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Engineering for Sustainable Energy Education within Urban Secondary Schools

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Engineering for Sustainable Energy Education within Urban Secondary Schools

A Dissertation Presented

by

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ABSTRACT

ENGINEERING FOR SUSTAINABLE ENERGY EDUCATION WITHIN URBAN
SECONDARY SCHOOLS

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In regards to mitigating global climate change it is evident that the transition to sustainable technologies is critical. Integrating sustainable energy engineering (SEE) within secondary school curriculum can have many lasting advantages for the future of global sustainability. There are numerous studies relating to aspects within SEE, not to mention the different demographics of secondary schools of which they are implemented. Our work focuses with the urban secondary school demographic. We use quantitative and qualitative research methods throughout our research to assess student's hope for sustainable development and interest in engineering after engaging with SEE problem-based curricula.

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INTRODUCTION

There is an urgent global need for the shift to sustainable technologies. Introducing sustainable energy engineering (SEE) within secondary school curriculum can potentially have many beneficial effects including: (1) increase numbers within the STEM field majors and careers, (2) develop individuals who assist in solving these world issues, and (3) spread awareness of these issues within the communities from which the students come. There is much research pertaining to aspects of SEE, not to mention the type of secondary schools. From a general perspective, Figure 1 below shows the various combinations of SEE research that can be implemented within secondary school curricula.
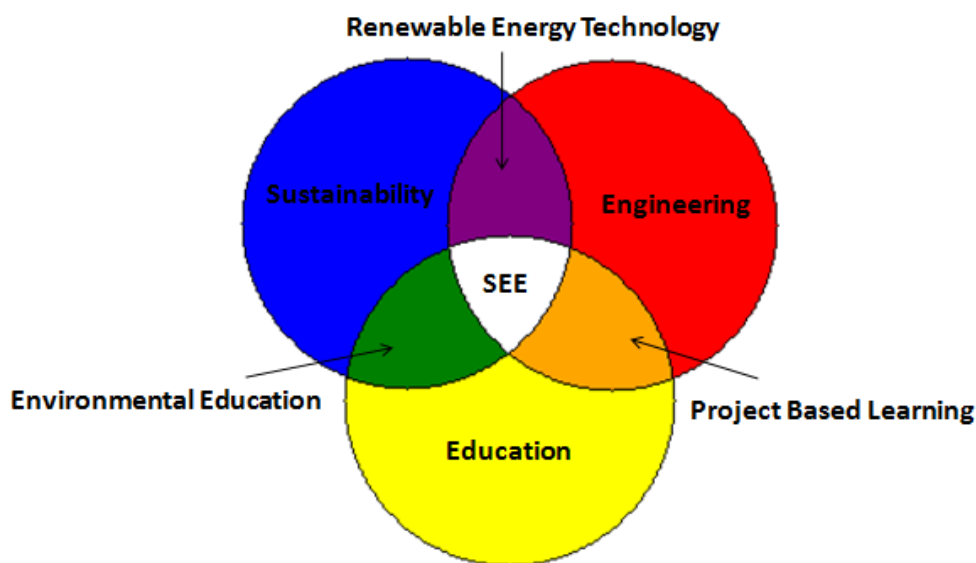
Figure 1: Example combinations of SEE Research within Secondary Schools

The objectives of this thesis are as follows:

- Review the literature on the implementation of SEE methodologies into secondary schools, with a focus on demographics;

- Create problem based curricula that incorporate SEE methods, based on literature review;

- Investigate how the context of sustainability effects students' hope for sustainable development and interest in engineering;

- Perform a qualitative analysis, in the context of SEE, into other factors that could support or hinder participation within STEM fields

The first essay of this thesis gathers literature to investigate recurring methods of promoting sustainability by way of engineering within secondary schools. We gather methods from previous studies and align each study to the school demographic within which it was conducted: suburban, urban, or rural. We identify holes within research and make suggestions for future studies.

