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A Survey of Best Practices and Key Learning Objectives in a Secondary STEM Academy Setting

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By

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Abstract

Specialized secondary schools, sometimes called academies, that focus on Science, Technology, Engineering, and Math (STEM) are becoming commonplace in the United States. Natrona County School District in Casper, WY, is opening such an academy called Pathways Innovation Center (PIC) in 2016, of which I am a part of. In an attempt to aid in the design of curriculum for PIC, and to provide a resource to others involved with STEM Academies, I reviewed the literature and conducted phone and email interviews with five different STEM Academy educators throughout the United States. Through this research, I addressed two questions, a) what are the best practices of STEM Academies, and b) what are the key learning objectives of STEM Academies? Subject Integration, In-house Engineering Curriculum Design, Student Cohorts, Community Involvement, and Internships were revealed as being some of the best practices for STEM Academies. I also found Problem Solving/The Engineering Design Process and Soft Skills, such as Student Collaboration, Communication, Presentation Skills and Time Management to be some of the key learning objectives. While these results are useful and a step toward providing better education for our students, these best practices and learning objectives must be implemented, further researched, and refined in STEM Academies.

Table of Contents

Chapter 1

Introduction

Background and Rationale

Throughout modern history, western education has mostly consisted of students passively sitting in classrooms, listening to teachers, taking notes, completing assignments, and testing. Many students do not thrive in this environment as they see it as a long list of unrelated tasks that have no practical meaning to their own lives (Dewey, 1938; Slough, 2013). This traditional approach to teaching has fostered learning for some, yet lacks the authentic approach to education that people have experienced in other cultures for thousands of years, which is on the job sharing and collaboration.

Many educators today are addressing this issue through inquiry, a strategy in which students are shown how to explore their world through a systematic and investigative process. Writers of the Next Generation Science Standards (NGSS) have identified and addressed this need through Engineering content and Science and Engineering Practices (NGSS Lead States, 2013). Academies are one approach to fulfill this hands-on ideology as they are located in high schools where students work in an environment that connects their science, math, and engineering classes, ideally resulting in a real-world experience. These schools offer a realistic hands-on and collaborative environment. Students spend most of their time working together, with their teachers, and community members to solve real-world problems (Marshall, 2010).

Science, Technology, Engineering, and Math (STEM) is a specific subset of education in which academies can specialize. One approach of STEM is to use science, math, and technology as tools to engineer something, with the engineering processes being the focus of the project (Capraro, 2008). This usually begins with students identifying a need in society, which is often an ill-defined task (Capraro, 2008). Students perform research, work with their community, and design a solution. The solution would then be created or manufactured, tested, and compiled into a final product. The scope of the projects can range anywhere from replacing an aging bridge to making a prosthetic finger for an individual.

Problem Statement

Beginning in 20th century and continuing into the present, society has grown significantly in the areas of STEM (Stevenson, 2014). As we progress through the 21st century, there has been repeated outcry that the United States is falling behind peer countries in STEM, and education needs to step up in order to meet this demand (Duran, 2013). Several issues arise when considering STEM Academies as possible answers to this shortage, such as are they viable, or even superior, alternatives to traditional schools? The development and/or implementation of STEM Academies is a difficult task and others have led the way and written about their experiences (Dubin, 2014; Hougham, 2015; Kaye, 2011; Morrison, 2015; Schachter, 2012). Simply labeling a school as a STEM Academy does not guarantee success, so my goal is to identify the best practices and key learning objectives as laid out by the literature and by existing academies in order to better help me in the development of Pathways Innovation Center, as outlined below.

Purpose

Natrona County School District in Casper, WY is in the process of developing an academy school, Pathways Innovation Center (PIC). This school is set to open in the fall semester of 2016, and I am involved with the curriculum planning processes. The primary purpose of this paper is to help me better understand the best practices and key learning objectives of existing STEM Academies. This process will aid me in my contribution to writing curriculum and I will share it with my fellow designers. The secondary purpose of this paper is similar in that anyone involved with STEM Academies will be able to use this consolidated source of best practices and key learning objectives to help them better run and/or design their school.

Questions

As I approach the design of curriculum for PIC, I have identified two main areas in which I have questions. These are: a) what are the best practices of STEM Academies, and b) what are the key learning objectives of STEM Academies? By finding answers to these questions, I believe that PIC (and other STEM Academies) can more fully meet student needs in an authentic and relevant manner.

Methodology

A two-phase approach is used to characterize the best practices and key learning objectives in STEM academies: a literature review and a series of interviews. Academic research involving STEM Academies is becoming commonplace, so answers to my research question begins with a literature review. The concepts that have been discussed above involving STEM Academies have been researched on major article databases and in libraries. Historical, defining, and important information are researched first. Ideas and themes are then consolidated and connections are made. I then discuss the theoretical framework behind these academies.

I have found five different STEM Academies that are located in the US through the use of internet searches involving the keywords “STEM”, “Engineering”, and “Academy”. I located a contact at each academy and through both email and telephone interviews, I investigate the following ideas:

1. Please give me a rough overview of your academy, including credits, curriculum, daily activity, projects, etc.
2. What are you doing that makes your academy run well and be effective?
   a. Describe what you believe are your academy’s best practices.
   b. Describe what you believe are your academy’s key learning objectives.
3. What have you changed about your academy that didn’t work well?
4. How do you assess success?
5. Please talk about:
   a. Integration
   b. Critical thinking/problem solving
   c. Soft skills
   d. Collaboration/communication

After obtaining results from the interviews, I summarize the interviewer’s field notes and the materials based on commonalities between the five schools. Finally, I make connections between the literature review and the interviews that I perform.

Chapter 2

Literature Review

Background

Academies that focus on STEM are becoming a common educational focus as there are certain components that make these academies effective. The literature provides several answers to my questions: a) what are the best practices of STEM Academies, and b) what are the key learning objectives of STEM Academies? This chapter begins with a description of STEM, its background, and the American desire for STEM education to be cultivated. The same discussion then occurs with academies. Next, I cover the theoretical framework underlying STEM Academies, which closely follows Dewey's Theory of Experiential Education.

STEM

Science, Technology, Engineering, and Math, or STEM, is an acronym that is not well defined regarding both education and occupations (Oleson, 2014). Duran states that the National Science Foundation considers, "…the fields of Chemistry, Computer and Information Technology Science, Engineering, Geosciences, Life Sciences, Mathematical Sciences, Physics and Astronomy, Psychology, Social Sciences, and STEM Education and Learning Research" to be STEM occupations (2013, p. 119). These categories are too broad for the scope of this paper, so I have focused on the Engineering component of STEM. The Science, Technology, and Math portions of STEM are supplementary, as they aid in the Engineering and design of a product that addresses a problem (Capraro, 2008).

Over the last decade, there has been a large push for increased STEM education in the United States. Competition in the global market is a strong factor for this, as other nations appear to be advancing more quickly than the US in training students in STEM (Duran, 2013). Conversely, the US seems to have a decreasing interest in STEM (Stearns, 2012), as the Committee on Prospering in the Global Economy states:

> Although many people assume that the United States will always be a world leader in science and technology, this may not continue to be the case inasmuch as great minds and ideas exist throughout the world. We fear the abruptness with which a lead in science and technology can be lost – and the difficulty of recovering a lead once lost, if indeed it can be regained at all (2007, p. 3).

Specific reasons for the necessitative continued development of STEM education in the US are laid out clearly by Marshall,

> To educate our children as STEM knowledge creators, innovators, entrepreneurs, and global change-makers with the capacities to understand complex issues, creatively invent solutions, and ethically catalyze change requires their immersion in mind and practice fields rooted in meaning, not memory; engagement, not transmission; inquiry, not compliance; exploration, not acquisition; personalization, not uniformity; interdependence, not independence; collaboration, not competition; challenge, not threat; questions, not answers; and joy, not fear (2010, p. 49).

President Obama stated that if the United States is to maintain its leading role in science and technology, one million more STEM professionals must be trained (President's Council of Advisors on Science and Technology, 2012). Obama goes on to say that, "…we'll reward schools that develop new partnerships with colleges and employers, and create classes that focus on science, technology, engineering, and math—the skills today's employers are looking for to fill the jobs…" (President Obama, White House Office of the Press Secretary, 2013). Finally, the National Science Board reported that between 1950 and 2009 there has only been a 1.2%

increase in Science and Engineering workers while there has been a 5.9% increase in the need for STEM occupations (2012).

