From Textbook to Hands-on Learning: How Leadership at the Elementary Level can Drive the Maker Movement through Next Generation Science Standards

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Background and Problem

STEM, which is an acronym for Science, Technology, Engineering, and Mathematics, is commonly used in the K-12 educational setting to emphasize a new found focus on the sciences and mathematics. The link between STEM and K-12 education is the result of the business worlds call for a labor force that is STEM-ready (Olson & Riordan, 2012). Lawmakers, administrators, and educators are positioning "Making" as a program that can be used to support the STEM initiative. Under the umbrella of the "Maker Movement" are Makerspaces and Maker Education. Learning in this environment can be classified as learning by doing, creativity, and innovation. These are skills that are reflective of STEM (Taylor, 2016).

The landscape of Making continues to evolve with educators and administrators working together to seek funding, create new facilities, and the infusion of best practices of Making into formal and informal learning (Brahms, 2014). Although this phenomenon is not new, there is a sense of familiarity when we think back to wood shop and tech classes. The reincarnation of the Maker Movement has advanced with its underpinnings being grounded in the Common Core Standards, 21st Century Skills, and Next Generation Science Standards. At the cusp of this movement is school leadership. As a result of this, the role of school leadership, in particular the school principal becomes that of a change agent in leading school change for improved student outcomes. The purpose of this study is to explore how school leadership at the elementary level can drive students' interest in STEM through the Maker Movement and Next Generation Science Standards.

Need and Value

In former President Obama's (2009) speech at the annual meeting of the National Academy of Sciences, he spoke of the need for Americans to not just be consumers of things but to be *Makers* of them. House Resolution 1020, the STEM Education Act of 2015 calls for educators in the K-12 arena to create systems wherein K-12 students are exposed to STEM. The law is supported by Next Generation Science Standards (NGSS) with the goal of promoting STEM growth within schools. The idea is that through students' current educational experiences they can experience activities that can potentially increase their interest in STEM and STEM careers.

Economically, our Nation cannot afford not to be proactivity in this endeavor. According to statistics from Science, Technology, Engineering, and Math: Education for Global Leadership, they have determined that between 2010 and 2020 we will see a 35% increase in STEM jobs (n.d.). To remain a competitive global leader, America will have to ensure that its youth are prepared to assume the role of these new positions or it will face filling these positions from abroad. The preparation begins with having school leaders ready to lead in supporting teachers in the Maker Movement. Much of the research that exists focuses on creating Makerspaces and less on the role of leadership in creating environments that can develop, sustain, and cultivate the Maker Movement.

This study will examine how leadership at the elementary level can drive students interest in STEM through the Maker Movement and Next Generation Science Standards. Specifically, the focus of this study is on the role of leadership. By examining leadership and the impact on students' interest in STEM and the Maker Movement, this study can add to the existing literature by identifying the leadership dispositions needed to support the Maker Movement.

Research Questions

1. What leadership traits are most impactful for supporting the maker movement?
2. How do school leaders effectively support teachers in the Maker Movement?
3. What are the observational indicators of how teachers are implementing NGSS based maker space activities?
4. How does NGSS impact student's perception of STEM and maker activities?

Outline of Relevant Literature

Before the Wright Brothers first flight in 1903, Americans were innovators and tinkers. Around that same period in 1908, Henry Ford's Model T rolled off the assembly line. Both cases demonstrated America's involvement in STEM and the maker movement. This established the nations ability to develop a globally competitive workforce.

The twentieth century was a critical time in American history, as this gave birth to the assembly line type of production and factories were successful because of management practices during that time. With the rise of factories, the industry looked at leadership models of that era. Leadership within the industrialized factories became a focal point reaching into other fields. Education was not spared from industrialization; in fact, it was heavily influenced by conformity, efficiency, and assembly line production (Ackoff & Greenberg, 2008).

For America to meet the demands of STEM-qualified workforce recruitment has gone beyond our borders (Olson & Riordan, 2012). Schools have adopted Makerspaces as being a viable way to meet the demands of the industry while building STEM capacity in students. School administrators are at a crossroad in determining how to support their use successfully.

The remainder of this literature review will begin with an examination of constructionism and constructivism, which underpins the Maker Movement. The researcher will proceed to

explore Makerspaces and the connections to constructionism. Furthermore this paper will also discuss the role of leadership and the school administrator's role in leading the change. Finally, the literature review will close with Next Generation Science Standards and the association to the Maker Movement.

