Transformations

Volume 3
Issue 1 *Winter 2017*

Article 5

June 2017

# Theoretical STEM Program Proposal

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**Cover Page Footnote**
The author gratefully acknowledges Dr. Berta Capo, Dr. Rochelle Green, and Dr. Hu Fang Su for their expertise, guidance, and support.

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**By Nancy Ledbetter**

## Introduction

In an existing school district, it is difficult to build a new school because of how difficult it can be to get funding, deal with construction issues, find personnel, and obtain all the other resources that go into any such endeavor. However, it is not impossible to take an existing school revitalize, re-envision, and reinvent it. Designating one elementary, one middle, and one high school as Model STEM Schools would provide an example for all other schools on how to grow a STEM program (NC DPI, 2016). Many STEM strategies are simply good practice for engaging students in their own learning. Taking those good practices to the next level and bringing in STEM integration is not as huge a step as one might think (Bybee, 2013). It takes planning and it should address four specific themes: global challenges, shifting perceptions of environmental sustainability, 21st century skills, and national security (Bybee, 2013.) Any restructure or revitalization of a school should also make sure that the new approach to required curriculum includes a focus on the goal of making sure all students are STEM literate, that they are prepared to enter a highly technical workforce, and that students emerge from school capable of being creators, innovators, and problem solvers (Bybee, 2013).

## Theory

The theories that would be important as foundations for any STEM focused school would be the constructivist theory, the Dunning-Kruger effect, and the self-determination theory (SDT). Constructivism as it is currently viewed was developed slowly over decades based on the work of theorists such as John Dewey, Jean Piaget, Maria Montessori, Lev Vygotsky and many others (Myers & Berkowicz, 2015). Constructivism is focused on how children learn and suggests that children learn by doing and build new knowledge on top of what they already know (Glancy &

Moore, 2013). The Dunning-Kruger effect is the theory, to put it simply, that a little knowledge is a dangerous thing. When teachers have only a slight understanding of something, they can be far too confident in what they think they know and as a result do a poor job of teaching (Graves, 2011). The third theory applies both to teachers and students, SDT looks at motivation (Deci & Ryan, 2008). When making a bottom up change in a school, teachers and students need to be motivated to learn. Teachers need to be motivated to adopt new practices (Deci & Ryan, 2008).

Constructivists encourage the use of student-centered learning strategies (Myers & Berkowicz, 2015). A student-centered strategy is explained in detail in the Lesh translation model, also considered a constructivist model. The Lesh translation model is a way of assessing student understanding that allows students to use any of five methods which includes use of pictures, building models, explaining world connections to the topic, using verbal communication, or using written symbols. This allows students to start with whichever method they are most comfortable with, then using other options as their understanding of the concept grows until they understand the topic so well that they are able to use any and all of the methods to explain their understanding (Glancy & Moore, 2013). Developing this level of understanding is not only important so that teachers can be assured students understand the material, but it is also important to the self-efficacy of children. As Bandura points out, the more confident a child is in their ability to understand, the more present and engaged they are in problem-solving and learning (Gray & MacBlain, 2012).

This engagement ties into SDT.  Students are engaged in their own learning when autonomous, intrinsic motivation is what is driving them (Deci & Ryan, 2008). STEM can provide for this type of motivation if the curriculum is correctly designed. This will take thorough involvement of the teachers. The teachers will absolutely need intense, quality professional development (Gray & MacBlain, 2012). Adults are affected by the same motivational influences as children. If they are forced to participate in professional development, the odds of them churning out quality work is much less than if they are autonomously motivated and they believe that the professional development will aid them in becoming better teachers for their students (Deci & Ryan, 2008). Teachers are the biggest factors in student success (Green, 2014). Therefore, teachers must be prepared through training that they feel is relevant and valid before the STEM school they are shifting into opens its doors to students.

A part of why this training must take place prior to beginning the school year is the Dunning-Kruger effect. Dunning-Kruger effect suggests that people who are only partially informed can do more harm than good if they presume that the knowledge they have is enough to make them experts (Graves, 2011). There has been a rise in poverty, and an influx of immigrants. These students are difficult to teach by standard methods (Myers & Berkowicz, 2015). Trusting them to teachers who only think they understand what they need to do will not lead to good practice in the classroom (Graves, 2011). Increasingly diverse student populations need teachers with the kind of training that makes them effective and the kind of engaging curriculum that can be offered at a STEM school.