However, some argue that the need for a large expansion in STEM education and careers is being blown out of proportion. Stevenson states that our current STEM crisis originated during the Cold War with the Soviet Union and its launch of Sputnik. Since then, the recurring cry for more STEM education resides in fear and "a perceived threat to U.S. economic and homeland security" (2014, p. 135). Oleson claims that STEM occupations are often poorly classified. He takes this further by stating that these classifications are used in studies that analyze and project present and future needs as well as salaries, many of which are inaccurate (2014). This does not negate the need for STEM education, but instead requires educators to be able to better discern and teach the skills and knowledge that industry is requiring in our advancing society (Carnevale, 2010).

Academies

Thomas describes how American academies began as specialized Science, Math, and Technology (SMT) schools (2010). The first, Stuyvesant High School, was opened in 1904 and was a manual training school for boys. Brooklyn Technical High School followed in 1922, then the Bronx High School of Science in 1938. The need for such schools arose to provide opportunities for the working force to develop certain required skills and not for the gifted and talented to excel. The Cold War against the Soviet Union spurred on much of the development of SMT schools in the United States from the 1950's through the 1980's.

Thomas continues with after the Soviet Union collapse, the rationale for the continued development of advanced schools shifted from military to economic, as there was fear that America would be losing its competitive edge. These new schools began to add the "E", or engineering, component into STEM, and most were state, not district, run in the US. Now including gifted and talented students, many were (and still are) located on college campuses and offered college credit. Part of the reason for state-run academies, instead of district-run, was (and still is) that the facilities, specialized equipment, curriculum development, etc. are expensive and states and the federal government are often better suited to handle these costs than districts are (Atkinson, 2007). The purpose of these schools was two-fold – to provide a rigorous program for advanced students and to facilitate research into the best approaches to teaching STEM, which can then be modeled to other schools. Thomas sums up the development of academies by stating that the need for these schools, "… has been driven by economics, politics, and international affairs, the last two decades have seen a shift in practice that asserts that specialized STEM education is beneficial to both teaching and learning" (2010).

Similar to the definition of STEM, the definition of academy is vague. Erdogan (2015) describes STEM Academies as often being Career Technical Education (CTE) schools where students typically spend half of their day focusing on STEM and the other half at their home school. Schachter defines emerging STEM Academies that have CTE components as, "Formerly called vocational-technical schools, these institutions have long been known for turning out auto mechanics, carpenters and cosmetologists, as well as graduates in dozens of other trades" (2012). Students often take a variety of hands-on CTE classes in addition to Math, Science, Language Arts, and/or engineering design classes. These classes may not be separated by a bell schedule, but instead might have common projects that span all the classes and promote cross curricular integration (Marshall, 2010). In addition to providing students with hands-on and real-world experiences, these schools prepare them for college and/or try to prevent them from dropping out (Erdogan, 2015).

There is evidence that the academy setting is an effective way to learn STEM. The CSI Academy (Kaye, 2011), Toledo Technology Academy (Dubin, 2014), "Orion Academy" (Morrison, 2015), AL@ (Hougham, 2015), and the Green Energy Academy (Schachter, 2012), just to name a few, all showed how students outperformed their counterparts in traditional schools and/or were better prepared for STEM related occupations than peers. The National Academy of Sciences has strongly recommended that specialty high schools be developed to enhance science and math, as these schools can,

> …foster leaders in science, technology, and mathematics. Specialty schools immerse students in high-quality science, technology, and mathematics education; serve as a mechanism to test teaching materials; provide a training ground for K–12 teachers; and provide the resources and staff for summer programs that introduce students to science and mathematics (Committee on Prospering in the Global Economy of the 21st Century, 2007).

Erdogan (2015) compiled statistics involving STEM Academies. He found that 9th graders in such academies were more interested in STEM subjects and more confident that they would graduate from high school and earn a college degree as compared to their traditional school counterparts. Also, STEM Academy students in Texas scored higher on the math and science portions of the state tests than did traditional students. Erdogan describes 1,032 students after graduation from STEM Academies and found:

> 75% indicated a desire to continue education beyond high school and 40% planned to obtain a doctorate degree. 51% of students who graduated from specialized STEM schools pursued a science major in college. Results from this study suggested 10% of students who graduated from specialized STEM schools went on to major in mathematics. In addition, results of this study indicated 60% of college freshman

participants expected to earn a STEM degree and 55% of college senior participants were about to earn a STEM degree (p. 85).

One potential issue with academies is student scores on standardized tests are frequently used to assess student achievement for a variety of reasons. These tests can potentially impact school autonomy, funding, extracurricular activities, electives, etc. Dixon describes how there is a lack of solid evidence showing that students who study in academies do better than their non-academy peers on science and math portions of the standardized tests. He goes on to say that if technology and engineering educators can reach a better point of collaboration with math and science teachers, standardized test scores will go up (2012). Roberts describes how most critics of STEM Academies do not dismiss their benefits, but instead say that the drawbacks outweigh the benefits, chiefly the difficulty in generating a functional integrated curriculum (2013). In other words, do students become more STEM literate in an academy setting as compared to a traditional school setting, as academies are more time and money demanding?

Best Practices of STEM Academies

STEM Academies are unique environments that require special approaches to make them effective. A review of the literate has returned the following best practices: having students in integration of various subjects, cohorts, and community involvement. Each of these will be discussed in further detail.

Subject Integration in STEM Academies is inherent in the definition of STEM itself, as the National Governors Association states:

> STEM literacy is an interdisciplinary area of study that bridges the four areas of science, technology, engineering, and mathematics. STEM literacy does not simply mean achieving literacy in these four strands or silos. Consequently, a STEM classroom shifts

> students away from learning discrete bits and pieces of phenomenon and rote procedures and toward investigating and questioning the interrelated facets of the world (2007, p. 7).

This is in contrast to what Hoachlander says about the current status of STEM in most schools, as it consists of science and math, with technology and engineering being left out or an afterthought (2011). Hoachlander continues, "Where connections do get made to technology and engineering, too often they happen through a hodgepodge of disconnected projects that lack coherence or strong grounding in content standards and student performance objectives" (2011). The need for such integration arises from the type of problems that society is presented with which often requires a multidisciplinary approach (Roehrig, 2012). Both Hoachlander and Roehrig go on to say that although educators understand the necessity for STEM integration, no common approach exists for carrying it out. One idea is to offer an engineering course and have its projects be the main focus of STEM (Asunda, 2016; Berland, 2013; Roehring, 2012). This approach potentially allows the integration of the STEM subjects, as, "…in the real world, engineering is not performed in isolation—it inevitably involves science, technology, and mathematics" (Katehi, 2009, p. 165).

Cohorts, sometimes called learning communities, are defined by Doolen as, "…an intentional linkage or cluster of two or more courses, often around an interdisciplinary theme or problem, which enrolls a common cohort of students", which usually consists of 20 to 30 students who share the same core class schedule (2014). These courses can consist of writing, mathematics, science, and engineering courses, with the engineering course serving as the primary focus course. Doolen goes on to discuss that cohorts can potentially help students develop strong relationships with each other which can substantially enhance academic success (2014). Ricks performed a study with engineering students at a university to attempt to address three main areas that the students struggled with: finances, math literacy, and a sense of belonging. The results of the study took cohorts to a high level, with:

> Scholarships were made available to address the financial issues; tutors, mentors, study groups, and a "freshman-to-sophomore bridge" summer program were provided to address math deficiencies; cohort engineering courses, active learning techniques involving field trips and hands-on projects, required group meetings, required study sessions, peer mentoring, dedicated study space, and dedicated faculty advisors were used to promote a sense of community and belonging as well as improved study habits (2014, p. 88).

The study also showed students in such a rigorous cohort had a high retention and graduation rate.

Community Involvement is another area that the literature indicates that significantly impacts learning in STEM Academies. Examples of community members include businesses, government agencies (Southern Regional Education Board, 2012), research lab scientists and engineers, university faculty, (Morrison, 2015), museums, professional organizations (Diaz-Rubio, 2013), clubs, and local activists and educators (Peters Burton, 2014). Diaz-Rubio describes how local businesses provide opportunities for students to engage in real world problems, as they:

- Offer career presentations that allow students to consider career opportunities.
- Support employees to become mentors to students and teachers in particular fields…
- Facilitate field trips to their sites for hands-on understanding of the organization.
- Work directly with teachers in the classroom to make lessons more practical for students.
- Offer high school students externships and the opportunity to augment classroom study with realworld work experience, as well as internships that offer applied training. Most

business people want to get involved with school partnerships because students are their future workforce (2013).

