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Criteria and Strategies for Applying Concept-Effect Relationship Model in Technological Personalized Learning Environment

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Abstract: Recent progress in computer and communication technology has encouraged the researchers to demonstrate the pivotal influences of technological personalized learning environments on student learning performance improvement. Many researchers have been investigating the development of such learning environment by basing upon the concept-effect relationship model; nevertheless, the criteria of establishing a technological personalized learning environment based on the concept-effect relationship model have not yet been clearly defined, not to mention the strategies of conducting effective conceptual learning problem diagnosis and effective learning activities. To resolve these problems, this paper presents the basic criteria and strategies of technological personalized learning based on the concept-effect relationship model, and identify the necessary check items as well for the development of such learning environment. Illustrative example of conducting technological personalized learning and the requirements of setting up learning environment are also presented at the end of this paper.

Keywords: Adaptive learning, e-learning, testing and diagnostic system, concept-effect relationships

1. Introduction

In past decade, the rapid advance of computers and communication technologies has promoted the utilization of technological applications in science, technology, and mathematics (STM) educations. The technology in STM education serves as a key ingredient to enhance learning as it helps produce creative and lifelong learning for individual students and promotes personalized learning as well. The technological personalized learning environment is referred to enable individual students to improve their own learning performance (Chen, 2008; Chen, 2011). Consequently, many researchers have developed technological personalized learning environment based on several approaches, models, and algorithms including Bayesian cybernetics, fuzzy rules, genetic algorithms, clustering techniques and concept-effect relationship model (Bai & Chen, 2008a; Cheng, Lin, Chen, & Heh, 2005; Kaburlasos, Marinagi, & Tsoukalas, 2008; Panjaburee, Hwang, Triampo, & Shih, 2010).

In the recent years, several researchers have applied concept-effect relationship model to develop technological personalized learning environment (Bai & Chen, 2008a, 2008b; Chen, 2008; Chen & Bai, 2009; Günel & Aşlıyan, 2010; Hwang, 2003; Panjaburee et al., 2010, Hwang, Panjaburee, Shih, & Triampo, 2013; Chu, Hwang, Tseng, & Hwang, 2006). Successful uses of this model not only demonstrated the benefits of applying it for coping with learning diagnosis problems but also enhanced learning performance in several areas including natural science, mathematics, and health education. However, the difficulty of applying it has been mentioned, not to mention the strategies of conducting effective conceptual learning problem diagnosis and effective learning activities. To cope with these issues, this paper attempts to propose the criteria and strategies of establishing a technological personalized learning environment based on the concept-effect relationship model; moreover, the necessary check items for the development of such learning environment are identified. In addition, several examples for conducting technological personalized

learning based on the concept-effect relationship model and the requirements of setting up learning environment are served as a useful reference for those who are in this area.

2. Characteristics of concept-effect relationship (CER)

Hwang's learning diagnosis procedure (Hwang, 2003), which will be referred to as the basic learning diagnosis procedure throughout the rest of the paper, serves as the starting point of the testing and diagnosing procedure development. The concept-effect relationship on topic 'System of Linear Equations' for ninth-grade Thai students based on a standard Mathematics curriculum in Thailand (Ministry of Education, 2002), as shown in Figure 1, was used to show characteristics of CER in this study. In Figure 1., there are 12 concepts to monitor students' comprehension of algebra course in grades 7 to 9:

C1 Pattern and Relation: the basic concepts of an unknown and development of a sequence of terms;

C2 Equation: the concept of equals sign (=) or equals or equivalence and equation;

C3 Number and Operation: generalized arithmetic laws such as basic number and operations, order of operations, commutative, distributive, and identity properties of addition and multiplication;

C4 Solution of the Equation: solving equations by substituting numerical values and simplifying, checking by successive trial and error and correction;

C5 Properties of Equalities: one of possible concepts used to solve linear equation with one variable;

C6 Constructing Linear Equation with One Variable: generating algebraic expressions;

C7 Solving Linear Equation with One Variable: substituting numerical values or properties of equalities and checking the solution;

C8 Least Common Multiple (LCM): one of the possible concepts used to solve linear equation with two variables;

C9 Ordered Pair and Graph: understanding co-ordinates and graphs in order to offer an algebraic solution;

C10 Word Problem of Linear Equation with One Variable: generating an equation from a descriptive statement, and solving problem;

C11 Solving Linear Equation with Two Variables: using the concepts co-ordinates, graphs, properties of equalities, and LCM; and

C12 System of Linear Equations: generating linear equations with two variables from a situation and solving the problem.

