

TABLET COMPUTING, CREATIVITY AND TEACHERS AS APPLIED MICROGENETIC ANALYSTS: A PARADIGM SHIFT IN MATH TEACHER PROFESSIONAL DEVELOPMENT

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1. ABSTRACT

This effort is funded by the Institute for Education Sciences (IES) [1] and the National Science Foundation (NSF) [2]. It advances a vision for personalized learning communities in mathematics education. Tablet computing provides entrée to naturalistic handwriting and symbolic notation at the core of mathematical manipulation in K-16 and graduate learning in mathematics. The project uses this affordance to help teachers customize instruction through development of video libraries that require freehand mathematical notation and drawing . It directs teachers to what can be considered the intersection of student cognition, mathematical content, and interactive digital media. The work bridges eclectic theoretical perspectives, while leveraging tablet computers functioning in tandem with screen-imaging software. Teacher interviews suggest multiple advances in professional development.

2. PROBLEM STATEMENT

This project arises out of three somewhat unrelated needs in mathematics education. These needs jointly lend themselves to novel solutions through engaging teachers in tablet-enabled professional development

Need 1: Internet-accessible digital library resources are difficult to use. The first need involves the limited usability in classroom and private study settings of internet-available digital resources for mathematics learning. Ironically, the largest single investor in digital content infrastructure, the National Science Foundation’s NSDL Program [3], outlines this deficiency succinctly: “... *it is often difficult to determine from a lengthy list of links how well an individual item suits a particular learner's needs. When resources are located, they can exhibit uneven reliability or stability particularly if they incorporate additional software elements for animations, audio, or video. In addition, the audience for these collections often lacks the support and expertise needed to select an appropriate resource, incorporate it into a coherent learning experience, and evaluate the impact of the new approach*” (page 2). The breadth and depth of the NSDL linked repositories are not yet matched by use or impact.

Need 2: Deficiencies in professional development and status of teachers. A second need this effort addresses professional growth and the declining status of mathematics teachers in the current high-stakes testing environments that now define state and federal K12 education policies [4]. Current policies respond, in part, to sustained and reform-resistant failures in US K12 education to produce higher general achievement in schooling and to reverse flat or downward trends in international mathematics and science comparisons [4]. Two recently-published reports by the National Academy of Education, for example, highlight teacher complaints about lack of

- Video objects should require no more than 1-4 minutes to execute.
- Objects should be self-contained, and open, execute and close in single clicks. Easy-on, easy-off, minimal searching by students, no disruption to classroom flow.
- When illustrating applets that require entering variable parameters by students, the teacher content should model the applet and show the student how to parameterize it, and provide a live link for their own experimentation.
- Objects should map to specific content standards and expectations for the teacher's school or LEA.
- The objects should form a trusted library that students can access autonomously both from within school firewalls and outside of school.
- The library should grow over the course of a teacher's career, and represent content sharable within the teacher's professional networks.
- Narration should be in the teacher's own voice where possible.

Table 1: Tablet and Screen Video Object Design Principles

personal agency or autonomy in teaching in high-stakes testing environments [5, 6]. While citing early-career teacher dropout rates and teachers' dissatisfaction and alienation in their profession, both reports highlight the need for more high-quality opportunities for professional growth than are currently available.

Need 3: Teacher creativity is undervalued and underused. A third need is related to the second, but has a lineage older than the current high stakes policy structures. It also unlocks the potential contribution of tablet-enabled innovation to national discourse on mathematical teacher professional development. The prominent role of traditional textbook or reform curriculum producers and curriculum standards and policies, the lack of effective tools for digital representation of mathematics, and the very limited time that teachers have outside of the classroom, all act to crowd out the **creative potential** of teachers to generate content. As in the past, mathematics teachers are not expected to be content *producers* but rather are content *conveyors*, following pre-defined curriculum in preparation for accountability tests. At a time of unparalleled ascendancy of user-generated content in society more broadly (as evidenced by phenomena such as YouTube), teachers are strangely left out. Mathematics teachers simply are not expected to be creative in producing content that maps to their student needs or to their own teaching styles.

3. SOLUTION EMPLOYED

In this project, public school mathematics teachers from Los Angeles, Orange and Ventura Counties have developed or adapted approximately 100 short videos, two of which are discussed below. They are designed in compliance with the principles that appear in Table 1, principles at the heart of attempting to improve the usability of digital media in mathematics.

