Engaging Pre-service and Inservice Teachers in Middle School Mathematics: Using Dynabook to Shape Unconventional College Classrooms

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Abstract: In this paper we report on a team project that has as goals to design, develop and evaluate an interactive Web-based tool for teaching mathematics content and pedagogy to middle school teachers. We will examine how special education faculty used Dynabook in their courses as this new technology was being developed, and how the teacher candidates in the classes responded to this new technology over the course of two semesters and one summer. The description of how the technology was used in the classroom includes methods used for evaluation, how candidates responded, and how the technology was changed based on their feedback.

Introduction

Many highly qualified and skilled teachers still have problems teaching challenging math content to students in today's classrooms. Therefore teacher preparation programs need to create a dynamic learning community where candidates can engage with mathematics in a way that encourages deep and connected mathematical understanding. While textbooks try to attend to diverse learners with pedagogical suggestions, they often fall short in providing adequate support that addresses the disparate math knowledge among teacher candidates. As teacher candidates engage with difficult math content that they must teach, they should be exposed to multiple solution paths, and suggestions for promoting student engagement. In turn, university instructors need a resource that promotes content knowledge, technology integration, and creative ideas for pedagogy. The purpose of this paper is to discuss the development and evaluation of the Proportionality Dynabook, an interactive resource that unifies these ideas. First, we describe the development of Proportionality Dynabook. Second, we explain the conceptual framework that drives the design of the Dynabook. Third, we report the findings from each iteration and implementation of the Proportionality Dynabook within a classroom activity system. Finally, we conclude with a synthesis of findings and thoughts for future research.

Dynabook Development

Dynabook is an interactive Web-based tool that assists teacher educators to more effectively teach mathematics methods to preservice and inservice teachers. Its development is a collaboration between SRI International, lead researchers; CAST, UDL developers; San Francisco State University, special education teacher educators working with graduate students; San Diego State University, general education teacher educators working with undergraduates; and Inverness, project evaluators. Collectively, we have a unique combination of expertise in mathematics, math education, special education, teacher training, technology supported math instruction, UDL pedagogy, and evaluation, which has been very productive in designing and building the Proportionality Dynabook.

Dynabook started out as an interactive mathematics textbook for teacher candidates and through the design process has morphed into a web resource that college instructors can use for teaching general and special education teachers concepts of proportionality, math pedagogy, and technology integration. Designers drew inspiration from Alan Kay's 1972 concept for a tablet-shaped personal computer (see, e.g. Kay & Goldberg, 1977), which he called a Dynabook. Like Seymour Papert (1993), Kay saw the dynamic, interactive capabilities of computational media as opening up new ways to playfully engage with powerful ideas – through activities like programming, interacting with visualizations, exploring mathematical models, and engaging with simulations. The current project expanded upon these ideas to bring the Dynabook from an online text to a versatile tool. But instead of using it as a stand-alone tool, teacher educators have found it to be more useful as part of curricular activity system, bringing together other activities and ideas and adding them to lesson plans and coursework that center around the Dynabook. It incorporates interactive problems, video, and aspects of universal design for learning (UDL) to increase access for teacher candidates to better understand proportionality and how to teach it to their students.

Informed by research from mathematics, and general and special education, Dynabook includes dynamic learning tools for teachers and students. The media rich environment includes dynamic representations, videos of students solving problems and their perceptions, and practice problems. The dynamic representations are interactive and assist the candidates in solving exemplar problems. For example, in a problem comparing the ratio of math to other classes in the school day, participants use a ratio bar visualizer. This tool can be manipulated to express any ratio in red and blue, which can be split to see if two ratios are equivalent. The videos show middle school students reasoning through example problems to demonstrate how students of that age think about ratio. Finally, the practice problems use a slideshow to introduce a context and then embed problems into that context. These components are intended to help candidates understand how middle school students think about proportionality, including their misconceptions, and provide strategies that they can employ in teaching these students. University instructors can create a social learning environment with candidates working on content in the Dynabook by sharing their work and ideas through a built-in whiteboard. Dynabook is designed to work within the context of a university classroom, wherein instructors use the contents as a springboard for deep mathematical and pedagogical discussions. This interactive resource is meant as part of a curricular activity system.