One example of community involvement was the North and South Glenbrook High Schools being invited by Allstate Insurance to attempt to better understand the severity of teen texting while driving and how to reduce this problem. Students clarified these research questions, determined how to collect data, analyzed the data, performed additional research, compiled their results in both written and oral form, then presented their projects to Allstate representatives (Southern Regional Education Board, 2012).

Key Learning Objectives of STEM Academies

The literature has revealed three Key Learning Objectives of STEM Academies: problem solving (Engineering Design Process or inquiry), soft skills (professionalism), and collaboration (communication or teamwork). This list is not exhaustive and crossover occurs regularly between these components.

Problem Solving is at the core of STEM Academies. Morrison defines problem solving as, "…students' collaboration, inquiry, creativity, and critical thinking while engaged in rigorous standards-based curriculum and authentic and meaningful learning involving real-world and open-ended challenges or problems" (2015, p. 245). Problem solving requires high levels of critical thinking in order to work with information that doesn't have a predetermined outcome (Morrison, 2015). Ill-defined problems use such information, and if students are able to personalize these problems, they become much more motivated to engage in higher levels of critical thinking (Pintrich, 1990). When properly trained, students can identify the underlying concepts and approaches to problems, which goes beyond simply making surface connections regarding similar problems (Dixon, 2012). Oleson states, "…employers are clamoring for workers who not only have technical expertise in a particular area such as STEM, but also those who can use their technical knowledge to engage in abstract reasoning, problem-solving, and trouble-shooting" (2014), which confirms the post-high school need for this skill.

Soft Skills is another learning objective that is found in the literature. Much of education is driven towards obtaining the hard skills, such as technical skill and knowledge, but the literature describes how both colleges and industry are looking for individuals with both hard and soft skills (Bancino, 2007; Harris, 2008; Oleson, 2014). Harris has compiled a list of such skills, including, "… work ethics, positive attitude, social grace, facility with language, friendliness, integrity, and the willingness to learn" (2008, p.19). Harris also assembled a panel of engineering professors, and through a Delphi study he found that the most important skill was written communication, with the others being, "…a high level of reading comprehension, demonstration of honesty, a willingness to learn, being open minded to new ideas, problem-solving skills, and the ability to follow directions" (2008, p 22). These were followed up with oral communication and a strong work ethic. Bancino describes in-person, nonverbal, active listening, writing, and presentation communication types along with the idea that there are several underlying skills that contribute to communications skills, including, "…interpersonal skills such as self-awareness, social awareness, relationship management, conflict management and diversity" (2007, p. 21). Harris goes on to share techniques that teachers can use to attempt to develop their students' soft skills, with:

> … 1) work in teams, 2) organize their thoughts, 3) communicate with team members, 4) solve a problem, 5) present their findings orally, and 6) evaluate their success through a written document. This type of learning activity should also cause students to work outside of their comfort zone, thereby stretching soft-skill development. (2008, p 22).

Collaboration is also an important aspect of STEM Academies. Emphasizing teamwork over individuality, it can be defined as "…a process by which individuals negotiate and share meanings relevant to the problem-solving task at hand… Collaboration is a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem" (Roschelle, 1995, p. 70). Havice (2009) describes how the goal of collaboration is not to have students complete tasks in group situations, but is instead to teach them how to work together to complete tasks. Students should be instructed in how to effectively work together, fulfill specific roles in the group, work under leadership, avoid allowing the strongest students to take on the majority of the decision making and work load, etc. Deadlines and high expectations enhance group work, which forces students to become efficient and capable. Also, the diversity of students allows a variety of viewpoints and expertise to be used to generate ideas and foster creativity for problem solving (Householder, 2012).

Theoretical Framework

STEM Academies line up closely with Dewey's Experiential Learning Theory. Academies are social environments where students work with each other, their teachers, the community, and business partners. Students build knowledge through real-world experiences in such a social environment (Duran, 2013). All students are at different points in their education so teachers should build experiences to meet the students where they are. Students are then able to transfer the skills and knowledge that they have developed to various situations, which demonstrates authentic learning and not simply the memorization of facts (Dewey, 1938; Roberts, 2003). Dewey calls this approach Progressive Education, which is in conflict with traditional education, both of which are outlined below.

Social Environments

According to Dewey, social environments are the foundation for nearly all human experiences. This environment has provided the opportunity for knowledge to be developed, enhanced, and spread. Education is a large component of human knowledge and the traditional setting does not allow a natural flow of this knowledge. Dewey gives one example:

> Call up in imagination the ordinary school- room, its time schedules, schemes of classification, of examination and promotion, of rules of order, and I think you will grasp what is meant by "pattern of organization." If then you contrast this scene with what goes on in the family, for example, you will appreciate what is meant by the school being a kind of institution sharply marked off from any other form of social organization (Dewey, 1938, p. 5).

Next, Dewey discusses social control, and its importance in society. As in a game, rules regarding society provide guidelines, protection, and fairness. Although one might view social control as a suppression of freedom, it instead offers opportunities for it. A game ceases to be a game when rules disappear and anything goes, which is the same for social interactions in school. Collaboration is extensively used towards a common goal. This lines up with Dewey's view that democracy fosters the best human environment, as students have the ability to make decisions together regarding their education. Traditional classrooms may remove this democratic component, so students are not nearly as collaborative, nor are they responsible for each other's success and are therefore are not active participators. Educators should design their lessons to foster collaboration to not only help the students grow socially but to also help teach each other. This removes the teacher and textbooks from the role of sole-knowledge providers.

Experience

Another one of Dewey's core components is student experience. Students must first be at a place where they can comprehend new material; if not, they can become frustrated and disillusioned with the topic that they are learning. The teacher begins with the students' pre-existing knowledge, which allows each new topic to be connected to previous understandings. This approach requires the teacher to be cognizant of where students have been and currently are, as well as develop lessons that propel them onto the next learning objective. Dewey summarizes this idea with, "He must be aware of the potentialities for leading students into new fields which belong to experiences already had, and must use this knowledge as his criterion for selection and arrangement of the conditions that influence their present experience" (1938, p. 33).

In a traditional classroom setting, students learn from external sources, such as teachers and textbooks. In progressive education, however, students learn best through hands-on and relevant experiences that often model the scientific method. These experiences must drive towards the objectives of the class that build on each other; they must not be isolated. Next, the experiences should be based on real-life examples. This approach allows students to make connections between core subjects and everyday situations (Roberts, 2003). Student interest increases dramatically, which has a synergistic effect on learning.

Not all experiences, however, are educative, according to Dewey. First, an experience fails to educate if it does not make connections to past knowledge and drive into the next area of knowledge. Next, student learning is hindered if the experience is too rigid and does not allow them to modify or flex the assignment. This can lead to automated habits and skills, which can squelch future learning. Finally, some experiences are enjoyable at first, but eventually can lead towards a careless attitude due to a lack of material depth. This affects future lessons, as students are more interested in having fun and not learning. These issues are prevalent in the traditional school setting.

Another piece of experience not directly addressed by Dewey is scaffolding. Coined by Wood, Bruner, and Ross (1976), they describe scaffolding as the

> Process that enables a child or novice to solve a problem, carry out a task, or achieve a goal which would be beyond his unassisted efforts. This scaffolding consists essentially of the adult "controlling" those elements of the task that are initially beyond the learner's capacity, thus permitting him to concentrate upon and complete only those elements that are within his range of competence (p. 90).

This approach allows students to step into activities and build new knowledge despite having a lack of pre-existing knowledge, which might bypass Dewey's theory that students must have the required background information. Holton and Clark state, "The analogy with construction of knowledge is that cognitive scaffolding allows learners to reach places that they would otherwise be unable to reach" (2006, p. 129), which creates opportunities for students to engage in relevant experiences that promote learning.

Vygotsky's Zone of Proximal Development (ZPD) mirrors scaffolding. Vygotsky defines it as, "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). When a student is at a point where he needs scaffolding to engage in an experience to solve a problem, he has entered his ZPD. After having an authentic learning experience, his ZPD has now shifted due to his gain in knowledge. Both scaffolding and Vygotsky's ZPD tie into the social environment that was previously discussed, as peers and teachers are expected to help students grow.