Tablet computers and screen video capture software are the project's foundational tools. The screen video capture allows teachers to narrate and record short videos on their tablet computers while using the tablet-enabled and natural flowing form-factor of handwritten mathematical notation enables them to replicate electronically board like instruction. The purpose of the effort includes but also extends far beyond allowing teachers to replicate math lectures electronically and using the tablets for the notation that makes that possible. A larger and more sublime purpose is to draw teachers into the process of **reflective anticipation of the subtleties and nuances** students face in facing challenging mathematical material. Our data suggests that this

occurs, as a natural by-product of engaging teachers in the craft of video production. The practices of that craft include video take and re-take, mixing, matching and refining video sequences, and calibrating individual image against audience



Table 2: Observed evolution of proficiencies in creating sharable content libraries.

perception. The practices appear, based on numerous interviews, to engender more of the deep mathematical probing and sustained attention to content and cognition that have been cited as critical needs in professional development [7]. This pathway is a direct response to Needs 2 and 3, to deepen professional development opportunities while helping teachers manage the high-stakes accountability requirements, and utilizing teacher creativity. The notion of teachers engaged in the disciplines of reflective anticipation through video production invokes a field of educational psychology called *microgenetic analysis*. Microgenetic analysis is an approach to cognitive science with a long history; its more prominent use began by the mid-1980s [e.g., 8]. The microgenetic approach to the study of cognitive process involves a high density of observations per unit of time – parallel, it turns out, to the exacting calibrations involved in video production. The approach has been critiqued as overly expensive and time consuming as a research methodology. But in the day-to-day rhythm of professional development, reflection, and the creation and testing of interactive digital media, teachers may indeed be able to become applied scientists - microgenetic analysts, in other words - who draw on their experience to reverse engineer student cognitive pathways and design media to help students address subtle and knotty conceptual obstacles. We have coined the term “applied microgenetic analysts” to refer to teachers probing and building media to match cognition, not to invoke the kinds of theoretical inquiries commonly associated with microgenetic study of cognition, **but instead to emulate the subtle and minute exploration of cognitive pathways, especially with digital media that tracks with those pathways.** The teacher comments below reflect this experience.

A model of the overall path to sophistication in resource creation appears in Table 2: Simple videos *de novo*, more complex videos *de novo*, and then revision and adaptation. Two examples illustrate the progression. Each has amateur edges, but they are authentic teacher constructions.

Creating New Content. Producing content from scratch is the straight-forward process of teachers generating explanations or illustrations that they can use and re-use. Because content creation takes place outside of the live classroom setting, teachers can reflect more carefully and collaboratively on what they want to communicate. Teachers, like media producers more generally, are able to edit, re-edit, and refine their presentations. Once they have developed the simple skills of producing short narrated videos, they transition to adding other audio or graphic or visualization tools, to help build richness and interest in the material. The various objects that they have developed in the pilot activities include 30-90 second video clips explaining mathematical ideas, which often require nothing more than clearly walking through the idea structure. The teacher may elect to include in the set of questions those that are related to specific exercises. Questions may be related to statewide standards in the curriculum area (Such as, “this question corresponds to state standard x, y, or z”). We also encourage teachers to develop

multiple, narrated versions of playback solutions to problems, differing by level of elaboration of each step. So, for example, a student can retrieve playback of a specific problem, and watch the teacher's solution unfold in real-time, with an audio narration. A student who is

$$x^2 + 13x + 36$$

$$1 \cdot 36 = 37$$

$$2 \cdot 18 = 20$$

$$3 \cdot 12 = 15$$

$$4 \cdot 9 = 1$$

$$6 \cdot 6$$

Section 9.2 Multiply Polynomials

Use a horizontal format to find the product.

20. $(w+1)(w^2+2w+1)$

$$w^2(w+1) + 2w(w+1) + 1(w+1)$$

$$w^3 + w^2$$

Figure 1: Two Simple Teacher-Made Videos

needs further help or clarification might retrieve a version of the solution that unpacks each step or starts at a more elementary level of explanation. Screenshots from the first example appear in Figure 1 (with the video available at <http://erichamilton.net/alaskavideos>). One is a simple review of sums and factors in quadratic factoring and involves a video screen capture of a handwritten explanation. The explanation is clear, has an easy-to-copy representational device (overlay the plus sign above a multiplication sign), is short, and can be replayed for the student. The other depicts simple polynomial multiplication, but again in a replayable and clear manner.

