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Frontiers
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**TOWARDS SUSTAINABLE
AND SCALABLE
EDUCATIONAL INNOVATIONS
INFORMED BY
THE LEARNING SCIENCES**

Edited by
Chee-Kit Looi
David Jonassen
Mitsuru Ikeda

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Towards Sustainable and Scalable Educational Innovations Informed by the Learning Sciences

Sharing Good Practices of Research, Experimentation
and Innovation

Edited by

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Preface

The 13th International Conference on Computers in Education (ICCE 2005) is being held from 28 November to 30 December 2005 in Singapore. It is the latest in a longstanding series of annual international conferences held in the Asia-Pacific region, highlighting top quality research on the application of computers in education.

The theme of the 2005 conference is "Towards sustainable and scalable educational innovations informed by the learning sciences" with a subtitle of "Sharing good practices of research, experimentation and innovation." This theme reminds us that we need to be cognizant of research that can inform and lead to sustainable and scalable models of innovation. In order to do so, we need to take an inter-disciplinary view of learning, such as that embraced by the learning sciences. One of the basic principles that underpin the learning sciences is to improve theories of learning through the design of powerful learning environments that can foster meaningful learning. Learning sciences researchers prefer to research learning in authentic contexts. They collect both qualitative and quantitative data from multiple perspectives and follow developmental micro-genetic or historical approaches to data observation. Learning sciences researchers conduct research with the intention of deriving design principles through which change and innovation can be enacted. Their goal is to conduct research that can sustain transformations in schools.

ICCE 2005 will also demonstrate that learning sciences exist in the Asia-Pacific context. We have researchers and young academics within the Asia-Pacific Society for Computers in Education (APSCE) community who are concerned with issues of conducting research that can be translated into practice. Changes in practice are especially important to Asian countries because their educational systems are more centralized. Therefore, we believe that there is a need to reform pedagogy in a more constructivist and social direction in a scalable way.

Overall, we received 271 submissions for full papers and posters, of which 75 (28%) were accepted as full papers and 87 (32%) were accepted as short papers. The conference also includes 9 interactive events, 2 panels, 9 papers in the Doctoral Student Consortium, as well as paper presentations in the Local Track in which teachers in Singapore share practices and experiences of using technology in the classroom. Also in the Proceedings are brief abstracts of the talks of the four invited speakers: Joseph Krajcik of the University of Michigan, Jeremy Roschelle of Stanford Research Institute International, Takashi Sakamoto of the Japan Association for Promotion of Educational Technology, and Stella Vosniadou of the University of Athens.

The work to organize a conference of this size is immense. We would like to thank many people who have helped to make it possible. We thank Seng-Chee Tan, the chair of the Local Organizing Committee, and in particular the committee members: Wenli Chen, Ching-Puang Chin, David Junsong Huang, Li-Ching Ng, Choon-Lan Quek, Shirley Seet, Qiyun Wang, Angela Wong, Sheryl Eunice Wong, Philip Wong, and Huay-Lit Woo.

The Program Committee is critical to having a strong program. Almost all full paper submissions had 3 reviews while every short paper had 2 reviews. Thanks to all the Program Committee members for completing their reviews. Thanks, too, to the reviewers who were recruited by Program Committee members to help out in this critical task.

The committees organizing the other events at the conference also have helped to make the conference richer and broader: Doctoral Student Consortium, chaired by Yam-San Chee and Kinsuk; Tutorials and Workshops, chaired by Gee-Kin Yeo and Tsukasa Hirashima; and Interactive Events, chaired by Mun-Kew Leong and Lung-Hsiang Wong. The local track programme, which is a platform for Singapore teachers to share best practices of using technology for learning, is chaired by Sai-Choo Lee assisted by Yew-Meng Kwan, Bee-Kim Lim, Elsie Mathews and Shoo-Soon Wee. Thanks to all these colleagues.

Finally, we would like to thank Ben Chang and Hercy Cheng who provided the excellent conference submission and review system, as well as helped us to construct the proceedings.

