Journal of Mathematics Education © *Education for All*
December 2016, Vol. 9, No. 2, pp. 72-80

The Development of a Transmedia STEM Curriculum: Implications for Mathematics Education

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Technological advances inside and outside the classroom enable students to become more active learners. In math, it is important to move instruction into a realm where students have an opportunity to create and apply foundational concepts. Having a framework for students to follow to integrate technology, with a strong educational theory base, can help foster the math part of STEM learning. Transmedia books can provide such a framework. This article strives to explain the underlying theory for using a transmedia book and the potential outcomes it can have on math attainment.

Key Words: *Transmedia, STEM, project-based learning.*

Math education continuously faces the challenge of ensuring all students have the skills necessary for life, the foundation for higher levels of math, and the capacity for engaging students to have the desire to be successful in math. Math education incorporates various mediums to engage and teach students. Songs, such as the quadratic formula to the tune of *All Around the Mulberry Bush*, tend to do little more than give a formula to students. Films were once thought of as, "…real and concrete, a medium for breathing reality into the spoken and printed word that stirred emotions and interest" (Goodenow, 1988, p. 11). While videos have become commonplace in many classrooms, they are still a one-way source of information. Learners sit passively and take in information that is presented to them, mirroring what a teacher would do in a classroom. One problem with this approach is that videos lack the personal connection often required to motivate students to care about the instruction. Educational math games tend to focus on the repetition of low-level skills, have un-engaging story lines, or do not have a play style that encourages repeat play. Students run through practices that drill at these low-level skills then get to the assessment and claim, "We have never done this!" even though they can give all the formulas through songs, walk through the fundamental skills they watched in movies, and recite basic math facts.

Students often lack the ability to put all the separate pieces together to solve a multistep, complex, real-life math scenario. In these practice mediums, the trend is that students do not move beyond the basic skills to the illstructured math scenarios they might encounter in real life or in multistep assessment questions. Students need to actually do and apply math through hands-on replications of real life. These hands-on experiences need to mimic real-world math problems that cannot be completed with simple rectangular connectable blocks that inherently limit the shapes, structures, and formulas used in real life.

Moving to Application

A transmedia Science, Technology, Engineering, and Mathematics (STEM) book is a framework that merges classroom instructional aides to move beyond the foundation of individually chunked math skills. Transmedia books create a story, and guide, through which students are connected to multiple media, digital and physical, to gain knowledge to complete the projects presented in the book (Cohen, Smolkin, & Bull, 2011). In this regard, transmedia methodology mirrors what many technology integrated classrooms already do, but takes it a step further. The transmedia book changes the student focus from, "The teacher says to do this, so I have to do this now," to the students thinking, "I need to solve this challenge, and here are some things that can help me complete that task." This shift is important because now the students can use different mediums to collect the information they need until they understand the challenge well enough to complete the project by applying math, and often other STEM subjects. Students are no longer focused on completing, producing, or consuming skills as directed by the teacher. Instead, students are engaged in different mediums to construct their response to a situation that involves using math.

The projects function well when paired with the constructivist learning theory, which proposes that people create meaning from the experiences they have by incorporating environmental inputs to create complex thinking about those topics (Ertmer & Newby, 2013). Constructivism learning theory places an onus on teachers to replicate realistic learning environments that will foster students' desire and their ability to construct knowledge of certain topics (Jia, 2010). No longer do teachers need to focus primarily on the presentation and repetition of facts for students to memorize. Instead, teachers can focus on framing a learning environment that utilizes technology to allow students to access multiple sources of information in order to investigate course content objectives. Once students have investigated the content, they can then apply that information in a manner that demonstrates mastery of the learning objectives.

