The emergence of social perspectives on the use of technology in mathematics education

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Of the three theories of intellectual development that have had greatest influence on school classrooms since the turn of last century, behaviourist, constructivism and socio-culturalism, all were initially conceptualised before digital technologies were available. Further, whereas current reform agendas that emphasise the importance of social aspects of learning can draw theoretical underpinnings from socio-cultural or socio-constructivist perspectives of knowledge acquisition and meaning making, theoretical frameworks that help explain the role of collaborative interaction in technology rich classrooms are only beginning to emerge. This paper will consider the emergence of recent developments in theorising collaborative practice that incorporate the use of digital tools from a socially orientated theoretical perspective and attempt to draw connections with this emergence from the history of ICMI's involvement in this area.

Introduction

At the Ninth International Congress on Mathematics Education, held in Makuhari, Japan, Stephen Lerman, in an address to the congress titled *The Socio-cultural Turn in Studying the Teaching and Learning of Mathematics* (Lerman, 2000b), stated:

> It is taken for granted today that research on teaching and learning mathematics must take into account the social, historical and cultural milieu of schooling and pupils and of mathematics. (p157)

and then further,

> 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. (p.157)

Lerman presents his position in this presentation, and in other work (e.g. Lerman, 2000a) and it is hard to argue, from a general point of view, that the influence of a social perspective on teaching and learning are not apparent in educational research, school curriculum reform movements or in current advice in relation to improving pedagogical practice. But is this position true of all branches of research in mathematics education? In particular, has there been a noticeable shift in interest by those involved in the study of how digital technologies can enhance the learning and teaching of mathematics towards social aspects of acquiring knowledge and of meaning making in mathematics classrooms?

This paper will address this question by reviewing the proceedings of a selection of ICMI sponsored activities over the last 20 years. Further, classes of digital technologies and the role they play in mediating collaborative activity will be discussed. Firstly, though, a brief description of theories of intellectual development that view social activity as central to the process of learning and teaching will be presented.

Social Theories of Learning

Of the three theories of intellectual development that have had greatest influence on school classrooms since the turn of last century, behaviourist, constructivism and socio-culturalism, only socio-culturalism was conceived with social activity as a foundation for intellectual development. Those who subscribe to constructivist theories, however, may now argue that a role for social interaction has been incorporated into the reconceived theory of socio-constructivism. While there has been considerable debate about the legitimacy of this claim (see for example Lerman, 1989; Steffe & Thompson, 2000) it is not the purpose of this paper to engage in this discussion or to attempt to resolve the dispute, and so research that incorporates the notion that social life has a role to play in effective teaching and learning will not be excluded from consideration, here, on the grounds of a particular theoretical position alone.

Socio-culturalism

Socio-cultural perspectives of learning emphasise the social and culturally situated nature of learning. Mathematical activity is viewed as a process of enculturation into the modes and methods of knowledge creation, sharing and validation which characterise the practices of the community of that discipline (Goos, Galbraith & Renshaw, 1999). Students learning within a mathematical community of practice are expected to engage in debate about the validity of ideas and to defend positions or offer critique via explanations, justifications and the provision of alternatives (Goos, Renshaw, Galbraith & Geiger, 2000).

Also central to socio-cultural theory is that human action is mediated by cultural tools and is fundamentally transformed in the process (Wertsch, 1985). These tools take the form of language, representations and sign systems, as well as physical artefacts. In the particular case of digital technologies, tools can be used to both amplify and reorganise cognitive processes through their integration into the practices of a community of learners. It is important to remember, however, that learning is about more than the changes to mental structures that result from tool use, but also the appropriation of methods of reasoning and discourse, as recognised by the community of practice, that incorporate tool use. Thus, the introduction of digital technologies into a learning environment represents challenges to the learner that go beyond the mastery of a tool to new modes of reasoning and action.

