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INVENTING THE INVENTED FOR STEM UNDERSTANDING

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ABSTRACT

The reverse engineering of simple inventions that were of historic significance is now possible in a classroom by using digital models provided by places like the Smithsonian. The digital models can facilitate the mastery of students' STEM learning by utilizing digital fabrication in maker spaces to provide an opportunity for reverse engineer and the creation of working models of the inventions. Students can start with understanding the original design, and then modify it to create working replicas and proximities showing the understanding of the underlying STEM concepts.

KEYWORDS

Maker space, 3D-printing, digital fabrication, Smithsonian

1. INTRODUCTION

Maker spaces with digital fabrication allow students to make creations that rely on digital technologies to design and help create physical models. Maker spaces vary from location to location, but tend to focus on things such as collaboration for people to share ideas, explore concepts, and craft or create (Moorefield-Lang, 2014). Students can imagine an object, design it digitally, then print, or cut, custom objects to construct, giving physical shape to an idea. In essence, students have the power to act as inventors in these maker spaces. Invention by definition is, "A new device, method, or process developed from study and experimentation." (American Heritage, 1994, p. 441). While students may not always be original inventors in maker spaces, they now have the opportunity to experience a process that parallels original inventors while applying science, technology, math, and engineering (STEM) to their inventions.

The process of inventing what has already been invented is called reverse engineering. The process involves taking apart another object to discover and understand how that object works (Badraslioglu, 2016). The fundamentals of the original object can then be applied to a different, similar product, to save time and energy on making the second, new object (Badraslioglu, 2016). In education, classes strive to teach concepts quickly, effectively, and in a way that transfers knowledge to situations and contexts outside the direct learning environment. Reverse engineering allows for these teaching goals to be met, but does not sacrifice the learning objectives for the students, as they are learning through the act of doing.

Students learn the STEM concepts through their actions of actually applying and doing STEM. Learning by doing is a process that has foundations in Dewey's educational view, and still shows positive learning results in studies today, including: encouraging student engagement, involving critical thinking, problem solving, and collaboration (Dewey, et al., 1915,; Schamk, 1995,; Yazici, et. al 2014). As students are actually building, designing, and creating there is no disconnect between what their hands are accomplishing and the digital version on the screen. Students have a concrete connection to abstract concepts that cannot be easily dismissed from a digital disconnect. Rather, the end object either functions or does not function as a result of how the project was reversed engineered. The act of learning by doing through reverse engineering and product creation with digital fabrication provides a valuable tool base for reaching the educational goals of teaching STEM concepts in a transferable and real life way.

2. REMAKING INVENTIONS

Learning in the digital age provides access to ideas, concepts, and resources that would otherwise be out of reach to the general populace. Some items of historic significance must be carefully preserved through special lighting, limited air exposure, or other means in a singular historical preservation location. These items may now be scanned with a digitizer and be accessible to people all over the world. The access to these items is possible as a 3-dimensional (3D) digital model that may be turned, rotated, broken apart and put back together. Instead of taking a field trip, where educators need to collect permission forms, entrance fees, and transportation to take students to look at objects behind a piece of glass for a few hours, teachers can now use technology to bring those objects into the classroom, allowing students to interact with the objects on a computer screen. Given the time and resources of maker spaces, that are gaining support as a learning tool (Chu, 2016), students and teachers can now re-create historical museum objects, make similar objects, and produce objects that they can physically hold, manipulate, and use in experiments.

2.1 Specific Invention Application

An example of this process is, “the Smithsonian and American Innovations in an Age of Discovery: Teaching Science and Engineering through Historical Reconstruction, (which) uses transformational inventions such as the telegraph, the telephone, and early electric motors as a context for reverse engineering.” (Bull, et. al., 2016, p. 490). In this type of project, students manipulate 3D versions of the original inventions and apply science and math concepts to reconstruct these devices in a physical form. The way in which things are made will determine how, and if, the physically printed artifact will work to accomplish the task for which it was designed. Having the 3D model of an invention is not enough to make a printed model work. Students must think through the science and apply what they know to reverse engineer from the given digital 3D model to create their own similar working model.

The early electric motor is an example of an invention that applies many physics concepts in a straightforward way. Constructing a simple working motor requires students to, “investigate and describe the relationship between electric and magnetic fields in applications…” (Texas Education Agency, 2010, 5G) which is a state standard in Texas physics classrooms. To understand how the motor works, critical learning connections must be made. Some of the fundamental concepts to make a working motor have been scaffolded for starting in elementary school science classes. For example, understanding the concept of what materials will conduct electricity and heat versus those that will insulate. Students must understand the differences between conductors and insulators in order to deduce which parts of a motor need to conduct electricity to work, versus the parts of a motor that need to act as an insulator. If students simply print the model with plastic, or cut it out of wooden pieces, the motor will not be able to produce movement. In order to create a design that produces movement, key pieces of the motor need to be conductors to produce an electromagnetic field, and other parts of the design need to be insulators like plastics and woods.

More advanced science concepts that must be understood include magnetic attraction and repulsion and how an electric current produces a magnetic field. Once these concepts are understood, students must take the next step to be able to apply these concepts to create a design that will produce movement. Key pieces of the motor must be able to produce an electromagnetic field and interact with other magnetic fields, including fixed magnets. Students start with reverse engineering the design of the original patented motor at the Smithsonian through the 3D version, to begin considering why the motorwas designed the way it was. Students can refer to the design elements in the 3D version to understand the placement of the various parts of the motor in regards to science principles. As students begin connecting design elements and design choices of the existing model, understanding will develop that indicates that parts of these original inventions were not a decorative or aesthetic choice of the creator, but rather a fundamental and essential part of the invention. The coils in a motor allow the electrical circuit necessary for powering the movement of a motor, but may be otherwise thought as an aesthetically drawing feature. Students do not need to figure out how to apply all these science concepts to an open-ended project, but rather how to reconstruct a motor by going through the process of connecting the science concepts, examining the model design, and hands-on inquiry to see science in action.

Although the basic scientific understandings are fundamental in many complex inventions today, the original inventions have a simplicity that is easy to grasp without having to chunk multiple complex understandings to see results. Looking at the complex applications used today for these same concepts, may seem overwhelming to students who are just beginning to develop such conceptual understandings. Examining some of the original inventions allows students to focus on the basic concepts that allowed for a simple design and a basic application of the underlying STEM concepts. Through reverse engineering these machines and creating similar features through digital fabrication and maker spaces, students apply what they are learning and receive immediate feedback regarding their level of understanding of the concepts at work by seeing the invention work the way it was designed.

3. CONCLUSION

Allowing students to digitally and physically explore some of history's inventions provides insights into fundamental concepts of STEM. Students know they are successfully applying the principals of STEM subjects when they have recreated versions of the original invention. Students may also feel ownership as their inventions draw on the same principles to work, but will not be an identical mechanism, thus providing student ownership of both the invention and furthering their learning. The end result may include student engagement, greater understanding of the content, and appreciation for science and history.

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