The Master, Servant, Partner, Extension-of-self Framework in Individual, Small Group and Whole Class Contexts

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This paper reports on an aspect of a three year longitudinal study which investigated students' use of technology in individual and collaborative classroom settings. A socio-cultural perspective was adopted to develop the MSPE framework which identifies modes of student technology use and describes the student-student-technology relationships that developed as students worked in individual, small group and whole class settings. Implications are discussed for how the framework might lead to more sophisticated technology rich pedagogies in mathematics classrooms.

Introduction

While there have been attempts to theorise students' usage of technology in the process of mathematical learning (e.g., Doerr & Zangor, 2000; Guin, Ruthven & Trouche, 2005), these appear to be founded on individualistic notions of knowledge development and so fail to incorporate the role of collaboration between classroom participants, in concert with technology, during learning, reasoning and understanding. This paper reports on aspects of a study that takes a socio-cultural perspective on the use of technology to learn and teach mathematics within both individual and collaborative contexts. Because socio-cultural theory places interaction and activity at the centre of theory development, the relationships that develop between both human and non-human agents are seen as central to an attempt to theorise the nature of the practices of both individual students and of collectives of learners when they work on mathematical ideas and tasks within collaborative, technology rich classroom environments. Specifically, this paper aims to examine the role of technology in mediating both individual and collaborative student learning. This will be done by proposing a framework for students' use of technology in individual contexts and illustrating the categories within the framework with representative student comments drawn from five Technology Questionnaires administered during the study. The remainder of the paper will then extend the framework to small group and whole class settings.

Theoretical Framework

The perspective offered by socio-cultural theory was chosen to frame the study as it emphasizes both the role of students' own activity and interaction in intellectual development, and the importance of tools in mediating learning. How tools, such as the digital technologies, mediate learning, particularly in collaborative contexts, is an area of limited attention in current research literature. Some studies have concluded that while the formation of technology as a tool for learning requires interaction and negotiation between students and teachers, the use of technology after this formation can inhibit productive, collaborative interaction in the mathematics classroom (e.g., Doerr & Zangor, 2000). Other investigations have attempted to incorporate a social dimension to how students learn in concert with technology by theorising the role of the teacher as an "orchestrator" of social interaction (e.g., Guin, Ruthven & Trouche, 2005). Neither of these positions, however, place social interaction at the centre of the process of thinking, reasoning and learning, nor do they support theory that suggests technology can be seamlessly integrated into ongoing collaborative processes.

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The theory of distributed cognition (see for example, Pea, 1993) and research into collaboration with digital technologies, such as that being conducted into interaction and discourse in Computer Supported Collaborative Learning (CSCL) (e.g., Stahl, 2006), appear to have greater potential to inform researchers of the nature of social interaction and collaboration in technology rich environments. Distributed cognition offers a perspective in which cognition is not viewed merely as a social practice but an act distributed across individuals, collectives, symbolic and physical artefacts, and symbolic, virtual and physical environments. Drawing on aspects of Vygotskian socio-cultural theory and recognising the potential of computer technology, Pea (1993) argues that humans are elements in a reasoning system that includes human minds, social contexts and tools. Stahl (2006), in considering the use of tools within CSCL environments, argues for the inseparability of cognitive activity from both the process of learning within the group and from the tools that help mediate the activity, a position consistent with a Vygotskian view of the social nature of learning and Pea's (1993) description of the role of cognitive tools in distributed cognition. The necessary to consider a single unit of analysis, humans-with-media, in studies that focus on learning mathematics through the use of technological tools has been outlined by Borba and Villarreal (2006), which points to a direction in research that attempts to conceptualise the role of technology in social contexts, such as school mathematics classrooms, in a more holistic manner. Many such studies, however, have been based around technologies designed for collaboration within virtual communities rather than those in which participants are physically proximate – as in most school mathematics classrooms.

Other authors (e.g., Geiger, 1998; Geiger & Goos, 1996; Goos, Galbraith, Renshaw & Geiger, 2000a, 2000b; Trouche, 2005), however, have claimed productive social interactions can take place in learning environments that make use of technological tools which have not necessarily been specifically designed for collaborative activity. Studies which exemplify the use of technologies designed primarily as mathematical tools to mediate collaborative practice include those of Geiger and Goos (1996), Manouchehri (2004) and Sinclair (2005). While these studies are encouraging, the role of technology in mediating learning in different types of collaborative contexts is yet to be fully theorised.

