BELIEFS ABOUT THE NATURE OF TECHNOLOGY IN THE CLASSROOM

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Research on mathematics teachers' beliefs about the use of technology in the classroom has repeatedly found teachers' hold strong beliefs about when technology should be used. Some teachers believe technology should be used only after students have mastered certain mathematical content while others believe technology should be used before, or in order to achieve content mastery (e.g., Brill, 1997; Fleener, 1995b; Turner & Chauvot, 1995). Although this dimension has proved valuable in gaining initial understandings into teachers' beliefs about teaching with technology, it seemed likely there existed other dimensions to teachers' fundamental beliefs about teaching with technology. A study (Leatham, 2002) was conducted to explore preservice secondary mathematics teachers' (PSTs) beliefs about teaching with technology. This paper reports on the portion of that study that sought to investigate beyond the "before or after content mastery" dimension so often reported in the literature.

Research on Teachers' Beliefs about Teaching with Technology

Brill (1997) located three positions along "the continuum of beliefs about technology use in the mathematics classroom" (p.20): exploratory, postmastery, and premastery. Teachers with exploratory beliefs believe technology can and should be used to introduce and explore mathematical concepts and procedures. Teachers with postmastery beliefs about technology believe that technology should be used only after mathematical concepts and procedures have been learned by hand. Teachers with premastery beliefs have begun to use technology before their students have attained full mastery of the mathematical content, but that technology use is either rare or unproductive. Use of technology before content mastery has, however, begun to find a place in their teaching. Teachers who have exploratory tendencies while still holding, for example, instrumentalist views of mathematics (Ernest, 1988) might be classified as having premastery beliefs.

Complementing Brill's (1997) study with elementary teachers, a study by Turner and Chauvot (1995), conducted in conjunction with project RADIATE, focused primarily on PSTs' beliefs about technology. They followed two PSTs through the four quarters of their undergraduate training program and found that both PSTs held the belief that successful exploration of a mathematical topic using technology required previously acquired knowledge of the mathematical topic. The PSTs believed they would teach their students how to work mathematics by hand before they turned to technology. Both PSTs would be classified as postmastery on the Brill (1997) continuum.

Finally, Fleener (1995a; 1995b) surveyed several hundred practicing middle and high school teachers and close to a hundred PSTs on their beliefs about the use of technology in the classroom. Using Brill's (1997) terminology, approximately half the teachers in each category

would be classified as having postmastery beliefs while the other half had primarily exploratory beliefs. Fleener found a correlation between these beliefs and teachers' philosophical orientations.

Conceptual Framework and Methodology

For the purposes of this study, I adopted Rokeach's (1968) definition of belief: "All beliefs are predispositions to action" (p. 113). In addition, beliefs, whether consciously or subconsciously held, speak "to an individual's judgment of the truth or falsity of a proposition" (Pajares, 1992, p. 316). I used coherentism and Green's (1971) metaphor of a belief system to form a conceptual framework for thinking about how the PSTs held their beliefs. In coherentism, beliefs become viable for individuals when those beliefs make sense with respect to their other beliefs. It is only when beliefs become viable that they are considered part of an individual's belief system. Coherentism provides an alternative way of interpreting apparent inconsistencies in teacher's beliefs systems. Actions are always a result of some belief; the belief upon which the action is based, however, may not always be what the researcher or the individual expected. Green's (1971) three dimensions of psychological strength, quasi-logical relationships, and clustering were used to visualize what a sensible system of beliefs might look like.

Qualitative research methodologies, in particular the grounded theory research tradition, were chosen as the most effective way of answering the research questions. Four PSTs were purposefully chosen to participate in the study. Data collection strategies included classroom observations (both where the PSTs were students and where they were student teachers), interviews, email surveys, and secondary data. The interviews and email surveys were conducted in tandem. Three of these, referred to as Pedagogical Brainstorming Sessions (PBSs), required the PSTs to explore how they envisioned teaching specific secondary mathematics topics. The constant comparative method of analysis took place while data was being collected, through an iterative coding process, and through writing data stories for each PST. NUD*IST (Richards & Richards, 1997) qualitative research software was used extensively to organize, categorize and synthesize the data.