Theoretical Framework

Creswell states that researchers are guided by a set of beliefs or philosophical paradigms that governs a study (2014). The paradigm that will guide this study is constructivism and constructionism theories. Our current educational system has limited the opportunity for students to apply their learning and test their thinking. Constructivist learning posits that people gain knowledge through experience; learning is an active process that becomes personally meaningful (Ackermann, 2011). Constructionism often confused with "constructivism" is a theory developed by Papert that moves constructivism to become tactile (Papert & Harel, 1991). The demonstration of knowledge becomes the defining difference between the two theories (Halverson & Sheridan, 2014). Students need opportunities to play and do; otherwise, they are missing out on learning opportunities and opportunities to construct their knowledge. The Maker Movement because it is tactile and learner-based it is well situated within the constructivist and constructionist learning theories.

Maker Movement & Makerspaces

The Maker Movement has roots that can be traced back to Jean Piaget, John Fedrich Frobel, John Dewey, and Maria Montessori (Bevan, Petrich, & Wilkinson, 2015). According to Halverson & Sheridan Seymour Papert has been called the "father of modern Maker Movement" his work centered on constructionism (2014). In 2005 the Maker Movement came to life with the creation of *Make* magazine (Dougherty, 2012). Dougherty classifies makers as people who

value the do-it-yourself process, creating, tinkering, and hands-on problem-solving learning (2012).

In a makerspace, students get to demonstrate their knowledge through active making. Makerspaces in schools support Dougherty's assertion that “we should be framing things in our schools not just regarding ‘how do we test you on that?’ however, on ‘what can you do with what you know?” (p. 12). Although the term Makerspace is seemingly new, there have been similar ideas that are not so new. For example, the Massachusetts Institute of Technology Fab Lab is a designated space with tools and equipment that students can use to create products (Blikstein, 2013). Most recently Makerspaces can be found in public libraries, museums, and schools. With a decline in the use of libraries, Makerspaces are being integrated into libraries across the country (Steele, 2015).

Martin (2015) delineates "three elements of making and the Maker Movement that are critical for understanding its promise for education and success" (p. 31). The first element is digital tools "prototyping tools" which are used for fabrication, for example, 3D printers. Included in this first element are subtractive tools such as laser cutters. Martin describes the second element as "community infrastructure." The idea is a sharing of ideas amongst the community both in and out of school. This time of interaction allows novices and experts to interact and share thoughts. During the making process, a self-perpetuating circle is established that maintains the Maker Movement underpinnings of constructionism with an emphasis on sharing (Dougherty, 2012). The final key feature is the Maker Mindset, which is based on values and dispositions. For this to take place, there has to be an inclination, sensitivity, and capacity. Martin has four additional elements that go beyond the three mentioned: asset and growth-oriented, being playful, being failure positive, and being collaborative. The aspects that Martin

has presented is useful for school administrators to know and understand how to support students and staff. The elements introduced are reflective of a hands-on approach to learning, which is in contrast to textbook rote learning.

The Role of Leadership

The Industrial Age had a tremendous influence on school leadership. Students and staff were managed with a top-down approach based on efficiency and production (Ackoff & Greenberg, 2008). Current trends in educational leadership call for innovation and creativity. Today's leaders must be equipped with skills that foster collaboration, vision, and growth. Twenty-first-century leadership requires leaders to imagine new systems and bring various stakeholders inside and outside of the school together. The goal of the industrial era of leadership was a top-down approach that ultimately led to the production of students who would have a particular role as a manual labor. In today's era, schools need to produce students that are innovative and creative thinkers.

The call is for transformational leadership "leadership that is future-oriented rather than present-oriented and that strengthens organizations by inspiring followers' commitment and creativity" (Eagly & Carli, 2003). Northouse describes transformational leadership as recognizing and combining an individual interest in support of common goals (2012). There are four components of this theory: intellectual stimulation, individual consideration, idealized influence, inspirational motivation (Kendrick, 2011). The transformational leader builds trust amongst the group, inspires those that are following, brings diverse groups together centered around a shared vision for the group, and goals are celebrated.

In a study conducted by Griffith (2004) he analyzed transformational principal behavior, staff turnover, and student performance in 117 suburban schools in a large metropolitan area.

The results revealed that principals have an indirect effect on student achievement as caused by the direct effect principals have on the work environment. His study yield three components associated with transformational leadership individual consideration; charisma; and intellectual stimulation. The research supports the notion that the school leader will be responsible for moving and inspiring staff forward to a vision of Makerspaces. Successful implementation will be based on meeting individual staff professional development needs. In meeting teachers target professional development need the school leader will provide intellectual stimulation.