Methodology

Data are drawn from a three year longitudinal study of two cohorts of students – one cohort of 11 students and one cohort of 12 students – from two overlapping two year periods (Years 11 and 12 for both cohorts). The two classes of students were situated in a co-educational, non-government school where the author was also the teacher of both groups. Students were enrolled in a specialist mathematics subject option designed for those intending to pursue serious study of mathematics at a tertiary level. Digital tools were freely available. These included graphing calculators and computers with a range of mathematical software applications and access to the internet.

Teaching and learning within these classrooms was conducted in a manner consistent with a socio-cultural framework as described above (for a more detailed description see Goos, M., Galbraith, P., Renshaw, P., & Geiger, V., 2003). This involved mutual teacher-student, teacher-students and student-student interactions, often mediated by the physical artefacts of digital technology, within individual, small group and whole class settings. Within theses settings, students used digital technologies to perform mathematical computations, to display different representations of mathematical problems and situations and, as an integral part of modes of reasoning and discourse, utilised to explore and investigate tasks set by the teacher and to defend and justify responses to such tasks.

Because data were gathered from within a complex learning environment a naturalistic methodology was employed. The investigation utilised participant observation (video and audio taping), student interviews and student surveys (employing both multiple choice and open response items). The metaphor of a zoom-lens was adopted for the different foci applied to student activity and interaction within the classroom. By "zooming in" the focus was fixed on how individual students worked and interacted with digital tools. By "zooming out" to the middle ground, the investigation examined technology mediated interactions between students and technology in small groups. Finally, by "zooming out" again, the broader landscape of how students worked with technology in public, whole class settings was brought into view. While the notion of a lens can imply a tightly focused search for knowledge, excluding any peripheral events that occur during an investigation, this study sought to embrace emergent uses of technology. As emergent uses of technology can sometimes provide the most exciting outcomes and point the way to more innovative and creative uses of a technology than for which it was designed (Ramsden, 1997), emergent uses have been actively sought after as part of the data gathering processes for this study.

Consistent with a naturalistic methodology, data collection and analysis were conducted simultaneously with theory building. Patterns of emergent behaviour were documented and categorised. Theoretical insight was then gained through an iterative process similar to that described by Goos (2004). This process included the phases of category creation, category confirmation, category refinement and theory development. Categories were initially created through the analysis of both qualitative and quantitative data, including field notes, video and audio recordings and discussion with participants in student-technology or student-student-technology interactions. Categories were then confirmed by the analysis of additional data viewed though the individual lens described above and were then extended to a wider range of settings by applying the emerging framework to data collected from the same classrooms but viewed through the different analytical lenses of small group and whole class contexts.

The Master, Servant, Partner, Extension-of-self Framework

The framework that evolved from the process described above is outlined below. Four metaphors were used to identify broad categories of student behaviour when using technology, as: a *Master*; a *Servant*; a *Partner* and an *Extension-of-self*. In addition, these categories were viewed through the three lenses described above, that is, within individual, small group and whole class settings. The combination of categories viewed through the different focal perspectives resulted in a two dimensional framework where each cell is representative of a mode of technological behaviour within a social setting. This framework will now be referred to as the Master, Servant, Partner, Extension-of-self (MSPE) framework.

This section will describe each cell within the framework. Initially, the first tier of the framework – individual settings – is described and supported via data drawn from students' responses to three Technology Questionnaires. The second and third tiers of the framework – small group and whole class settings – are then outlined but, because of limitations on space, presented without supporting data.

Technology Use in Individual Contexts

The first tier of the MSPE framework is related to students' individual use of technology. Student behaviour in this context is described under the categories of *Master*, *Servant*, *Partner* and *Extension-of-self*. Each category and associated sub-categories of student use of technology is described below and appears in Table 1 supported by an example of a representative student comment.

Technology as Master

Students' responses indicated that their relationship with technology was one of subservience in some way for the following reasons. Firstly, a lack of competence with using a technology restricted a student's capacity to make progress with a task that required a specific facility. For example, a lack of confidence with the use of the matrix module of a graphing calculator would restrict a student's progress on a problem that required the manipulation of large matrices as this would prove very difficult using pen and paper methods alone. Secondly, students' comments indicate that there is a danger of developing a dependence on technology that supplanted the need to understand underlying mathematical processes. This reflects the concern that the use of technology can take a "black box" approach (e.g., Buchberger, 1989) to the study of mathematics. Thirdly, the input and output conventions (syntax) used by different technologies was identified as a negative influence on students' confident use of calculators and computers.