Four Brief Case Studies

Before describing the dimensions of beliefs about the nature of technology posited as a result of this study, I first provide brief case studies of the four PSTs who will be used to illustrate the dimensions. These case studies serve as a context for understanding how these beliefs about the nature of technology fit in with the PSTs' other beliefs about technology as well as their beliefs about mathematics, its teaching and learning.

Ben

Ben thought of mathematics as a toolbox containing, among other things, rules and procedures, concepts that underlay those procedures, and skills such as reasoning and problem-solving. He believed his primary role as a teacher was to create an environment where students were motivated to learn. All students could learn when given the proper motivation and

confidence. Ben had used calculators for years and he felt comfortable using most any model he came across. He had similar confidence with computers although he was less experienced with them. He believed technology was particularly valuable for facilitating exploration and visualization.

Jeremy

Jeremy saw mathematics as a human endeavor, one that had great impact on humankind. He considered it his responsibility to provide the type of environment in which he could engage students in learning mathematics. Learning mathematics was an often difficult process that required individual perseverance and dedication. Jeremy had had considerable experience with technology, particularly with graphing calculators. He was motivated to learn new computer programs and mastered them quickly. Because he had experienced powerful ways of using technology in learning mathematics he felt it was necessary that he use technology as a teacher. Jeremy believed technology could be effectively used to free up tedious calculations, to dynamically illustrate mathematical concepts, and to facilitate mathematical exploration.

Katie

Mathematics, for Katie, was a way of thinking and a way of explaining the world. She wanted her students to be excited about mathematics and she felt that the key was that she be excited. All students could learn if they were sufficiently motivated. Learning required frequent repetition of the basics and variation in teaching strategies. Katie had considerable experience with computers and calculators starting in high school. She loved calculators and carried hers with here whether or not she was taking a mathematics class. Katie saw technology as a means of enhancing mathematical procedures and facilitating conceptual understanding.

Lucy

Lucy's beliefs about mathematics were primarily focused on the interplay between seeing mathematics as a set of skills and procedures and finding value in mathematics by applying it to the real world. She believed it was her responsibility as a teacher to motivate students to enjoy and want to learn mathematics and she intended to accomplish this by making students comfortable, using a variety of teaching approaches, and demonstrating the applicability of mathematics. Lucy viewed learning mathematics as hierarchical—as a process of making connections between new and previously learned ideas. Lucy had limited experience with technology before college, but was excited by the ways she learned to use technology in her mathematics teacher education program. She believed technology use in the classroom was motivational to students, was a nice tie-in to the real world, and could help students visualize and explore mathematics.

The Nature of Technology in the Classroom

As expected, there were overarching beliefs at play in the way the PSTs in this study thought about teaching mathematics with technology. Although they talked of the various roles they wanted technology to play and the expected outcomes from those roles, as well as their

concerns about teaching with technology, there were beliefs that seemed to encompass and significantly influence all of these. I refer to these centrally held beliefs as beliefs about the nature of technology in the classroom. In a sense, beliefs about the nature of technology in the classroom are overarching beliefs about the prominence of technology in the classroom. These are the centrally held beliefs about which other beliefs about technology were clustered. Teacher's beliefs about when technology is used, whether before, during, or after instruction, as discussed by Brill (1997), are an example of beliefs about the nature of technology in the classroom. Beliefs about the nature of technology in the classroom are described in terms of a broader dimension within which Brill's continuum fits, as well as several other dimensions that emerged in this study.

Because of their central location in the PSTs' belief systems, beliefs about the nature of technology in the classroom can be thought of as, in essence, the PSTs' "definition" of teaching mathematics with technology. In sum, no PST believed that technology should be *the* driving force behind the teaching of mathematics. Each PST, however, viewed technology as a force to be reckoned with; one that in many ways could be beneficial but that also needed to be controlled lest it compromise their overall educational objectives. Their beliefs about the nature of technology in the classroom reflected both their desires to use technology in meaningful ways *and* to control or predict in some way the outcome of that usage. The dimensions of beliefs about the nature of technology in the classroom that emerged from this study—availability, purposeful use, and teacher knowledge—are discussed below.