If you enjoy participating in ICCE 2005 or reading the Proceedings, we recommend that you consider joining the Asia-Pacific Society for Computers in Education (APSCE – <http://www.apsce.net/>), an active scientific community that helps to forge on-going interactions among researchers in the Asia-Pacific region. The Society organizes the annual ICCE conferences and will start its own journal, namely, *Research and Practice in Technology Enhanced Learning*.

We certainly hope that you will enjoy the ICCE-2005 conference, and that you find it illuminating, stimulating, and enjoyable.

Programme Co-chairs

Chee-Kit Looi, National Institute of Education, Singapore

David Jonassen, University of Missouri, USA

Mitsuru Ikeda, Japan Advanced Institute of Science and Technology, Japan

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Growth of Teacher Understanding of Mathematics within a CSCL Environment

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Abstract. This study focused on growth of understanding about ratios and fractions by a group of four pre-service teachers engaged in a computer-supported collaborative learning (CSCL) environment. Participation in the CSCL environment was found to facilitate the processes of “folding back” and “thickening” [1] of mathematical concepts and thus contributed to the pre-service teachers making considerable advances in their understanding of ratios and fractions.

Keywords: cscl, mathematics education, pre-service teacher education, rational numbers

Introduction

Most current pre-service teacher education programs attempt to address pre-service teachers' limited understandings of mathematical concepts such as ratios and fractions by having them engage in workshops/seminars based on constructivist principles. However, most pre-service teachers find the experience of applying constructivist frameworks to themselves and of actively and reflectively constructing (or in most cases, reconstructing) mathematical knowledge results in much uncertainty, because they have construed their education around assumptions that their professors knew “the truth” and all that the pre-service teachers need to do is write it down, study it, and pass a test on it to prove they know it [2]. Many pre-service teachers find that unresolved uncertainty such as that engendered whilst engaged in the process of constructing mathematical knowledge in these workshops/seminars to be a disabling experience [3].

CSCL knowledge-building communities have been proposed as a means to address these feelings of uncertainty that hamper many pre-service teachers' construction of adequate repertoires of mathematical subject-matter and pedagogical content knowledge [4]. In knowledge-building communities, participants are engaged in the collaborative production of conceptual artefacts (e.g., mathematical models) that can be discussed, tested, compared, hypothetically modified and so forth and the participants see their main job as producing and improving such artefacts, not simply the completion of tasks [5].

In this paper, we trace the growth of understanding about ratios and fractions by a group of pre-service teachers participating over a period of three weeks in a computer-supported collaborative learning (CSCL) knowledge-building community [5, 6].

1. Conceptual framework

The educational effectiveness of CSCL environments is highly dependent on the quality of tasks [6, 7, 8] and the cognitive scaffolds [8, 9] provided to participants within the CSCL

environment. Therefore, the major foci of conceptual framework that informed the design of the CSCL environment in this study were on the design of tasks and design of cognitive scaffolds.

Knowledge-building discourse is predominantly derived from investigations of real, authentic problems that learners really care about [6]. Scardamalia [6] also has suggested that idea diversity is essential to the development of knowledge advancement - idea diversity creates a rich environment for ideas to evolve into new and more refined forms. Therefore, the design of the task was influenced by Scardamalia's [6] *socio-cognitive* principles of: (1) real-world authentic problems (i.e., it should be a real and authentic problem for the pre-service teachers that they would want to invest time and effort in), and (2) diversity of ideas (i.e., it should provide a context that would stimulate a diverse set of ideas from the pre-service teachers).

According to Berenson [10] the task of lesson planning provides a 'real-world' authentic context for pre-service teachers to investigate and advance their subject-matter and pedagogical content knowledge of mathematics topics such as ratios and fractions. Also, previous research by proponents of Lesson Plan Study has suggested that lesson plan study provides contexts that encourage the presentation and discussion of diverse ideas by pre-service teachers [10]. Therefore, in this study, the task administered to the participants was to design an initial lesson plan for the teaching of fractions and ratios to Year 7 students. It was hypothesised that because this task was consistent with the principles of real-world authentic problems and encouragement of diverse ideas, it would provide a context to engender knowledge-building discourse about the subject-matter and pedagogical content knowledge of ratios and fractions.

