Growth of Teacher Knowledge within an On-line Collaborative Learning Environment

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This paper focuses on the growth of understanding about ratios and fractions by a group of four pre-service teachers engaged in an on-line knowledge-building community Pirie and Kieren's (1994) model for the growth of mathematical understanding was used as the framework for analysing their growth in understanding This analysis revealed that the pre-service teachers made considerable advances in their understanding of ratio and fraction instructional representations and mathematical constructs embedded in ratios and fractions

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 (Bereiter, 2002; Scardamalia, 2002) engaged in the design of lesson plans about ratios and fractions We had two reasons for studying prospective teachers' understanding of ratio and fractions First was that we consider the ideas subsumed under ratios and fractions to be foundational to many mathematical topics Second was that many teachers have limited understandings of ratios and fractions (Post, Harel, Behr, & Lesh, 1988; Stacey, Helme, Steinle, Baturo, Irwin, & Bana, 2001)

Most current preservice teacher education programs attempt to address preservice teachers' limited understandings of mathematics by having them engage in workshops/seminars based on constructivist principles However, according to Lampert (1988), most preservice teachers find the experience of applying constructivist frameworks to themselves and of actively and reflectively constructing (or in most cases, reconstructing) knowledge results in much uncertainty, because they have construed their education around assumptions that their professors knew "the truth" and all that the preservice teachers needed to do was write it down, study it, and pass a test on it to prove they knew it (Lampert, 1988, p 165) Many preservice teachers find that the unresolved uncertainty engendered whilst engaged in the process of constructing mathematical knowledge in these workshops to be a disabling experience (Floden & Buchman, 1993) CSCL knowledge-building communities have been proposed as a means to address these feelings of uncertainty that hamper many preservice teachers' construction of knowledge (Brett, Nason, & Woodruff, 2002) In knowledge-building communities, participants are engaged in the collaborative production of conceptual artefacts (e g , mathematical ideas and 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 (Bereiter, 2002)

The educational efficacy of CSCL environments is highly dependent on the quality of tasks (Barab, Moore, & Cunningham, 2000; Chaney-Cullen & Duffy, 1999) and the cognitive scaffolds (Scardamalia & Bereiter, 1994; Weinberger, Fischer, & Mandl, 2002) provided to participants within the CSCL environment Therefore, in this study, much thought went into the design of the tasks and the cognitive scaffolds

The task given to the participants in this study was to design an initial lesson plan for the teaching of fractions and ratios to Year 7 students Proponents of Lesson Planning

Study (e g , Stigler & Hiebert, 1999) have suggested that as teachers prepare their lesson plans, they are influenced in particular by their knowledge and views in three areas: the subject matter, students' learning, and the reasons for inclusion of the topic in the curriculum Therefore, it was hypothesised that having the participants engage in the lesson planning task would provide a context to engender knowledge-building discourse about the subject matter and students' learning about ratios and fractions

The design of the scaffolds used in this study was informed by previous research on scaffolding knowledge-building discourse within CSCL environments (e g , Brett, Nason & Woodruff, 2002; Scardamalia, 2002) 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 , Brett et al , 2002), 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 a deeper level of understanding about ratios and fractions

Design and Method

This study used a teaching experiment methodology (Steffe, 1991) Lesson plan study (Stigler & Herbert, 1999) 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 (c f , Brett, Nason &, Woodruff 2002) 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 Queensland University of Technology 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, returning to the university after previous career and family experiences Karen felt that she had a good understanding of ratios and fractions However, in an assessment of her knowledge about ratios and fractions conducted prior to this study (Berenson & Nason, 2002), it was found that her understanding was instrumental (Skemp, 1979) 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 (Berenson & Nason, 2002)

Procedure

This study proceeded in three phases: 1) Generation of initial group lesson plan, 2) Evaluation and revision of group lesson plans, and 3) Presentation of final group lesson plan