Availability

As previously discussed, the primary dimension Brill (1997) found with respect to elementary teachers' beliefs about using technology in their teaching dealt with *when* (with respect to mathematical content) they felt it was appropriate to use technology. She posited a continuum on which, on the one end, teachers did not choose to use technology until after the students already knew how to do the mathematics by hand (postmastery) and, on the other end, teachers chose to use technology in an exploratory way before students fully understood the mathematics (exploratory). She further described a middle ground in which teachers were beginning to use technology before full understanding of a concept was assumed (premastery). One of the intents of this study was to explore whether these dimensions of postmastery, premastery, and exploratory were also valuable in describing PSTs' beliefs about technology. I purposefully chose participants who had significant experience with technology in hopes of further delineating that dimension, as well as finding similar dimensions. I believe that, through this research, other dimensions have indeed emerged. In particular, I found it more valuable to think of Brill's categories as part of a broader dimension which I refer to as the availability of technology to students. I start with a discussion of Brill's categories and then expand on this dimension to discuss further the notion of availability.

Postmastery, Premastery, and Exploratory

Brill's (1997) exploratory dimension nicely described both Ben and Jeremy. They made little distinction between whether students were allowed to use technology before or after they had mastered mathematical content. They believed that technology could and should be used to facilitate mathematical understanding and thus could be used profitably at most any stage of the learning process. Each expressed the belief that it was not when technology was made available to students but their decisions as teachers that made the difference. Katie seemed to be in the premastery category. Because of her focus on students' ability to do things by hand, she felt there were times when she might not let them use technology, but she expressed the desire for this restriction to occur only rarely. In general, she too wanted to take the responsibility herself, in the presence of technology, to ensure that her students were gaining the understanding she desired. Thus, she felt confident in using technology before her students understood mathematical concepts or in order that they might come to that understanding.

The beginning stages of premastery best describe where Lucy was with respect to when she believed technology should be used with her students. For the most part, Lucy believed that technology should only be used after her students had gained a certain level of understanding of any given mathematical concept. This format was very important to Lucy, as, in order to enhance instruction, she believed technology needed to come afterwards. Students needed some understanding already, and then the technology could be used to enhance that understanding. This central belief is illustrated well through her beliefs about students' learning of graphing. Lucy wanted her students to know how to graph by hand. She did not mind them using technology after they had demonstrated mastery of this technique. There were several times, however, when Lucy expressed (somewhat to her own amazement) that there were times when she would use technology before her students understood how to do things by hand. Lucy envisioned using the visual capabilities of technology in order to introduce a new topic. She felt this use of technology had significant potential for motivation. Still, closely connected to her belief that technology should always be supplementary, Lucy primarily saw technology as being used in a postmastery way. This belief had less to do with *when* and more to do with *how often* technology was used in the classroom. I now turn to further elaboration on beliefs about whether technology is constantly or periodically made available to students.

Constant Versus Periodic

Whether technology should be constantly or periodically available was one dimension of the nature of technology use in the classroom that emerged from this research. Katie believed strongly that technology should be constantly available to her students. Constant access, however, did not equal constant use. The constant availability was intended, rather, to provide constant choice to both teacher and student. In this environment the teacher could turn to technology whenever she deemed it valuable or appropriate. Similarly, during certain classroom activities, students could be given the option of whether to use technology. Lucy did not want constant access. In fact, it was important to her that technology not be constantly available. She did not

want technology to be perceived as the primary source of instruction. It was a supplement. This notion of supplement did not fit Ben's belief about the nature of technology availability in the classroom. It was all or nothing for him. It was okay if you did not use technology; sometimes it just was not available or feasible. But, if you were going to use technology, then you had better use it in all aspects of instruction (e.g., in class, on homework, and on tests). Jeremy, on the other hand, was willing to use technology in whatever ways were possible. He wanted his students to have constant access to graphing calculators; constant access to computers would be great, but he did not deem it likely. He would be satisfied if he at least had access to a computer. He wanted to use whatever technology he had as much as possible. His students would be allowed and encouraged to use technology at all times unless he told them otherwise, something he figured he would do only rarely.