Conceptual Frameworks

The design of this innovative tool draws on two complementary and synergistic conceptual frameworks – Universal Design for Learning (UDL) and Technological Pedagogical Content Knowledge (TPCK). Universal Design for Learning supports the needs of diverse learners by providing multiple means of representation, expression, and engagement (Rose & Meyer, 2006; Rose, Meyer, & Hitchcock, 2005). This idea of UDL originated from the concept of Universal Design, a common term used to refer to designing products and buildings, including the environment, to be aesthetic and usable to the greatest extent possible by everyone, regardless of age, ability, or status in life. Curb cuts or sidewalk ramps, essential for people in wheelchairs, but also used by all, are a common example. UDL is an educational framework based on research in the learning sciences; it stems from the cognitive neurosciences theoretical tradition and has a major goal to guide the development of flexible learning environments that can accommodate individual learning differences. The benefit of UDL as a framework in the Dynabook is that it provides a research-based organization of the kinds of supports that learners may need and that technology can provide. These supports include variations for (a) connecting multiple representation of important ideas, (b) interacting with ideas and expressing ideas in new ways, and (c) maintaining a high-level of engagement. With regard to these three kinds of supports, UDL concisely summarizes a vast literature on the brain, learning, and the role of technology. For example, UDL suggests that providing for multiple representations of a concept not only enables deeper engagement with that concept, but also enables access for a broader range of learners (McGuire, Scott, & Shaw, 2006). In the Proportionality Dynabook, UDL principles are introduced through videos, text, and diagrams as a framework to interpret the digital text. In this way, as Dynabook users employ UDL features, they establish an understanding of the principles and can transfer them to inform instruction in other content areas.

In Dynabook, various features are embedded to provide pre-service teachers access to, and engagement with, challenging mathematics. For example, a glossary is available which defines unfamiliar words and concepts by using a mixture of pictures and explanations. Multiple means of expression are available to users who can highlight words or sections in the Proportionality Dynabook and take notes in the margins. Further, when answering a question, users can write, draw a picture, explain verbally (into a microphone), or upload a file. To enhance engagement, "Stop and Think" prompts are strategically embedded in the text to encourage candidates to process the text more deeply. These UDL features were consciously and vigorously embedded into the Dynabook in an attempt to make this particular tool useful and effective.

Technological pedagogical content knowledge (TPCK) provides a second conceptual framework for the Dynabook. Emerging technological advances combined with Shulman's (1987) work on pedagogical content knowledge have led to the TPCK framework (AACTE, 2008; Mishra & Koehler, 2006). Shulman's pedagogical content knowledge focused on the most powerful analogies, illustrations, examples, explanations, and demonstrations—the ways of representing and formulating the subject that make it comprehensible to learners. Since there is no single most powerful form of representation, the teacher must have at hand a veritable trove of alternative forms of representation, some of which derive from research and others from practice. It is important for preservice teachers to access the Proportionality Dynabook with guidance and thoughtful pedagogy. The content must also be rich and challenging for candidates to increase understanding of the complexities of TPCK while engaging in content that increases their knowledge of technology, pedagogy and content. Dynabook contains many access points to these components. Videos of students working out various problems are assigned to candidates so they have a framework for thinking about pedagogical strategies when addressing student misconceptions. The content is distributed through many parts of the Dynabook, especially through guided problems that include prompts to help users access the underlying mathematics through “How Do I Say It?” and “Get Me Started” features when working through the problems. Finally Dynabook makes use of several interactive representations that can help the university instructor demonstrate solutions to problems in different ways and allow credential candidates to work through problems independently using visual cues. These interactive representations of ratio concepts enable the user to work through word problems within and beyond the Dynabook. Dynabook can only be effective when embedded in the curriculum as an access point for candidates to interact with important math ideas. It is one part of an interactive lesson in which the instructor creates social learning opportunities for candidates to increase their TPCK knowledge and engage in deep discussions.

Formative Evaluation at SFSU

In the first iteration, advisors and candidates reported that the Dynabook retained too many limitations of a paper-based textbook. It was linear, text-heavy, and lacked the rich media possible in modern web applications. The revised structure of the “book” is a 3x3 matrix that can be navigated through different pathways and makes use of video and shared spaces. The columns of the matrix are set up in three related strands of middle school mathematics that develop students’ proportional reasoning: ratio (in the number strand), similarity (in the geometry strand), and linear function (in the algebra strand).

