Liu, C.-C. et al. (Eds.) (2014). Proceedings of the 22nd International Conference on Computers in Education. Japan: Asia-Pacific Society for Computers in Education

Circuitously Collaborative Learning Environment to Enhance Metacognition

Tama DUANGNAMOL[a,b*], Boontawee SUNTISRIVARAPORN[b], Thepchai SUPNITHI[c] & Mitsuru IKEDA[a]

[a]*School of Knowledge Science, Japan Advanced Institute of Science and Technology, Japan*
[b]*School of Information, Computer, and Communication Technology*
Sirindhorn International Institute of Technology, Thammasat University, Thailand
[c]*National Electronics and Computer Technology Center, Thailand*
*d.tama@jaist.ac.jp

Abstract: This paper reveals the design of an ongoing research that investigates the effectiveness of an alternative learning environment Circuitously Collaborative Learning Environment (CirCLE), which is designed to enhance metacognitive awareness on the learning processes in mathematical word problem (MWP) solving environments. We perform the research based on the hypothesis that a student will be encouraged and can reflect his own thinking when he practicing a role of an inspector together with receiving appropriate feedback to revise his solutions.

Keywords: Metacognition, problem solving, peer assessment, collaborative learning

1. Introduction

In a usual collaborative learning environment, students have opportunities to share and are engaged in discussion to take responsibility for their own learning (Gokhale, 1995). However, research in Computer-Supported Collaborative Learning (CSCL) showed that it is difficult to clearly define the interaction between the initial conditions of collaboration and learning outcomes. Moreover, collaboration leads to positive outcomes only when students engage in knowledge-generative interactions, (Dillenbourg & Jermann, 2007), to say that, it is not effective in noncompetitive groups or inactive students. To solve mathematical problems, it is necessary for students to think on their own cognitive strategy to understand deeply how the problems solved. Therefore, in this study, we propose an alternative learning environment, namely Circuitously Collaborative Learning Environment (CirCLE), which provides chances for participants to learn actively to solve algebraic mathematical word problems, in which students learn to solve MWP's by translating context problems into mathematical notations. There are a lot of research established that metacognition is also linked to mathematical capacities (Veenman & Spaans, 2005; Kramarski & Mevarech, 2003). For instant, Teong (2002), knowing when and how to use cognitive strategies is an important determinant of successful word problem solving. Two key components, which are used to compose CirCLE, are a management strategy, named Peer Inspection (PI) strategy, and a communication media, named Inferential Diagram (ID). We intentionally design them to support students' metacognition by providing chances to reflect their cognition and rethink their learning strategy. The detail of PI and ID will be revealed in the rest sections.

2. Peer Inspection Strategy

PI is counted as a *formative peer assessment*; peer feedback is given while the learning is actually happening, helping students plan their own learning, identify their own strengths and weaknesses, target areas for remedial action, and develop metacognitive and other skills (Topping, 2009). The aim for designing PI is to be a learning management strategy for raising the learning of students both as *assessors* (reciprocal teaching (Palincsar & Brown, 1984)) and *assessees* in meta-level through modified peer assessment activities. The modified peer assessment activities in PI are composed of three main stages;

i) *Problem providing*: Nakano, Hirashima, and Takeuchi (2002) mentioned that it is important to consider the differences of problems in understanding the problems deeply. In PI, to encourage students to focus on their own problem, a teacher, therefore, provides distinct problems for each student.

ii) *Peer selection*: Each student will be assigned to inspect suitable works of peers by their learning performance; high performance (HP), average performance (AP), and low performance (LP), to simulate an environment that he/she can learn effectively. For example, for LP students who have no idea how to start, at least two correctly complete examples (If there is no correctly complete solution, a teacher will provide) should be assigned to them to let them follow or learn how to solve problems correctly and they also can use those examples as keys for inspecting assigned solutions of other peers.

iii) *Peer feedback*: Challenging feedback corresponding to students' performance are also important (Mevarech & Susak, 1993), e.g., an HP student should receive feedback to against his idea, which will make him rethink on his own solutions. AP and LP students should receive properly correct feedback as guidance to revise their solution not to confuse them.