The design of the scaffolds used in this study was informed by Scardamalia's socio-cognitive principles for knowledge-building classrooms [6], by Nason's [4] previous research on scaffolding knowledge-building discourse within CSCL environments for pre-service teachers, and by Berenson's [10] research on Lesson Plan Study. The following set of cognitive scaffolds was inserted into Knowledge Forum to facilitate knowledge-building discourse: 1) APPROPRIATE PRAISE, 2) HOW YOUR IDEAS HAVE INFLUENCED MY IDEAS, 3) HOW ARE YOUR IDEAS LIKE MY IDEAS, 4) HOW YOUR IDEAS ARE DIFFERENT FROM MY IDEAS, 5) QUESTION (I need to understand), and 6) PROPOSAL (How you can improve your lesson plan). Based on findings from previous research with pre-service teacher computer-mediated knowledge-building communities [e.g., 4], it was hypothesised that the critiquing and the posing of questions about other groups' lesson plans facilitated by this set of cognitive scaffolds would induce knowledge-building discourse in the following ways:

- Encouragement of the presentation and discussion of diverse ideas (consistent with Diversity of Ideas Principle [6])
- Focusing pre-service teachers' attention on similarities and differences between the lesson plans (consistent with Knowledge Building Discourse Principle [6])
- Encouragement to re-examine key notions imbedded in lesson plans (consistent with Epistemic Agency Principle [6])
- Improvement of lesson plans (consistent with Improvable Ideas and Rise Above Principles [6])

2. Design and Method

This study used a teaching experiment methodology [11]. Lesson plan study [10] was the vehicle chosen to frame the teaching experiment. This methodology was extended by

having the pre-service teachers collaboratively design lesson plans for the teaching of fractions and ratios within the context of a computer-mediated knowledge-building community. The ten participants (all Caucasian females) in the study were volunteers from a cohort of preservice teachers (N=350) enrolled in a four-year Bachelor of Education degree course at an urban Australian university. At an initial meeting at the beginning of the study, the participants were asked to form three small working groups. One group of four participants (Group 1) and two groups of three participants (Groups 2 and 3) were formed. These three self-selected groups were formed on the basis of friendships and the pragmatics of timetabling of the participants' classes.

This paper focuses on the growth in understanding by Group 1. The four members of this group (Karen, Tracey, Liz and Natasha) were in their mid-30s. Karen felt that she had a good understanding of ratios and fractions. However, an assessment of her knowledge about ratios and fractions conducted prior to this study found that her understanding was instrumental and rote in nature. Tracey, Liz and Natasha felt that they had very limited understanding of ratios and fractions. Their perceptions were confirmed in the assessment of their knowledge about ratios and fractions conducted prior to this study.

2.1 Procedure

2.1.1 Phase 1 - Generation of initial group lesson plans

Each group was asked to meet twice face-to-face and engage in the development of an initial lesson plan on ratio and fractions for a class of Grade 7 students. These sessions were videotaped for later analysis. To facilitate this process, each group was provided access to a library of mathematics education source books and curriculum materials, teachers' manuals and teaching journals and to a wide variety of continuous and discrete concrete teaching aids. At the conclusion of these meetings, each group was required to post its lesson plan onto Knowledge Forum[®], a computer-supportive collaborative learning environment. Once the lesson plan had been posted onto Knowledge Forum, it could be viewed by the participants in other groups and by the two expert mathematics educators who acted as mentors to the knowledge-building community.

2.1.2 Phase 2- Evaluation and revision of lesson plans

During this phase that occurred over a period of two weeks, each group was engaged in two types of activities: 1) reading and constructive critiquing of other groups' lesson plans, and 2) iteratively evaluating and revising their own lesson plans.

During this phase, as well as reading the other groups' lesson plans posted on Knowledge Forum, the participants also were encouraged to engage in constructive critiquing of and the generation of explanatory/elaborating questions about the lesson plans. The process of commenting and critiquing was facilitated by the set of cognitive scaffolds inserted in Knowledge Forum.