Technology as Servant

In this category students identified a range of ways in which technology could be used as a fast reliable replacement for mental computation or pen and paper algorithms. Technology is used to complete tasks more quickly, more neatly or more efficiently rather than transforming the task. A possible anomaly within this category is the sub-category *Accurate calculation and checking answers* as students were often observed working interactively with the calculator over a series of checks; adjusting their initial solutions on the basis of the output they received from the technology. While students are essentially using technology as a *Servant* in this case there is a sense of partnership in the way they progress toward a solution. Operating with technology in this way may well be an indicator that the student is in transition towards using technology at a more sophisticated level.

Technology as Partner

Responses in this category indicate that students believed there were two different ways that technology assisted them in approaching mathematical tasks. These sub-categories describe the capacity technology provides to take an exploratory approach to looking at a problem, and so gain a different perspective, or to facilitate understanding by providing scaffolding such as the provision of a visual representation of a task. The first sub-category represents the level of operation described by Templer, Klug, Gould, Ramsden and James (1998) who advocate that the genuine promise of working with technology lies in the potential for students to explore and investigate new mathematical ideas and concepts. An example of scaffolding, to illustrate the second category, was observed when students were challenged by a problem in which algebraic facility was required but was not the focus of the task. Students who were not strong users of algebra were sometimes able to achieve success through the use of the computer algebra systems to scaffold over the gap in their algebraic facility.

Technology as Extension-of-self

At this level students have a complete repertoire of technological skills. Such mastery permits students to seamlessly transform a task via technology in order to explore conjectures that are the product of a student's intuition. Students who provided responses in this category commented on the way technology expanded their capacity to explore mathematical situations in ways they could not have done without the assistance of digital tools.

Table 1
MSPE Framework categories and sub-categories of technology use in individual contexts

Category	Sub-category	Student comment
Master	Lack of technology skill	Technology can also cause confusion if you are not competent enough with the machine to understand why it may make mistakes.
	Mathematical dependence	Sometimes you can rely on it too much. And then not understand the full process
	Unfamiliar conventions	Technology can often confuse the issue because it uses different conventions and symbols than normal
Servant	Accommodating large calculation and tedious repetitive methods	It gives you something to blame when things go wrong. It does all the small calculations you can't be bothered to do.
	Performs calculation more efficiently	I much prefer technology because of its efficiency. The work can be done much quicker.
	Accurate calculation and checking answers	Less chance of error in calculations.
	Presentation	Displays everything in a neater and more succinct manner. You can illustrate equations, graphs etc.
Partner	Exploration and different perspectives	With the learning of integration and differentiation, the seeing of the examples graphically helps understand the whole concept, and thus makes you think on a wide scale (graphically and manually) when doing a problem
	Facilitating understanding (e.g., scaffolding, support via visualisation)	Can do problems that I usually cannot do myself because of lack of basic skills
Extension -of-self	Mind expander	Technology allows you to expand ideas and to do the work your own way
	Freedom	You have much more freedom

Technology Use in Small Group Contexts

This tier of the MSPE framework describes the type of behaviours displayed by students when working on mathematical tasks within small groups – generally of 3 to 4 students sin size.

Technology as Master

Firstly, the use of technology may be problematic because of a group's limited cumulative knowledge of the available facilities of a digital device. Such a limitation may mean a technological resource that might have provided insight into a problem, or a more direct approach to solving a problem, is left unexploited. Secondly, a disposition towards using technology in a particular way may inhibit a group using an alternative and potentially productive technological approach. For example, the ease with which a problem can be investigated numerically is an exploratory vortex into which students can find themselves drawn and from which they have difficulty extracting themselves. Finally, technology can act as a *Master* if students are unaware of the nature of the constraints on mathematical representation imposed by software design (Strasser, 2006), for example defaults such as those related to the floating decimal point display.

