in the experimental group 2 (E2) who followed the proposed learning unit based on the 5E learning cycle model–based learning with the instructional interactive multimedia were satisfied with the engagement method. Moreover, the experimental 1 (E1) and 2 (E2) groups felt that they had the opportunities to explore the SQL commands and explain their knowledge in the classroom during the proposed learning activities. Furthermore, these two groups agreed that they could discuss with their peer from the active learning activities. Thus, the experimental group 2 (E2) realized that they could assess and evaluate their knowledge according to the learning objectives.

Table 5. Students' responses to the questionnaire (N = 95)

Items	Mean			SD		
	(a)	(b)	(c)	(a)	(b)	(c)
Engagement 1. These learning-teaching activities can increase encouraging in learning 2. These learning-teaching activities can help learners to relate prior knowledge to the current topics 3. These learning-teaching activities can engage learners to the content	3.85	4.06	4.15	0.66	0.51	0.51
Exploration 4. I learn by manipulating via these learning-teaching activities 5. There are many encouraging questions along the active learning activities via these learning-teaching activities	3.69	4.02	4.03	0.73	0.61	0.61
6. These learning-teaching activities help learners self-performing						
Explanation 7. These learning-teaching activities concern the learners' explanation and share learning concepts by self practicing 8. There are many encouraging questions for evaluating the individual understanding via these learning-teaching activities 9. I understand the additional concept from teacher explanation	3.68	3.91	4.01	0.73	0.52	0.71
Elaboration 10. There are many exercises for learners practicing and learning via these learning-teaching activities 11. I can learn from sharing, observing, and problem solving with my classmates 12. I can learn from asking and suggesting from teacher 13. I can link the learning concepts with real situation	3.74	3.90	3.94	0.67	0.52	0.63

Items	Mean			SD		
	(a)	(b)	(c)	(a)	(b)	(c)
Evaluation 14. I have assessed my knowledge and understanding after learning this topic 15. The learning evaluations are relevant to learning objectives 16. The evaluations are clear, suitable and able to measure	4.03	4.01	4.29	0.71	0.60	0.64

(a) Control group CG: traditional learning; (b) Experimental group E_1: 5E learning cycle model–based learning without interactive multimedia; (c) Experimental group E_2: 5E learning cycle model–based learning with the instructional interactive multimedia.

Discussion

This study was conducted to investigate the effectiveness of the three methods of learning SQL (5E learning cycle model with instructional interactive multimedia, 5E leaning cycle instruction, and traditional instruction) for the second-year undergraduate students. From previous research, there was no report of applying the 5E learning cycle approach supplemented with interactive multimedia for SQL learning. The overall results of this study indicated that the 5E learning cycle model–based learning unit with the instructional interactive multimedia significantly outperformed the 5E learning cycle model instruction and the traditional method in promoting students' understanding of key aspects and concepts involved in SQL, especially regarding basic knowledge of SQL and ability to apply SQL on the students' projects on the database system. The students could explore SQL syntax errors via the game in the interactive multimedia and came to understand the concepts of SQL commands. This study thus could be an original contribution to the 5E learning cycle–based instruction supplemented with interactive multimedia.

Possible reasons for this observed difference might include the value associated with alternative ways of acquiring knowledge in science, particularly inquiry, and the confirmation value of active learning activities. During the 5E learning cycle instruction, the students learned through their own actions and reactions by being involved in the active learning activities. They were engaged by the SQL game and the responses from dragging, dropping, and clicking the exemplified statements encouraged them to modify and mark parts of the commands in order to find the correct answers. They explored SQL commands and the responses from running the given statements encouraged them to modify the commands to find the correct answers. Students' explorations involved trying out and learning from errors. The students in the 5E learning cycle instruction group were also involved in active learning activities that helped them to examine the adequacy of their prior conceptions and encouraged them to discuss about those conceptions. This led to disequilibrium where predictions based on their prior beliefs were contradicted and provided the opportunity to construct more appropriate concepts. The 5E learning cycle model–based, interactive multimedia-supplemented SQL instructional unit incorporated a teaching strategy in which students had enough time to identify and express their preconceptions and examine their usefulness, before a group of related new concepts was introduced and explicated. Students elaborated by applying and extending newly constructed knowledge to other database case studies and small projects. The evaluation in the 5E learning cycle model–based instructional interactive multimedia required the students to evaluate what they have done. The students in the 5E learning cycle instruction went through the same teaching strategy as those in the 5E learning cycle model–based, interactive multimedia-supplemented instructional unit except for the engagement stage wherein these students were engaged by reviewing the database concepts related to SQL commands. Meanwhile, the students in the traditional group mainly focused on concepts related to the subject, the process that required less conceptual restructuring.