This CER represents the relationships among concepts, for example, the concept 'Properties of Equalities' must be learnt before 'Solving Linear Equation with One Variable'. Likewise, the concept 'Solving Linear Equation with One Variable' must be learnt before 'Word Problem of Linear Equation with One Variable' and 'Solving Linear Equation with Two Variables'. In addition, the concept 'LCM' and 'Ordered Pair and Graph' may be possible concepts that can be used to solve linear equation with two variables. When the relationships among concepts are defined, it is possible to explore the learning barriers of each student and provide personalized suggestions of remedial learning. For example, if a student fails to learn the concept 'Solving Linear Equation with One Variable' this may be because he/she did not learn the concept 'Solution of the Equation' and 'Properties of Equalities' well. In this case, we would suggest that the student should study 'Solution of the Equation' and 'Properties of Equalities' more thoroughly before attempting 'Solving Linear Equation with One Variable'.

Following the construction of CER the main problem is how to diagnose student conceptual learning problems. Obviously, previous research used the CER to diagnose student conceptual learning problems in five steps (Hwang, 2003; Hwang et al., 2008):

(1) Constructing the CER for the subject unit.

(2) Presetting the weight values between test item and related concepts.

(3) Calculating the incorrect answer rate for each student in each concept.

(4) Defining a concept which affects the learning of other related concepts.

(5) Providing feedback and corresponding learning material to each student.

These five steps of the use of CER are called the CER model in diagnosing student conceptual learning problem in technological personalized learning environment.

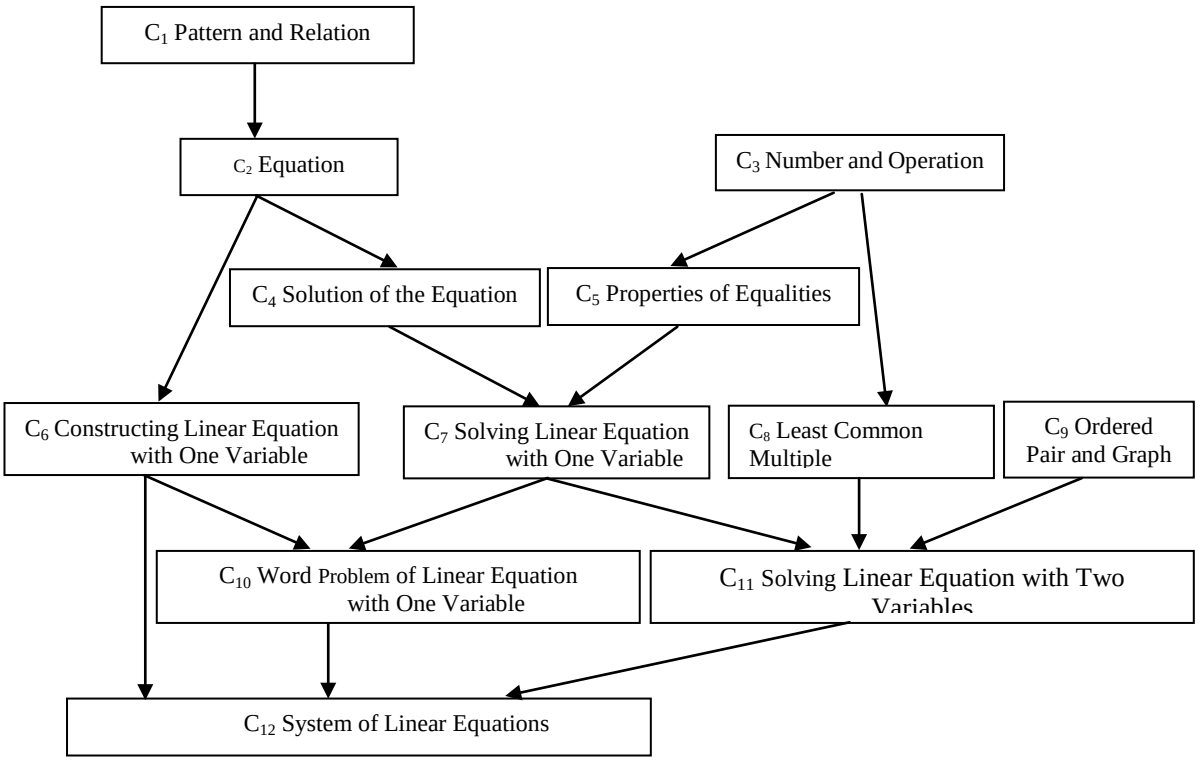


Figure 1. A concept-effect relationship (CER) for topic "System of Linear Equations" (Panjaburee, Triampo, Hwang, Chuedoung, & Triampo, 2013)