The rows of the Proportionality Dynabook are organized by three different “entry points.” Teachers can become familiar with the mathematics by exploring “challenging problems” – mathematics problems that are designed to help candidates develop their own mathematical thinking by solving and explaining context-rich math problems. They can also watch “video cases” of student thinking as students solve problems with ratio, similarity and linear functions. Finally, candidates can also explore lessons that are specially designed to take advantage of the dynamic medium of the Proportionality Dynabook by presenting mathematical ideas in a visual and interactive format. For example, in the linearity section, candidates develop the idea of linear function as they explore the relationship between the timing of thunder and lightning reaching a campsite. This matrix of related concepts takes advantage of individual teacher’s ability and need to use a resource that does not follow a strict linear ordering of pages.

Curricular Activity System

With each iteration and introduction of Dynabook to our credential classes across three semesters (including summer), we not only learned what features and interfaces worked especially well with new teachers, we also learned what classroom activities and assignments encouraged the best engagement with Dynabook. The more time candidates interacted with Dynabook features, the more rich and in-depth their conversations became. For example, the first time we introduced candidates to Dynabook, they just looked over it and asked questions like, “Is this something we use with kids or is it for us?” We realized that the role we had assumed for them was not clear to them; they needed an assignment to clarify their role when interacting with Dynabook. In hindsight, we realized that just because we put a novel form of teaching technology in front of teachers they would not benefit from the features without more context and instruction. During the second introduction, we gave the class of teacher candidates a role in relation to Dynabook and an assignment to help take on the role. We started with a Dynabook features scavenger hunt so they could navigate and utilize the components. Then, we asked them to watch a video of a middle school student incorrectly solve a ratio problem. Next, we asked them to work in pairs to create a script that could address the misconceptions of ratio the student demonstrated in the video. Finally, we asked them to put the script into Xtranormal to create an animation of the exchange between teacher and student. In this way, teacher candidates more readily took on the role of a teacher with a goal of addressing the learning challenge of a student who had not mastered the concept of ratio.

Spring and Summer 2010

During the first year, faculty from SFSU and staff from SRI visited preservice teachers who were attending a class at San Francisco State University. This class was an advanced curriculum class where the instructors were teaching about how to work with struggling middle school students in the areas of math and reading. Part of the course was taught in the classroom and part was taught in an afterschool program where children who were having difficulties with math and reading were tutored in those areas. The staff at SRI and the faculty team members at SFSU visited the after school program and observed the SFSU preservice teachers teaching children math at the middle school. The purpose of these observations was to acquaint the SRI researchers with the credential candidates and the environment in which they often work or attend class.

Fall 2010

In the Fall of 2010, twenty pre-service and intern special education teacher candidates participated in one three-hour class dedicated to interacting with the ratio section of the Proportionality Dynabook. This involved a tour of the functionality and navigation of the Dynabook followed by solving ratio problems and watching videos of students solving problems. After they worked with the Dynabook, they were given time to talk in class about what they learned and how they might like to see Dynabook change. Some students were also interviewed individually. These preservice teachers were surveyed on their attitudes toward math and their abilities to solve ratio problems before and after the lesson. Researchers took this information and used it to help revise the first version of the Dynabook.

Spring and Summer 2011

During the spring semester of 2011, the faculty at San Francisco State used the Dynabook with two of their advanced methods classes. At that time the Dynabook had been completely revised and now had a graphic interface with its current 3X3 matrix. In the first class, 13 pre-service and intern special education teacher candidates participated in two three-hour classes dedicated to interacting with the ratio section of Proportional Dynabook. Participants had varying levels of mathematics proficiency and teaching experience. Over two class periods, teacher candidates navigated the Dynabook starting with an activity that introduced the Ratio section and aspects of UDL. After becoming familiar with Dynabook, the candidates worked on solving a ratio word problem, discussed the various solutions, watched instructional videos related to the shifts in proportional reasoning (Khoury, 2002; Labato, Ellis, Charles, & Zbiek, 2010; Lamon, 1999), watched video of a student incorrectly solving the problem, and composed scripts to correct the student's misconceptions. The second class only interacted with the Dynabook during one class session. They had a similar introduction to the Dynabook and concept of UDL, but then solved problems in the "challenging problems" section and discussed their mathematical thinking as a whole group. Both classes also informally evaluated the usability of the Dynabook and provided feedback for the next iteration.

In the summer, thirteen pre-service and intern special education teacher candidates participated in two three-hour classes dedicated to interacting with the ratio section of the Proportionality Dynabook. They completed the same activities as the 2-session Dynabook introduction as the candidates from the Spring semester. However, after using the Dynabook in class, these candidates were observed in a middle school summer program for children with learning and behavioral challenges. This gave researches an opportunity to explore how activities around Dynabook transferred to the middle school teaching context.