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® (Scardamalia & Bereiter, 1998), 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

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

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

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 (1994) 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 (Pirie & Martin, 2000) 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 (Pirie & Kieren, 1994)

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 (1994), 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 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

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 , 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 (2000) 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

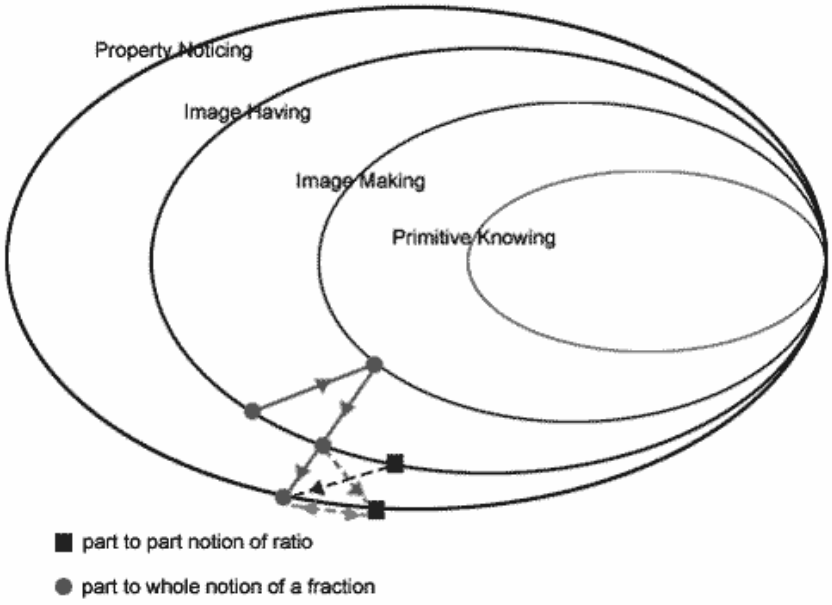

Figure 1 Tracing Group 1's growth of understanding of fractions and ratio

This 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

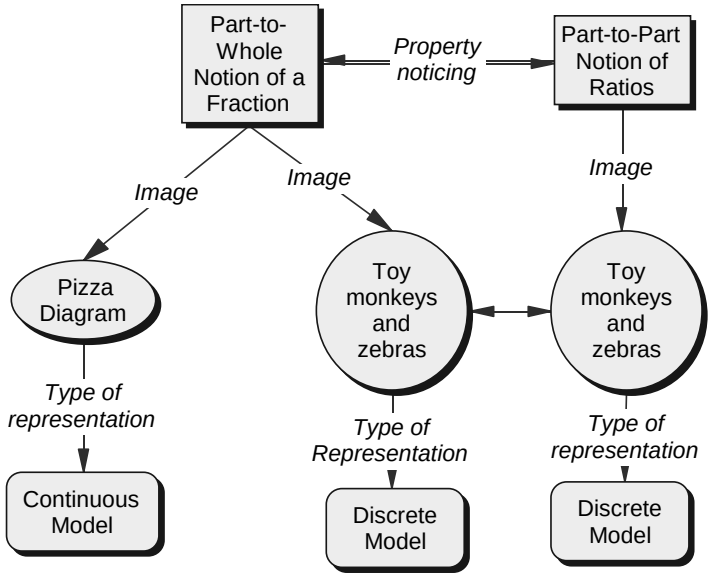

Figure 2 Group 1's Final understanding of ratios and fractions

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 (Scardamalia, 2002) 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 coming to the fore as the study progressed

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 (e g , Barab, Moore, & Cunningham, 2000; Chaney-Cullen & Duffy, 1999) 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 preservice 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 (2002) 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 many and diverse repertoires of real-world exemplars

Previous CSCL research (e g , Scardamalia & Bereiter, 1996; Weinberger, Fischer, & Mandl, 2002) 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 (2002) contends knowledge-building discourse could also be 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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