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The Developing Influence of Social Theories of Learning on Technology Enhance Mathematics Classrooms

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This paper will document the emergence of a social perspective on teaching and learning mathematics in conjunction with digital technologies by examining the proceedings of events sponsored by the International Commission on Mathematical Instruction over the past 20 years. Recent research literature that addresses the role of technology in mediating collaborative learning practices within mathematics classrooms will also be reviewed with particular attention to theoretical frameworks which seek to describe and explain the interactive processes which take place when students work with technology as individuals and when working with teachers and peers.

Introduction

Schrage's (2001) reflection that ICTs have instigated a relationship revolution rather than an information revolution, because of the communities that emerge through the use of digital tools, parallels Lerman's (2000) observation of an emergence of a social-perspective on teaching and learning mathematics. At the 9th ICME, held in Makuhari, Japan, Lerman presented a plenary lecture to the congress entitled The Socio-cultural Turn in Studying the Teaching and Learning of Mathematics (Lerman 2000). In this address he argued that there was growing interest in, and increasing research support for, theories of learning in which thinking, reasoning and meaning making originate in and/or are mediated by social activity.

> The term social turn in my title is intended to signal something different, however, namely the emergence into the mathematics education research community of theories that see meaning, thinking and reasoning as products of social activity. (Lerman, 2000, p.157)

Prominent among social theories of learning are those of socio-culturalism and socio-constructivism. While these theories are fundamentally different in terms of the role of social interaction in learning, thinking and intellectual development, both assign a central role to social activity in mathematical learning. A summary of key elements of these theories is presented below.

Social-constructivism

Constructivist theories of intellectual development assign an active role to the learner in the construction of unique and personal knowledge through the development of symbolic representations that are used to interpret and interact with the world (Noddings, 1990). Intellectual growth begins, from a constructivist perspective, when a learner encounters an idea, phenomena or practices that conflict with their world view. This state of cognitive conflict, or disequilibrium, was identified by Piaget as fundamental to the process of intellectual development. Learning occurs when an individual is able resolve the conflict by rearranging their cognitive structures in such a way that the conflict is accommodated and assimilated into the individual's cognitive structure. While this process portrays learning as an individualistic enterprise that takes place "in one's own head", more recent developments within constructivist theory acknowledge the role of interaction between teachers and learners and between learners themselves in provoking the necessary state of disequilibrium and also in the resolution of cognitive conflict (see for example, Cobb & Bauersfeld 1995). Thus, while social interaction can be a source of disequilibrium, it can also be the means by which a cognitive conflict is resolved by mediating the development of new knowledge and meaning structures.

Socio-culturalism

By contrast, socio-cultural theories of learning are founded on a position that intellectual development originates in, and so is not just facilitated by, social interaction. Learning is a process of enculturation into the practices of a learning community. Enculturation into the community requires the appropriation of modes of reasoning, discourse and knowledge creation that are accepted by the discipline around which the community is based. Learning mathematics in such a community means a learner must participate in debate about new ideas and practices , offer critique of others ideas, and defend their own propositions via explanations and justifications (Goos, Galbraith, Renshaw, & Geiger, 2000).

In addition, socio-culturalism acknowledges the role of both cultural tools, such as language representations and sign systems, and physical arefacts, such as calculators and computers, in mediating learning. The appropriation of tools into accepted modes of reasoning and discourse is also an important part of the enculturation process. Thus, a learner must acquire more than facility with such tools - they must also appropriate new modes of reasoning, argumentation and knowledge validation in which digital tools are seamlessly integrated.

It is not the purpose of this paper to argue in favour of either theoretical position; the descriptions presented above are included to provide a backdrop for a review of the emergence of social perspectives on mathematical learning through the history of ICMI. The review presented below, is inclusive of all theoretical frameworks that assign an important role to social interaction in the learning and teaching of mathematics.