3. Criteria and strategies for applying concept-effect relationship model in technological personalized learning environment

Although CER model has attracted much attention from the researchers in developing testing and diagnostic system for technological personalized learning environment, when applying the CER model, the criteria of constructing the CER and presetting weight values between test item and related concepts have not been clearly defined. In the recent years, researchers in this area have different views of those criteria. One view is using single expert/ teacher to construct CER and define weight values between test item and related concepts, which is a very subjective or unintentionally inconsistency decision making (Hwang 2003; Hwang, Tseng, & Hwang 2008; Lee, Lee, & Leu, 2009). With this imprecise decision, different expertise or understanding of each portion of knowledge in the same domain subject unit that allows multiple experts/ teachers to making decision cooperatively can be to integrate the opinions of multiple experts/ teachers to get more high quality CER (Hwang et al., 2013) and weight values between test item and related concepts (Panjaburee et al., 2010; Wanichsan, Panjaburee, Laosinchai, Triampo, & Chookaew, 2012). It is clearly identified that the cooperation of multiple experts/ teachers makes more precise in diagnosing conceptual learning problems and truthful conceptual learning suggestions to individual students during learning in technological personalized learning environment.

Accordingly, from previous literature review, we shall provide STEM educators the potential criteria when applying the CER model in technological personalized learning environment as follows:

1. A CER is a construction of prerequisite relationships among concepts in specific subject unit before starting learning in technological personalized learning environment; that is, multiple experts/ teachers which have the same domain subject learning unit and similar teaching experience

can work together, implying that the precise CER is able to construct by the cooperation of multiple experts/ teachers.

2. Following the precise CER construction, a test sheet in multiple-choice format is needed to develop coving all concepts in the CER.

3. Weight values between test item and related concepts are need to set before diagnosing conceptual learning problem in technological personalized learning environment; that is, multiple experts/ teachers which have the same domain subject learning unit and similar teaching experience can work together, implying that the precise weight values are able to define concept which affects the learning of other related concepts correctly.

4. An application of CER model in technological personalized learning environment can actively provide personalized conceptual learning guidance to students in the right way at the right time based on the submitted answers of all test items.

To conduct the technological personalized learning environment based on the CER model, it is necessary to define the strategies in the real classroom as follows:

1. Upon showing an illustrative example of CER, guide the teachers to construct their own CER in specific subject unit. An expert system needed to be developed to automatically integrate those given by multiple teachers. If there is any conflict occurs during constructing CER, it can be conducted by using online or face-to-face discussions.

2. Guide the teachers to develop a test sheet in multiple-choice format coving all concepts in the integrated CER from multiple teachers.

3. Upon showing an illustrative example of determining weight values between test item and related concepts in the test sheet, guide teachers to presetting their own values (i.e., 1, 2, 3, 4, or 5 ranging from weak to strong relationship). Accordingly, an expert system needed to be developed for automatically integrating those given by multiple teachers. If there is any conflict occurs during integration, it can be conducted by using online or face-to-face discussions for reconsidering the conflicting values.

4. Take the online tests provided by testing and diagnostic system. The testing and diagnostic system will analyze the test results, detecting conceptual learning problems, generate learning guidance, and provide corresponding learning material to each students. The enhanced learning paths and corresponding learning material can be provided when the testing and diagnostic system must be connected to the personalized learning environment.

4. Examples

To address the applications of CER model in more details, the cooperation of multiple experts/ teachers with several illustrative examples of constructing CER and presetting weight values between test item and related concepts is given in this section.