After learning through experiences, Dewey's goal for students is to be able to transfer their knowledge to other semi and/or un-related experiences and problems. This is in contrast to students who simply memorize facts and procedures and in doing so struggle with this transfer as is often found in traditional education. One potential advantage of approaching experiential education, as described above, is that students develop the habit and joy of learning. In doing so, they become lifelong learners both inside and outside of the academic setting. The transfer of experiential learning is the final step in Dewey's cyclical process.

Conclusion

Reports indicate that the creation of new STEM jobs exceed the number of graduates in the US, so educators are scrambling to determine how to fill this gap. STEM Academies are one such solution, as they are specialized schools and/or programs inside of schools that give students opportunities to focus on engineering. This allows students to experience authentic engineering pre-college environments which aids in their career decisions; if they decide to pursue engineering in college, they will then be prepared for success. The literature shows subject integration, the use of student cohorts, and involving the community as being some of the best practices in these academies. There are also several key learning objectives for STEM Academies that the literature reveals, including problem solving, the development of soft skills, and collaboration. These key learning objectives and best practices line up with John Dewey's Experiential Learning Theory, as students should interact with others regularly and engage in hands-on real-world activities.

Chapter 3

Method

Background

For the purpose of obtaining answers to my research questions during the Spring of 2016, I performed 5 interviews with educators who are involved in STEM Academies, which are located throughout the United States. I found these academies by using internet searches, then by browsing their websites. I then used the following criteria for determining whether or not to pursue an academy: (1) Is it an engineering academy? (2) Is it located in the US? (3) Does its website describe an academy that is at least somewhat similar to the academy that I am involved with, Pathways Innovation Center (which is further discussed in chapter 5)? If an academy seemed to meet these criteria, I looked for a primary contact and sent him/her an email. I stated who I was, what I was doing, and asked if they would be interested in visiting with me on the phone to aid in my research. Some websites had no contact, so I called those schools and asked if they could give me the email address of someone who is very knowledgeable about the academy and/or is in charge. Three of the interviews that I procured were with coordinators who were also instructors in their academy. Another interview was with someone who is an educator, and the last was with someone who coordinates the program. After the phone interviews, I emailed the contacts with several more clarifying questions; all responded back and answered my questions. The following sections describe some of the programs used by the schools, the schools themselves, the answers that they provided to my questions.

Many of the individuals that were interviewed use curriculum from Project Lead the Way (PLTW), which is a nonprofit organization that offers a variety of pathways for high school, including Engineering, Biomedical Science, and Computer Science. PLTW develops curriculum collaboratively with its own staff, and its customer's students, teachers, and administrators. It is problem-based which is demonstrated through its projects and activities having the goal of providing scaffolding experiences for students to solve problems. In order to be involved with PLTW, schools must pay for teacher training, equipment and supplies, and the participation fee. Once a school is set up, it has a variety of courses from which to choose, which for the Engineering Program includes two foundation courses: Introduction to Engineering Design, Principles of Engineering, and 7 advanced courses: Aerospace Engineering, Civil Engineering and Architecture, Computer Integrated Manufacturing, Computer Science Principles, Digital Electronics, Environmental Sustainability, and Capstone Course - Engineering Design and Development. Each of these courses contain modules, which are focused areas of content that take approximately 10 hours of class time to administer ("Project Lead the Way", 2013).

Another common organization that was involved with interviewed schools was the National Academy Foundation (NAF). Established in 1982 in New York City, it has grown to facilitate 716 academies and approximately 89,000 students nationwide. Its mission is to, "solve some of the biggest challenges facing education and the economy by bringing education, business, and community leaders together to transform the high school experience" (National Academy Foundation, 2016). In order to facilitate this mission, NAF focuses on four main educational design areas: Academy Development & Structure, Curriculum & Instruction, Advisory Board, and Work-Based Learning. Finally, it facilitates five main themes, including Finance, Hospitality & Tourism, Information Technology, Engineering, and Health Sciences.

Academy Interviews

The Engineering Academy at Hoover High School (EAH)

Located in Hoover, Alabama, Hoover High School has approximately 2,900 students. It is a public school and consists of a variety of academies and specialty programs, one of which is EAH. Approximately 200 students are enrolled in EAH. This four-year program involves students taking math, science, and engineering courses with a mission of, "…exciting students about the engineering profession and preparing them to be successful in engineering at the undergraduate level." (Hoover High School, 2016). Eighth graders go through an application process to get into the academy which helps them better understand the courses, level of commitment, etc. This application process aids in setting high expectations and a productivity-orientated atmosphere in the program.

My contact at EAH shared what he believes are some of the best practices at his academy. Much of the curriculum at EAH was developed by in-house teachers who have a background in engineering. This provides a flexible yet focused framework that offers students an excellent opportunity to learn. This curriculum connects learning project by project, and year by year. Next, feedback is emphasized over grading. He described how teachers spend a significant amount of time with individual students as they discuss where students are, where they want to be, and how they will get to that point. Students readily buy into this approach. When asked about cohorts, my contact said that the large number of students and the variety of their schedules do not allow for cohorts. Also, due to the diversity of student schedules, integration between courses is minimal, and teachers are not yet at the point where they collaborate cross-content.

Next, he shared some of the main learning goals that the academy has for the students. Problem solving is heavily emphasized, as students step through the engineering design process regularly in their assignments and projects. My contact stated that they, "…encourage students to approach assignments like technical papers and presentations from a design perspective, designing what and how they will communicate given the specifications and constraints for a particular assignment" (2016). Soft skills are another key learning objective. My contact described how university and industry assumes that students have acquired these skills, but they are seldom taught and developed. EAH focuses on, "written & oral communication (formal and informal), working effectively as part of a group, time management, asking questions, and taking responsibility for personal learning" (2016). This also includes public speaking, email, hard copy reports, and technical writing pieces, just to name a few.

Finally, when asked how his academy assesses student success, my contact said that one way is through the documentation of the year-to-year retention of students in the program, which is excellent, and eight graders consistently enroll in their program. They also monitor how well the Academy students do in their math and science courses as compared to other students in the school. EAH's primary measure of success is tracking what students do post-graduation, as the school attempts to stay in contact with students after they move on. Many graduates come back to the school and share their college and work-related experiences on a voluntary basis.

Mallard Creek High School Academy of Engineering (MCAE)

Mallard Creek High School is a public school in Charlotte, North Carolina, and has approximately 2,200 students. It has a variety of specialty programs, including the Academy of Engineering, in which approximately 200 students are enrolled. Its mission statement is:

> …devoted to preparing students in a global society through a quality education. Its goal is to help students prepare for post-secondary education while exposing then to full range of careers in engineering. The focus of the program is to expose and develop skills necessary for success at the next level of education (Mallard Creek High School, 2016).

Students take their core Science, Math, and English courses in conjunction with Project Lead the Way driven engineering classes over the course of 4 years. The program is also heavily involved with NAF.

When asked about their approach to an effective academy, my contact at MCAE discussed the importance of their academic team, which consists of the director, the instruction coordinator, the career development coordinator, and the teachers. They are a cohesive group that complement each other well and work together to form the best academy possible. The MCAE contact also discussed the importance of collaboration and communication amongst the teachers. They have the same lunch and meet unofficially to discuss curriculum, and starting next year they will have specific times set up for weekly meetings. Both subject integration and having students in cohorts are two other important pieces that are still in the development at MCAE. The limited implementation of both of these approaches has yielded positive results, so there are plans to enhance them starting the next academic year.

Key learning objectives at MCAE include soft skills, as the academy relies heavily on the Mayor’s Youth Employment Program to teach this objective. This program, specific to Charlotte, NC, has the goal, “To improve neighborhood quality of life through a community engagement strategy that ensures children are safe, succeeding in school, and supported by their community” (Mayor's Youth Employment Program, 2015). Here students interact with local business members and associated programs in a purposeful manner to learn employability skills, with one such event being an etiquette dinner. Also, problem solving is another essential learning goal. Students use a hands-on collaborative approach when engaging projects which enhances learning and the ability to solve complex problems.

The MCAE contact shared that the end of the course test and standardized tests are used to assess the effectiveness of MCAE. At this time 100% of the students received internships, graduate, and go to postsecondary schools. The program continues to grow as more students enroll in it each year.