The Development of a Social Perspective on Using Digital Tools to Enhance Mathematics Learning through the Activities of ICMI

A growing body of research is developing around the idea that there is now great potential to think *with* technology. Pea (1985, 1993a, 1993b), for example, draws on a Vygotskian view of learning to argue that learning and reasoning should now be considered the activity of a system which involves minds, social contents and tools such as computers, that is, that thinking is *distributed* among and between these elements. It has been argued by Geiger (2005, 2006), Goos, Galbraith, Renshaw and Geiger (2000, 2003) and Goos, Galbraith, and Renshaw (1999), that productive social interaction in mathematics classrooms can be mediated by technology. Goos and associates developed a typology of technology use in which two metaphors, *Technology as Partner* and *Technology as Extension-of-self*, are used to describe patterns of student-student-technology behaviour where the boundaries between human and technological agents are blurred when students are learning and using mathematics. Consistent with this view, Borba and Villarreal (2005) propose a unit of analysis for research in mathematics learning in technology rich environments, *humans-with-media*, which recognises the integral role technology can play in the reorganisation of mathematical thinking and that the contributions of humans and ICTs in promoting learning are not easily separated.

While these examples of research are representative of a body of knowledge that recognises the role of both technology and social interaction in mathematical learning, they do not in themselves demonstrate a broad acceptance of this view. In order to establish the validity of Schrage's (2001) observation and Lerman's (2000) claim of a shift in interest towards a more social view of teaching and learning, selected documents are reviewed that record the activities of ICMI over a period of approximately 20 years. To benchmark interest in the role of social activity in technology influenced mathematics teaching and learning, the proceedings of ICME 5 (Carss, 1986) and proceedings of the first ICMI study *The Influence of Computers and Informatics on Mathematics and its Teaching* (Churchhouse, 1986) were chosen for review. These two sources were selected because it was in the 1980s that computer technologies became widely available to mainstream schools. Judgement about growth of interest in social perspectives on the potential of technology to enhance mathematics teaching and learning will be achieved by contrasting evidence from the two sources in 1986 with a review of relevant sections of the proceedings of ICME10 (Niss, 2008), the most recent congress for which proceedings are available, and the proceedings of ICMI's seventeenth study symposium, *Digital Technologies and Mathematics Teaching and Learning: Rethinking the Terrain* (Hoyles, Lagrange, Son & Sinclair, 2006).

Early Interest in Technology for Enhancing Mathematics Learning

The proceedings of the Fifth International Congress on Mathematics Education (Carss, 1986) includes the report of a theme group, *The Role of Technology*, and a record of a plenary debate between Hugh Burkhardt and Philip Davis entitled *The Microcomputer: Miracle or Menace in Mathematics Education*. The theme group report includes a vignette related to a presentation by Rosemary Fraser in which she invited the audience to participate as "pupils" in a simulated classroom. By working with participants in this way and using only a single microcomputer and two programs, *Pirates* and *Eureka*, Fraser "illustrated clear role-shifting with children taking over computer and teacher roles, resulting naturally in problem solving and open-ended activities" (Carss 1986, p. 160). While this indicates a clear interest in pedagogical aspects of computer use in school mathematics classrooms and, in particular, on the role technology can play is transforming traditional classroom roles, there is no indication of the type of social interaction which took place during this session. This theme group appeared to be more concerned with the potential of technology to transform mathematics itself rather than the way it was taught and learned as is illustrated by the following quote from the theme group's report.

> Computer science changes the philosophical foundations of mathematics. It affects what mathematics is to be taught, the development of symbolic systems, doing more experimental mathematics, new skills, observation, visualisation, simulation and numerical verification.
> (Fraser, Meissner, Ralston, Roseveare, & Mohyla, 1986, p.174)

The only reference in the theme group report to pedagogy, or the types of interaction which might take place in a classroom, concedes "Computer science changes pedagogical styles. The computer will alter the pupil teacher relationship" (p. 174). There is no discussion of how the pupil teacher relationship will change or any comment on the role of student-student interaction in learning or how peer interaction might be influenced by the availability of computer technology.

The diagram that accompanies the quote above, Figure 2 below, identifies the interactions that that computers were perceived to have the power to influence.