Another study by Gerard, Bowyer, & Linn (2008) examined the role of principles in the implementation of curricular initiatives. Their study looked at a group of principles that worked together to implement a technology-based science curriculum. During a three-year period, the group met to discuss leadership practices and to share ideas for curriculum implementation. As a result, their content knowledge increased as well as their understanding of the curriculum. This research demonstrates the pivotal role that the 21st century leader plays in the success of students. The study further situates the principal as an instructional leader.

Next Generation Science Standards

In 2015 the NGSS were released. Before the release of the NGSS the Framework for Science K-12 Education: Practices, Cross-Cutting Concepts, and Core Ideas began in 2011 with the National Research Council. According to Hira, Joslyn, & Hynes, the Makerspace environment is comfortably situated within the NGSS because of the technology and tools that can be used (2014). The NGSS are arranged in three domains: practices, crosscutting concepts, and disciplinary core ideas. Technology and engineering are new to NGSS making it an excellent fit for Makerspaces. This makes it even more important for school leaders to ensure that there is content available otherwise students will miss out on the opportunity for contextual learning.

In a study conducted by Sikma and Osborne they investigated the shift of a K-5 campus to a STEM-centered campus (2014). Their study revealed that teachers had apprehension regarding STEM content. In a 2012 study conducted by NSSME, it was determined that of all the content areas only 39% of teachers felt prepared to teach science (Banilower et al., 2013). The inclusion of the NGSS presents both opportunity and challenges in pushing the national STEM agenda. The literature is clear, indicating that the success of the Maker Movement will be dependent on school leaders ability to be creative in finding ways to meet teachers needs so that it will translate into student success. Furthermore, transformational leadership will help support the Maker Movement.

Methodology

Today's education system has to keep pace and be in line with what is happening beyond our borders. Educational leaders must think globally on how they approach teaching and learning to ensure that students are taught the necessary skills to compete both at home and abroad. These changes or adaption require leaders to look at pedagogy and the content that is being taught. Makerspaces are being viewed as a means to incorporate NGSS to prepare our students for STEM-related fields. Even with the best-developed plans, curriculum, and content administrators must be at the forefront leading the way. Careful examination of conditions and supports must be taken to support purposeful implementation.

Research Questions and Design

Research Questions

The role of leadership is essential in the successful implementation of new initiatives in education. Looking at success models of Makerspace implementation can be used to guide

school leaders as they transform their schools' pedagogical practices. The following research questions will guide this study:

1. What leadership traits are most impactful for supporting the maker movement?
2. How do school leaders effectively support teachers in the Maker Movement?
3. What are the observational indicators of how teachers are implementing NGSS based makerspace activities?
4. How does NGSS impact student's perception of STEM and maker activities?

Research Design

To address these questions a qualitative research study will be employed. According to Yin (2009), qualitative methods will allow the researcher to answer questions that ask: "who, " what," "where," "how," "why." Case study methodology allows the researcher to collect various data to understand a phenomenon. Specifically, a multiple case study has been chosen. According to Stake (1995) and Baxter & Jack (2008), the researcher studies multiple cases to understand the similarities and differences between the cases. Creswell, (2014) states that this methodology includes the use of interviews, documentation, and observations. The primary data collection tools that will be employed in this study are interviews, observations, and surveys. In this study, three K-5 elementary schools will be looked at Rolling Hills School district with a focus on the leadership within each of those locations.

Population and Sample

The researcher has decided to employ a purposive sampling to identify a site for critical informants for the investigation of the phenomenon (Bernard, 2002). The researcher will follow NIH guidelines and recruitment will not take place until after Institutional Review (IRB) approval. The population for this study will be school administrators, teachers, and students. This

population has been taking part in a district STEM and Makerspace initiative for the past three years in a suburban New Jersey School district. All three K-5 schools in the district will be invited to participate. The study will focus on building administrators across the three sites, teachers of students in grades 5, and students in grades 5. Fifth grade will be chosen because students and teachers in those grades have been engaged in the district initiative for the pas two years. Teachers and students will be invited to participate in interviews and surveys based on consent. Bertaux (1981) argue that fifteen should be the smallest sample size in a qualitative study. Bernard (2002) contends that the average is based on thirty-sixty interviews in qualitative research. According to Nastasi (n.d.) saturation will be achieved when there is "nothing left to learn."

