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A Cognitive Tool in Handheld Devices for Collaborative Learning: Comprehending Procedural Knowledge of the Addition of Common Fractions

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Abstract. The aim of this research is to design a scenario for collaborative learning using a handheld or mobile device to aid the comprehension of new procedural knowledge. A cognitive tool (CT) – the graphical partitioning model (GPM) – that aids the development of the procedural knowledge needed to add fractions with unlike denominators was established from the results of a series of experimental studies. This paper discusses the redesign of the CT for use in handheld or mobile devices. The key to mediating the generation of procedural knowledge of the addition of fractions with unlike denominators is the process of searching for common denominators in the GPM. A scenario for collaborative learning is depicted, and the distribution of the cognitive load of learners across the GPM and their collaborative learning partners is elaborated. Three essential structures that promote collaborative work are discussed, namely, task structure, incentive structure, and group motivation.

Keywords: cognitive tool, collaborative learning, common fraction, handheld/mobile devices.

INTRODUCTION

Cooperative learning promotes self-directed and active learning through group interaction on interdependent tasks (Johnson & Johnson, 1999). It has the potential to promote lifelong learning skills, such as critical enquiry, reflection, and communication capabilities, that are not as readily attained by other means. We attempt to explore the pedagogy of deep learning through cooperative learning of the subject matter in this study, which is the addition and subtraction of fractions. This topic was selected because learners seldom understand the procedural knowledge that is associated such operations (Lamon, 2001; Pitkethly & Hunting, 1996), and there is a need to overcome the separation of knowledge from meaning that occurs in classroom instruction. The goal of cognitive technology is to develop cognitive tools (CT) that work naturally for human users and meet their needs (Janney, 1999). We adopt the view that CTs are both mental and computational devices that can support, guide, and mediate the cognitive processes of learners (Kommers, Jonassen & Mayes, 1992). The aim of this research is thus to devise a computational CT to help learners to comprehend new procedural knowledge in a collaborative learning environment.

A COGNITIVE TOOL FOR COMPREHENDING THE ADDITION OF FRACTIONS

Procedural knowledge is the knowledge that guides the performance of a task without providing the knowledge that underlies the performance. The procedural knowledge that we are interested in teaching in this study is the addition of fractions with unlike denominators. Traditional classroom teaching adopts the algorithmic approach, which has the disadvantage of separating knowledge from meaning. We aim to design a CT that assists learners to generate this new procedural knowledge. The CT to support the generation of procedural knowledge of the addition of fractions originated from a Cognitive Task Analysis (CTA) of the domain. We formulated an initial prototype from the CTA and defined a model of affordances from a case study evaluation (Kong & Kwok, 2002a, Kong & Kwok, 2002b). Figures 1 and 2 show the scaffolding support of the CT. The graphical partitioning model (GPM), which is a rectangular bar with partitioning capability, was designed as the mechanism that provides the learning support. The pedagogical benefit of the GPM is that it reveals the procedural structure for evaluating fraction expressions. It links the concrete manipulations of the partitioning of the fraction bars to search for a common fractional unit with the meaning of finding a common denominator.