4.1 Constructing CER with the cooperation of multiple experts/ teachers

An expert system: Please consider concepts in “Computations and Applications of Quadratic Equations” unit.
Experts/ Teachers: Polynomial arithmetic, Factor theorem and multiple theorem, Factorization, Cross method, and Quadratic equation in one unknown.
An Expert system: Please consider the direction of concept relationships.
Experts/ Teachers: Assign the direction of concept relationships.
An Expert system: Integrate the corresponding relationships given by multiple experts as following condition:

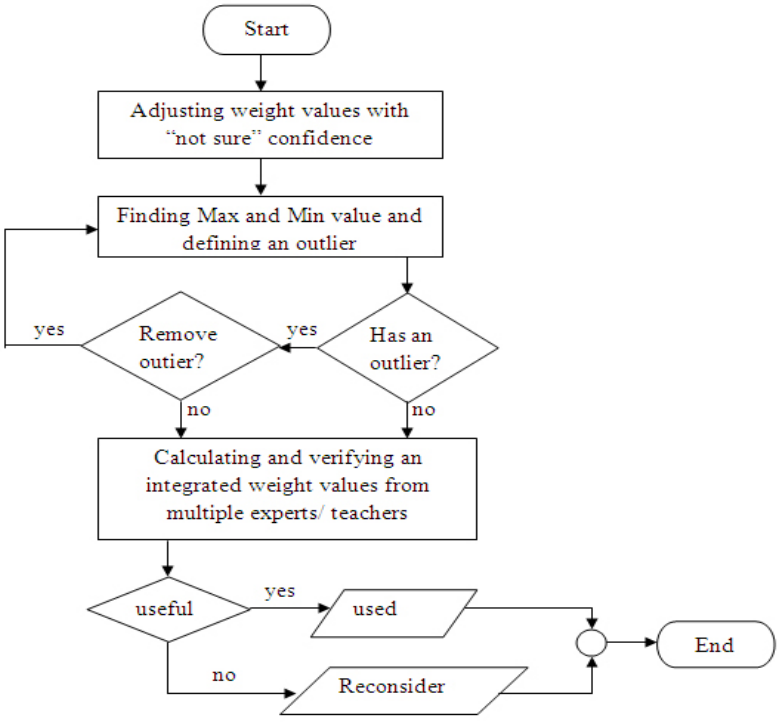
- If all of the domain experts agree on the same prerequisite relationship direction, set this direction on constructing CER.
- If there are opposite opinions, that is, the domain experts have assigned the different prerequisite directions for two concepts, ask the experts to check and reconsider their opinion.

- If there are some experts who have assigned no prerequisite relationship and most of domain experts who have assigned the prerequisite relationship direction, set this direction on constructing CER based on most of domain experts' opinion.
- If there are some experts who have assigned the prerequisite relationship direction and most of domain experts have assigned no prerequisite relationship, set no relationship on constructing CER based on most of domain experts' opinion.
- If there is the same number of domain experts who have assign both the prerequisite relationship direction and no relationship direction, ask the experts to check and reconsider their opinion.

Experts/ Teachers: check and reconsider their opinion by using online or face-to-face discussion.
An Expert system: no further checking and considering
Testing and Diagnostic System linked with technological personalized learning environment: Get a final CER which is then used to provide enhanced learning paths to individual students accordingly.

4.2 Presetting weight values between test item and related concepts with the cooperation of multiple experts/ teachers

An expert system: Please determine weight values between related concepts in this test item: find X in 2X + 5 = 15.
Expert/ Teacher *A*: Determine values 1 for concept "Equation" with sure
Expert/ Teacher *B*: Determine values 3 for concept "Equation" with not sure
Expert/ Teacher *C*: Determine no relationship for concept "Equation" with sure
An expert system: Integrate their opinion as follows:



Experts/ Teachers: check and reconsider their opinion by using online or face-to-face discussion.
An Expert system: no further checking and considering
Testing and Diagnostic System linked with technological personalized learning environment: Get a final weight value between related concepts in this test item which is then used to detect concept learning problem students accordingly.

5. Conclusion

Although CER model or concept-effect relationship model has attracted the attention of researchers in developing technological personalized learning environment area, the criteria for applying a CER model is still unclear, especially in constructing the CER and presetting weight values between test item and related concepts. In this paper, we have attempted to define the basic criteria when applying the CER model in technological personalized learning. Moreover, the strategies in the real classroom to conduct the technological personalized learning environment based on the CER model are clarified. In addition, it can be recognized that the cooperation of multiple experts/ teachers makes more precise in diagnosing conceptual learning problems and truthful conceptual learning suggestions to individual students during learning in technological personalized learning environment.

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