TIPS, TRICKS & TECHNIQUES

Enhancing Learning Using 3D Printing: An Alternative to Traditional Student Project Methods

PATRICIA McGAHERN, FRANCES BOSCH, DOROTHYBELLE POLI

Abstract

Student engagement during the development of a three-dimensional visual aid or teaching model can vary for a number of reasons. Some students report that they are not "creative" or "good at art," often as an excuse to justify less professional outcomes. Student engagement can be low when using traditional methods to produce a model, but 3D printing gives both the teacher and the student new ways of experiencing classroom activities. The simple (and free) software offers students valuable skills, "professional" modeling results, a stronger understanding of the topic at hand, and new confidence.

Key Words: *3D printing; student engagement; project creation; professional skills.*

For the past year, our college has been investigating how to use 3D printing (Sachs et al., 1992, 1993) to enhance classroom experiences. The biology department has focused on inexpensively producing replicas of fossils, bones, and molecular structures (proteins, RNA, DNA, etc.). Although 3D printing has become a valuable asset in many areas of biotechnology (Dimitrov et al., 2006), so far the educational uses have been limited. These economical prints can easily be taken into a classroom and passed around to emphasize a point, without worrying about breaking an expensive model. As we (F.B. and D.P.) were evaluating how this technology might help teachers introduce topics through visual learning aids, it was a student (P.M.) who showed us how to use 3D printing for student learning!

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In our undergraduate biology seminar for seniors, students work on professional skills – such as how to teach, how to write science for various audiences, and how to design a visual aid for a talk or for use during instruction. Visual aids are often necessary to make a critical point during a job presentation, when giving instructions to coworkers, or in a classroom, and therefore this is a unique skill to possess upon graduation. The visual-aid project represents a substantial portion of the grade, but every year, few of the students' projects are impressive, and many lack imagination and do not represent the work of an engaged learner. Even though the projects are graded in relation to each other (and not to the work of professionals), students often claim they are not very creative, while others say that they do not have the time to invest in a high-quality product.

Upon being presented with the assignment, P.M.'s plan was to build a root-tip cross section, but she was concerned that her project would not be as professional as she wanted it to be with the use of basic arts-and-crafts supplies available at local stores. Clay seemed like the best option to her, but she was limited in her access to clay tools and an oven; the clay would likely have been soft and uncooked, and the cross section messy. Also, the clay would have been only one color, lacking visual excitement. Therefore, she investigated the 3D printing option. The college's 3D printing was in pedagogical development and not openly accessible for student use, but she was approved to move forward. The results are worth sharing.

She used the 3D sculpting and artwork software Sculptris Alpha 6 (Pixologic, Los Angeles, CA), which can be downloaded for free (for student use) for Mac and Windows systems. She used it to mold and sculpt an object that looked quite similar to diagrams found online (Figure 1). The software allows the user to create textures from jpeg images, so she created the root-tip texture by using a scanning electron microscope image of a corn root-tip found on the Internet (e.g., http://www.biologie.uni-hamburg.de/). She had to pay close attention to morphology, physical dimensions, cellular differentiation, and cellular placement. Further details of the root-tip were based on diagrams found through a Google image search, with creative liberties and interpretations being taken as necessary. The best parts of different diagrams were combined to make the best possible 3D model. Scupltris has the capacity to export the image as an .obj file, which is compatible with the 3D printer. The root-tip designed in Sculptris was printed on a MakerBot Replicator 2x Experimental 3D printer using 1.75-mm ABS filament, via the free

The American Biology Teacher, Vol. 77, No. 5, pages 376–377. ISSN 0002-7685, electronic ISSN 1938-4211.
DOI: 10.1525/abt.2015.77.5.9

