An Online Platform for Problem-Based Learning with Operational Concepts Map

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Abstract: Problem-based learning (PBL) encourages learners to acquire new knowledge through cognitive model development and hypotheses-deduction process. Graphical modeling tools, such as concept map, can help learners to exteriorize the process of knowledge construction and visualize learner's cognitive model to support meaningful learning. But few of those tools integrate hypothesis-reasoning mechanism into the process to support the discovery of knowledge deficiencies and foster in-depth reflection. To that end, this paper proposes a novel graphical tool, *operational concept map* (OCM), for supporting the PBL. In OCM, it combines the merits of conceptual modeling tool and computer-based simulation. The OCM not only inherits all basic functions of concept map, also facilitates the learning-by-doing approach for problem solving. Application of the proposed idea is illustrated in learning a well-known sort algorithm, *bubble sort,* in the sort problem.

Keywords: Problem-based learning, Concepts map, Operational concepts map, Simulation, Learning by doing.

Introduction

Problem-based learning (PBL) has been seen as an active learning approach to promote meaningful learning [1, 2]. This active approach encourages learners to acquire new knowledge through an iterative hypotheses-deduction process when solving a problem. During the process, a learner analyzes the problem by identifying key fact with the problem scenario, proposing hypotheses and solutions, and evaluating the hypothesis by monitoring outcomes of the solutions. Among this process, research shows that the development of cognitive model and the evaluation through experiments can help a learner to identify the key concepts and evaluate the hypothetical relationship among these concepts [3, 4].

Cognitive model [5, 6] is a representation of key elements with relationships among these elements in the specific phenomena or knowledge. When solving a problem, cognitive model can provide a learner with reference framework to facilitate the thinking of a problem[7]. Some graphical modeling tools, such as concepts map[6], have demonstrated their usefulness in construction of learners' cognitive models. With a concept-mapping tool, a cognitive model can be represented as a well-organized graphical map composed of verbal and symbolic elements. This useful tool provides scaffolds to assist a learner to develop and represent the structure of knowledge as personal cognitive model regarding a problem or topic [8].

While, in problem solving, it often requires a learner to reflect and then refine his/her own cognitive model by iteratively evaluating the model's effectiveness, the mechanism for evaluating hypothetical relationship among key concepts to facilitate learning by experimenting is seldom integrated with a concept-mapping tool. To this end, computer-based simulation[9] seems to provide an environment in which the learners can evaluate their hypotheses by experimenting. The simulation functions assist learners to develop critical skills including identify key concepts of a problem, generate hypotheses, and propose solutions for the problem[10]. These simulation environments not only facilitate the development of cognitive model by evaluating hypotheses, but also provide learning goals for learning by doing activities. Based on the necessity of evaluation mechanism of graphical modeling tool and the need of learning by experimenting in PBL, this paper proposes a novel graphical tool, namely *operational concept map* (OCM), which incorporates the basic functions of concept map with additional hypothesis evaluation mechanism. The intent is to foster effective problem solving through developing cognitive models and evaluating hypothesis in a computer-based simulation environment.

The remainder of this paper is organized as follows. Section 1 introduces a conceptual framework of OCM. In this framework, learners can construct a knowledge model with hypotheses-reasoning mechanism. Then, Section 2 describes how the OCM can enhance the process of PBL. In this section, we present an example to illustrate how the OCM can be applied for learning the concept of bubble sort in the sort game followed by a conclusion in Section 3.

1. Operational Concept Map

1.1 Overview

Operational concept map (OCM) is a graphical modeling tool for organizing and representing knowledge with deductive-reasoning mechanism. An OCM is composed of concepts, hypothesis links among these concepts, and propositions. Firstly, concepts, which are enclosed in circles as shown in Figure 1, are perceived regularity in events or objects, or records of events or objects, designate by label. Secondly, the hypothesis link, indicated by rectangle with round corners and several connecting lines linking concepts, is a possible causal relationship among these concepts. Each link contains a hypothetical statement that describes nominal, logical or mathematic formulations. Finally, a proposition contains one hypothesis link connecting two or more concepts to form a meaningful statement. To implement hypotheses-reasoning mechanism, each operational concept and corresponding hypothesis links in OCM are bound with specific set of problem instances. These problem instances are collected to provide real world problem data that helps learners to evaluate the effectiveness of an OCM. Then, learners apply different sets of problem instances to ensure the satisfaction of hypothetical statements in hypothesis links.