Both Lucy and Katie felt strongly that students needed to know how to do things by hand, not just with technology. Their beliefs about the nature of technology, however, were very different, although in the same vein. In essence, Katie's solution was to make technology constantly available to her students but to use it in ways that supported her desire to have the students learn the procedures by hand. Lucy's solution was to make technology only periodically available.

The PSTs in this study believed that, as teachers, their own access to technology depended greatly on the factors (such as school funding and school priorities) that would be, at least initially, out of their control. They also recognized, however, that given these constraints, they as teachers needed to make decisions about their students' access to technology. They believed that the nature of technology use in the classroom differed significantly based on how available the technology was. When technology is periodically present, its use by both teacher and students must be premeditated. Teachers are likely to make technology available only on days when they have specific plans to use technology. One of the implications of periodic availability for student use is similar to that which is implied by so-called problem-solving exercises relegated to final section in many mathematics textbook problem sets (or marked with a star to warn the unsuspecting). Their very context, separated from what is considered to be "normal" mathematics, and sometimes labeled as an application, often redefines the problem for the students as, "Let's see. This problem comes in the chapter on solving systems of linear equations, so they must want me to set up a system of linear equations to solve this problem." This is not to say that in either of these situations, there is not potential for valuable use. The context, however, has limited that potential. So, although periodically available technology may serve quite valuable roles in learning, the nature of its use, despite the role, puts students in a different position. When technology is periodically available, students associate appropriate use of technology with when it is made available. When technology is constantly available, students must choose when to use it. Of the PSTs in this study Lucy desired most to control her students' access to technology. Ben and Jeremy wanted the students to have significant access and for that access to be aligned with their instruction. Katie wanted constant access so that technology was always an option.

When technology is constantly available to teachers and students, the choice of whether to use technology can be based on the needs and circumstances that arise in daily mathematical discourse. On the other hand, if technology is only available periodically, someone (most likely the teacher) will decide ahead of time when to make technology available—when to hand out the calculators or when to go to the computer lab. In these situations, it is fair to assume (as an outside observer, certainly, but more importantly, as a student) that the teacher expects the students to use technology that day. This expectation gives a different flavor to a students' choice not to use technology that day. With periodic access, one can envision a student saying, "But look, I can do it without technology"; with constant access a student might say "But look, I can do it with technology." The nature of technology availability in the classroom is influenced by teachers' decisions and greatly influences both their and students' decisions with respect to technology use. That this use should have some purpose is the next dimension of belief about the nature of technology in the classroom. Before describing that dimension, however, I discuss briefly the notion of alignment.

Alignment

Another aspect of technology availability dealt specifically with alignment. The PSTs were committed to the idea that their use of technology in the classroom be aligned across their classroom activities. As was the case with so many of these beliefs about the nature of technology in the classroom, the PSTs had had classroom experiences in which they believed technology use had not been well-aligned and they were determined to do otherwise in their own classrooms.

Jeremy's experience using MAPLE in his college Linear Algebra course convinced him of the need to fully integrate technology use in his classroom. He was primarily concerned about the lack of alignment between homework and tests. Ben's belief about the need for technology alignment was also closely connected to his MAPLE experience in linear algebra. That experience, along with another experience he had observing in a high school classroom, convinced Ben that it was critical that technology use be fully aligned across classroom instruction, individual work, and formal assessment. He was adamant that if his students were allowed to use calculators at all, they should be allowed to use them in all situations.

Katie was concerned that her students might not have constant access, in which case she did not believe that she could really use technology in a natural way because technology would not be available to them, for instance, when they were doing their homework. It needed to be used in every part of instruction. She wanted to turn to it like she might turn to a piece of paper or turn to a graphical representation. This issue came up when it came time for her FE. The students in that classroom were not allowed to use technology, so she knew that even if she used it in class, the students would not have technology available to them when they went home, and they would definitely not have technology available to them after her two weeks were over. Although she wanted to use technology with them, she decided that it was impossible to give them sufficient access and experience in such a short time in order to make technology a natural part of the classroom. She did use it herself, however, for demonstration and discussion. As one might

imagine, alignment of technology use was not a major concern for Lucy. She believed that technology should be used periodically in order to enhance her teaching in various ways. In many ways, her core beliefs about the periodic availability of technology precluded the possibility of technology being fully aligned.