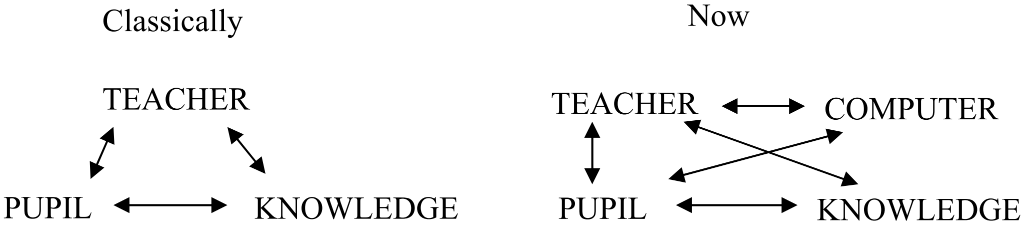

Figure 2. Pupil teacher relationship (Fraser et al. 1986, p.174)

Noteworthy, in this view of a future technology enhanced classroom, is that pupils are looked upon as individual agents in the learning process and that negotiation between themselves and the teacher, while bidirectional, are conducted on a one-to-one basis. Again, no space is allowed for student-student interaction or how this type of interaction might affect learning and teaching.

At the same Congress, Burkhardt and Davis debated the potential benefits of computers in mathematics classrooms with both presenters outlining the advantages that were perceived to, at the time, lie within the capacities of the computer. Burkhart, in particular, painted a picture of a future classroom in which teachers would be supported by a digital teaching assistant that would assume a substantial part of a teacher's load of explaining and managing task setting, thus freeing teachers to assist students with less directed activities such a problem solving. There was no discussion of how technology could be used to facilitate productive interactions between teachers and students or between students and their peers.

In March of the same year, the first of ICMI's seventeen studies was initiated via a symposium held in Strasbourg, Germany. The proceedings of that meeting, *The Influence of Computers and Informatics on Mathematics and its Teaching* (Churchhouse, 1986), document the activity of the symposium under the following themes:

1. How do computers and informatics influence mathematical ideas, values and the advancement of mathematical science?
2. How can new curricula be designed to meet changing needs and possibilities?
3. How can the use of computers help the teaching of mathematics?

The report on the third theme opens with a discussion of what mathematics and mathematical activity might look like in a classroom of the future. The report argues that, in the future, the availability of computers in classrooms will mean:

> ...the experimental aspects of mathematics assume greater prominence, and there is a corresponding wish to ensure that provision should be made for students to acquire skills in, and experience of, observing, exploring, forming insights and intuitions, making predictions, testing hypothesis, conducting trials, controlling variables, simulating, etc. (pp. 24-25)

Curiously, despite a description of what we would consider now to be activities students might engage in as a group, there is no commentary of how students might work together, or how they might learn from each other during such activity. Later in this section there is acknowledgement that computers have the potential to transform the roles of teachers, students and technology in the mathematics classrooms.

> ...this creates new interactions and relationships between student, knowledge, computer and teacher. (p. 25)

While there is recognition, here, that interaction has a role to play in teaching and learning, the sense is still that interactions are between an *individual* student, their teacher and technology.

In summary, interest in computers during the late 1980s, in relation to the teaching of mathematics, focused principally on the capacity of digital technology to provide teachers with tools to assist the individual learner and in the way the mathematics itself, in schools, would be transformed.

Recent Interest in Technology and Mathematics Teaching and Learning from a Social Perspective

Moving forward to ICME-10, held in Copenhagen in 2004, the most recent Congress for which proceedings are available, there is a marked change in the attention given to social interaction in the process of learning and to the role of technology in mediating collaborative learning in mathematics. Celia Hoyles, in a plenary that described her work over two decades, reports:

> In a later project, WebLabs (www.weblabs.eu.com/), we extended our design work still further and shifted its focus to iteratively building tools and activity sequences in which students, in different sites across Europe, program models of their mathematical and scientific knowledge and then share, discuss and modify the models through a web-based system, WebReports. We try to ensure that the potential of collaboration is exploited in all its forms, by including asynchronous discussion and exchange around WebReports as part of any activity sequence, alongside synchronous interchange, both face-to-face and at a distance. We also aim for a more explicit promotion of learning mathematics through the processes of modelling and sharing, collective reflection and participation in a joint enterprise. (Hoyles, 2008, p. 258)

This passage indicates a change from the type of research reported at ICMI events 20 years earlier as there is a clear emphasis on the collaborative interaction, collective argumentation and cooperative meaning making that is afforded by the synchronous and asynchronous discussion made possible by web based networks. Hoyles goes onto to acknowledge:

> With the benefit of hindsight, I now recognise that in my early Logo research, I may not have given sufficient attention to the complexities underlying the introduction of microworlds into institutionalised mathematics teaching, even microworlds that had been carefully designed in terms of computer tools, sequenced activities and the teacher's role. These complexities include a recognition of the ways the 'computer' shapes mathematical knowledge and the interactions between learners and between learners and teachers, and crucially, how computers frame the language in which mathematics is expressed and the meanings of 'doing maths' and communicating mathematically. (Hoyles, 2008, p. 259)

At the same congress, the report of Topic Study Group 15: *The Role and the Use of Technology in the Teaching and Learning of Mathematics* included a commentary by Healy and Kaput (2008) on a plenary lecture by Jim Kaput which noted a similar recognition of the role of interaction in learning mathematics and which indicated this has become increasingly possible because of the affordances of web based technologies.

> Alongside the aspects of technology linked to its representational infrastructures, Jim Kaput, USA, brought into focus the communicational affordances of digital technologies. With advances in connectivity, he described how it is becoming possible for learners to interact alongside computational agents as well as other learners in mathematical explorations, bringing a new layer to what we understand by an experiential approach to learning mathematics – and another possibility with both epistemological and cognitive repercussions. (Healy and Kaput, 2008, p.357)

This new acknowledgement is even more evident in the study volume of the 17th ICMI study, *Digital Technologies and Mathematics Teaching and Learning: Rethinking the Terrain* (Hoyles and Lagrange, in press). Strong evidence for Lerman's "turn to the social" is found in the inclusion of an entire chapter on social practices in learning mathematics through technology entitled *Technology, Communication, and Collaboration: Re-thinking Communities of Inquiry, Learning and Practice* (Beatty & Geiger, in press) in the 17th ICMI study volume. The chapter traces the emergence of technology mediated collaborative practices in mathematics classrooms, in both proximate and remote contexts, from the late 1980s until the time of the symposium in 2006. Beatty and Geiger (in press) report that up to 31% of papers presented at the symposium focused upon the role of social interaction directly or included a theoretical perspective that could be considered social in origin, indicating a noteworthy level of interest in this perspective on mathematics learning.

Beatty's and Geiger's (in press) chapter also detailed a topology for how different types of technology are designed or utilised in order to support collaborative learning communities. They argue that collaborative practices can be promoted through technologies designed for:

1. both learning mathematics and collaboration
2. learning mathematics but not specifically for collaboration
3. collaboration but not necessarily learning mathematics
4. neither learning mathematics nor collaboration.

These authors point out that although the studies reviewed in developing the typography documented the use of technology to facilitate collaborative practice in very different ways there were characteristics common to each study.

> Some look at the discourse between two or three learners in front of a desktop computer, others the interaction of many users contributing to an online database. In all studies, the underlying theoretical frameworks emphasized the importance of discourse and collaboration as essential to the process of learning mathematics. All used rich open-ended tasks, and all specified the affordances of the particular kind of technology used for engendering collaborative communities of practice – whether based around aggregated dynamic representations, or archiving threads of discussion in student-managed discussion platforms. And in all studies, technology was viewed as a means of mediating social interaction. (Beatty and Geiger, in press)

Although Beatty and Geiger (in press) document a substantial corpus of literature that now exists in the area, they conclude that social theories of learning, such as such as socio-culturalism and social-constructivism, were conceived before technology had any great influence upon mainstream mathematics classrooms, and so, while there is now increasing interest in technology influenced collaborative practice, much research needs to be undertaken before the role of technology in mediating collaboration can be genuinely integrated into social theories of learning.

The Growth of Interest in the Social Perspective on Teaching and Learning Mathematics with Technology

The discussion presented above, documents a shift in interest among researchers towards theoretical perspectives where social interaction is acknowledged as a key influence on students' intellectual development and that technology is viewed as a powerful agent in facilitating collaborative learning practices. This interest has changed from the late 1980s where there was little evidence of a need to consider the role of social interaction when learning mathematics with the assistance of technology. Twenty years later, however, the influence of technology enhanced collaborative practices in teaching and learning is now a major area of activity within the field of mathematics education although further research is needed into the potential offered by technology to mediate productive collaborative learning practices. Further, although there is now a considerable body of research literature in this field there is still much work to be done in relation to the advantages of the affordances offered by ICTs to collaborative teaching and learning practices.

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