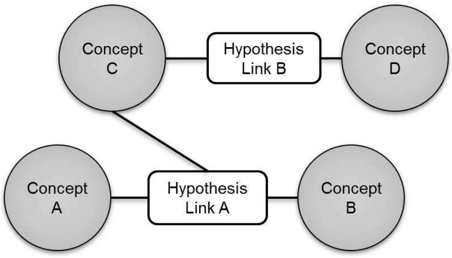

Figure 1. A simple operational concept map

1.2 Key Features

1.2.1 Development of cognitive model and hypotheses evaluation

Like concept map, the OCM assists learners to incorporate new information into the relevant concept framework of which they have already built when a learner generates his/her cognitive model for a problem. The OCM helps the learner to identify general concepts held by the learner prior to instruction and on more specific concepts, and anchor the new knowledge into the conceptual framework. Moreover, the relationship among these key concepts in OCM represents not only the semantic relationship, but also the rule of constraints. The rule can be represented as a mathematic formulation, such as “A=B+C, or logical representation, such as “IF A > B, then Swap(A,B)”. For hypothesis evaluation, hypothesis links represented as a constraint serve not only as semantic description of model to be simulated, but also as rules telling that certain conditions must be satisfied [11-13]. A learner maintains the satisfaction of their hypothesis constraints by iteratively revising their problem cognitive models. Moreover, in OCM, the just-in-time feedbacks of hypotheses evaluation are offered immediately as simulation outcomes. A learner refines his/her cognitive model according to the just-in-time feedbacks.

1.2.2 Construction process of OCM

The construction process of OCM is one kind of externalizing internal and hidden mental model. Some kinds of modeling process [14, 15] facilitate the learner to construct cognitive model with verbalizing and writing. But, in this process, OCM is an external memory tool to facilitate the cognitive process by visualizing. Because the thinking process of problem-solving is represented as organization of concepts and hypothesis links in OCM, the simulation then can not only facilitate the exploration of what-if situations and also support the hypothesis-reasoning process for identifying the knowledge deficiencies. Finally, the visualization with graphical cognitive model facilitates this constructive process with guidance of what to do and how to do.

2. Application of OCM to learn a concept of Bubble sort in the sort problem

To demonstrate the application of OCM in supporting PBL, a well-known learning issue in an introductory college computer science course, the sort problem, is adapted for this study. A learner will learn various sort algorithms to solve the sort problem. In this example of sort problem, the bubble sort algorithm is chosen because it is a simple algorithm that compares each pair of adjacent items and swaps them through the list to be sorted until no swaps are needed. Figure 2 displays the role of instructor and learner played in the process of applying the OCM in the sort problem.

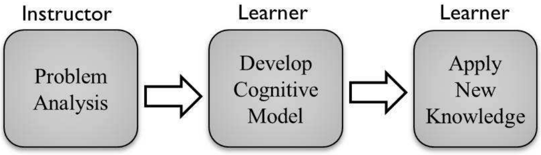

Figure 2. The process of applying the OCM in the sort game.

2.1 Analyzing problem scenario by Instructor

In order to apply OCM to sort problem, the instructor has to analyze a problem scenario at first. In the example of sort problem scenario, four values are randomized and placed individually in the four cells in sequence. A learner has to sort this set of values in ascending order. The instructor has to analyze this problem to identify the key concepts and possible relationships among these key concepts. In this case, the key concepts are the position of each cell. Therefore, the instructor uses four cells of array B to represent the key concept. So, in the figure 3, these key concepts (the four cells of array, B(1) to B(4)) are included in the Concepts Repository for learners to construct their own OCMs, and the Simulation Panel will represent the sort process and result of this array for evaluation. The instructor then identifies the relationships between two adjacent cells and constructs possible reference models to evaluate learner's cognitive model.

2.2 Learner develops his/her cognitive model

In this phase, the learner has to construct his/her personal cognitive model for the sort problem. But, at first, the learner has to read the description of bubble sort algorithm which is prepared by the instructor. Then, the learner has to realize the learning goal and key concepts of a sort problem. The learning goal is defined by the instructor to tell learners that some conditions they have to satisfy. The goal of sort problem is that the unsorted list has to be sorted in ascending order. The key concepts have been identified in the concepts repository.

After realizing the problem scenario, the learner starts to develop his/her cognitive model by OCM. In this example of sort problem, the learner will describe each step of the bubble sort algorithm in sequence. In this case, the learner places two adjacent elements, B(1) and B(2) in the OCM Construction Panel, to determine hypothesis link among them. The possible relationship between B(1) and B(2) is that if the value in B(1) is larger than the value in B(2), these two values have to be swap. Therefore, the learner places a hypothesis link, named "swap", and establish connection lines between two concepts and hypothesis link to form a proposition. Next, the rule of "swap" is established to represent a logical representation: "if B(1) > B(2), then swap(B(1), B(2))". Then, this hypothesis can be evaluated by simulation. In the simulation, the learner observer the result generated from the problem scenario for this hypothesis. If this hypothesis link is work, the learner can observer that value in B(1) will be swap for value in B(2) (if B(1) is larger than B(2)). Then, the learner will apply this hypothesis link to the next two adjacent concepts repeatedly. The cognitive model of bubble sort algorithm is represented as Figure 3.