Adapting Existing Content. The mathematics education cyber-community has developed a growing cyber-sphere of content applets that teachers may confidently direct their students to use. But, as noted earlier, if a teacher can locate a valuable or compelling applet resource freely available online, it might not be useful with a whole class or lend itself to adaptation to full class lesson; and it might not be readily available when a student poses a question during a class discussion. It likely requires trial-and-error parameterizing and validation. A teacher may run a visualization prepared in advance, and determine which parameters (e.g., values for variables, or scale of axes, etc.) most effectively highlight an idea. That is, the teacher can fill in values, move sliders, use pallets etc. and actually carry out a visualization that resides in an existing digital repository. By capturing the teacher's running of the applet to video, students have easy access to the underlying mathematical idea, and see how to perform the applet if they wish to parameterize it on their own. What is the advantage? First, such instruction on individual applets is time intensive and distracting in classrooms. It just cannot happen frequently, nor is it realistic to expect otherwise. On the other hand, pre-testing, authenticating and storing the applet reference in the library can make it reliably and safely available to students. A second advantage goes directly to the use of annotation to furnish a new layer of explanation appropriate for extra assistance where desired. This further responds to Need 1, to render new and existing digital content more usable in live classroom settings.

Conic section visualization. In the free-throw applet [10] that Figure 2 depicts, a short video of Justin Timberlake shooting free-throws at the ESPY awards is narrated by the teacher, who identifies salient features of the arc before shifting into a discussion of parabolic properties, demonstrating what effect each of the three (quadratic, linear and constant) coefficients has on the arc. The video is less than one minute long. It maps sports and entertainment to parabola instruction, enabling a visualization of the factors influencing function behavior. It shows how to use parameter sliders on a visualization applet and invites students to manipulate the sliders themselves. The tablet permits additional annotation layer over the applet that allows the teacher to insert written comments over the applet. In this case, the teacher “steps out” of the applet and provides explanatory information.

4. EVALUATION

Teachers in this pilot work have shared an abundance of observations about the approach, through both informal and formal surveys and structured interviews. Each of these benefits corresponds to addressing the needs cited at the beginning of the paper, to make digital libraries more

usable in classrooms, to enhance teacher professional development, and to leverage creativity. Teachers made these observations about the model:



Figure 2: Conic Section Video First Shows Justin Timberlake Shooting a Free Throw, then an Interactive Applet Modeling the Free Throw Trajectory

- It promotes **technological fluency**. We are likely experiencing one of the first times in social history in which the generation being taught has greater overall fluency in the tools and media for knowledge archiving and expression than the generation that is teaching. One teacher wrote: *“The library tool is a great addition to my teaching tool box. Not only does it allow me to be technologically more advanced and up-to-date with the latest innovations, it also makes me a much better critical thinker.”*
- The model promotes **intense pedagogical concentration**. The teachers anticipate the subtleties of potential misunderstandings. One teacher wrote in a formal survey, *“(The professional development) definitely does exercise creativity because it makes me anticipate common mistakes students make and design media accordingly. It made me think like a student and allows me to use different visual effects to enhance the learning process.”* Another wrote, *“Development of the templates for algebraic procedures has helped me focus on the degree to which students’ spatial intelligence is as important as their math/logic intelligence.”* A third wrote *“(Anticipating subtlety and nuance)... is one of the major advantages to using this library system. It has forced me to think of every little thing that students may have trouble with.”* Finally, one teacher wrote, *“Designing the content is primarily based on anticipating the misconceptions.”*
- It creates **cumulative bodies of personalized, reusable and modifiable pedagogical knowledge**. *“It made me realize that using technology allows me to focus more on content rather than delivery because the library eliminates the need to worry about delivery on a daily basis. I create it once, and it’s out there for students to refer to over and over again.”* Another wrote: *“The library exercises my creativity in new ways by forcing me to perfect every single detail. I have this ability because I can erase and record the content. Also I can review my work and make changes if necessary.”*

5. FUTURE WORK

Two primary strands for future work appear most promising. On the **application side**, we are seeking to expand the number of teachers who build video content and can help refine the

design principles for doing so. Additionally, project sites are in formation in several international venues in Asia, Africa and Europe. On the **research side**, our interests involve understanding the evolution of teachers who create media in advance of the classes that they teach. This work is currently supported by IES . Additionally, the NSF National STEM Distributed Learning (NSDL) Program issued a grant in September, 2010 to carry out targeted impact research on the project. As noted earlier, this work is connected to an underlying theory of personalized learning communities [11] and one avenue of research will entail applying that research. We will rely on and expand the construct of microgenetic analysis discussed earlier as one means to understand more fully teacher reflections and efforts to effectively map mathematical content tightly to student cognition through the creative use of digital media. Additionally, teachers as microgenetic analysts of student cognition lead to another major inquiry. **Does assuming a more proactive role in media design to match student cognition alter the teacher’s own cognitive processes?** We hypothesize that engaging teachers in such analysis of learner cognition during development of digital media enhances their pedagogical flexibility, expertise and sophistication. These research questions do not focus on the interface tools of tablet computing. Instead, tablet computing furnishes a path to enable teachers to join the ranks of digital content producers in mathematics, and thus a new way to conceptualize professional development and the evolution of teachers as “connoisseurs” of learning.

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