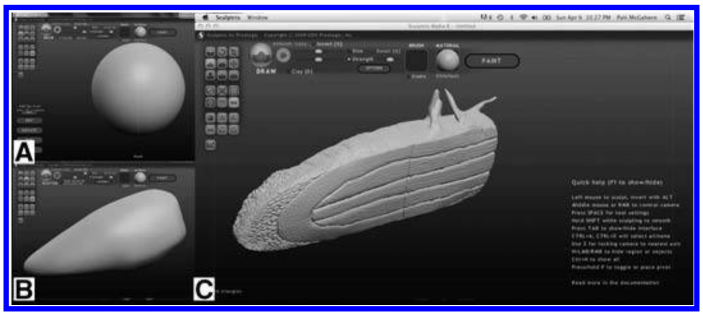

Figure 1. Sculptris Alpha 6 (Pixologic) screenshots showing the sculpting process. (A) Original (new) project state in the program. (B) Student has created an axis of varying thickness and length. (C) Final project file prior to printing.

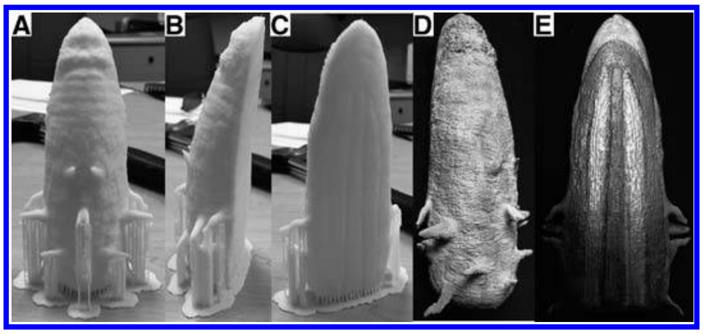

Figure 2. The physical print of the student's designed root tip. (A–C) Different angles of the raw print of the student's file. (D–E) Final print with additional painting done by the student.

and downloadable MakerWare software that formats (.thing and .x3g files) the model for printing (available at https://www.makerbot.com/makerware/). Finally, the root-tip was painted with nail polish and acrylic paint to accent the features of the model (Figure 2). The total cost to print this project was under $5.

For F.B. and D.P., watching our student spend several weeks completely invested in her project was impressive and inspiring. Other students reported spending from 1 to 4 hours on their projects. We wondered what the difference between investments was – just the opportunity in learning the technology, or a sense of pride in the final product? Students using traditional methods reported that their project "would only look so good, so why invest a ton of time." For P.M., the quality of the outcome and the new skills were equally important. She reported that

> It is difficult to imagine that I would have committed the same amount of time to the project if I had opted for a more traditional route, because I would not have been as invested, engaged, and interested in the outcomes. My clay model would not have looked as nice overall, because clay is harder to work with, mold, and fix mistakes than a model designed in Sculptris. I first had to research what root-tips looked like and what the different parts of the root-tip did. My efforts resulted in a much more realistic and enticing model than I could have made from clay or a simple drawing. I had what I considered a professional-quality root-tip model.
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> I feel using the 3D printer to design and create a project allowed me to learn a lot more about the subject than I otherwise would have. However, the most valuable part of this project was the skill set I gained in learning how to operate 3D software and upload and print these designs. Knowing how to use a 3D printer as an undergraduate student gives me an edge and a skill that sets me apart from other students and makes me more marketable in the modern employment market.

P.M. has since been accepted into a bioengineering graduate school, and her 3D project was something she spoke about during her interviews and added to her portfolio. She has also been asked to attend a summer conference on 3D printing as an invited speaker because of her efforts! It's easy to say that this simple and straightforward assignment took on a whole new meaning once it was transformed by this technology.

As educators, F.B. and D.P. are now rethinking how we will use and assign 3D printing for enhanced student outcomes. We have begun printing the proteins to help students understand molecular processes like respiration, photosynthesis, transcription, and translation. We have also begun designing incomplete 3D structures that require the student to construct the rest of it, as a way to enhance true learning in a way that memorization of terms and locations cannot. However, as the technology becomes more established at our institution, we plan to develop assignments that require students to create visual projects for diversity, evolution, cellular, and molecular courses. Current limitations include the number of 3D printers on campus and costs to the student. We are examining ways to absorb the printing costs into a course's materials costs to ensure that students are not being burdened with the expense. Overall, the cost-to-experience value is worth the efforts by all!

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