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Internship Experience in an Educational Technology Laboratory: Autoethnography of an Eighth-Grade Student-Researcher

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This paper attempts to diverge from the traditional social-science methodology employed in education research, namely that of treating texts containing student reflections as data to be parsed, coded, and analyzed by subject-matter experts. Instead, this paper models the inclusion of student-originated texts as worthy of lead authorship. Specifically, the paper presents a written autoethnography describing a middle schooler's volunteer internship experience in an educational technology research laboratory. The autoethnography describes the student's experiences serving the lab in this position, and the student's original text was combined with observations and editing by the lab's directing professors and by a mathematics education professor who is the student's father and an occasional collaborator of the lab's directors. For narrative cohesion and clarity, first-person is the student's voice. The contributions from the three professors are primarily in the form of inserted references, photos, and details of the overall project.

Key Words: Mathematics education, student autoethnography, middle school, educational technology laboratory, internship experience.

During my time as an eighth grader in the 2012-2013 school year, I volunteered weekly after school in Drs. Daniel Tillman and Song An's educational technology laboratory at The University of Texas at El Paso, officially known as the UTEP College of Education's Educational Technology Research Laboratory. My duties were varied, but mostly involved:

- supporting the lab's 3D-printers and software, including fixing and modifying the hardware,
- designing and fabricating simple musical instruments to be used in teaching math concepts, and
- volunteering as a facilitator for a math-themed summer camp hosted in the laboratory.

Learning about 3D-Printers by Fixing and Modifying Them

This section does not intend to be a technical guide to 3D-printers, but some background is necessary to explain my contributions during the internship experience. Dr. Tillman's lab made available five of the first-generation Cube 3D-printers made by Cubify, a brand of 3D Systems. While later models in the second- and third-generation included more advanced features such as printing with multiple colors of filaments simultaneously, these original "Cubes" could print with one color at a time. These printers were among the first intended for home use that did not require assembly. Accordingly, very few of the internal mechanisms were user-accessible and the printing software was closed-source. Each proprietary reel of filament for the printer was enclosed in a sealed opaque plastic case with an embedded identification chip and cost $50 for about one-third of a pound of filament.

Due to the proprietary nature of their identification chips, which were designed to induce very frequent purchasing of their own brand of plastic filament, I experimented with hardware modifications to increase the printers' material economy. These included extracting tangled filament from the sealed cartridges as well as rigging together a homemade filament-feeder and spool that allowed us to print objects with a filament at about one-fifth the cost of the original filament (see Figure 1, right). I also studied the practicality of assembling objects that were printed as separate pieces, such as a model of the Mars Rover, which often requires less filament be used as support material and is therefore more economical. The physical limitations of the printers were explored as well. Even as recently as 2013, at the time of the summer camp, the consumer 3D-printers' resolution was substantially less impressive than 2016's consumer printers (see Figure 1, left). Thus, small areas of detailed models that the other students and I printed became noticeably coarse, and complex prints were prone to errors such as gaps and dangling strands.

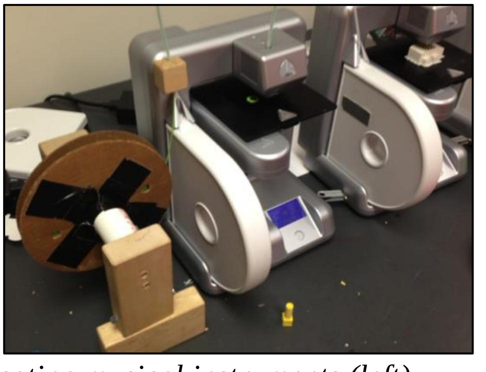

Figure 1. *Students designing and fabricating musical instruments (left), and 3D-printer rigged to use custom spool (right).*

Unfortunately, reminiscent of ink cartridges for two-dimensional laser and inkjet printers, the supply level feature for the reel often grossly under-estimated how much plastic was left, and the printer would not start unless there was enough (estimated) filament in the reel to complete it, leading to a significant amount of wasted material. Additionally, the filament often tangled inside the reel, causing a “feed error” when the modest motor in the print-head could not pull forth filament from the jumble. The only solution at that point was to pry open the plastic case, damaging it beyond repair in the process, and untangle the filament by hand, which was often impractically tedious. To find a use for the tangled reels and broken plastic cases, I built an apparatus similar to what I had seen at http://www.instructables.com/id/Low-Cost-3D-Printer-Filament-Spool-Stand/. This crude structure, constructed of wooden blocks and dowels, allowed an auxiliary reel to be placed beside the printer, with its filament feeding the machine, instead of the proprietary reel (see Figure 1, right).