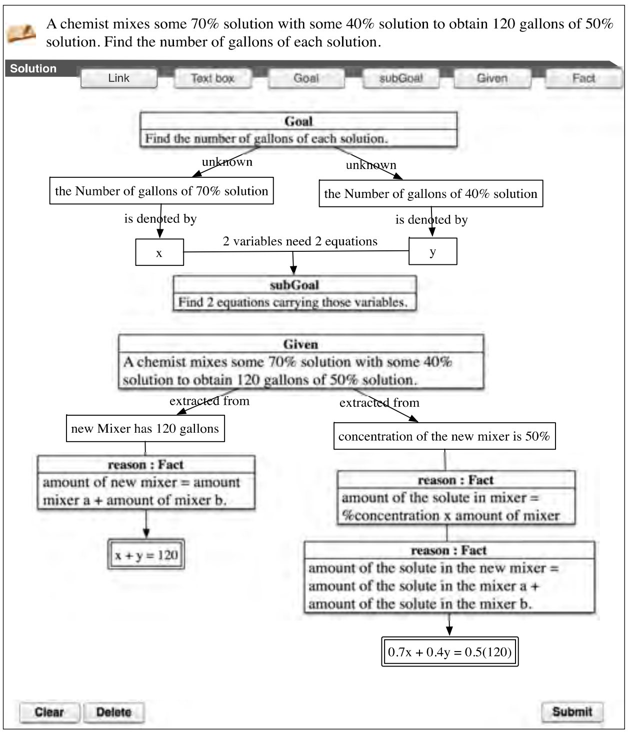
Furthermore, in this research, we also propose Initial Diagram (ID) as a solution method to be a communication media among participants to support and enhance potential of PI. The detail of ID is revealed in the following section.

3. Inferential Diagram

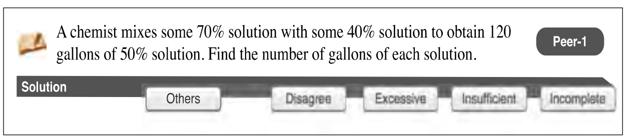
Perceptual inferences can be made more easily than symbolic inferences (Koedinger, 1991), therefore we design ID as a tool to externalize steps of inference when students solving MWP. It is used as a communication media among participants to reduce the complexity of commenting process and to foster students in reflecting their thinking process when solving MWP. This section illustrates some examples of how to provide solution of MWP using ID and how a student comments via ID.

3.1 Providing a solution of MWP using Inferential Diagram

To encourage a student to aware of solving MWP, we propose solution method, called Inferential Diagram (ID), in which a student has to explicitly state any information or statement by expressing its source or reason why he need it. In the user interface of the proposed system, see the figure 1(a), there are six necessary buttons; 1) 'Goal' button is used to state a problem goal, 2) 'subGoal' button is used to state sub-goal of a problem, 3) 'Given' button is used to illustrate information given, 4) 'Fact' button is used to refer common fact, theorems, common rules, or axioms, 5) 'Text' button is used to state reason or any other statements, and 6) 'Link' button is used to create a link between information nodes. To illustrate the relation between information nodes, a student can put any text box on the link. See figure 1(a), the diagram could be



(a)



(b)

Figure 1. Providing solution using Inferential Diagram; (a) student interface and (b) peer interface

interpret as follows, ‘the Number of gallons of 70% solution is denoted by x’, ‘Since, there are 2 variables (x and y), then 2 equations carrying those 2 variables are required’, ‘The problem gave that the mixer has 120 gallons and because there is the fact that “*amount of new mixer = amount mixer a + amount of mixer b*” and from the assumption, then the equation could be formed as x + y = 120’, etc.

3.2 Commenting peer’s solution via inferential diagram

It is not an easy task for some students to comment on peers’ works. Therefore, ID is designed to support students in this task. In CirCLE, by using ID, we provide five example comments as options; i) ‘*I do not agree with an Information in node A*’, ii) ‘*I do not agree with an Information in node A*’, iii) ‘*Does this reason make sense?*’, iv) ‘*Insufficient Information to infer A*’, and v) ‘*Incomplete solution*’. The difference between the student interface and the peer interface are the command buttons; see figure 1(b) comparing to the figure 1(a). To indicate that, for example, if one does not agree with information in a node-A, he can click on the node-A following by clicking on ‘Disagree’ button. In addition to provide an opened comment, a student can use the ‘Other’ button to add additional comments. To construct connections between previous and new knowledge, metacognitive questions, such as, ‘what are the similarities/differences between the problem you are assigned and the problems you have to inspect? and why?’ and questions, such as, ‘what are the strategies/tactics/principles appropriate for solving the problem and why?’, will be used to criticize students during their learning process.

4. Circuitously Collaborative Learning Environment

Since, in CirCLE, students are not directly assigned to work in group, but in a class of specific topic in which all students have the same goal, the students share their solutions anonymously, they comment peers’ solutions, together with receiving feedbacks from peers’ inspection, then, revise their own solutions using those comments and experiences from inspecting peers’ works, therefore the term ‘Circuitously Collaborative Learning’ was used.