The second essay reports on an experiment inspired by gaps in research identified in the literature review. We compare two identical science classes in an urban secondary school. One classroom received an engineering project involving the context of wind energy, whereas in the second classroom the sustainability context was withheld (control group). Before and after the projects, both classes completed identical surveys measuring levels of hope for sustainable development and interest in engineering.

The third essay extends the research methods conducted in the previous essay. Here the participants were from two shop classes in an urban vocational school. These students were already familiar with project-based learning. Therefore, rather than a control group, we looked for increases in hope and engineering interest with wind and solar projects. These projects had longer durations and included more challenging concepts pertaining to sustainability and engineering, in comparison with the students in the second essay. The same pre and post surveys were completed as the previous essay.

In the fourth and final essay, we develop a semester-long curriculum that incorporates SEE and career development. We use the theoretical framework of Social Cognitive Career Theory (SCCT) and qualitative research methods to investigate specific factors that contribute to the discrepancy of underrepresented minorities in STEM fields. Also, we contribute hope and competence as factors within SCCT to discover new findings in student's post-secondary school interest.

CHAPTER 1

ENGINEERING FOR SUSTAINABLE ENERGY EDUCATION WITHIN SUBURBAN, URBAN AND DEVELOPING SECONDARY SCHOOLS – A LITERATURE REVIEW

1.1 Introduction

It is crucial that the conversations of sustainable development include the younger generation, given the urgent need for a global transition to cleaner energy solutions. Sustainable energy engineering (SEE) taught as early as secondary school can not only increase the number of students that will potentially study engineering to solve global energy issues but also will spread a social awareness across the students themselves, their families and their communities. This literary review gathers articles that study different methods in teaching SEE across different secondary schooling demographics to compose a future curriculum that can be used to implement SEE in a range of high-school settings. Some critical results found were that most research gaps in SEE were identified in urban schools, whereas college programs hold many resources that would be beneficial to promoting SEE but are not implemented on a high-school level.

On the one hand, developing economies lack access to essential modern energy services while, simultaneously, more urbanized economies are being left behind in the transition to cleaner, more sustainable energy solutions. Overall, at least one-fourth of the world's population, 1.6 billion people, currently live without electricity and this statistic has hardly changed in absolute terms since 1970. Hence, we now face a two-sided issue—meeting the essential energy demands of billions of people globally while participating in a global shift to clean energy systems that currently accounts for 19.5 percent of the world's electricity generation (Ahuja & Tatsutani, 2009). With the urban population accounting for 54 percent of the total global population in 2014, primarily concentrated in the lesser-developed areas of the world (World

Health Organization, 2014), it is vital that discussions of clean energy include these underdeveloped communities, as well as current practices around the world. One area to focus on is the implementation of sustainable energy education (SEE) within their secondary schooling systems.

This review surveys the literature to see what insights can be drawn about the following question: To what degree would incorporating knowledge about engineering sustainability in secondary school, influence students to pursue engineering as a field of study to make a significant social impact within their communities? We focus mainly on the differences and similarities of findings across different demographic groups, including suburban, urban and developing country schools. We investigate to what degree the literature addresses the question and to what degree there are gaps.

We find that no article answers this specific question in its entirety; we found mainly articles that suggest methods for addressing sustainability education, and a few that address aspects of the question. At the end of this review, we suggest some future research that can start to fill in the many gaps.

1.2 Defining School Demographics

In most sources such as the U.S. Census Bureau (2014), demographics are classified as suburban, urban or rural by the characteristics of a city and its population density. However, for the purposes of this article, we define the urban school demographic as American schools with students primarily of color and of lower income (Watson, 2011). Developing country schools are classified similarly but in an international, rural setting with even fewer resources. What we call schools of the suburban demographic draw students primarily from moderate to higher income, and may or may not be ethnically diverse (Debertin & Goetz, 1994).