Belief about the proper alignment of technology across classroom activities is an example of how important availability was to these PSTs. Beliefs about alignment are concerned with both when and how technology can be used in conjunction with formal and informal assessment. The connection between alignment and availability, however, can look quite different for different teachers. For one teacher, constant access might mean access except during formal assessment. Other teachers might use graphing calculators all the time in their classrooms, and yet others might use them infrequently; but all might prohibit students from using calculators on their tests. Or, a teacher might use the computer a lot in their own instruction, but students are never given a chance to use it on their own even though they are required to know certain things about it. The PSTs in this study demonstrated an awareness of these issues and a desire that their own use of technology be aligned with their instructional practice. Regardless of whether technology is made constantly or periodically available, the PSTs in this study believed that it should serve a useful purpose.

Purposeful Use

The PSTs believed that, although there are many reasons one might choose to use technology in the classroom, at least one of those reasons should be present when you use it, namely, that technology should be used purposefully and not just for the sake of using it. The reasons teachers choose to use technology in their teaching are diverse (and many of these roles of technology will be discussed later in this chapter). In addition, what one person deems purposeful may not be deemed purposeful by another. As mentioned previously, these central beliefs about the nature of technology in the classroom seemed to be strongly related to poignant, often negative, experiences learning with technology. Although at times the PSTs expressed sentiments such as, “I loved this so I want to do it too,” their discussions were more likely to have this flavor: “That experience was horrible, so I plan to do this instead so that my students do not have to go through what I went through.” Several of these experiences will be revisited as I outline how the PSTs defined purposeful use of technology.

For Ben, purposeful use was when he could envision some advantage to using technology. He believed that there almost always would be such an advantage. It was his responsibility as the teacher to ensure the presence of that purpose. For Jeremy, although he believed he could always find some way to use technology, technology use was purposeful if it was made integral to the lesson. It was important for Jeremy to integrate technology whenever possible because he felt it was necessary to use it. If he did not use it, he believed that he would not be being true to himself. His beliefs about the purposeful use of technology were also influenced by his experience in a Linear Algebra course, as he felt that the use of MAPLE in that class had not been beneficial at all. For technology use to be purposeful, he believed that the

technology needed to help you better understand the mathematics, not just execute some calculations that you did not understand. For Jeremy, it was necessary to link technology use with understanding or else it was pointless. Katie defined purposeful use as having a point to using technology. In order to use technology in a natural way, there needed to be some purpose to the use and the teacher needed to know what that purpose was. Lucy, perhaps more than any of the PSTs, believed that, if you were going to use technology, there had better be a good reason. For Lucy, that reason needed to enhance student learning. In order for technology to enhance learning it needed to be used in supplemental yet relevant ways. This belief was connected to her postmastery beliefs about technology. For example, using technology before students understood how to graph by hand defeated her purpose of the students knowing how to graph by hand. Using technology after students understood how to graph something by hand did not defeat this purpose; in fact, it could enhance their learning as it could expedite the process so that they could focus on some other related mathematical concept.

There are certainly other variations on purposes that did not fully emerge from this study but that one might imagine. A teacher might believe, for instance, that one reason to use technology is because you have it. The purpose is to take advantage of an available resource so that it does not go to waste. A teacher might believe that, in order to be purposeful, technology use in the mathematics classroom must have pedagogical purpose; another might be less lenient, restricting pedagogical purpose to mathematical roles of technology. In addition, one can imagine a teacher having a purpose with neither mathematical nor pedagogical ties. For instance, a teacher might choose to use technology because they were told to: “Here is a set of graphing calculators. The district has spent a lot of money on these, so you had better use them.” The teacher who has no vision as to why technology should be used is not likely to use technology with purpose. As far as the theme of purposeful use that emerged from these PSTs, they believed that, to be purposeful, there must be something important that the technology might accomplish. It seems, then, that purposeful use is necessarily connected to an awareness of the possible roles of technology. If a teacher gives an assignment and says, “Feel free to use your calculators,” the teacher may not have a specific purpose in mind in allowing that use. That the PSTs in this study were aware of multiple roles technology could play in their classrooms will be discussed shortly. There is one other aspect of this purposeful use, and what the PSTs considered not so purposeful, that came out of this study, namely, the distinction between using technology as a tool or as a crutch.