STEM Academy of Hollywood (SAH)

SAH is a pilot school in Hollywood, California, that offers two different pathways – engineering and medicine ("Medicine" replaces "Math" in STEM). Their mission is to have a strong program to meet high standards, to offer enrichment opportunities to help students grow "cognitively, socially, emotionally, morally and physically," and to provide a "focused and comprehensive series of course in the fields of… STEM" (STEM Academy of Hollywood, 2016). With approximately 600 students, it is a neighborhood school of choice. Students must go through an application process in order to gain admission here on a first come first serve basis. This school uses PLTW for curriculum, yet is a full-service school in which students take their foreign language, social studies, art, etc. classes.

When discussing with my contact some of the best practices at SAH, she emphasized the importance of students being in cohorts. They take most of their classes together, develop relationships, learn how to work well together, and carry over much from class to class and year to year. A competitive atmosphere is also a significant component in the program as students engage in a variety of projects. This elevates student energy, enthusiasm, work ethic, commitment, and standards. Also, she described her use of mini-projects built within larger projects. Students need smaller goals and connecting points in order to obtain individual learning objectives and piece together steps towards an overarching idea. Next, my SAH contact discussed the integration of projects throughout three to five courses. At least once per year such a project takes place which is driven primarily by the engineering course. Teachers meet at the beginning of the year to plan out these projects, and they create/modify projects in such a way that each year students are exposed to different types of engineering problems. Finally, community involvement is an integral part of SAH. Local engineers help in the creation of projects and serve on judging panels. For example, some engineers have attended classes and helped, planned, and mentored students during a bridge contest. Internships are also a part of the program, but the school struggles in securing positions for students, which is becoming more of a priority for future classes.

One learning objective at SAH is the use of the engineering design process, which is a common thread throughout most all assignments and projects. The SAH contact described how students ask many questions when presented with a task or problem as they seek out the "right" solution. However, they are often reminded that their constraints help to focus their creativity in approaching solutions, which is an important goal for the students. Soft skills are also a priority at SAH, such as collaboration. Students are generally required to work in groups, and the projects are scaled such that a single student cannot do all the work alone. This forces students to work together and become better team players. Leadership is also emphasized, as the instructor chooses students who have excelled in the content to head up groups. This approach prevents those who are strong academically from becoming bored, and gives them an opportunity to grow in a relevant area of life.

Success at SAH is measured by the instructors, most of whom have degrees in engineering. As discussed previously, practicing engineers also come in and help assess student work, particularly projects. Finally, students who attend SAH have additional requirements that go beyond the state's minimum college requirements, which demonstrates the rigor of the program. SAH is also compared to the other schools in the Los Angeles Unified School District through the ACT, SAT, Smarter Balanced Assessment Consortium assessment, California Standardized Tests, graduation rates, and college acceptance rates.

Vance Academy of Engineering (VAE)

Zebulon B. Vance High School is located in Charlotte, North Carolina, and is a public school with about 1,700 students. It contains VAE which has approximately 230 students, grades 9-12. Much of the students' courses are pre-determined, such as Math, Science, Social Studies, English, Foreign Language, Engineering, Career and Technical Education, etc., excluding some electives. PLTW is used to direct the engineering curriculum, and the Academy is also associated with NAF. VAE's vision includes exposing and preparing students in STEM fields, to make them competitive post-graduation, and to provide authentic work-based experiences, all of which are reflected in the advanced degree that they receive upon graduation (Vance Academy of Engineering, 2016).

My contact at VAE shared several best practices that they focus on for creating a successful STEM Academy. First, community involvement is essential, as is indicated by the 34 hours of internship that is tailored to each student's program. Various business community leaders serve in quarterly advisory board meetings to brainstorm potential solutions to various problems. They also provide financial support, such as the recent $20,000 donation to upgrade classroom technologies. Next, he discussed the importance of cross-subject integration, but he believed the Academy has plenty of room to grow in this area. He also described how advocating for students during registration and making direct connections with parents are important. This allows both students and parents to have an excellent idea as to what VAE consists of, what opportunities exist for the student, and to make personal connections with teachers and administrators.

College and Career Readiness skills drive the learning objectives at VAE. Soft skills, such as collaboration, teamwork, and communication are such objectives. My contact elaborated on this further in that soft skills are just as important as technical skill attainment, and, “this type of learning best happens in a problem-based, project-based learning environment (which is) reflective of what businesses experience” (2016). Students are expected to use the engineering design process and grow in creativity and critical thinking throughout each Career/Technical and PLTW course that they take. My contact emphasized that these courses are designed with a focus on workplace learning in tandem with local businesses in order to, “…best serve students skill development in both areas of soft skills and technical skill attainment” (2016).

VAE’s success is assessed in a variety of ways. The student survey is an online survey that asks a variety of multiple choice and essay questions to get feedback on whether or not the program is meeting student needs. The program also has an advanced high school degree, a STEM/Academy of Engineering Diploma, which is available to students who meet VAE’s requirements. Post-graduate statistics are collected for post-secondary enrollment, entry-level employment after high school in professional career fields, and NAFTrack Certifications.

Engineering and Design Academy at Antioch High School (EDAA)

Antioch High School is a public school located in Antioch, California, and has approximately 2,000 students. It houses a variety of academies and eighth grade students must choose an academy prior to entering high school, which involves an application and lottery process. Each academy has its own counselor and vice principal, and teachers in the same cohort share a common prep period. The Engineering and Design Academy has a mission of, “Engaging students in engineering, environmental science, and design to prepare them to be innovative leaders ensuring a sustainable society through success in education, career, and life”, (“Antioch High School: Engineering and Design Academy”, 2016). There are approximately 400 students in EDAA, and it uses the NAF model and PTLW.

When discussing some of the best practices at EDAA, my contact emphasized the community aspect of the academy. Most teachers and students know each other, which enhances accountability both inside and outside of the classroom. Parents are also heavily involved, with those in the Engineering and Design Academy far outnumbering the parents in the other academies within the school. The personalities and complimentary aspects of the teachers are also important, as they work well together. Next, subject integration is prevalent at EDAA. There is at least one major project each semester that is integrated throughout the core and engineering courses. Students often work on these projects in cohorts, as they attend the same classes together, year after year. Projects begin freshman year with simple and broad concepts, then become more focused each year, with the senior project being individualized and of a more focused scope. Community involvement is another important aspect of the academy, as local industry brings in real-world projects for the students to work on. My contact stated that,

> In all of these activities plus many others, the community and industry partners come in as volunteers to assess, critique, evaluate, offer feedback and suggestions, or judge projects both to offer assistance during the project and to determine the project that best meets the requirements or needs presented. (2016)

There are several learning targets for students at EDAA. My contact stated that soft skills are the single most important skill that they learn in the program. They grow in their presentation skills, oral skills, written skill, choosing appropriate clothing, greeting, punctuality, etc. These skills are emphasized in most, if not all, of their classes. Next, collaboration is important, due to its real-world relevance. Students are often given roles of actual engineering jobs, and they learn how to work well in teams to manage a project. This experience is enhanced through the use of cohorts, as previously discussed. Problem Solving is also heavily emphasized at EDAA. Beginning in their freshmen year, students are taught that this process is just as important as the final product and that they can learn as much from failures as they can from successes. My contact shared the school's abbreviated 5 step Engineering Design Process:

1. Problem: identify and define the problem to be solved.
2. Possibilities: brainstorm and research possible solutions to the problem, then refine the definition of the problem if necessary.
3. Plans: design and develop the plan for how the problem will be solved and the solution will be implemented. If flaws in the plans are found, then return to the prior steps and refine.
4. Prototypes: construct a working model or test case to implement the plans. Again, if flaws are found, return to the prior steps and refine. Use the prototype to conduct tests to ensure the solution works as intended and solves the problem as defined.
5. Products: (finalize and present) the solution with all supporting documentation, models, analysis, budget, and marketing plan.

EDAA measures success in a variety of ways. First, attendance has increased significantly since the inception of the academy. My contact attributes this in part to the community feel of the Academy, as teachers and students hold each other accountable. Next, students are passing standardized tests at higher rates than before EDAA opened, which is emphasized in conjunction with the fact that engineering students are heavily tested in college. Finally, the retention rate of the program has been 100%. Although students sometimes move onto other academies in the school, all have graduated.