Socio-constructivism

The constructivist position holds that learning is a process whereby the learner actively constructs symbolic representations of the world and uses interpretations of these representations to interact with the world (Noddings, 1990). Fundamental to the constructivist understanding of intellectual growth is the Piagetian concept of disequilibrium which results from the cognitive conflict that ensues when an idea contradicts a learner's current world view. From a constructivist prospective, intellectual growth takes place when the learner is able to rearrange their cognitive structures in order to firstly accommodate the conflict and eventually assimilate it into their understanding of the world.

More recently, some constructivist researchers (e.g. Cobb & Bauersfeld, 1995) have argued that interaction has an important role to play in constructivist theories of learning. In this view, interaction is fundamental to the process of disequilibrium as it is in social contexts that conflicting ideas between individuals may emerge. Collaborative discussion also plays a role in the resolution of the conflict and its incorporation into new knowledge and meaning structures. While the role of tools receives less explicit attention in constructivist literature compared to writings in the socio-culturalist frame, socio-constructivists do recognise the role of cultural tools as catalysts of cognitive conflict (Cobb, 2002).

Social and Technological Aspects of Learning in Mathematics Education Research

In order to benchmark, in a short paper, the validity of Lerman's optimistic appraisal of a turn towards socially orientated theoretical frameworks in relation to the use of digital technologies, three ICMI sponsored events have been chosen across a span of some two decades. The first event, the first of ICMI's seventeen studies to date, *The Influence of Computers and Informatics on Mathematics and its Teaching*, was chosen because it was in the mid-1980s that micro-computers were having their first significant impact in educational contexts. The proceedings of this event will be reviewed in order to establish a baseline for gauging interest in the role of digital technologies in promoting social aspects of learning at this early stage. The ninth ICME in 2000, was included because of the significances of the year, and because it was at this congress that Lerman made the observation that frames this paper. Finally, because of the its recency, and because of its focus, the proceedings of the symposium associated with ICMI's seventeenth study, *Digital Technologies and Mathematics Teaching and Learning: Rethinking the Terrain*, have been included in this scan.

Early Accounts

The symposium, *The Influence of Computers and Informatics on Mathematics and its Teaching* (Churchhouse, 1986), was organised under three themes, and the third, *How can the use of computers help the teaching of mathematics?*, is of relevance here.

The report on this theme opens with a discussion of what mathematics and mathematical activity might comprise in a future classroom. It was felt, in particular, that "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." (p. 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 with each other, or how such interaction could promote learning.

Later in this section there is acknowledgement that technology has the potential to influence classroom dynamics as "this creates new interactions and relationships between student, knowledge, computer and teacher" (p.25). The use of the singular "student" is a further indication, however, that interactions between students were not a concern at that time. The advantage of the computer was seen as supporting the development of mental images that would assist in the acquisition of mathematical concepts and processes within individuals.

A New Millennium

Despite Lerman's optimism for the uptake of social perspective in education research articulated at the ninth ICME in 2000, the working group *The Use of Technology in Mathematics Education,* provided only a modicum of support for his position. The reports of each subgroup of this theme reveal only one reference to the contribution of technology to the social aspects of learning. This appears within subgroup 4: *Conceptual and professional development of learners and teachers in technologically rich classrooms* which notes "several informative empirical studies were presented that were routed in theoretical work in the socio-cultural perspective" (p.277)

One such paper, *Classroom voices: Technology enriched interactions in a community of mathematical practice* (Goos, Galbraith, Renshaw & Geiger, 2000), theorised four roles for technology as a tool for amplifying students' cognitive processes and reorganising interactions between human and technological agencies. This paper demonstrates a clear association with socio-cultural perspectives on teaching and learning but was only one of a very few of its type.