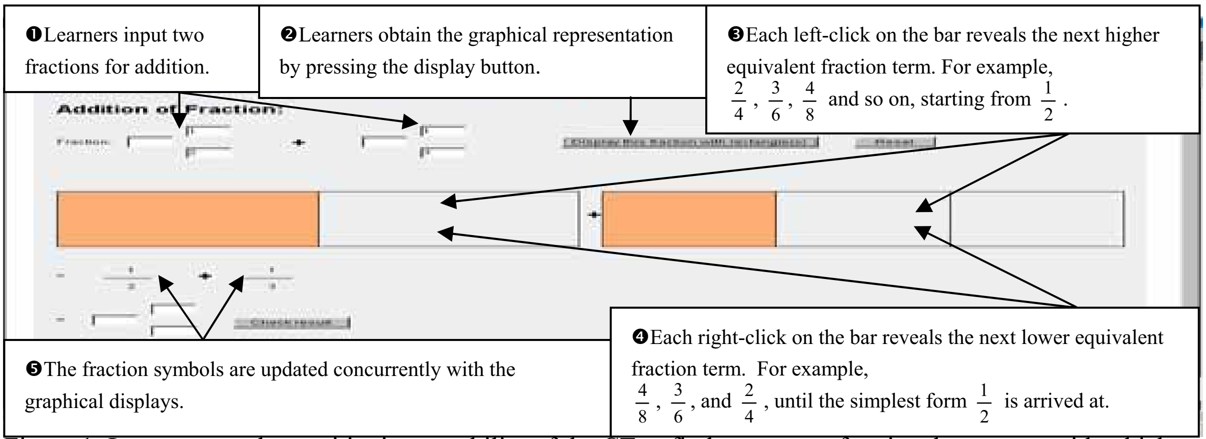

Figure 1: Learners use the partitioning capability of the CT to find a common fractional part state with which to carry out the addition process

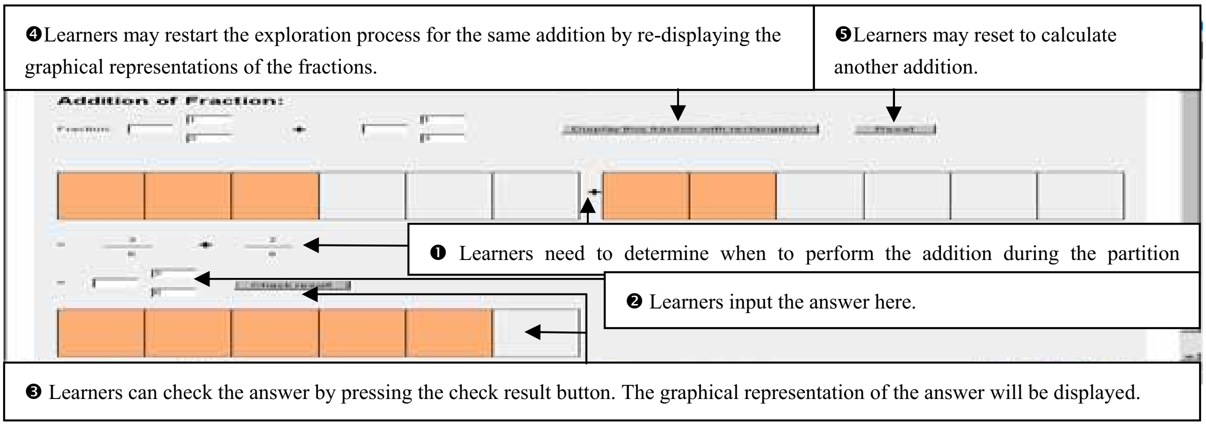

Figure 2: CT for developing the concept of requiring a common fractional part for the addition of fractions with unlike denominators

A series of experimental studies was conducted to test the effectiveness of the CT in helping students to learn about the addition and subtraction of fractions with unlike denominators (Kong & Kwok, 2002a; Kong & Kwok, 2002b Kong & Kwok, 2003, Kong & Kwok, in press). These studies explored the potential of the CT, and validated the effectiveness of the dynamic graphical model through evaluation studies. Figure 3 shows the improved hypothesis-testing interface of the GPM, which promotes reflection on the procedural knowledge that is needed for the addition of fractions with unlike denominators.