Chapter 4

Summary of Results

The teachers that were interviewed shared a variety of over-arching themes in answer to my research questions: a) what are the best practices of STEM Academies, and a) what are the key learning objectives of STEM Academies? In this chapter I will summarize those themes. These results are generally reflective of the schools but are not entirely comprehensive, as some of the interviewees may have either inadvertently or purposefully left out details during the interviews that took place.

Best Practice Results

The interviews with my contacts yielded a variety of best practices, some of which are mentioned by several schools. Table 1 outlines these results, with the most common response being Subject Integration. This was most often accomplished through each Academy's Engineering Class, which would have a large project that drew in the students' other courses (English, Math, Physics, etc.). Most of my contacts stated that they would like to step more fully into the development of Subject Integration for their academies. Next, most schools indicated that they value designing their curriculum in-house (or modifying PLTW curriculum to better suit their needs). The use of Student Cohorts was also a priority, but this was often described as being difficult to implement (due to the variety of student schedules, course offerings, etc.), so they are in the process of attempting to enhance this best practice. Community Involvement was another common component, which was often manifested through local business helping to develop lessons, offer real-world projects and problems, and provide grading/feedback, just to name a few. Government agencies, national business, and other organizations also contributed to the schools. Internships were another common aspect of many of the academies, which were provided for by businesses that practice in relevant areas. Having a Cohesive Teaching Team, Recruitment and Parent Involvement, Feedback being prioritized Over Grading, having a Competitive Atmosphere, using Mini-Projects to Connect Bigger Projects, and Teacher-Student Relationships were other less often mentioned Best Practices.

Table 1

Best Practice Results

Best Practices	**EAH**	**MCAE**	**SAH**	**VAE**	**EDAA**	**Count**
Subject Integration		x	x	x	x	4
In-house Engineering Curriculum Design	x	x	x			3
Student Cohorts		x	x		x	3
Community Involvement			x	x	x	3
Internships		x	x	x		3
Cohesive Teaching Team		x			x	2
Recruitment and Parent Involvement				x	x	2
Feedback Over Grading	x					1
Competitive Atmosphere			x			1
Mini-Projects to Connect Bigger Projects			x			1
Teacher-Student Relationships					x	1

Key Learning Objective Results

A variety of Learning Objectives were assimilated from the interviews that I conducted. All five schools described Problem Solving (also referred to as the Engineering Design Procedure) as being an essential component of their program. Soft Skills was also discussed as being essential by all five schools, with some indicating that it is the most important. This importance was emphasized, as the remainder of the learning objectives were all subsets of Soft Skills. From most to least often mentioned, Student Collaboration, Written Communication, Oral Communication, Presentation, Time Management, Appearance, Social Engagement, Asking Questions, Taking Responsibility for Personal Learning, and Leadership were various soft skills that were discussed, as outlined below in Table 2.

Table 2

Key Learning Objective Results

Key Learning Objectives	**EAH**	**MCAE**	**SAH**	**VAE**	**EDAA**	**Count**
Problem Solving/Engineering Design Process	x	x	x	x	x	5
Soft Skills	x	x	x	x	x	5
Student Collaboration	x	x	x	x	x	5
Written Communication	x		x		x	3
Oral Communication	x		x		x	3
Presentation	x				x	2
Time Management	x				x	2
Appearance					x	1
Social Engagement					x	1
Asking Questions	x					1
Taking Responsibility for Personal Learning	x					1
Leadership			x			1

Chapter 5

Implications for the Pathways Innovation Center

Introduction

Opening in the fall semester of 2016, the Pathways Innovation Center (PIC) is a facility located in Casper, WY, and is run by Natrona County School District (NCSD). PIC will service up to approximately 500 high school students in the morning and a separate 500 students in the afternoon. These students will be 11^{th} and 12^{th} graders, and will spend half of their school day at their public home school, and the other half at PIC. In order to help facilitate this, all the public high schools are on the same schedule for the start times of their first block, start and end of lunch (which is when students will travel between their home school and PIC), and the end of the last block for the day. PIC will consist of 4 different academies: Architecture, Construction, Manufacturing, and Engineering (ACME); Business, Agriculture, and Natural Resources (BANR); Creative Arts, Communication, and Design (CACD); and Health Science and Human Services (HSHS). The overall vision of these academies is to:

> …enable students to learn through the lens of a career or academic theme in a personalized learning community. Through their chosen academy, students will be exposed to a multitude of career and college opportunities, industry skills, and potential employers by way of classroom speakers, site visits, job shadowing and internships (Pathways Innovation Center, 2016).

Each Academy has three Pathways that students choose to participate exclusively in. These Pathways are shown below in Table 3.

Table 3

PIC Academy Pathways

ACME	BANR	CACD	HSHS
Manufacturing	Business	Production Arts	Health Sciences
Technical Service	Culinary Arts	Visual Arts	Human Services
Design and Engineering	Agriculture	Digital Media Arts	Early Childhood Education

The goals of PIC include: "…(a) increased graduation rates, (b) increased student academic performance and achievement, (c) close academic achievement gaps across system,(d) improved 21st century focus and readiness, (e) successful smaller learning communities within large high schools, (f) increased career-focused counseling, and (g) expanded connections with business and industry partners" (Pathways Innovation Center, 2016).

Eighth through 11th grade students heard a variety of presentations from principals, PIC representatives, and school counselors during the 2015-2016 school year. They then had the opportunity to choose to enroll in one of the 4 Academies or to choose the "traditional route" (no Academy involvement). While freshmen and sophomores can enroll in an Academy, they will only be taking prerequisite courses at their home school, and will not spend any time at PIC. Both juniors and seniors that are enrolled in an academy will attend PIC. Students who are not enrolled in an Academy will not be able to go to PIC and take courses that are offered; they must be willing to spend the entire half of their day at PIC and take the required courses that line up with their Academy.

Recommendations

I have compiled a list of recommendations based on the literature's and interviewee's discussion on the best practices and key learning objectives for STEM Academies. While these recommendations are geared towards the Engineering and Design Pathway (EDP), which is located in the ACME Academy at PIC, many might be applicable to the other Pathways. Also, my recommendations will be interwoven with my knowledge of the preliminary structuring of EDP.

Best Practices

Subject integration is a practice that should be employed at EDP. During the design of the curriculum, the planning team took the approach of making each day in EDP very open during the school year. Instructors would create projects that would be linked through all the courses that the students would be taking. Students would in turn meet with various instructors on a non-repeating schedule in order to (1) learn the content that they are required to learn based on the standards and (2) work on the parts of the project that align with that credit. In this regard, students would not be attending specific classes at specific times, but would instead be learning through some spontaneous class time and much project work-time. However, later in the design phase of the Academies at PIC, a variety of stakeholders became concerned that students would be too pigeon-holed with this setup. They felt students who wanted to take only a course or two at the Academies would be overlooked. Also, the lack of concrete time spent in a given class was a concern in that the students would not be meeting the standards in order to legitimately earn their credits. The stakeholders requested that the designers consider breaking up the courses into specific time slots, a traditional approach, which addressed their concerns but also jeopardized the ease of fully integrating all the subjects. After hearings and input from the student body, it was decided that the original comprehensive integration would take place. It appears that EDP is well on its way to fully integrate the courses that students will be taking.

In-house curriculum design was another best practice that was revealed in my interviews. Some of the original PIC pioneers visited several academies in the US in an attempt to glean some insight as to how to best approach creating the Academies in NCSD. While they did acquire some vision, they decided to write nearly their entire curriculum from scratch. In this regard, they are easily meeting this best practice.

The use of cohorts is another area that EDP should consider. While this approach is not directly emphasized in the planning phase as of yet, it goes hand-in-hand with their desire to have all the classes fully integrated. While at PIC, the same students will spend nearly all their time with each other while working on the same projects together. However, when students are at their home schools, they will be taking their own classes that are unlikely to be related and/or shared with their PIC peers.

Community involvement is heavily emphasized at PIC. Since the earliest planning, designers have shared names of potential community partners and began contacting them. Many of these contacts have eagerly agreed to participate by contributing materials and/or provide sponsorship, helping to plan and/or share projects, and being willing to help as needs arise. Internships have not been discussed, so as of yet, they are not being considered.

The need for a cohesive planning and teaching team is another important best practice that the PIC designers have pursued. Curriculum designers were directly exposed to this as they began to work together in planning curriculum for PIC. Later, Wonder, By Design was brought in to help facilitate purposeful collaboration amongst the planners. This involved many small and larger tasks to be assigned to the different Academy planners, which forced them to learn how to work well together. Developing norms during meetings (agreed upon practices, approaches, and rules for engaging each other), the best approaches to solving problems, delegation techniques, and a variety of other components to collaborative work were important goals of the training administered by Wonder, By Design. These approaches have been emphasized not only to strengthen the team, but to show the planners how to model for and teach the future students in PIC how to better work collaboratively.