Project-based learning replicates the world that students experience outside of structured learning by using open-ended problem-solving techniques that draw on multiple knowledge domains (Kumar & Natarajan, 2007; Schwalm & Tylek, 2012). As students work through the projects they will seek the necessary knowledge, across multiple content subjects, to reach an end project result based on the parameters the teacher outlines. A combination of skills from different STEM subjects are required to fully address the complex problems of the world that students will face outside the classroom. In this regard, the project-based learning platform found in transmedia books can help students see the connection between what they are doing in the classroom and their future lives.

Transmedia Application

Transmedia books provide a framework for collaborative projects that can be spread out or completed in sequential order, depending on the needs of the classroom. The projects rely on students completing math in application, instead of rote repetition. Teachers help guide students through the transmedia framework while providing feedback on progress, skills, and correcting misconceptions that may arise. Teachers may choose to do all or only some of the chapter projects in a book. In addition, critical math prerequisite skills, such as the ability to see and manipulate objects in space, can be enhanced through 3D printing projects associated with transmedia books (Zimmerman, 2016).

In one such transmedia book, students have the opportunity to create a digital object to be printed and combined with a physical object to create a project solution. The process required an understanding of math concepts to make sure that the two objects, created in the different mediums of physical and digital, will fit together when the digital file is 3D printed. Students developed a better understanding of measurement, scale, and math models while trying to create and blend digital and physical models of their own creations (Stansell, 2016). The creation of digital objects requires a focus on the measurements to ensure accuracy when printing, otherwise an object that 'looks right' on the screen will not 'fit right' when printed. Students must plan how to mix the objects together instead of having only physical items that they can manipulate and modify to work without ever having to apply math concepts.

The addition of digital fabrication and 3D printing has the potential to positively impact the way students perform in math assessments (Stansell, 2016). The New Media Consortium's 2016 K-12 report addresses makerspaces and 3D printing. The report indicates that school leaders consider makerspaces an addition to formal learning and that makerspaces provide a way to, "[engage] learners in creative, higher-order problem-solving through hands-on design, construction, and iteration" (Johnson, et al., 2016, p. 36). Makerspaces are associated with projects that students create, often utilizing technology to enhance an initial prototype and thereby develop a refined final product (Chu, Angello, Quek, Suarez, 2016). The 2015 New Media Consortium expresses that 3D printing, "can help students visualize graphs and mathematical models…" (Johnson, et al., 2015, p. 40). The ability for students to create objects in different mediums provides repetition of skills where students can immediately see the outcome of their work as being correct and successful, or incorrect and unusable.

Ongoing research seeks to determine the way digital fabrication and makerspaces impact learners' conceptualization of math concepts and education (Tillman, An, & Boren, 2014; Chu, Angello, Quek, Suarez, 2016; Stansell, 2016). Applying and combining the principles of project-based learning, constructivism, essential questions driving a central story arch, and makerspaces with digital fabrication, work towards meeting the National Council of Teachers of Mathematics' *Principles of Action* to "engage students in mathematical thinking, reasoning, and sense making to significantly strengthen teaching and learning" (National Council of Teachers of Mathematics, 2016, p. 1). These skills are important for 21st century learners and transmedia stories can combine all these elements into a single framework.

Examples from a Transmedia Book

To obtain more information on the uses of transmedia books in math instruction, a classroom observation and trial run was made in a middle school classroom where students had the opportunity to use a transmedia book. The transmedia book, *Engineers Needed! Help Tamika Save the Farm!,* was focused on agricultural engineering. Students progressed through chapters completing projects that included math, but did not focus on the math itself. For example, in the first chapter, students evaluated the amount of water they used in an average day. The book provides an online resource to help calculate students' water usage. However it was necessary for students to first track how long they used water and for what purposes. Collecting numerical data in a logical way that can be understood later provides many teaching opportunities for tables and how to collect numerical data. Students were encouraged to attempt calculation on water usage on their own first, and then jump into the online tool. However, students were often surprised at how much or how little water other people used. The act of questioning if the online tool was accurate, led students through algebraic equation formations and discussions to find out if they, and others, really did use that much water for different tasks.