The findings in this study regarding better performance of students in the 5E learning cycle model–based, interactive multimedia-supplemented group were consistent with the view claiming that correct use of the 5E learning cycle instruction accomplished both effective learning of concepts and an ability to apply concepts. The positive effect of 5E learning cycle instruction on students' achievement was supported by previous studies in the literature (Gerdprasert et al., 2010; Kaveevivitchai et al., 2009; Kaynar Tekkaya, & Cakiroğlu, 2009; Liu et al., 2009). For example, Kaynar et al. (2009) revealed effectiveness of the 5E learning cycle model over traditional learning on students' achievement in cell concepts. Studying the achievement of third-year university nursing students and midwifery, Gerdprasert et al. (2010) showed that supplementing the conventional lecture with the developed web-based learning unit made learning significantly more effective than the traditional lecture alone and students responded positively toward this learning unit. They developed the web-based learning unit by integrating the principles of the mechanism of labor with the 5E inquiry cycle model. The results of the present study were also consistent with the results reported by earlier studies that indicated positive effect of 5E learning cycle instruction on students' ability to apply their knowledge. For example, Van Hook and Huziak-Clark (2007) implemented the 5E learning cycle model in which students used the understanding gained in the previous learning steps to apply their ideas about how things work through collaborative active learning inquiry guided by a knowledgeable teacher. Students in the constructivist classroom were able to adopt their learned concept and used active learning materials to describe how multiple magnets would interact with each other.

This study indicated the positive effect of integrating interactive multimedia with a learning approach on students' understanding and their motivation. The present study is also consistent with the study by Murray and Guimaraes (2008) who found a positive rating on the value of animated courseware by students and faculty. This learning tool could help students find a pathway to increase understanding and generate a high level of learning. In another study, Valdés et al. (2000) provided multimedia resources for students as alternative study tools. Their work showed that students found the learning tools easily understandable and were motivated to learn. Overall results of this study suggested that when students participated in appropriate instruction which helped them understand relevant ideas, sound understanding of SQL concepts could be achieved.

Conclusions

The finding of the present study indicated that the 5E learning cycle model–based, interactive multimedia-supplemented instructional unit caused significantly better acquisition of principal conceptions related to SQL commands than traditional instruction. For the students who followed the 5E learning cycle model supplemented by the instructional interactive multimedia activities, the emphasis was on practicing and learning from errors found. The students were involved in the activities that helped them activate their prior knowledge and allowed them to struggle with their own practices. These activities also provided evidence that the students' initial conceptions were insufficient to write SQL commands. To deal with these errors found by practicing, for instance, SQL syntax errors, students became dissatisfied with their existing conceptions. This dissatisfaction led them to accept better explanations for the situations that were introduced. In this way, students were allowed to think about their prior knowledge and reflect on it. The important part in the implementation of the SQL-concept instruction was the intensive teacher-student interaction. The use of the 5E learning cycle model–based instructional interactive multimedia activities could clarify students' thought processes and corrected their errors found by practicing. When students dealt with a new concept through an exploration, their new experiences caused them to reevaluate their past experiences. This produced disequilibrium in the students, and they needed to accommodate the new concept to reach new equilibrium. They had the opportunity to explain, to argue, and to debate their ideas, which allowed them to accommodate the concept. In the elaboration phase, students became familiar with the introduced concept and either assimilated or accommodated the new concept into their schemata. The persistence of inadequate cognitive structures was attacked by applying the new concept to a broad range of new examples. The study presented here revealed that teacher-centered and textbook-oriented science instruction did less to improve students' conceptual understanding and leaved many errors found by practicing unchanged.

To apply the proposed 5E learning cycle model–based, interactive multimedia-supplemented instructional unit, several points need to be taken into consideration:

1. The 5E learning cycle model supplemented with interactive multimedia can be applied as an alternative method to traditional instruction. It is important to be aware of students' prior knowledge and to manage the classroom activities accordingly.
2. Various assessment tools allow teachers to assess students' abilities to apply their knowledge in the information system area.
3. Since the learning process in this study enables students to learn based on their own exploration and explanation, formative assessment to follow students' progress during the learning process should be considered.

In addition, to introduce the proposed 5E learning cycle model–based instructional interactive multimedia into the classroom, a step-by-step guideline for the teachers/ practitioners/ researchers is as follows:

Step 1: Introduce SQL commands to the students by showing the animation in the interactive multimedia. This step will take 10 minutes.

Step 2: Ask the students to play a game in the interactive multimedia program to investigate the cause(s) of SQL syntax error(s). Usually the Microsoft Office Access program has a guideline that shows all command errors. This step will take 30 minutes.

Step 3: Encourage the students to share and discuss the cause(s) of SQL syntax error(s). This step can be carried out in groups or individually, depending on the practical needs.

Step 4: Ask the students to practice SQL commands using the animation in the interactive multimedia. Usually the Microsoft Office Access program has a guideline that allows the teachers and students to learn about the error message responses. This step will take 20 minutes.

For researchers who would like to compare students' learning achievement before and after receiving the learning activities supplemented with the interactive multimedia, a post-test is needed. If the objective of the research is to investigate the effectiveness of the treatment, control groups might be needed to compare the performance of the students who participate in different treatments. Furthermore, for those teachers/practitioners/researchers who have difficulty in implementing their own learning activities supplemented with the interactive multimedia, the authors are willing to provide a lesson plan, a manual of the interactive multimedia, the multimedia source code, or technical assistance upon request.

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