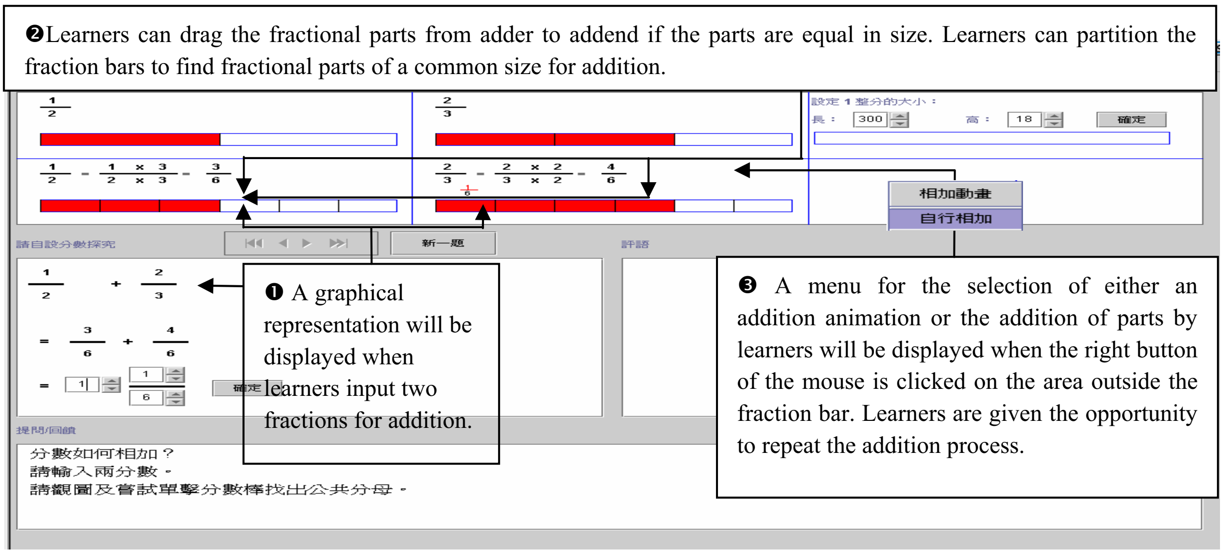

Figure 3: The GPM as hypothesis-testing bed for reflection on procedural knowledge of the addition of fractions with unlike denominators

The effectiveness of the enhanced CT was then further validated in a quasi-experimental pre-test-post-test control group study (Kong & Kwok, 2003, Kong & Kwok, in press). The results of the evaluation study indicated that procedural knowledge of the addition and subtraction of fractions with unlike denominators would indeed be generated in learners who worked with the CT if the knowledge of fraction equivalence were developed from a conceptual understanding of its meaning.

AIM AND OBJECTIVES OF THE STUDY

Scaffolding refers to the focused support that is offered to learners to help them to accomplish tasks, and especially difficult tasks, at critical times. We developed the CT for learning about the addition of fractions with unlike denominators by first assessing the learning difficulties of learners, and then designing the necessary scaffolding to support them. As handheld devices and mobile technologies are readily available nowadays, we saw the potential for developing the GPM as a collaborative learning tool for use with such devices, and thus decided to redesign the CT accordingly. Pervasive learning is a new way of using mobile and wireless devices to facilitate learning everywhere. In this study, we take pervasive learning to mean learning anywhere within a classroom. Pervasive learning through handheld devices and wireless technology provides a new dimension of mobility and connectivity, which increases communication between students and teachers, allows for a new type of collaborative learning experience, and, more importantly, increases the motivation of learners to participate actively in the learning process. We wanted to develop a pervasive learning environment to promote learning by reflection through collaborative learning in a physical-affordance environment (Roschelle and Pea, 2002). Thus, the aim of the study is to address the problem of redesigning the CT to facilitate collaborative learning. There are two objectives: to redesign the CT for handheld devices, and to add new functions to the CT to facilitate collaborative learning.

A COGNITIVE TOOL FOR COLLABORATIVE LEARNING

We needed to address two main issues in redesigning the CT for collaborative learning in handheld devices: the human-computer interface and the communication model between students and teachers. In designing the human-computer interface, we needed to preserve the original features of the CT, but also provide a new interface to facilitate collaborative learning and to allow for the constraints and limitations of handheld devices. Figure 4 shows the interface of the redesigned CT in handheld devices for paired collaborative learning.