Modifying the 3D-printers themselves was also a major focus of mine. Since I had access to the use of multiple 3D-printers, and I had been encouraged to take them apart and modify them in other ways, I experimented with optimal design parameters for successful prints. One such experiment consisted of a multitude of arches of different steepness on a base. Since a 3D-printer of this type and quality cannot print an unsupported horizontal line, a very shallow arch would have droopy, unsupported strands hanging from the middle. Not only did this experimental print have droopy strands, but it was entirely a clump of loose plastic threads with no defined shape. This was not an indicator that the printer was unable to print complex objects, but instead showed that the object had probably become unsecured from the printing platform and simply rolled around while the print-head continued to extrude. Perhaps if the print had not had become unsecured, the shape would have been successfully created. This highlighted another weakness of the printer because it relied on a heated print platform and heat-activated glue to hold objects stationary while printing. Even if an object did not become unsecured, it almost always had curled corners. While heated platforms are still a staple of high-quality printers, the Cube was overall an entry-level machine. For example, a design for a Mars Rover model sourced from the Internet (http://www.thingiverse.com/thing:10057) could not be assembled after printing because the rough surface of the parts required sanding to fit together.

Fabricating Musical Instruments with 3D-Printers

During my time there, a major component of the research lab’s focus was to design simple musical instruments that a student could build with ordinary materials and tools (e.g., An, Capraro, & Tillman, 2013; An & Tillman, 2014, 2015; An, Tillman, & Paez, 2015a; An, Tillman, Shaheen, & Boren, 2014; An, Zhang, Tillman, Lesser, Siemssen, & Tinajero, 2016). As Drs. An and Tillman have noted in their previous studies, students can learn to understand and recognize the principles of conducting scientific research through the iterative process of musical instrument development, including these steps:

(1) drawing up blueprints on paper,

(2) fabricating the instrument with different materials and/or shapes,

(3) formulating hypotheses about how changing the properties of an instrument will affect its sound,

(4) testing the hypotheses, and

(5) re-designing the instruments based on the results.

The process of making musical instruments (e.g., Louisiana Tech University College of Engineering and Science, 2011) offers students opportunities to explore multi-dimensional geometric concepts as well as the relationships between different types of musical instruments (e.g., guitars, drums, and trumpets) and in doing so, there is occasion to discover how variables such as shape and materials impact the generated sounds and tonal quality. Of the many types of instruments in existence, we recognized that a monochord, an instrument with only one string, would be one of the simplest and therefore most accessible physical manipulatives to support STEM learning opportunities (e.g., COMAP, 2002; Haak, 1982). Unlike a guitar's fret which is not moveable and allows playing the string on only one side of the fret, a monochord usually has a moveable bridge that allows plucking the string on either side of it. For example, if the ratio of the string lengths on each side of the monochord bridge is 4:3, then the notes produced by plucking each side form a musical interval is known as a perfect fourth. While working in the research lab, I built several monochords, usually beginning out of a block of wood, then adding eye screws, and guitar strings, which sufficed for our instructional purposes. I also designed and 3D-printed some frames to hold a guitar string, but they ended up breaking under the high tension required to tighten the string for a clear pitched sound, since none of the 3D-printed frames created with the ABS plastic filament were strong enough to hold a string taut.

At the end of the summer camp, we asked the students to respond to the prompt: "Please tell us what you think went well during the summer camp and why." Numerous student participants answered that they liked designing and fabricating with the 3D-printers, as represented by the following quotation: "I've never used a 3D-printer, and now I did … and I wanted to learn more, and it was pretty fun and interesting. .... It was pretty much fun, like the math lessons, instead of just doing math you get to draw in math to music, so it would be just not math, it would kind of entertain you more, like in school they just do math."

Another student said: "The 3D-printing because then I could turn the creation from my head into something that I could hold in my hand … you can actually see how it will be thin, it could be thick, it will be short or be tall, you can actually see it before you print it."

To illustrate the above quotations, as well as to present some of the evidence used to assess the curricular materials, Figure 2 shows images of student activities involving the 3D-printers: students learning how to use a

3D-printer to fabricate musical instruments, and students making 3D-printed musical instruments from files. Figure 3 shows a close-up of a Cube 3D-printer fabricating a 6-inch guitar neck (left), as well as the finished prototype of that neck (right).