Outcomes

Throughout these past two years, we have collected data including (a) observations, (b) survey information about attitudes and familiarity with technology and proportionality content, and (c) pre- and post-tests examining ratio content and pedagogical knowledge. In the Fall 2010 semester, students began the class reluctant to add to a discussion about proportionality. They were interested in learning the one "best" way to teach ratio and requested a video of a teacher explaining ratio. After working with the Dynabook and creating scripts to teach a student with misconceptions, they were all willing and enthusiastic to discuss the mathematical thinking behind the videos. However, the early participants did not internalize the idea that there are many ways to explain ratio problems and they would need conceptual understanding to reach students who may need multiple means of instruction. In later semesters, the researchers found that after utilizing Dynabook in a well-designed curricular activity system, teacher candidates were reintroduced to concepts such as ratio and were better able to recognize and understand the math content. Many of them did not realize how much they had forgotten since they originally learned about proportionality in junior high and high school. The candidates realized that they needed to go back to this curriculum and review and remember what they learned in those grades. Following their use of the Dynabook, they were able to talk more precisely about ratio and how to assess students' understanding of ratio. They were more confident in their ability to teach the subject. After a relatively quick review, candidates were able to discuss their solutions to ratio problems and analyze other perspectives that they may not have considered. Moreover, the candidates were enthusiastic during the discussions, often carrying them over into breaks and after class.

Teacher candidates were surveyed about their attitudes toward teaching proportionality and familiarity with terms such as TPCK and UDL. They showed increases in self-efficacy for teaching ratio conceptually to struggling learners. They were also more consistently confident with addressing the Common Core standards for teaching ratio, such as generalizing from patterns and making sense of word problems. Teacher candidates reported an increased understanding of, and familiarity with, Universal Design for Learning and TPCK. These increases could be due to two reasons. First, UDL was well explained in the Dynabook. Second, the Dynabook and the activities helped them understand UDL because the Dynabook itself was an example of Universal Design for Learning. It also helped them to think about math pedagogy using the UDL framework. They increased their ability to solve proportionality problems and recognize misconceptions in children

However, some still fell back on old patterns of teaching when working with children in the field, especially when children displayed behavior problems. Faculty observed student teachers in middle school placements falling back on old patterns. The same teachers who were able to articulate multiple explanations and ways of solving ratio problems relied on procedural teaching with manipulatives. They guided their students through lessons in a way that demonstrated that candidates did not have a deep understanding. For example, one candidate was teaching a small group of students about equivalent ratios and the students were able to understand this concept in a much quicker than anticipated. Instead of moving on to a different ratio concept, such as comparing ratios, she continued to teach the same concept in exactly the same way as she had planned. Other student teachers planned a lesson around manipulatives and did not incorporate any of the interactive tools or deep discussions from the Dynabook lessons into their plans. Instead, students worked with candy to demonstrate ratio without engaging on conversations about ratio ideas. They were teaching in a rote way that did not draw upon a conceptual understanding of ratio. This small group of credential candidates was participating in a summer class and the school program they worked with included only students with emotional disturbance. These particular candidates had limited classroom experience and struggled with the daily behavior problems in class. Consequently, they spent more time with behavior issues and struggled to complete lessons. In the future, we plan to observe candidates with more classroom experience teaching ratio concepts in authentic classrooms.

Implications

Dynabook is designed to help teacher educators teach general and special education teachers to better understand math content and pedagogy. Through Dynabook, teacher educators will also learn more about technology and the use of technology to teach math concepts, especially as they relate to interactive representations. It will allow teacher educators to work with candidates on improving their understanding of proportionality and pedagogy, with the hope that this will extend to the teacher candidates' classrooms. The Dynabook allows teacher educators to not only impart a conceptual understanding of proportionality, but also to offer interactive activities, where students actually produce interactive demonstrations that use multiple representations. Since many teachers were trained to think about math procedurally, using Dynabook in university classrooms opens up a dialogue for participants to better understand how to think about and explain math problems. Through explaining their solutions to other candidates, they build the language that they will use to teach students in the classroom. For special education teachers, Dynabook helps candidates become more comfortable combining knowledge of individualized instruction with a deeper understanding of mathematics. It adds to a toolbox that includes videos, context-rich problems of varying levels and interest, interactive representations and other teaching tools that will make their jobs more effective and efficient. Finally, Dynabook developers are working to provide mathematics and education instructors and candidates with math content that they can explore alone or together. As teachers and teacher educators explore how to teach proportionality, and how children think about proportionality, they will broaden their own understanding.

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