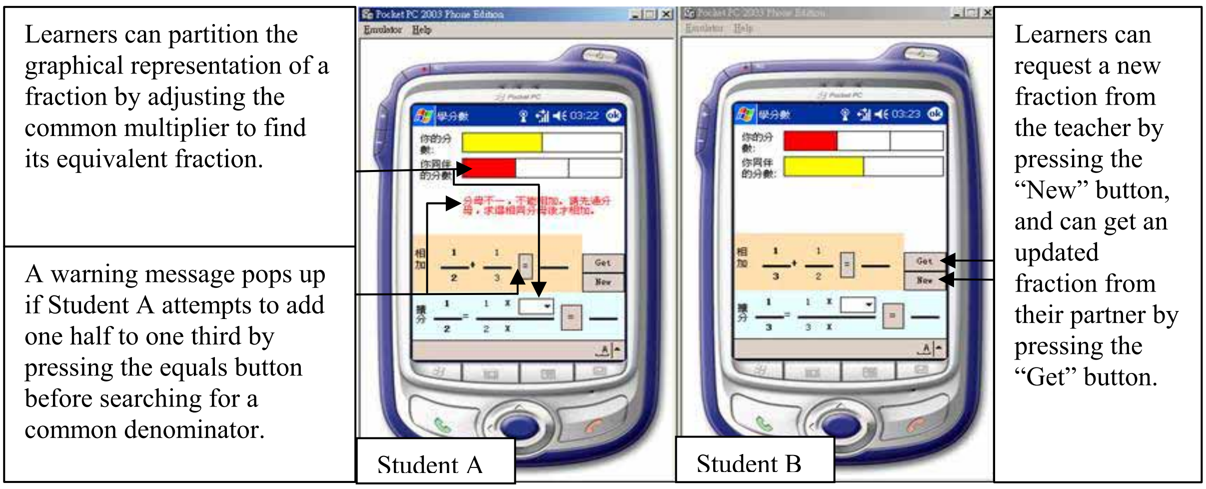

Figure 4: The interface of the redesigned CT in a handheld device for paired collaborative learning

The original GPM of the CT was preserved in the redesigned version, in that learners can still partition the graphical representation of a fraction by adjusting the common multiplier to find its equivalent fraction. However, two new features to aid communication between students and teachers were added: the Get and New functions. Learners can request a new fraction from the teacher by pressing the "New" button, and can get an updated fraction from their partner by pressing the "Get" button. The key to mediating the generation of the necessary procedural knowledge is the process of searching for common denominators. Our pervasive collaborative learning environment allows learners to distribute their cognitive load to the handheld device and to their learning partner during the search process. However, for this to work, there is a need to encourage genuine collaboration. There are three important factors in the promotion of cooperative behavior: task structure, incentive structure, and group motivation (Slavin, 1980). To promote cooperative behavior, the task structure, incentive structure, and group motivation must be designed so that the group member are mutually dependent (Sharan & Shaulov, 1990). In this section, we discuss the design of a pervasive collaborative learning environment in the classroom to aid the comprehension of the procedural knowledge through cooperative behavior.

Task Structure

The basic task that must be collaborated on is to evaluate a common fraction expression that has unlike denominators. Fraction expressions with two common fractions are generated by the computer system. All of the learners in the class are assigned to work in pairs by the teacher, and each pair of learners is assigned a fraction expression to evaluate. However, each learner receives only one half of the pair of fractions in the expression, and has to obtain a "New" fraction from the computer system for each task. Each learner then has to "Get" an updated version of the other fraction from their partner to start and continue the addition. Figure 4 shows that both learners have obtained a new fraction to add and a fraction from their counterpart to start the addition process, and that Student A has attempted to add one half to one third by pressing the equals button before searching for a common denominator. A warning message pops up and advices the student to search for a common denominator before undertaking the addition.

To accomplish this task, the learner must therefore determine an equivalent fraction to the fraction that is initially given to attain a pair of common denominators with their learning partner. This task requires cooperation between the learners in a pair. The rule that guarantees collaboration is that a learner has no right to change the equivalent state of the common fraction of their partner. In summary, the design of this task has three implications for the promotion of collaboration. Firstly, learners must cooperate before they can successfully add together two fractions with unlike denominators. Secondly, learners have to communicate and learn how to improve the efficiency of the search for a common denominator, which means that they have to reach a consensus with their partner to obtain the lowest common denominator. Thirdly, learners may seek to understand the procedure by discussing the graphical meaning of the search for the common denominator with their partner. Figure 5 shows Students A and B attempting to find equivalent fractions in the search for a common denominator.