Current Climate

The seventeenth ICMI study, *Digital Technologies and Mathematics Teaching and Learning: Rethinking the Terrain,* provides greater support for Lerman's optimism. The proceedings of this symposium were examined for indicators of a study's alignment with a social theme. These included references to socio-cultural theory, collaboration, learning communities and classroom discourse. Of the 77 papers included in the proceedings, 14 papers were framed abound these ideas or made direct reference to them in their theoretical frameworks. This represents. 18% of the studies included in the symposium. Further, an additional 10 papers were framed around, or made reference to, the theoretical position of instrumentalisation. While it is arguable that this is a social perspective, the concept of semiotic mediation through technological tools is often traced to Vygotskian theories of intellectual development and by association socio-culturalism. If these papers are included in this analysis, then 31% could be considered to be exhibit traces of educational theory related to the social aspects of learning and teaching. Considering either figure, and acknowledging the broad brush nature of the analysis, 18 – 31% of papers represents a noteworthy shift in the interest of this branch of mathematics education towards the social and supports the claims of Lerman seven years earlier.

The Use of Different Technologies in Fostering Social Interaction

On examination of papers from ICMI 17, four categories emerge for uses of technology to promote social activity based around the type of technology utilised. These include technologies designed for: both mathematics and collaboration; mathematics but not specifically for collaboration, collaboration but not necessarily mathematics; neither mathematics nor collaboration. These categories are elaborated upon and exemplified below.

Both mathematics and collaboration

This category includes the use of tools with the facility for learners to work with mathematical concepts in a virtual environment designed for collaboration. Technologies of this type include the *Space Travel Games Construction Kit* developed by Kahn, Hoyles, Noss & Jones (2006). In this simulation of computer game development, participants are provided with a construction kit that includes small program fragments together with tools for customising and composing them. Game development is designed to take place within the context of a metagame where learners are presented with a goal and need to interact with other members of their team in order to share components and acquire the knowledge to proceed. A component of this knowledge is mathematical in nature and so learners acquire mathematical ideas through interaction with peers.

Mathematics but not specifically for collaboration

Technologies in this category include those designed for working with mathematical ideas but not necessarily for the promotion of social interaction. This group of technologies includes devices such as graphics calculators and mathematically enabled software, for example, Maple. A paper that reports on the use of this class of technology is Geiger's (2006) account of a series of episodes in a secondary mathematics classroom in which a learner, who initially rejects his teacher's attempts to conduct his mathematics classroom according to socio-cultural principles, is eventually drawn into the developing the community of practice. His "recapture" is facilitated through his interest in designing mathematics based videos through the programming of his calculator. His need to share his creations with other members of the community catalyse his participation in whole class interaction during this incident and then into the future.

Collaboration but not necessarily mathematics

A number of papers from this symposium concerned the use of internet clients, designed for use as a communication tool among groups of learners, as the medium for interaction in on-line mathematics courses. Beatty and Moss (2006), for example, describe research into the use of a web-based collaborative workspace, *Knowledge Forum*, to support Grade 4 students in generalizing with patterns as part of their research in early algebra. The investigation revealed that the opportunity to work on a student-managed database supported students in developing a community practice in which the offering of evidence and justification for their conjectures form part of the discourse of knowledge sharing and validation.

Neither mathematics nor collaboration

Reports from other participants noted the collaborative activity of learners which ensured from interaction with technologies that were not designed specifically for the learning of mathematics or to act as catalysts for social interaction. A study by Fernandes, Fermé & Oliveira (2006) of K-8 level students investigated the potential for the use of robots to act as mediators between students and mathematics. This paper documented the collaborative practice that ensued when students were presented with problems that challenged them to program robots to follow a predetermined path. The researchers reported that the collaborative activity of teams of students lead to the co-definition of knowledge and understandings gained from the activity.

Conclusion and Final Remarks

When considering the developing role of digital technologies in the educational landscape, the evidence presented above suggests that it is only recently that the role of these tools in learning has been considered from the perspective of socially orientated theories of intellectual development. It is important to remember that these theories were all initially conceptualised before the ready availability of digital technologies. Lerman's recognition of a change in the theoretical persuasions of a noteworthy number of mathematics researchers represents an important shift in focus of this community. While there does appear to be a shift in interest toward social perspectives on learning (e.g. Hoyles, 2005), the bench marking exercised presented in this papers also suggests that this development is at an early stage. Further research is required before any mature understanding of the roles digital tools play in fostering the type of social interaction that supports the learning of mathematics is achieved.

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