To some extent, EDP has seen the remainder of the best practices that I previously discussed. Recruitment and Parent Involvement has been difficult due in large part to the difficulty in solidifying the curriculum of EDP. One reason for this is the conflicting vision of some of the main stakeholders for the program. This area will hopefully see more growth as the program begins and parents and students have a better idea as to what they will experience if they decide to join EDP. Feedback Being Prioritized Over Grading has not been discussed extensively as the curriculum is still in its early stage of development. Having a Competitive Atmosphere has been emphasized heavily by the EDP planning team. From the opening project of the school year to the capstone project, students will most likely be competing to develop and present on their designs. The use of Mini-Projects to Connect Bigger Projects was another idea that was actively discussed. Planners regularly conceptualized using this approach to scaffold students onto more advanced projects. Finally, Teacher-Student Relationships were not regularly discussed. While it can be assumed that teachers would emphasize these relationships after they met and began working with their students, this practice should be purposefully discussed and pursued both before and after students arrive at PIC.

Key Learning Objectives

Problem Solving (or the use of the Engineering Design process) is one of the foundational components of EDP. This was the first and main piece that was identified when curriculum planning began, as it outlines each arc of the students' projects. One important piece of the projects is that they are relevant to the real-world. This allows students to make more authentic connections to problem solving.

The development of the students' Soft Skills is another learning objective that has been emphasized repeatedly during the development of EDP. Student collaboration was one such soft skill. Tying into the cohorts and subject integration pieces that were previously discussed, collaboration solidifies both. Students should learn how to work together in an authentic manner which will propel them into college and/or the workforce. Communication is another important piece that has been built into the EDP curriculum. In addition to communicating with each other (i.e. through collaboration), students will be expected to communicate with their instructors, community partners, and during presentations. They will take a language arts class geared specifically towards growing in communication. Time Management has not been actively discussed during planning, but is an area that many students struggle in, so it should be considered during future development. Similarly, Student Appearance has not brought up during planning, but should be considered, especially in the context of interactions with community partners. Finally, the last three key learning objectives, which are also soft skills: Asking Questions, Taking Responsibility for Personal Learning, and Leadership, are reasonable areas for students to grow in, which will be discussed in the future with the planning committee.

Conclusion

Academies at the secondary level are an exciting approach to STEM education. They facilitate hands-on, real-world experiences that not only allow for deeper, more meaningful learning, but also provide students with the opportunity to both better identify and begin their journey down a career path. The best practices and key learning objectives of STEM Academies revealed by the literature and through interviews help to verify the above statements, as they also line up with Dewey's Experiential Learning Theory. I believe this approach is clearly superior to the traditional model of learning in which students sit through lectures (often involving copious amounts of theory) and engage in labs that may or may not have relevant connection to the lectured material. I have experienced this traditional style through nearly all of my secondary and post-secondary education. After graduating from high school then college with a degree in Civil Engineering and finding employment at an engineering firm, I was disappointed to see how different my educational experiences were as comparted to working as an engineer. Collaboration, working with clients, permitting, 8 (or more) hour work days, and generating as well as comprehending extensive designs, just to name a few, were mostly left out of my 18 years of education. Being able to mimic a job while at school is ideal, as students should be receiving training on how to best step into their potential future. Also, this approach is not exclusive to academies, as individual (or groups of) instructors at "traditional" schools can attempt to integrate some of these best practices and key learning objectives into their classrooms.

There are several limitations to this project. First, I may have missed literature that addresses my research questions. ERIC was the primary database that I used, and while I found a wide variety of articles, books, etc., some other valuable sources may exist in other databases. Next, my interview pool was relatively small and was selected based on my brief internet searches. While this approach meets the requirements of this Plan B paper, it lacks the comprehensive research requirement to have a statistically significant pool in order to better solidify my conclusions.

In addition to the limitations that I discussed above, there are several follow-up research topics to this paper that can be considered. While I identified some of the best practices and key learning objectives for STEM Academies, I did not develop any ways to implement them. There are many intricacies involved with running such a program, including, but not limited to: course/credit offerings; locations and facilities; budgets; deciding between full subject/course integration, keeping all classes separated, or something between these approaches; soliciting community support; and understanding how to involve the community. Coinciding with these ideas, a curriculum could be researched, then developed, based on the best practices and key learning objectives that I uncovered, which would be an extremely large task. This could involve creating units, lessons, activities, projects, assignments, etc. that address the standards for the chosen courses and also meet the key learning objectives as well as follow the best practices identified in this paper. Both formative and summative assessments should also be included in a curriculum design, which would reveal if students are obtaining the standards and learning objectives; I touched briefly on this during my interviews. While all these are daunting tasks, researching them would help to enhance the educational value of STEM Academies.

STEM Academies are schools that give students an opportunity to specialize in STEM and experience real-world as well as hands-on situations. Through this paper, I have identified several best practices and key learning objectives that can be used when implementing these academies. While the list that I generated is not all-inclusive, it provides an outline for me, as I help in the development of PIC, and for others who are involved with STEM Academies.

References

Antioch High School: Engineering and Design Academy. (2016). Engineering and Design Academy. Retrieved March 29, 2016, from http://ahs-antioch-ca.schoolloop.com/Engineering

Asunda, P. A., & Mativo, J. (2016). Integrated STEM: A New Primer for Teaching Technology Education. *Technology and Engineering Teacher*, *75*(4), 8–13.

Atkinson, R. D., Hugo, J., Lundgren, D., Shapiro, M. J., & Thomas, J. (2007). *Addressing the STEM Challenge by Expanding Specialty Math and Science High Schools*. Information Technology and Innovation Foundation. Retrieved from http://eric.ed.gov/?id=ED506571

Bancino, R., & Zevalkink, C. (2007). Soft Skills: The New Curriculum for Hard-Core Technical Professionals. *Techniques: Connecting Education and Careers*, *82*(5), 20–22.

Berland, L. K. (2013). Designing for STEM Integration. *Journal of Pre-College Engineering Education Research*, *3*(1), 22–31.

Capraro, R. M., & Slough, S.W. (Eds.). (2008). *Project-based learning: An integrated science, technology, engineering, and mathematics (STEM) approach*. Rotterdam, the Netherlands: Sense.

Carnevale, A. P., Smith, N., & Strohl, J. (2010). *Help Wanted: Projections of Jobs and Education Requirements through 2018*. Georgetown University Center on Education and the Workforce. Retrieved from http://eric.ed.gov/?id=ED524310

Committee on Prospering in the Global Economy of, & the 21st Century. (2007). *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, D.C.: National Academies Press. Retrieved from http://www.nap.edu/catalog/11463

Dewey, J. (1997). *Experience And Education* (Reprint edition). New York: Free Press.

Diaz-Rubio, I. (2013). *Business Partnerships to Advance STEM Education: A Model of Success for the Nation*. Committee for Economic Development. Retrieved from http://eric.ed.gov/?id=ED544373

Dixon, R. A., & Brown, R. A. (2012). Transfer of Learning: Connecting Concepts during Problem Solving. *Journal of Technology Education*, *24*(1), 2–17.

Doolen, T. L., & Biddlecombe, E. (2014). The Impact of a Cohort Model Learning Community on First-Year Engineering Student Success. *American Journal of Engineering Education*, *5*(1), 27–40.

Dubin, J. (2014). Keeping It Real: A Toledo Public School Prepares Students for College and Career. *American Educator*, *38*(3), 18–23.

Duran, M., Höft, M., Lawson, D. B., Medjahed, B., & Orady, E. A. (2013). Urban High School Students' IT/STEM Learning: Findings from a Collaborative Inquiry- and Design-Based Afterschool Program. *Journal of Science Education and Technology*, *23*(1), 116–137. http://doi.org/10.1007/s10956-013-9457-5

Erdogan, N., & Stuessy, C. L. (2015). Modeling Successful STEM High Schools in the United States: An Ecology Framework. *International Journal of Education in Mathematics, Science and Technology*, *3*(1), 77–92.

Harris, K. S., & Rogers, G. E. (2008). Soft Skills in the Technology Education Classroom: What Do Students Need? *Technology Teacher, 68*(3), 19–24.