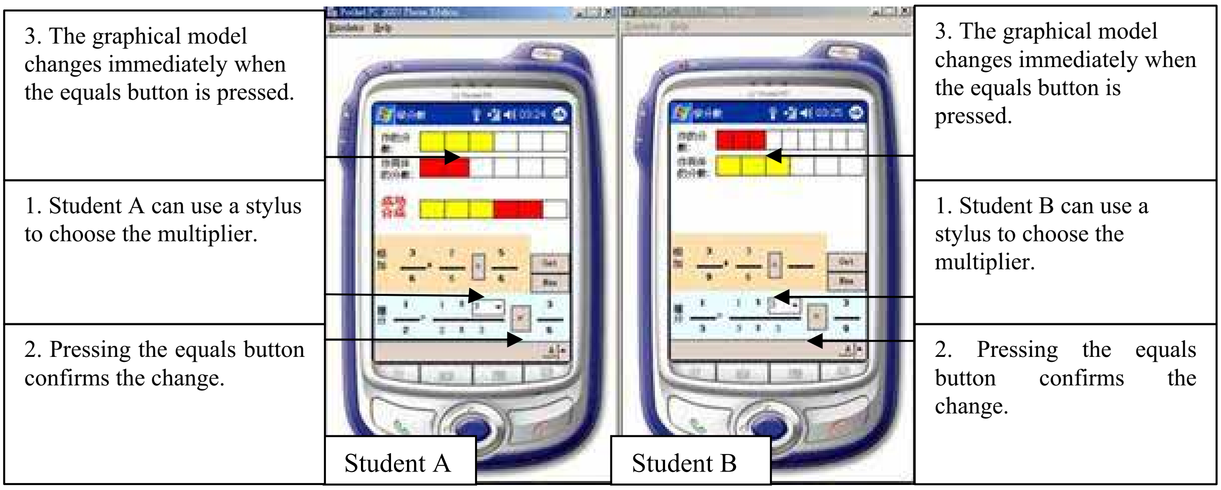

Figure 5: Students A and B attempt to find equivalent fractions in the search for a common denominator

Incentive Structure

According to Slavin (1980), incentive structure and group motivation are as important as task structure in the promotion of collaborative learning. A common practice in the assessment of performance in group work is to assign the same score to each individual learner in the group. However, this structure of assessment does not provide the individual with the incentive to contribute to the learning process, because learners obtain the same result regardless of how much effort they put in. Therefore, an incentive structure that encourages individual effort was attempted in this study. The computer checks the time that each individual takes to accomplish the task. Figure 5 shows that Student A has successfully found the common denominator for the addition, but that Student B is still searching for it. In this instance, Student A will get a higher score than Student B. The performances of learners with greater ability will thus be reflected by a shorter task accomplishment time.

Group Motivation

A teacher can define the tasks as group work, so that learners have to complete the addition tasks as a requirement for the completion of the entire task. This encourages group motivation in the learning process. In particular, group motivation can be achieved by organizing a competition between groups to complete as many of the addition tasks as possible in a given period of time. Giving awards will promote collaborative work and will provide more opportunity for learners to carry out reciprocal tutoring, which in turn will help them to better comprehend the meaning of the task. Therefore, in addition to the task and incentive structures, group motivation tactics should also be considered to motivate learners to work as a group. This is particularly applicable at the consolidation stage of the learning process.

CONCLUSIONS

In this study, we designed a collaborative learning environment using a CT for handheld or mobile devices that aids the comprehension of new procedural knowledge. A scenario for collaborative learning is depicted, and methods for distributing the cognitive load of learners across the graphical partitioning model and their collaborative learning partners are elaborated. Because the key to mediating the generation of procedural knowledge for the addition of fractions with unlike denominators is the process of searching for common denominators, the graphical partitioning model allows learners to comprehend the meaning through graphical representations. Some learners may gain this meaning through individual effort, but some learners may not be able to comprehend the meaning by themselves. Thus, three essential structures for the promotion of collaborative work – task structure, incentive structure, and group motivation – are designed and discussed. Learners in this collaborative learning environment will have more opportunity to learn from their partners, and thus more chance to comprehend the necessary procedural knowledge.

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