Technology as Servant

The role of technology in this category is in supporting group argumentation by providing evidence for conjectures and refutations through representations of a problem that can be shared or by handling large or tedious calculations. This role is closely aligned to, but is different from, that of technology as a *Partner,* as the role of *Servant* does not imply a strategic use of a digital tool. The calculator as *Servant* also has a physical dimension when the sharing of information is facilitated by passing a calculator from one group member to the next, or when shared by all members of a group at the same time.

Technology as Partner

The capacity to mediate discussion is one of the potential benefits of the use of technology. During the study, it was observed that students often passed their calculators between members of a group as a way of confirming or challenging the conjectured solutions or suggested approaches to a task. Calculators were used as a digital canvas on which two or more students progressed their work on one display; the ownership of the work in progress being shared between students. This action led to further interaction and discourse in the form of argumentation.

Technology was also observed to provide support for a student, initially working as an individual, to join a discussion in order to share findings with a group. In this case technology provided the physical facility necessary to present findings in a more public forum and also seemed to offer a form of moral support, as he waited until, through the assistance of his calculator, he was sure he was correct before offering a contribution.

Technology as Extension-of-Self

No evidence was found, in the available data, for technology in this category for small group settings. However, it is possible to hypothesise the existence of such a role on the basis of its identification by students working as individuals as well as the evidence presented for the existence of this mode in the role of technology in *Public* contexts, which follows in the next section of this paper. Given the identification of this category of use in both private and public contexts, it seems likely that technology will also have a role in mediating collaborative practice when students work in small group settings.

Technology Use in Whole Class Contexts

Data gathered during whole class interactions demonstrates the potential of technology, including associated presentation tools, for mediating whole class collaborative activity. This included the drawing in of students who are initially reluctant to engage in, or in some cases resist, the social and cultural norms of this community of learners (for more detail see Geiger, 2006). This extends MSPE framework to encompass uses of technology which promote student-student-technology interaction in whole class settings. This further elaboration is described below.

Technology as Master

The use of technology in public forums is problematic. This might be due to an inability to make effective use of the available technology or an inability to make corrections “on the fly” when errors are identified during a presentation. Technology also acts as *Master* if an audience blindly accepts a faulty idea or solution to a problem by deferring to the authority of the technology without question.

Technology as Servant

In this mode technology is used for the public delivery of pre-worked solutions to tasks. Because of the non-contentious nature of the presentation, little exploration or debate results as a consequence. Technology is essentially used as an electronic blackboard.

Technology as Partner

Technology is used to explore and investigate a problem or idea “live” in a public forum. Here, technology assists in focusing the intellectual resources of the community in order to explore ideas, offer critique of existing work, or suggest improvements to work where faults are identified. Technology is also used to provide support for the engagement of members of the community.

Technology as Extension-of-Self

This expression of the framework is characterised by the seamless use of technology for public investigation of problems or presentation of proposed solutions. Technology may be used to orchestrate and sustain community wide enquiry into a task or problem or to invite the critique of a proposed solution to a novel task.

Discussion and Conclusion

The MSPE framework portrays the use of technology as a series of relationships between technology and individual students and between technology and different sized collectives of students. As the notion of relationship implies interaction, the ways in which students engage with technology includes the potential for dynamic, two-way working relationships between human and non-human partners. This portrayal of mathematical learning as an activity that is distributed across individuals, collectives, physical and symbolic artefacts, as well as environments, is consistent with Pea’s (1993) concept of distributed cognition, and Borba and Villarreal’s (2006) notion of humans-with-media, and also extends related theory by identifying the different types of interaction that take place between human participants and digital tools when working as individuals, or in small groups or whole class settings. Further, the ways these modes of interaction are enacted within different settings, as defined by the number of participants engaged in an in-class episode, represents a differentiation in technology influenced behaviour that has not been previously addressed in research literature.

The different categories of technology mediated collaborative practice identified in this study indicate consideration should be given to which practice best resonates with a teacher’s learning intentions. Small group work, for example, was enhanced by the ready availability of different representations of a mathematical idea through technology and these images provided the stimulus for collaborative discussion within a supportive environment. In larger group settings, ideas and solutions to problems were publicly debated using a student's presentation as a starting point and focus. Presented work was adapted and improved "live" and subjected to further debate until consensus, including that of the teacher's, was achieved. The different settings, from individual to small group, to whole class, also provided a structure for students to grow through until they feel confident they can contribute in all learning formats and forums.

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