Havice, W. (2009). The power and promise of a STEM education: Thriving in a complex technological world. In International Technology and Engineering Educators Association (Ed.), *The Overlooked STEM Imperatives: Technology and Engineering* (pp. 10-17), Reston, YA: ITEEA.

Hoachlander, G., & Yanofsky, D. (2011). Making STEM Real. *Educational Leadership, 68*(6), 60–65.

Holton, D., & Clarke, D. (2006). Scaffolding and Metacognition. *International Journal of Mathematical Education in Science & Technology*, *37*(2), 127–143.

Hoover High School. (2016). Specialized Academics at Hoover High School. Retrieved March 25, 2016, from http://hooverhigh.al.hch.schoolinsites.com/?PageName=bc&n=104084

Hougham, R. J., Eitel, K. C. B., & Miller, B. G. (2015). Technology-Enriched STEM Investigations of Place: Using Technology to Extend the Senses and Build Connections to and Between Places in Science Education. *Journal of Geoscience Education*, *63*(2), 90–97. http://doi.org/10.5408/12-399.1

Householder, D. L., & Hailey, C. E. (2012). *Incorporating Engineering Design Challenges into STEM Courses*. National Center for Engineering and Technology Education. Retrieved from http://eric.ed.gov/?id=ED537386

Katehi, L., Pearson, G., & Feder, M. (2009). *Engineering in K-12 Education: Understanding the Status and Improving the Prospects*. National Academies Press.

Kaye, K., Turner, J. F., & Emigh, J. (2011). The CSI Academy: Encouraging Diverse Students to Consider Science Careers and Science Teaching. *AILACTE Journal*, *8*, 66–82.

Mallard Creek High School. (n.d.). Building Tomorrow. Today. Retrieved March 25, 2016, from http://mchsaoe.weebly.com/about.html

Marshall, S. P. (2010). Re-Imagining Specialized STEM Academies: Igniting and Nurturing "Decidedly Different Minds", by Design. *Roeper Review*, *32*(1), 48–60.

Mayor's Youth Employment Program. (2015). About MYEP. Retrieved March 25, 2016, from http://charmeck.org/city/charlotte/mayor/myep/Pages/AboutMYEP.aspx

Morrison, J., Roth McDuffie, A., & French, B. (2015). Identifying Key Components of Teaching and Learning in a STEM School. *School Science and Mathematics, 115*(5), 244–255. http://doi.org/10.1111/ssm.12126

National Governors Association (NGA). (2007). *Innovation America: Building a science, technology, engineering, and math [STEM] agenda.* Retrieved from http://www.nga.org/files/live/sites/NGA/files/pdf/0702INNOVATIONSTEM.PDF

National Science Board. (n.d.). Science and Engineering Indicators 2012 - US National Science Foundation (NSF). Retrieved April 1, 2016, from http://www.nsf.gov/statistics/seind12/

NGSS Lead States. (2013). Next Generation Science Standards: For States, By States. Washington, DC:The National Academies Press.

Oleson, A. K., Hora, M. T., & Benbow, R. J. (2014). *STEM: How a Poorly Defined Acronym Is Shaping Education and Workforce Development Policy in the United States. WCER Working Paper No. 2014-2*. Wisconsin Center for Education Research. Retrieved from http://eric.ed.gov/?id=ED556481

Peters Burton, E., Kaminsky, S. E., Lynch, S., Behrend, T., Han, E., Ross, K., & House, A. (2014). Wayne School of Engineering: Case Study of a Rural Inclusive STEM-Focused High School. *School Science and Mathematics*, *114*(6), 280–290.

Pintrich, P. R., & De Groot, E. V. (1990). Motivational and Self-Regulated Learning Components of Classroom Academic Performance. *Journal of Educational Psychology*, *82*(1), 33–40.

President's Council of Advisors on Science and Technology (2012). *Report to the President. Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering and mathematics*. Washington, D.C.: Executive Office of the President.

Project Lead the Way. (2013, October 1). PLTW Engineering - Curriculum [Text]. Retrieved March 29, 2016, from https://www.pltw.org/our-programs/pltw-engineering/pltw-engineering-curriculum

Ricks, K. G., Richardson, J. A., Stern, H. P., Taylor, R. P., & Taylor, R. A. (2014). An Engineering Learning Community to Promote Retention and Graduation of At-Risk Engineering Students. *American Journal of Engineering Education*, *5*(2), 73–90.

Roberts, T. G. (2003). An Interpretation of Dewey's Experiential Learning Theory. Retrieved from http://eric.ed.gov/?id=ED481922

Roehrig, G. H., Moore, T. J., Wang, H.-H., & Park, M. S. (2012). Is Adding the E Enough? Investigating the Impact of K-12 Engineering Standards on the Implementation of STEM Integration. *School Science and Mathematics*, *112*(1), 31–44.

Roschelle, J. & Teasley, S. (1995). The construction of shared knowledge in collaborative problem solving. In O'Malley, C. E., (ed.), *Computer supported collaborative learning*, (pp. 69-97). Heidelberg: Springer-Verlag.

Schachter, R. (2012). Not Your Grandparents' Vocational School. *District Administration*, *48*(9), 66–68.

Slough, S. W., & Milam, J. O. (2013). Theoretical Framework for the Design of STEM Project-Based Learning. In R. M. Capraro, M. M. Capraro, & J. R. Morgan (Eds.), *STEM Project-Based Learning* (pp. 15–27). SensePublishers. Retrieved from http://link.springer.com/chapter/10.1007/978-94-6209-143-6_3

Southern Regional Education Board. (2012). *Focusing on Challenging Content and Practical Applications in Science, Technology, Engineering and Mathematics (STEM) Studies in Middle Grades Schools, High Schools and Technology Centers. High Schools That Work*. Southern Regional Education Board (SREB).

Stearns, L. M., Morgan, J., Capraro, M. M., & Capraro, R. M. (2012). A Teacher Observation Instrument for PBL Classroom Instruction. *Journal of STEM Education: Innovations & Research*, *13*(3), 7–16.

STEM Academy of Hollywood. (2016). Mission and Vision / Overview. Retrieved March 26, 2016, from http://www.stemweb.org/domain/28

Stevenson, H. J. (2014). Myths and Motives behind STEM (Science, Technology, Engineering, and Mathematics) Education and the STEM-Worker Shortage Narrartive. *Issues in Teacher Education*, *23*(1), 133–146.

Thomas, J., & Williams, C. (2010). The History of Specialized STEM Schools and the Formation and Role of the NCSSSMST. *Roeper Review*, *32*(1), 17–24.

Vance Academy of Engineering. (2016). About VAOE. Retrieved July 9, 2016, from http://vanceaoe.weebly.com/about-us.html

Vygotsky, L.S., 1978, *Mind in Society: The Development of Higher Psychological Processes* (Cambridge, MA: Harvard University Press).

White House Office of the Press Secretary (2013, Feb 12). Remarks by the president in the state of the union address. Washington, D.C. Retrieved from http://www.whitehouse.gov/thepress-office/2013/02/12/remarks-president-state-union-address

Wood, D., Bruner, J. S., & Ross, G. (1976). The Role of Tutoring in Problem Solving. *Journal of Child Psychology and Psychiatry*, *17*(2), 89–100. http://doi.org/10.1111/j.1469-7610.1976.tb00381.x

Author's Biography

Paul Kasza grew up in North East Colorado and has always enjoyed nature, science, and music. In 2001 he began his study of music and civil engineering at the University of Wyoming (UW). He practiced as an engineer for four years, then returned to UW and received teaching certifications in Physics and Earth/Space Science. Two years later he enrolled in the UW Science and Math Teaching Center, Middle Level Science Master's program, and plans on completing it in the summer of 2016. Kasza currently teaches Physics and Physical Science at Kelly Walsh, in Casper, WY, which he thoroughly in enjoys. He strives to counter the idea that it is taboo for scientists to be spiritual, as he loves both science and Jesus. Beginning in 2014 he has taken an active role with the development of Pathways Innovation Center, an Academy school being developed in Casper, WY. Kasza plays hockey, tennis, and soccer and enjoys the outdoors with his two Westies through backpacking, cross country skiing, and hiking excursions. He also regularly gets his nerd on through science fiction. Finally, Kasza strives to have fun, love on others, and provide opportunities for people to laugh and learn.