Each group made three revisions to their lesson plan. These revisions were based on the feedback via Knowledge Forum from the participants in other groups. Revisions to the group lesson plans occurred in face-to-face group meetings. In these meetings, the groups reviewed and evaluated the comments they had received from the other groups, referred to source documents such as curriculum guides, text books and teaching guides, and then made revisions to their lesson plan. The revised lesson plan was then posted onto the

Knowledge Forum shared database to enable further feedback. These face-to-face meetings were videotaped to observe the process of developing the content and structure for the lesson plan.

2.1.3 Phase 3 - Presentation of final group lesson plan

At the end of Week 3 of the study, each group was required to submit a final group lesson plan via Knowledge Forum. At the conclusion of this phase, each group of participants engaged in a focus interview during which they were required to reflect on what and they had learnt.

2.2 Analysis of data

The primary focus of the analysis of data from videotaped observations, interviews, Knowledge Forum notes and lesson plans was on the growth of knowledge. The model developed by Pirie and Kieren [1] provided the framework for tracing the growth of understanding about ratios and fractions. Pirie and Kieren's model is one of actions and interactions where growth in understanding occurs through a continual movement back and forth between and among eight layers of understanding activities as the individual reflects on and reconstructs current and previous knowledge [12]. In this study, we focused on the first four layers. The innermost layer is that of *primitive knowing* consisting of all of one's previous knowledge and serves as the reservoir from which to build subsequent understanding. Moving outward within the model are the *image making* and *image having* layers. Image making is the activity of creating an internalised image, a representation that can be used in place of something that may once have been in the learner's perceptual field. The result is a state of image having, where the constructed image is accessible and comparisons to it can be made. These two layers of activities play a prominent role in our analysis. The other layer of activities used here is *property noticing*. Identifying properties of the constructed image defines property noticing [1].

When faced with a problem at any layer that is not immediately solvable, an individual often returns to an inner layer of understanding. This shift to working at an inner layer of understanding actions is termed *folding back*. It enables the learner to make use of the current outer layer of knowing to inform inner understanding acts, which in turn facilitate further outer layer understanding. Consideration of the concept at a more basic level may result in the *thickening of a concept*. That is, the construction of a thicker, more robust understanding of the concept that can then be examined from the higher-level perspective. According to Pirie and Kieren [1], folding back and thickening are the primary mechanisms that give rise to a more sophisticated and deeper understanding of a concept.

The secondary focus of the analysis of data from the videotapes of the planning sessions, Knowledge Forum database and from the interviews was on the factors that influenced the growth in mathematical knowledge. Therefore, quantitative data about participation in the on-line discourse was collected. As each lesson plan was posted, Knowledge Forum tracked the number of times it was read and by how many people. Knowledge Forum also was used to track the number of times each feedback comment was read and reacted to. The content of each of the comments was qualitatively analysed to note its contribution to the advancement of knowledge. The number of times each scaffold was used was also recorded. In addition to this, the notes produced each time a scaffold

was utilised were qualitatively analysed in order to ascertain how they contributed to growth in knowledge by the recipients of the comment.

3. Tracing Group 1's Growth in Understanding

In their initial lesson plan, Group 1 focused on the part-to-whole notion of a fraction (i.e., $\frac{3}{8}$ means three parts out of eight equal parts) and the part-to-part notion of ratio (i.e., 3:5 means 3 parts to 5 parts). Group 1's understanding of part-to-whole notion of fractions as reflected in their selection of instructional representations and the questions they utilised with the instructional representations was at Pirie and Kieren's image having layer of understanding: their understanding was related to the image provided by the continuous pizza model representation of a fraction. Similarly, their understanding of the part-to-part notion of ratio was at the image having layer. However, their understanding of the part-to-part notion of ratio was related to the image provided by a discrete set model (toy monkeys and zebras). The group failed to make conceptual linkages between the part-to-part notion of ratio and the part-to-whole notion of fractions.

When their initial lesson plan was viewed by pre-service teachers from the other two groups, most of the constructive critique and questions focused on the instructional representations they had chosen. Based on an analysis of the Knowledge Forum on-line discourse, the revisions made to lesson plans, and data from post-study interviews with members of Group 1, it was found that the following thread of Knowledge Forum on-line discourse played a crucial role in advancing Group 1's understanding of ratios and fractions.