The hands-on project in the chapter was where students started developing an understanding of geometric reasoning to create origami cups. After manipulating flat sheets of paper into a functional 3D object, students moved into digital fabrication to use a 2-Dimensional cutter that would trace cut their digital cup pattern on a sheet of paper or cardstock. Students could then fold the paper pattern into a cup and effectively mass produce cups if they so desired.

Then, students moved into the creation of a rain gauge to capture water. Students were required to think about the volume of the container they created in order to make comparisons to the water collected by other groups. Students had to think about how to measure rain, the shape of the container, how to mark the container, and how much water the container could actually collect. Later, employing science principles, students designed a filtration system for a model farm by using common household objects. The filtration system was then enhanced through the aid of digital fabrication. To do this, students took measurements of the physical objects already created to design a digital object that could enhance filtration but still work within the pre-existing filtration system. Students calculated measurements for size, volume, and shape, considering the exiting tubing, model farm size, and filtration system to ensure that the digital and physical would mesh properly to create a final product that fit tightly enough together that it would not lose water.

Students completed math along the way to make sure they could accomplish a bigger goal that they felt was not specifically a math goal. The combination of STEM learning and collaboration through the chapter projects took the focus off specific math calculations. When students were not focused on the math, but rather how to get a measurement of the tube to include that exact size in the digital size that would allow water to flow through the tube, students started considering math principles of circumference and diameter. They discovered what math concepts they needed to know, determined how to locate that information, then found the words to explain what they needed to each other. In math education, the opposite approach is often taken. The vocabulary words are given, the formulas are given, and then the concept practice is undertaken, sometimes without students ever having paid attention to what they need to know.

The use of transmedia books help from a design stand point, demonstrating why students need to know a math concept in regards to the real world. When a story can be created, it pulls the students in by showing a "why" or rationale behind math concepts. Transmedia books provide an opportunity to find and explore the definitions, practice, and formulas used in math all while using the mental lens of the real life "why" in the story.

First Steps towards Transmedia

Transmedia stories are a way to provide a framework to start developing lessons that are based on real life applications of STEM subjects. These lessons can be expanded into a series of connected projects that can be enhanced with makerspaces, digital fabrication, and 3D printing to help students move beyond repetition and into the application of math concepts. Teachers can develop their own transmedia stories and digital fabrication projects, much like connecting several lesson plans into one cohesive story arch. Teachers understand the big picture of the objectives they teach and the fundamentals needed to reach critical learning objectives. Teachers can take existing lesson topics, outline projects that will utilize critical skills, and connect those projects to the big picture while creating a story arch for a transmedia book. As students progress through the story, lessons, and projects, teachers can further evolve and adapt the projects and stories. Adapting the story and projects is already within the realm of what teachers do to continually improve the lessons they give a class and to meet individual student needs

Teachers and students can develop these math models and projects using different types of free and paid-for computer-aided design (CAD) software. After the initial investment of a 3D printer, 3D printed versions of the digital models can be created relatively quickly and affordably. When a learning opportunity necessitates a physical representation be available, students and teachers can work together to create an example or application of that math concept. Overtime, these examples can be linked together to create project chapters of a book. However, as teachers and students develop digital fabrication and maker skills, it is possible to pull from online repositories where numerous ready-made designs can be found, such as thingiverse.com's Pythagorean Theorem model (see Figure 1).