**Literature Review**

*STEM Education: How to train 21$^{st}$ century teachers*, edited by Satasha L. Green, brings up the need for teachers to be trained in all four of the STEM disciplines. They need to be STEM literate in order to be instructionally effective. To be scientifically literate they must understand inquiry and the scientific method. To be technologically literate they must understand how to use technological tools for research and innovation. To be literate in engineering they must use technology, math, and science to identify challenges, create solutions, and problem solve real world issues. To be literate in mathematics they must understand how to apply math skills to science, engineering, and technology challenges (Green, 2014). This level of STEM literacy is essential for teachers in a STEM school. Instruction at a STEM school must be inclusive, allowing for all sorts of learning styles, and abilities. A STEM school must also allow students to bring their own diverse backgrounds, cultures, and understandings to what they are learning. This means that teachers have to allow for multiple methods of instruction and provide a safe and accepting learning environment for authentic learning to take place (Green, 2014).

Marc Prensky is a noted expert on combining technology and education in ways that help engage students in learning, in his book *Teaching digital natives: Partnering for real learning*, he discusses how to create a successful learning environment using technology. There are too many teachers who settle for using technology as something to replace or supplement textbooks. Students in the K-12 school system today have never known a world without computers, cell phones, and electronic gaming devices (Prensky, 2010). They are, as Prensky calls them, 'digital natives' (2010). They want less lecture and more inquiry learning that lets them use digital tools. Prensky encourages teaming and partnership; keeping the focus of lessons real; connecting 'content to questions' and 'questions to skills'; using available technology as tools; promoting creativity and problem solving; take the time to get students to improve on what they have done and share about what they are doing; and save standardized tests for summative data, use data to compare new scores to previous scores, peer assessment, authentic assessment, and self-assessment for formative data (Prensky, 2010). Most of what is being encouraged is already a part of the engineering design process and are essential in a STEM school.

*Secondary STEM educational reform*, edited by Carla C. Johnson, starts with a chapter about how STEM must be for everyone. STEM should be accessible and understandable to every student, not just a select few. There is an imbalance in the numbers of individuals by ethnicity and by gender entering STEM fields (Oljace, 2013). What Johnson's book looks at is how a STEM school located in a lower economic, high minority area can still target every student no matter what their current performance level is (2011). Two of the keys to making this type of school successful are teacher preparation and keeping data that gives a true picture of what is working (Johnson, 2011). The book also notes the importance of early STEM education. Even though the book focuses on changes, support, and reform in secondary STEM, students need to have a solid foundation in STEM that begins in the early years of education (Green, 2011).

*Design, Make, Play: Growing the next generation of STEM innovators* edited by Margaret Honey and David Kanter offers a look at how the maker movement and STEM in schools can blend in with standards and objectives even in early education for the youngest learners (2013). One reason to merge the maker movement into STEM with education is that it helps grow students' beliefs in themselves and their ability to take on any challenge (Honey & Kanter, 2013). There is a theme throughout the text that emphasizes that learning should be fun. Children like to play, they should like coming to school. They should enjoy learning (Honey & Kanter, 2013). Innovators and inventors are not created in a school setting that is rigid and focused solely on results of standardized testing. Innovators and creative problem solvers are people who take things apart, put things together, figure out how things work, and how to make them better (Honey & Kanter, 2013). There is less time for play in schools, but play is necessary if brains are going to develop the capacity to be creative. Bringing play back through STEM keeps it the play learning focused and it helps students gain the skills they need to be successful in science, math, and literacy. Four learning indicators are identified as: engagement, intentionality, innovation, and solidarity. Meaning that students are engaged in the activity, they can explain what they are doing and why, they are moving beyond following a standard pattern, and they are working together towards a common goal (Honey & Kanter, 2013). A STEM school needs to use those learning indicators in every classroom.

**Program Design**

In setting up a STEM program, it should be done with an eye towards establishing a firm foundation for learning. Elementary school should be where that foundation is located (Oljace, 2012). Therefore, the STEM elementary school should be the first one established and when the kindergarteners move to the sixth grade then the STEM middle school should be ready to receive them. Then when the STEM middle school students are ready to move into high school, a STEM high school should be in place and ready for them.

The first step, is to establish a STEM elementary school. To address concerns of not having enough diversity in STEM fields the school should be located in an area where there is a diverse population or a location where a diverse population could be enticed to enroll at. After selecting the location, choosing a faculty and staff. The next step would be to determine the context for the model elementary STEM school. There are so many areas of science to select from, so many kinds of engineering, so much technology available, and so many kinds of mathematics that it is impossible to do it all. For the sake of continuity within the school there needs to be a guiding theme (Bybee, 2013.) The focus for this model would be mathematics. Mathematics is the language of science, engineering, and technology. Mathematics is immensely important in education (Green, 2014).

Once students learn the language of math, then math becomes easier for them to understand. Students who understand what math terms mean have a better understanding of the math concepts that are used for problem solving (Molina, 2012). STEM allows students to explore mathematical concepts with hands-on activities. When combined with technology, mathematics can be understood by even the youngest students. For example, when introduced to robotics in kindergarten students developed a stronger understanding of sequencing than their counterparts who did not participate with the robotics programming projects. What is more, these students were able to keep the knowledge they had gained (Kazakoff, Sullivan, & Bers, 2012).