Carolyn: [PROPOSAL] To make it easier for children to learn, you should use your part/part example (i.e., toy monkeys and zebras) rather than the pizza model to link the part/part ratio and the part-whole fraction idea

Lauren: [PROPOSAL] I agree with your comment. Why don't you use the monkey and the zebra toys to model the part-part and part-whole ideas?

The on-line comments by Carolyn and Lauren proposing the use the discrete set model rather than the continuous pizza model provided Group 1 with the catalyst to fold back from the image having layer of understanding to the image making layer of understanding (see continuous line in Figure 1). At the image making layer, they were able to investigate the part-to-whole aspects of the discrete model by quantifying not just only how many monkey and zebra toys were in the set (i.e., the parts) but also how many toys were in the whole set. They thus were then able to remake the image of the part-to-whole notion of a fraction to include not only the continuous models (such as pizzas) but also discrete set models (such as toy monkeys and zebras). Thus, instead of their understanding of part-to-whole notion of a fraction being limited to just continuous model images (such as pizzas), the group now also had alternative discrete model images of fractions to complement their discrete model image of the part-to-part ratio notion. The generation of this extended (or what Pirie and Martin [12] refer to as "thickened") part-to-whole fraction image led the group members' understanding of both part-to-part ratio and part-to-whole fraction notions to progress from image having to the property noticing layer of understanding (see Figure 1). That is, the group members had extended their understanding to notice the commonalities and differences in properties between the mathematical notions and were now able to make conceptual links between these two fundamental mathematical notions.

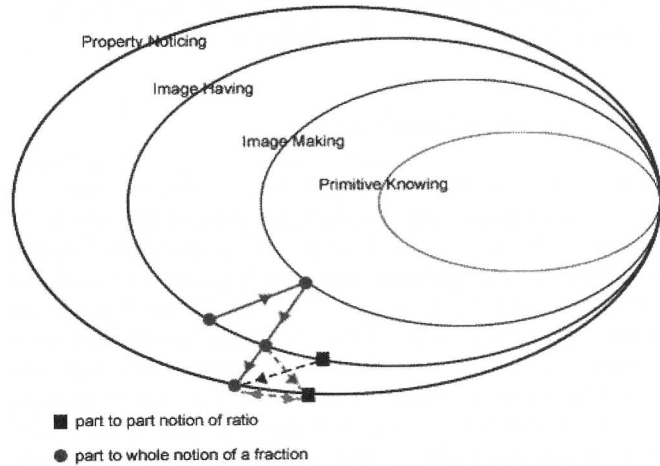


Figure 1 Tracing Group 1's growth of understanding of fractions and ratio

Their growth in understanding illustrated in Figure 2 was reflected in their final group lesson plan where: (1) discrete set models (dingo and echidna toys and unifix) were used as instructional representations for both part-to-part ratio and part-to-whole fraction notions, and (2) clear two-way linkages were made between part-to-part and part-to-whole fractions and ratio.

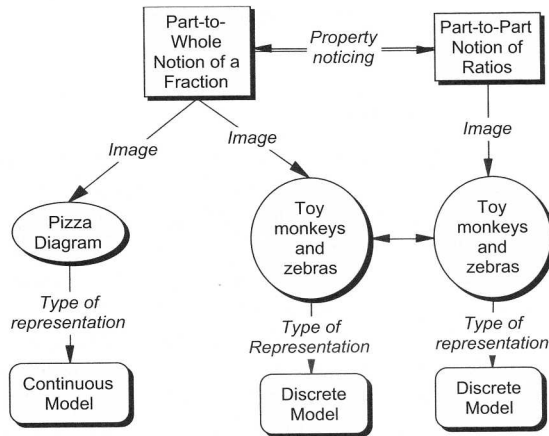


Figure 2 Group 1's Final understanding of ratios and fractions

4. Factors influencing growth of knowledge

The analysis of the data revealed that the lesson planning task and the cognitive scaffolding both played crucial roles in the growth of knowledge.