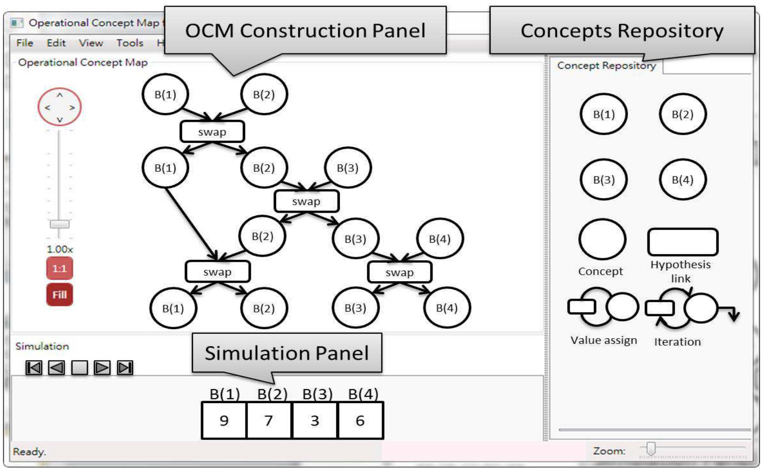

Figure 3. OCM Construction Environment

2.3 Learner acquires and applies new knowledge

When personal cognitive model is completed, another scenario of sort problem is applied to evaluate it. If this model cannot reach the learning goal of new scenario, it has to be revised.

For example, an unsorted list consist of 100 elements cannot be solved by the model for four elements of list. The learner may develop various models for different size of lists, or deduct a general model for different scenario by using the iteration construct. This is an adaptive process that personal cognitive model will be adapted by various problem scenario.

3. Conclusions

This paper has proposed an operational concept-mapping approach for supporting PBL. In OCM, it combines the merits of conceptual modeling tool and computer-based simulation. During the iterative construction process, OCM can foster in-depth learning by experimenting with the proposed game simulation environment. Learners can have better understanding of what they do and why they do in the problem-solving. While the preliminary results look interesting, more issues remain to be further investigated, including application of OCM for supporting various learning through problem solving, and development of better online environment for supporting PBL with OCM.

References

[1] Hmelo-Silver, C. E. (2004). Problem-Based Learning: What and How Do Students Learn? *Educational Psychology Review*, 16(3), 235-266.

[2] Liu, C.-C., Cheng, Y.-B., & Huang, C.-W. (2011).The effect of simulation games on the learning of computational problem solving. *Computers & Education*, 57(3), 1907-1918.

[3] Macklin, A. S. (2001). Integrating information literacy using problem-based learning. *Reference Services Review*, 29(4), 306-313.

[4] Torp, L., & Sage, S. (2002). *Problems as Possibilities: Problem-Based Learning for K-16 Education (2 ed.):* Association for Supervision & Curriculum Development.

[5] Novak, J. D. (2002). Meaningful learning: The essential factor for conceptual change in limited or inappropriate propositional hierarchies leading to empowerment of learners. *Science Education*, 86(4), 548-571.

[6] Novak, J. D., & Cañas, A. J. (2008). The Theory Underlying Concept Maps and How to Construct and Use Them, *Technical Report IHMC CmapTools*. Florida Institute for Human and Machine Cognition: Florida Institute for Human and Machine Cognition.

[7] Ormrod, J. E. (2010). *Educational Psychology: Developing Learners (7 ed.):* Prentice Hall.

[8] Rendas, A. B., Fonseca, M., & Pinto, P. R. (2006). Toward meaningful learning in undergraduate medical education using concept maps in a PBL pathophysiology course. *Advances in Physiology Education*, 30(1), 23-29.

[9] Schank, R. C. (1995). What We Learn When We Learn by Doing, from http://cogprints.org/637/1/LearnbyDoing_Schank.htm

[10] Savery, J. R. (2006). Overview of Problem-based Learning: Definitions and Distinctions. *The Interdisciplinary Journal of Problem-based Learning*, 1(1), 9-20.

[11] Lai, K. R., & Lan, C. H. (2006). Modeling Peer Assessment as Agent Negotiation in a Computer Supported Collaborative Learning Environment. *Educational Technology & Society*, 9(3), 16-26.

[12] Lan, C. H., Graf, S., Lai, K. R., and Kinshuk (2011). Enrichment of Peer Assessment with Agent Negotiation, *IEEE Trans. on Learning Technologies, Vol. 4, No. 1, pp. 35-46*.

[13] Mitrovic, A. (2010). Modeling Domains and Students with Constraint-Based Modeling. In R. Nkambou, J. Bourdeau & R. Mizoguchi (Eds.), *Advances in Intelligent Tutoring Systems* (Vol. 308, pp. 63-80): Springer Berlin / Heidelberg.

[14] Collins, A., Brown, J. S., & NewMan, S. E. (1989). Cognitive Apprenticeship: Teaching the Crafts of Reading, Writing, and Mathematics. In R. Lauren B (Ed.), *Knowing, Learning, and Instruction: Essays in Honor of Robert Glaser* (pp. 453-494). Hillsdale, New Jersey: Lawrence Erlbaum Associates, Publishers.

[15] Pedersen, S., & Min, L. (2002). The Transfer of Problem-Solving Skills from a Problem-Based Learning Environment: The Effect of modeling an Expert's Cognitive Processes. *Journal of Research on Technology in Education*, 35(2), 303.