Figure 2. *Students learning to use 3D-printer to fabricate musical instruments.*

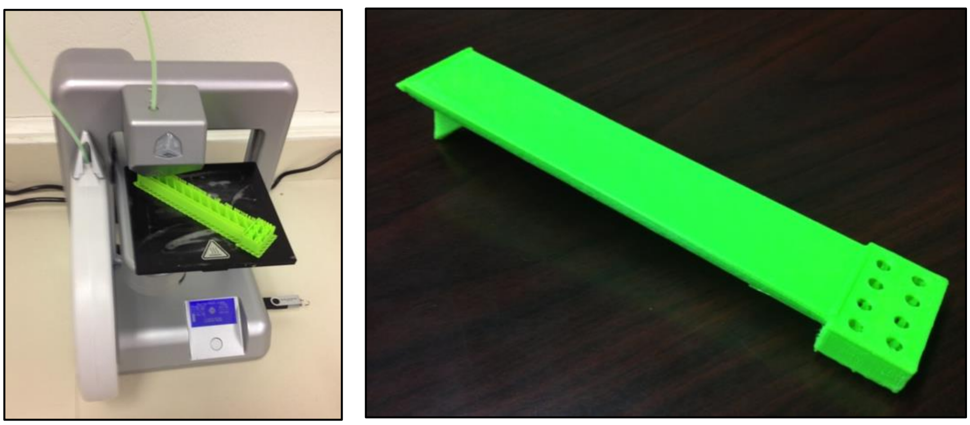

Figure 3. *A 3D-printer fabricating a 6-inch guitar neck (left), and the finished prototype (right).*

Students discussed how they enjoyed learning to use 3D-printers and software, such as in the following example of a student comment: "I learned that you can actually create stuff and make it in real life so that way you can use it, turn ideas just thoughts and inklings, into something you can hold and use. I made a working whistle, and somebody printed a teacup, and that can be used in daily life."

The digital and physical artifacts created by the camp participants served as evidence of the effectiveness of the music-math curriculum. Figures 4 and 5 show sample musical instruments that the students designed and fabricated. Figure 4 shows both a musical whistle instrument design (left) and a combination musical whistle and rattle instrument (right). Figure 5 shows two of the student-created musical rattle instruments.

Figure 4. *Student-designed and fabricated musical whistle (left), and dragon-shaped musical instrument combining whistle and rattle (right).*

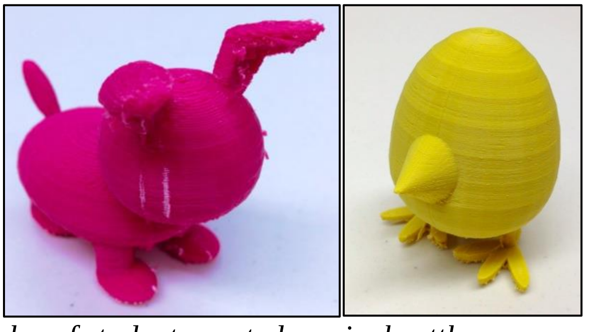

Figure 5. *Examples of student-created musical rattles.*

Math-themed Summer Camp

During the summer of 2013, I continued to volunteer at the educational technology lab, as a facilitator for Drs. Tillman and An's "World Music & Math Summer Camp". This two-week interdisciplinary program focused on music-themed design challenges utilizing 3D-printing technology. The camp featured university faculty and local experts with diverse backgrounds in world music, math education, and design technology. Participants in the summer camp included: (1) upper elementary students from local schools (*n*=21), and (2) preservice (*n*=21) and (3) inservice (*n*=5) elementary teachers. Detailed study results can be found in the following three articles: (1) teachers' lesson plan analysis (An & Tillman, 2014), (2) teachers' reflection about implementing music-themed mathematics lessons (An et al., 2016), and (3) assessment of impact of the summer camp on students' mathematical dispositions (Tillman, Zhang, An, Boren, & Paez, 2015).

Throughout the camp curriculum, all participants learned about math-related topics through design challenges supported by the 3D-printers made available. The two primary design challenge strands that were employed as contexts for math pedagogy were: (a) math themed music-video productions, and (b) musical instrument design challenges. Figures 6 and 7 show still images from some of the introductory music-themed activities experienced at the beginning of the summer camp.

