3D Printing: Providing Motivation for STEM Achievement

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3D Printing and Motivation within STEM Studies

Education has long had a tradition of appropriating new technologies in an effort to improve the quality and efficiency of learning. 3-Dimensional (3D) printing is one of the latest technologies to have made this jump from industry to education. 3D printing is by no measure a new technology but has existed within manufacturing, engineering and prototyping for years (Griffey, 2014). The rapid rise of 3D technologies of the last decade has been due to developments that have led to inexpensive consumer and prosumer grade products. The shift from strictly commercial to everyday household use has placed the technology in a position that is both beneficial and available to learning environments.

Implementing 3D printing within the classroom serves as a way of pushing students to go beyond just obtaining knowledge and skills but also as a means to understand identity and value in education. A problem students' face is the inability to grasp real world uses for the skills that they acquire within the classroom (Thornburg, 2014).

> For too many years we have focused on the stuff of learning, not on the processes needed to develop a deep understanding of what we've learned in the context of the discipline itself. As a result, we have, for example, students who do well on standardized math tests but have no idea why there are mathematicians (Thornburg, 2014, p.38).

As a tool, 3D printing can help build connections between the *stuff of learning* and the *processes*. It engages the learner on a level of exploration and facilitates learning through rewarding the student after they have done all of the hard work: calculation and design.

Kostakis, Niaros and Giotitsas (2015) conducted research into utilizing new open source 3D printing technologies within two high schools in Ioannina, Greece. Through using theories of constructionism, they developed an experiment to see the usefulness and test the effectiveness of having 3D printing technologies within the learning environment. The teacher began the curriculum by giving the students a brief introduction to 3D printing and demonstrating how collaborative efforts can produce effective and useful products without the need for competition. They allowed the students to either learn the 3D modeling software from tutorials or through their own exploration and tinkering. Instructors facilitated learning by clearing up any misconceptions and slowly acclimating and reinforcing the appropriate vocabulary. Upon completion of creating a 3D object, students were then asked to produce a paper detailing why they created the object and touching on the challenges they faced during development and execution of the object.

The aim of their constructionist foundation was to facilitate the building of bridges or connections in the belief that the more a learner is able to construct these bridges to their personal experiences the more they will retain and learn. Upon completion of the experiment, Kostakis, Niaros and Giotitsas (2015) concluded that 3D printing has potential for classroom implementation by referencing the fact that many of the participants not only learned to effectively use 3D modeling software and 3D printers but also learned braille to inform and produce useful artifacts for communicating with a class of blind students.

The process of designing 3D models for printing is one that utilizes many disciplines while also having multiple applications. 3D printing encourages and supports the transition from internal personal cognitive processes of Piaget’s constructivism to Papert’s constructionism, which promotes the idea that people learn through making and that learning is a consolidation of the universal into the experience of the individual (Thornburg, 2014). 3D printing effectively teaches learners how ideas transform through different approaches and technology.

Steven Pryor (2014) explored the implementation of 3D printing services at Southern Illinois University Edwardsville's Lovejoy Library. The idea of using 3D printing services within a public library is growing in popularity; however, Pryor explored its use in an academic library, an environment that has seen slower adoption of the technology. Pryor (2014) found that while 3D printing has great potential within the academic space, his experience suggests that 3D technologies should be implemented in conjunction with 3D modeling tutorials or classes to assist students in acquiring the skills to interact with the technology. Pryor (2014) came to this conclusion after seeing how well students responded to the addition of 3D printing services to the library in comparison to how much it was actually utilized by the students. Data collected showed that 75% of all 3D printing services were original designs and only 25% were design printed from a repository (Pryor, 2014). The few students who took advantage of 3D printing appeared to possess the skills necessary to create their own 3D models. Pryor (2014) theorized that more students would utilize the technology if they possessed the skills necessary to design 3D models in CAD programs.

The strengths of 3D printing make it an attractive tool to add to the classroom; however, its implementation requires learners to be proficient in STEM skills because of the technology's reliance on users constructing 3D models. This dependence on STEM skills, combined with the novelty of the new technology, could position it as a great tool to motivate learners and improve STEM achievement.

Van Soom and Donceh (2014) conducted a research study that looked at correlations between autonomous motivation and early academic achievement by collecting data for 1,400 first-year college students within STEM studies at a Belgium university. Improvements within STEM achievement are important because of the high market demand for science, technology, engineering and mathematics graduates and the declining success of first-year STEM college students (Van Soom & Donceh, 2014). Van Soom and Donceh (2014) found that students who exhibited a high motivation level had a higher rate of success during their first year; however, students who exhibited low motivation level were at a higher risk of performing poorly within their STEM studies. The results suggest that a key to ensuring success in STEM is to facilitate and maintain high levels of motivation within learners.

A study conducted by Solak and Cakir (2015) looked at the motivation level of learners in an English as a second language classroom towards the materials designed for Augmented Reality (AR) course implementation and the correlation between motivation and learner achievement. The study utilized 130 participants (82 females, 48 males) who had all received instruction in English as a second language during primary, secondary or high school but were all recognized as beginners due to inadequacies in previous instruction (Solak & Cakir, 2015). The team was interested in motivation because learners often lack motivation during second language studies. This is attributed to the idea that learners place most of their interest and focus within their chosen degree fields. Solak and Cakir (2015) determined that the novelty of the AR technology significantly increased learner motivation and that there was positive correlation between high motivation and high learner achievement. These results suggest that the novelty of 3D printing could possibly work in the same way and help motivate learners to take an interest in STEM studies.

Verner and Merksamer (2015) conducted a case study looking at the effects of implementing 3D printing in combination with the conceive-design-implement-operate (CDIO) approach within a technology teacher education course at the Technion Department of Education in Technology and Science University in Isreal. A key principle of the course is to develop visual literacy and to transition learners from thinking to doing. The teacher education students were given an educational problem and asked to produce 3D visual aides printed by 3D printers, in addition to traditional lectures and presentations, to improve a 10^{th} grade class's visual literacy in being able to internally visualize 3D projections and cross-sections, as well as construct 3D objects from projections. Results showed that above 60% of learners acquired more advanced skills and understandings of 3D printing (Verner & Merksamer, 2015). Verner and Merksamer (2015) also observed that visual literacy and understanding of pedagogy, content and pedagogical content knowledge was enhanced significantly. These results indicated that 3D printing has the ability to improve and enhance courses designed within a constructionist framework.

Because of the growing demand for STEM graduates, the declining interest of high school students in STEM studies and the low success rates of first-year STEM college students, there is a need to identify alternative means of getting learners interested and motivated to improve their achievement within STEM studies. Though research is still relatively new on 3D printing, it suggests that 3D printing is a viable option for exploring effects on learner behavior and achievement in STEM. Pryor (2014) suggested that learners are interested but lack the foundation in STEM studies, Kostakis and co-authors (2015) exhibited that it serves as an effective means of teaching and Verner and Merksamer (2015) explained that it improves learner achievement by comparison to traditional course implementation. Therefore, the purpose of this study will be to answer two research questions: (1) Are 3D printing technologies effective at attracting and motivating learners to join STEM studies (2) and the correlation between motivation and achievement.

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