The PSTs, in general, defined tool and crutch in this way: Technology is being used as a tool if it is being used either with or to gain understanding; it is used as a crutch if it is used without or in order to avoid understanding. Note that this dimension is not the same as Brill’s (1997) categories, although many connections between these dimensions seem clear. In part, however, this dimension explains why the Brill continuum was limited in describing these PSTs’ beliefs about the nature of technology use in the classroom. It is likely that someone who is classified as *postmastery* would view any use of technology before students have understood a concept as using technology as a crutch. Those who are *premastery* have started to recognize that there are some ways that technology can be used as a tool before students have completely

understood a concept. Those classified as *exploratory* likely see many ways to use technology as a tool both before and after students understand a given concept.

Teacher Knowledge

The PSTs recognized their own knowledge about technology greatly influenced the possibilities for the nature of technology in their classroom. It influenced the ways they did and could think about technology use. Although connected to the PSTs' ownership of technology, this belief has to do with their personal awareness of that ownership. This dimension is defined by the knowledge the PSTs recognized in themselves and how important they believed that knowledge was to their successful use of technology in the classroom. All the PSTs felt the responsibility to know what they were doing and why they were doing it when it came to using technology in their classrooms. These beliefs are compared in the paragraphs that follow.

Jeremy was confident in his knowledge of technology and how he could use it in classes above and including Algebra I. In a sense, he took this knowledge for granted. When he considered teaching a General Mathematics or Pre-Algebra course, however, he recognized that, until he gained further knowledge of that curriculum, he would not know how to integrate technology into his teaching. Ben, too, was confident in his knowledge of how to use technology; but he was mostly confident in his abilities to explore mathematics himself. He recognized that he still had much to learn about teaching with technology. Ben's confidence in his own teaching abilities and in his knowledge of technology, however, seemed to be sufficient for him to learn as he went. This uncertainly was somewhat problematic, however, as he believed that uncertainty with respect to technology was more disconcerting to students than uncertainty with respect to mathematics. He wanted to ensure that he always had the right answer when it came to questions about technology whereas he was more willing to let students constructively flounder with the mathematics.

Katie believed a teacher must be knowledgeable with respect to technology in order to use it effectively in the classroom. This knowledge was critically important to Katie. In order for her to naturally use technology, she really needed to understand what she could do with it. Then, as the opportunities presented themselves, she could use technology "in the moment." Without that knowledge and confidence, she did not believe that she could use technology in a natural way in the classroom. In many ways, Lucy recognized this same need. The difference, however, was that Katie believed that she had the knowledge that she needed to use technology, and Lucy believed that she did not have that knowledge. This lack of knowledge would limit the possibilities for her use of technology. Lucy recognized that she had a limited understanding of technology, which fit in very well with her notion of supplemental use. She could take the time to learn the things she wanted to do with technology, or she could simply bring it out when she came across something where she already had the knowledge.

Conclusion

Although beliefs about using technology before or after content mastery were still evident in the beliefs of the PSTs in this study, these beliefs were conceptualized as just one aspect of a larger set of core beliefs about the availability of technology. PSTs also held strong beliefs about whether technology should be constantly or periodically accessible, and the alignment of technology use across their various teaching strategies and classroom activities. In addition, further centrally held beliefs surfaced with respect to the purposeful use of technology and the importance of teachers' knowledge of technology and how it can be used in the learning and teaching of technology. This set of core beliefs, referred to as beliefs about the nature of technology in the classroom, provide a foundation on which mathematics educators can base classroom discussions and activities related to the use of technology in the classroom. PSTs need opportunities to explore their beliefs about teaching mathematics with technology in order to be best prepared to make informed pedagogical decisions as novice teachers.

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