Knowledge transforming discourse is central to knowledge building because it is the means through which knowledge is formed, criticised, and amended [6]. Therefore, it is

important to have most participants actively engage in the knowledge-building activity of the community. An analysis of the Knowledge Forum data clearly indicated that the lesson planning task provided the catalyst for high levels of participation and rich discourse in the Knowledge Forum environment by all participants. On three occasions, a single posting was read over 60 times. This occurred after each of the three groups had posted their initial lesson plans on the Knowledge Forum shared database. The number of different people reading these comments also showed that a majority of the community reviewed and critiqued these lesson plans. The community participants read each of the comments an average of 16.65 times.

However, as well as simply being active in the reading and posting of comments, participants need to engage in deep-level critiquing of knowledge objects being constructed. To facilitate the process of building greater depth of understanding within the Knowledge Forum community, this study employed scaffolds to promote community discourse and cognitively prompt the participants in developing teacher knowledge through critiquing of the lesson plans. The analysis of the data indicates that the cognitive scaffolds facilitated discourse leading to in-depth analysis of important issues pertaining to the teaching and learning of ratios and fractions. The PROPOSAL scaffold was used fourteen times. It was found that comments that utilised this scaffold were crucial in helping each group of participants overcome impasses blocking the advancement of their lesson plans (and their growth of knowledge about ratios and fractions). The scaffold QUESTION was utilised ten times. It was found to help each group to organise and clarify their ideas about fractions and ratios. The scaffolds (HOW YOUR IDEAS HAVE INFLUENCED MY IDEAS; HOW YOUR IDEAS ARE LIKE MY IDEAS; and HOW YOUR IDEAS ARE DIFFERENT FROM MY IDEAS) were very effective in interconnecting ideas between the three groups that lead to the best ideas about the teaching of ratios and fractions rising up and coming to the fore as the study progressed.

5. Discussion

By the end of this study, the group of four pre-service teachers had developed deeper understandings about ratios and fractions. This was evidenced by: 1) a thickening of their knowledge about the part-to-whole notion of a fraction at the image having layer from being one based on the continuous pizza model image to one that was also based on discrete model images too, and 2) the extension of their understandings about the part-to-whole notion of a fraction and the part-to-part notion of ratios beyond the image having layer to the property noticing layer. Thus, by the end of the study, this group of pre-service teachers not only had richer, thickened conceptions about both the part-to-part notion of ratio and the part-to-whole notion of a fraction but also were able to conceptually link these two notions.

The analysis of the data with respect to factors that underlay the growth in knowledge indicated that the Knowledge Forum discourse mediated by the lesson planning task and the set of cognitive scaffolds played a crucial role in facilitating the growth in their understanding.

Previous CSCL research [6, 7] has highlighted the importance of providing participants in CSCL communities with rich authentic tasks that encourage discourse. The lesson planning task provided to the participants in this study situated the learning about ratios and fractions in a context that was authentic and meaningful for the pre-service teachers. This enabled the participants to relate ratios and fractions to their own previous experiences and to utilise their combined knowledge to engage in discourse about real-

world exemplars and instructional representations of ratios and fractions. Ironically, their limited but diverse repertoires of knowledge about ratios and fractions that they brought to this lesson planning task probably was one of the major factors that led to this particular task being so successful in acting as a catalyst for the knowledge-building discourse. This is consistent with Scardamalia's [6] viewpoint that diversity of ideas is an important condition necessary (but not sufficient) for knowledge-building discourse. The implications of this for future studies involving lesson planning study within CSCL knowledge-building communities is that the topic(s) chosen for lesson planning should be complex, multifaceted and interrelated in nature (like ratios and fractions) and ones in which the participants have limited repertoires of formal knowledge but diverse repertoires of real-world exemplars.

Previous CSCL research [8, 9] also has highlighted the importance of providing effective cognitive scaffolding within CSCL environments. The findings from this study confirm these previous findings. In this study, the scaffolds focused primarily structuring the preservice teachers' endeavours to construct their lesson plans. However, Reiser [13] contends knowledge-building discourse maybe could also advanced by provoking issues with students where they are forced to confront key disciplinary ideas in their solutions to a problem. Therefore, in future studies involving preservice teachers engaged in lesson planning tasks within a CSCL environment, knowledge-building discourse possibly could be further enhanced by including what Reiser refers to as problematising scaffolds as well as structuring scaffolds.

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