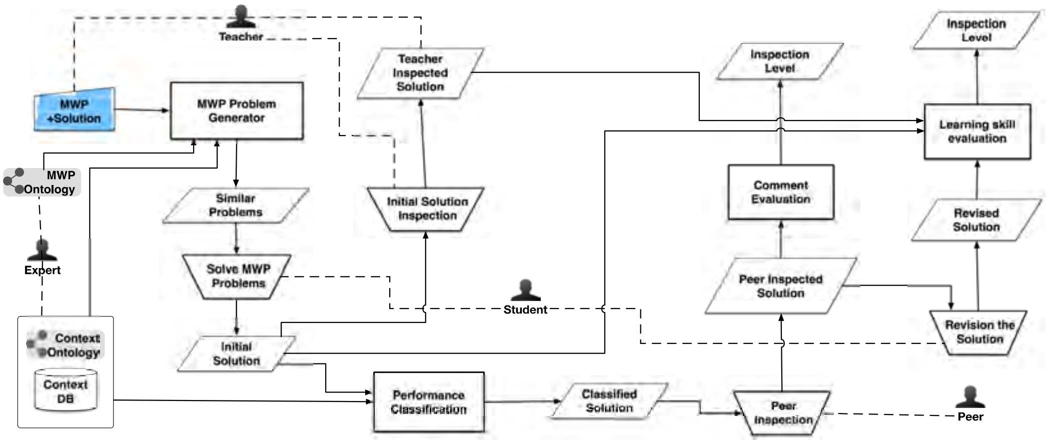


Figure 2. Architecture of Circuitously Collaborative Learning Environment

The system architecture is designed as shown in figure 2. A teacher initially provides some questions to the system and then the system generates similar problems and distributes the generated problems to students. In CirCLE, each student is assigned to solve distinct MWP individually. The initial solution of which students submitted to the system will be used to classify students into three classes, as mentioned in the section 2, for assigning peers. Once peers are assigned, any peer is required to give comment or feedback on other students’ work. Each student has an opportunity to revise their work from what he/she learnt from peers’ work and what they gained from peers’ comments. The system is expected to evaluate students’ learning skill from initial solution and revised solution, and it is also expected to evaluate student’s commenting skill by learning from teacher inspection. An expert in the system is a facilitator providing knowledge base to the system.

5. Methodology

The participants will be eighth-grade students (including boys and girls). All classes will study MWP in algebra unit. The main purpose of this course is to develop students' understanding in MWP solving. In particular, students; (i) can set up or pinpoint the goal of a problem, (ii) know what they have and do not have, (iii) think of strategies and can choose the most appropriate strategy for solving the problem, and (iv) can verify the consistency of the solution.

The instructional methods will be as follows: control group (CI+TS), group A (CI+ID), group B (PI+ID) and group C (PI+TS), in which CI and TS stand for '*Classical Instruction*: a teacher gives explanation and show some examples' and '*Traditional Solution*' respectively. The study will utilize two measures for the pre-test and post-test: (i) mathematical test; and (ii) metacognitive questionnaire, which is modified from the 'metacognitive self-regulation' subscale of the MSLQ (Pintrich & de Groot, 1990).

6. Research Expectation

In this research, we aim to develop a computer-supported learning environment, which supports students' self-learning regulation to motivate students' metacognition. To accomplish our goal, we propose ID, which is expected to assist students to depict and reflect the whole process of solving MWP and PI, which simulates a learning environment for students to realize varieties of solutions and support them to learn from pro and con of other strategies comparing with their own strategies. Consequently, by using PI and ID we compose an alternative learning environment, CirCLE, which is designed to encourage a student's metacognition by supporting a student's self-regulated learning and reflecting his learning process. It is aimed that students can learn more effective and deeply understand MWP and they can be enhanced their metacognition via CirCLE.

References

Dillenbourg, P., & Jermann, J. (2007). Designing integrative scripts. In *Scripting Computer-Supported Collaborative Learning - Cognitive, Computational, and Educational Perspectives (Computer-Supported Collaborative Learning Series)* (pp. 275-301). Heidelberg: Springer.

Gokhale, A. A. (1995). Collaborative Learning Enhances Critical Thinking. *Journal of technology education , 7* (1).

Koedinger, K. (1991). *Tutoring Concepts, Precepts, and Rules in Geometry Problem Solving.* Pittsburgh: Carnegie Mellon University.

Kramarski, B., & Mevarech, Z. R. (2003). Enhancing mathematical reasoning in the classroom: effects of cooperative learning and metacognitive training. *American Educational Research Journal , 40*, 281–310.

Mevarech, Z. R., & Susak, Z. (1993). Effects of learning with cooperative-mastery learning method on elementary students. *Journal of Educational Research , 86*, 197-205.

Nakano, A., Hirashima, T., & Takeuchi, A. (2002). A Support Environment for Learning by Describing Problem Map. *International Conference on Computers in Education* (pp. 119-123). Auckland: IEEE Computer Society.

Palincsar, A. S., & Brown, A. L. (1984). Reciprocal teaching of comprehension fostering and comprehension monitoring activities. *Cognition and Instruction , 1*, 117-175.

Pintrich, P. R., & de Groot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology*, 82, 33–40.

Teong, S. K. (2002). The effect of metacognitive training on mathematical word problem solving. *Journal of Computer Assisted Learning , 19*, 46–55.

Topping, K. J. (2009). Peer Assessment. *Theory Into Practice , 48* (1), 20-27.

Veenman, M. J., & Spaans, M. A. (2005). Relation between intellectual and metacognitive skills: Age and task differences. *Learning and Individual Differences , 15*, 159–176.