Figure 6. *Student participants learning about music-math patterns via color-coded bells (left), and music-math connections from a music educator (right).*

Figure 7. *Student participants learning about math concepts through dance and percussion activities (left), and by playing instruments in a group (right).*

My main focus as a facilitator was supporting the participants as they used 3D-printers and accompanying design software. This camp was the first time most of the upper-elementary attendees had seen a 3D-printer and they were thoroughly rapt. One of the main reasons for the summer camp was to continue a line of research trying out innovative math curriculum that would be more engaging to students (e.g., An et al., 2015b; Robertson & Lesser, 2013; Tillman, An, & Boren, 2013, 2015; Tillman et al., 2015). As part of the camp's curriculum, I taught the campers how to use a basic, free, and online, 3D-design program called Tinkercad. While not as advanced as programs like SketchUp, AutoCAD, and SOLIDWORKS, the Tinkercad program was very easy to use and sufficed for all projects the campers wanted to undertake.

The campers were allowed to design some items of their choice, but were also tasked with designing simple musical instruments. One pair of campers designed a chessboard (the actual board, not the individual pieces) and wished to print it. I thought this a bit impractical as large flat objects tend to warp during printing, and the posts they had included under the chessboard to elevate it would require extensive support material. Most of all, any piece of wood or cardboard would perform much better as a chessboard than a 5-inch 3D-printed plate. Aside from such occasional off-task behaviors, campers designed interesting and practical objects that were suited to a 3D-printer.

As for their final musical instruments, some of the campers were quite creative. One student designed a dinosaur that held a string between its feet.

Another pair designed a simple five-pointed star with their initials on it, called me over, and said matter-of-factly, “We’re ready to print.”

“What is it?” I asked.

“It’s a drum. You tap on it,” they answered.

Hearing this liberal definition of a drum, I suggested to them that they strive to make it undeniably a musical instrument—knowing that in truth, 3D-printed objects are not well-suited to musical instruments that require vibration to make sound. A plastic drum skin would break long before it could be tightened enough to produce a resounding note, and the same applies for a plastic string. Reedless wind instruments, however, are suited to 3D-printing, and the lab did have several whistles and recorders produced in this manner. But I knew from listening to Dr. Tillman and An that a goal of constructivist mathematics teaching was not to show the students the answer, but instead to help them find it themselves. And so I let them continue working on their percussion instruments, and the results were surprising even to me.

In my opinion, the campers enjoyed the 3D-printing activities far more than the music activities that involved playing or composing music. During such activities they would often attempt to sneak into the secondary room where the 3D-printers and I were located, rather than participate in circle singing with percussion instruments. By the end of the two-week summer session, the attendees were proud to show their parents what they had designed and printed, and I heard several say, “I’m definitely coming back next year.” Sadly, there was no “next year,” as the research lab’s focus shifted shortly thereafter to an NSF-funded grant (mentioned in the Acknowledgement section of this paper) that involved students’ building water-filters and terrariums, so rather than run their own camp inside the research lab, Drs. Tillman and An decided to move the camp to a local dual-language institution named La Fe Preparatory School.

Conclusions

During the 2012-2013 school year and the following summer, I volunteered at Drs. Daniel Tillman and Song An’s educational technology laboratory at The University of Texas at El Paso, and this paper is a summary of that internship experience. The main focus of my activity there was the development of techniques to assist in the teaching of music and math to middle school students and operate the lab’s five 3D-printers. Under the supervision of Drs. Tillman and An, I designed several stringed musical instruments that were either 3D-printed or made of 3D-printed parts combined with commonly available wood materials. This demonstrated the viability of such simple instruments in the teaching of math as it relates to music. In essence, all that was needed to show the relationship between a note produced by a plucked string and the length in which it can vibrate is a sturdy frame that can hold a string taut. The multiple methods of teaching math concepts that were derived from this exploration were put to use during a summer camp in which I was a full-fledged facilitator who took the lead in assisting the camp's student attendees in creating their own instruments.

Upon entering high school, my tighter schedule no longer allowed me to attend the research lab weekly. This worked out fine because in the second half of 2013, Dr. Tillman announced that the lab would focus on an NSF-funded water-themed project while taking a break from research on 3D-printing until the hardware technology further evolved. This paper presents several illustrations of how the time I spent at Dr. Tillman's lab was a valuable educational experience that encouraged me to further pursue 3D-printing-related activity, both as a hobby and possibly as a future profession. I also learned quite a bit and got to contribute toward the accomplishment of the research lab's goals. As I write this, I am now volunteering at UTEP's W.M. Keck Center for 3D Innovation, within the College of Engineering, and feel highly encouraged as I continue to explore the professional trajectory that began in part with an educational technology laboratory internship.

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