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Circuitously Collaborative Learning Environment to Enhance Metacognition in Solving Mathematical Word Problem

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Abstract: This article 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 algebraic 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 such as giving explanations, and engaging in argumentation, negotiation, conflict resolution or mutual regulation (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 deeply understand 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. 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 (the teacher provides this), 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.

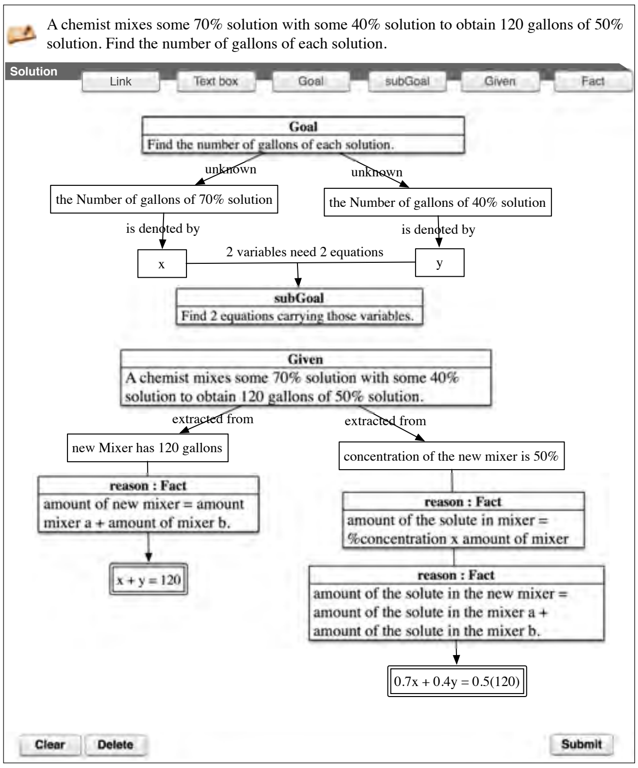
Furthermore, in this research, we also propose Initial Diagram (ID) as a solution method to be a communication media among participants to support and enhance potential of PI. The detail of ID is revealed in the following section.

3. Inferential Diagram

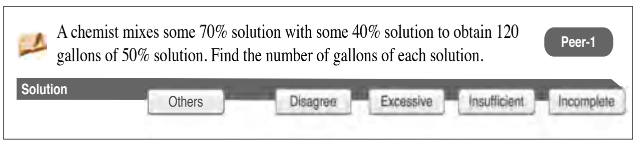
Perceptual inferences can be made more easily than symbolic inferences (Koedinger, 1991), therefore we design ID as a tool to externalize steps of inference when students solving MWP. It is used as a communication media among participants to reduce the complexity of commenting process and to foster students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

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



(a)



(b)

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

any text box on the link. See figure 1(a), the diagram could be 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. Conclusion

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.

In this study, we aim to develop a computer-supported learning environment, which supports students’ self-learning regulation to motivate students’ metacognition. Therefore, CirCLE 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.

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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.

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.

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