Math terminology should be taught in context using science, technology, and engineering to support understanding of the various concepts from kindergarten on through high school. One thing that is necessary is for teachers to understand the math terminology well enough that they are comfortable teaching it and that takes professional development (Johnson, 2011). The teachers must also be given the opportunity to plan strategies and objectives based lessons prior to the start of school. STEM is a collaborative effort and teachers must work together to team teach STEM concepts (Bybee, 2013).

Teachers must also be aware of the standards that they are being measured against if they are going to provide excellent STEM learning opportunities for students. Therefore, intensive professional development for teachers would be the next step after determining the STEM focus of the school. Unless teachers are trained to have a solid understanding of STEM and how it fits with the curriculum they can be at a loss and have gaps in their teaching (Dow, 2014). In order for teachers to understand how to teach STEM and determine what their goals in regards to STEM are teachers need to participate in strong professional development (Pinnel, et al, 2013).

Once teachers are trained they need time to work and plan together to ready for their incoming students. Again, the focus should start with kindergarten and then the program should build with each subsequent year. To grow the program successfully, teachers must have something against which to measure their efforts. There are different rubrics for measuring

STEM programs. One that focuses on STEM lessons is the *STEM Quality Framework & Rubric* put together by Washington STEM (2013). This rubric identifies ten components that make a quality STEM learning experience. The first references diversity, reminding teachers that they have to remember that all students need to be engaged in learning (Washington STEM, 2013). This goes with the idea that both the Universal Design for Learning (UDL) and culturally and linguistically responsive instruction (CLRI) must be considered when developing a STEM program (Green, 2014).

The second component is the degree of STEM integration. While it is true that not every activity will fit naturally in every lesson, integration has to exist if STEM is going to be a successful curriculum (Oljace, 2013). The third component focuses on how STEM is integrated with other disciplines, including art and literacy. Tying into this is the fourth component which is the quality and accuracy of content being presented (Washington STEM, 2013). Accuracy is extremely important which ties back to making sure teachers have a strong understanding of the curriculum they are being tasked with teaching (Dow, 2014). Component five is the quality of the task being assigned for students to. The task has to not only engage the student, it must also promote higher order thinking skills (Washington STEM, 2013). The level to which the lesson makes connections to STEM careers is component six. When students are aware that what they are learning to do relates to a real-world occupation it lends the activity a higher degree of relevance (Johnson, 2011). A part of real-world STEM work is that it is done in collaborative teams. To help students learn teamwork many tasks in STEM lessons involve teamwork and collaboration (Vasquez, Sneider, & Comer, 2013). Component seven addresses that part of STEM, the need for students to develop collaboration skills, and the needs for individuals to be accountable for the work they are responsible for within the group (Washington STEM, 2013).

Component eight is focused on assessment. It is imperative to know that the activities being assigned are accomplishing the goals of the lesson. Assessments can be formative or summative, but they must exist and students must be accountable for their learning (Washington STEM, 2013). The final two components address the two pillars of STEM that tend to be underrepresented in STEM education, engineering and technology. Engineering tends to be ignored by educators because they do not have the background training to understand how to make engineering relevant to the curriculum without losing focus on tested areas (Oljace, 2013). Technology tends to be relegated to the role of an electronic textbook unless it is deliberately placed into the activity as a tool for research, production, communication and innovation (Prensky, 2010). If teachers use this rubric to assess the quality of their lessons before they implement them, use formative assessment strategies while they are using the activities, and afterwards compare how the data from student understanding of the concepts compares to the goals of the lesson to make sure the lesson met those goals, they will have developed a strong bank of lessons.

As the program grows it is important to make sure that the school as a whole is progressing. To do this, a rubric such as the North Carolina STEM School/Program Attributes should be used to make sure the program is meeting the standards for being a STEM school (NC DPI, 2016). Not only would the STEM program need to use self-evaluation tools, they would need to invite an outside group of experts in the field of STEM education to conduct an investigation to make sure that the program is meeting its goals (Yarbrough, 2011). Each level of education, elementary, middle, and high should follow the same pattern of preparation, assessment, and evaluation.

**Conclusion**

An existing school can be transformed into a model STEM school if it is located in an area that will draw on a diverse population of students, teachers are given the training they need to thoroughly understand STEM, the school is provided with the materials and tools teachers and students need, and the program undergoes a constant series of assessment and evaluation. A STEM school should have ties to community support, including local STEM businesses, and colleges with STEM related programs. STEM schools should also have after school programs that allow students from all socioeconomic and cultural backgrounds to participate in order to grow their skills and interests in STEM. A model STEM school has the potential to influence individual lives and promote STEM literacy for every student.

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