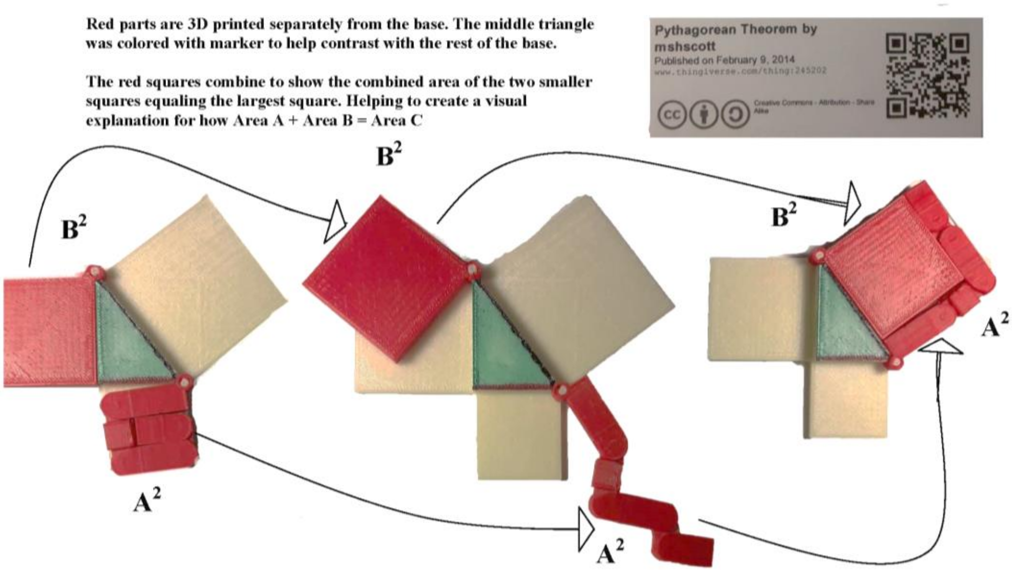

Figure 1. *A 3D printed object that can be manipulated to explain the Pythagorean Theorem. The red squares are on hinges that slide back and forth to show how the two smaller squares can combine to create a larger square.*

Teachers may provide examples like the one above and challenge students to apply the theory to other situations, such as in creating a miniature house piece by piece. The Figure 1 example print could be used to demonstrate and explore the concept before students design and create a roof structure. Students could apply different math concepts in different chapters slowly building a miniature house in phases, replicating the process of architectural engineers. Each lesson would then be tied together through the act of building a house, with a final project resulting in a fabricated miniature house. At the end of the transmedia book, students could have a complete miniature house that serves as a reminder of the math concepts needed to develop the house to certain guidelines and expectations outlined in the transmedia book.

Concluding Considerations

Teachers can take what needs to be taught and develop real life applications that tie into a central story arc that can draw on project-based learning, constructivism, and the transmedia framework, to engage students in the application of math objectives, not just memorizing the skills of math. The focus is not on an object that was created through step-by-step directions, but rather the development of complex concepts and how those concepts can combine to create a solution to a project challenge. Students move through different mediums of digital and physical space collecting all the individual pieces and skills they need to reach that level of understanding. Students might each achieve that understanding at different times, but they are no longer consigned to repetition that drives out the desire to master math. Instead, they apply the math skills, directing their own their skill development until the math works in a way that accomplishes the student's goal; creating an environment that is focused on math understanding and application, not just fundamental skills disconnected from real life meaning.

Through participation in a transmedia unit, students apply math in ways that allows for a direct, real life connection. Students no longer start by asking, "When will I ever use this?" and mentally checking out while moving through the repetition of basic skill building. Instead, math is viewed as a necessary part needed to complete a specific challenge or goal. As the transmedia unit progresses, students start to understand math concepts and their applications because their projects' success depends on the acquisition of specific math concepts and skills. Students cannot go to another group and copy their paper because every project is different, possessing its own unique math problems. Instead of having to make different versions of worksheets, students naturally pick different numbers as they generate various project solutions. The math was correct or incorrect based on if the final project or product works the way it was designed to work, in the space it needed to occupy, using both digital fabrication and physical manipulative. If the final product does work, students have to evaluate their own thinking to find the problem and determine how to fix the product. Overall, the transmedia unit engages students in the act of mastering math concepts because the unit does not focus on the math, but instead uses math as a means to an end.

Acknowledgments

The study and research was made possible in part by the collaborative NSF grant #1510289 and the Fab@School NSF ITEST grant # 1030865.

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