Procedures

Before the commencement of this study IRB approval will be required from New Jersey City University. Site approval will be needed from the district's superintendent of schools. Further participation will be required from each of the building principles. During this study, there will be a collection of data in the form of interviews, surveys, and observations. Because the research involves students parental consent will be required.

Potential Instruments

Surveys will be distributed to participating administrators, teachers, and students with consent given in late September. The survey questions will be geared to the intended audience. The time frame for completing the survey is one week. The survey will be distributed electronically via district email for staff. A list of participating students will be given to students' teachers for the survey to be administered via Google Classroom. Sample survey questions are found in Appendix A.

The last question of the teacher and administrator survey will ask for their participation in the interview portion of the study. The researcher will maintain interviewee participant confidentiality. Interviews will be scheduled once all surveys have been collected. Based on participant responses meetings will be scheduled around their schedule during the school day. Semi-structured interviews lasting approximately 20-30 minutes will be scheduled. The researcher will be assigned a designated space within each building to conduct interviews. The interview format will be semi-structured. The researcher may go off script as the conversation progresses. Interviews will be recorded and transcribed. Sample interview questions are found in Appendix B.

The researcher will establish a schedule to complete the nine observations across the three sites. The researcher will focus on observational indicators of how teachers are implementing NGSS based makerspace activities. The researcher will use field notes with an emphasis on the activities of which students are engaged. The field notes will be coded using an open-coding process. Sample codes are found in Appendix C. Sample observational indicators are found in Appendix D.

Equipment

Each of the proposed sites has a dedicated Makerspace housed within their building. Each Makerspace is equipped with various pieces of equipment to support the space. Each Makerspace is outfitted with Chromebooks, which will be utilized for participating students to take the survey.

Potential Risk for Failure

In any endeavor, there is always the potential risk for something to go wrong. To avoid failure, the researcher will communicate with district officials and mainly building administrators

regularly sharing study background, timelines, and other requirements. Several site visits will be made so that participants are familiar with seeing the researcher on campus. All communication will be concise and use precise language avoiding any jargon. This will be of importance when it comes to garnering the support of participants. The researcher will make every effort to convey that the study is not punitive and all information shared will remain confidential. This will assist in having enough participants included in the study. Although a dedicated space will be assigned to the researcher participants will be given the option of choosing a location of their choice within the building.

Timeline

Action	Completion Time Frame
Submit IRB to NJCU	July 2019
Request Site Permission from Superintendent or Designee	August 2019
Communicate with Building Principals	August 2019
Send Initial Communication to Teachers via Email and Hard Copy	August –September 2019
Arrange with Principals to Meet with Teachers During Welcome Back	September 2019
Request Parental Consent	September 2019
Teachers will Forward Electronic Survey to Students	September 2019
Have Administrators and Teachers Complete the Survey	September 2019

Conduct Administrators, Teachers, & Student Interviews	October – December 2019
Conduct Makerspace Observations	October – December 2019
Complete Data Analysis	December 2019 –January 2020
Complete Findings	January – February 2020
Submit Completed Report	March-April 2020

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Appendix A

Sample Survey Questions

Student

1. Describe the projects that you complete in the Makerspace?
2. What has been your favorite STEM activity?
3. What do you know about Next Generation Science Standards?

Teacher

1. How much training have you received on the following topics: STEM, Makerspace, & NGSS?
2. How supportive has the administrators been in the Makerspace initiative?
3. What role does your administrator play in the implementation STEM and Makerspace and NGSS?

Administrator

1. Describe your leadership style?
2. How do you support your staff in the Maker Movement?
3. Do you align yourself with transformational leadership why or why not?

Appendix B

Semi-Structured Interview Questions

Teacher

1. Do you feel that you have received adequate training in NGSS? Why or why not?
2. Have you witnesses any differences in students creative and critically thinking abilities?
3. How is Professional Development handled for you personally and building wide?

Administrator

1. What has been your greatest learning curve in the Makerspace process?
2. Has your leadership style changed as a result of the Makerspace?
3. How do you determine the needs of your staff?
4. Explain your daily and weekly role in the Makerspace?

Appendix C

Observation	Code
Students using Science related equipment	Hands On
Students working together	Collaboration
Teachers/Students focused on product not assessment	Culture of Creativity
Students challenging each others thinking	Analytical
Students using computers	Technology

Appendix D

Observational Indicator	Example
Use of Computational Reasoning and Mathematics	
Engaging Discussion about Evidence	
Using and Creating Models	