1.3   Approach

This literature review gathers readings using a systematic review method to discover which practices work best in teaching various areas that relate to SEE. This study required research from a few disciplines ranging from engineering, environmental education, urban and international education, to sociology. Borrego et al. (2014) suggest analysis conducted in a more algorithmic method to help narrow down the thousands of literature, allowing more objective critique of prior efforts, identifying gaps and proposing new directions for research. Therefore, a variety of databases and websites were used in our systematic review in an attempt to cover the many practices prevalent in these interdisciplinary fields; some of which include: Engineering Village, ERIC (Education Resources Information Center), ASEE (American Society of Engineering Education), Web of Science, National Society of Black Engineer's SEEK (Summer Engineering Experience for Kids), Engineers Without Borders and the GREEN Program (Global Renewable Energy Education Network).

Studies that specifically investigate SEE across several demographic areas are rare. We have included a number of articles that focus on particular sub-categories of SEE in secondary schools. For purposes of this literature review, we define these subcategories as SEE elements. These SEE elements include:

1. Providing the awareness and motivation that will cause students to take action on global energy issues

2. Environmental education and research in SEE

3. Education that integrates realistic energy projects

4. Problem and project-based learning applied to aspects of SEE

5. Renewable Energy Technology Education

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1.4   Findings from Literature Review

1.4.1   Awareness and Motivation to Tackle Energy Issues

When discussing sustainable development among secondary school students, we define this SEE element as the initial steps to assess a student's knowledge about energy issues and encourage an interest in learning ways they can make an impact, whether it is immediate or further down the line, as a field of collegiate study. This section includes research articles that achieve one of the three following goals: (i) measuring students' awareness of energy issues, (ii) providing motivation to monitor their energy use or take action, or (iii) providing the tools to do so. Students can see global climate change as a very massive and daunting matter. As potential future leaders of society that are more likely to witness the transition to global sustainable development, one could argue that it is essential to engage the younger generation in societal deliberations about the current issues. However, Ojala (2012) shows that although many young people show an interest in global problems, feelings of hopelessness, pessimism, denial, as well as inactivity are common. Results from this study reported significant positive correlations between having the knowledge and interest in these social issues and pro-environmental behavior. Ojala suggests that finding ways to instill hope to encourage the assuaging of the many broad issues within climate change is vital if young people are to take an essential role in restructuring the energy system.

Schelly et al. (2012) argue that public awareness of the economic costs and environmental impacts of energy consumption at a local scale has caused individuals and organizations to consider altering their habits. She reports that public schools are an ideal location for energy conservation measures; that schools can reduce their energy use by 20 to 30 percent with a variety of behavioral and operational strategies. Results from her findings indicate that educational initiatives that engage students in monitoring their energy consumption may lead

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students to act as role models in their communities. In her study, she found that once the students started monitoring their energy consumption, the faculty, administration and school organization made a shift towards becoming more environmentally responsible. In a similar study, Gottlieb et al. (2012) had students track their energy use (defined as an ecological footprint); this led to the students gaining a deeper understanding of the impacts of their lifestyles beyond the narrow limits of their schools, homes, and communities. Including methods similar to the ecological footprint analysis used in Gottlieb et al. (2012) in SEE has the potential to provide schools with the knowledge to plan and manage changes towards sustainability within the school community. In addition, results in Fujihira and Osuka (2009) also show that when students have knowledge of their energy consumption they have the control to deal with it themselves, in turn enabling students to take action within their communities and globally.

Riel (2007) would call this ecological footprint method as the start of a cycle defined as collaborative action research, a path of learning from and through one's practice by working through a series of reflective stages that may not only lead to personal and social change, but also affect the community in which it is implemented. Similarly, MacDonald (2012) describes self-monitoring energy use as participatory action research where the empowerment of oppressed individuals to partner in social or economic change encourages a larger capacity of change for all in the community who participate. The same reading recommended utilizing focus groups, participant observations and interviewing methods for data analysis when conducting action research.

In this section, we see some evidence that when students are aware of SEE issues, they are motivated to take action. This concept is related to our central question in the following way: as awareness leads to action, and engineering is a crucial way to take action, we hypothesize that

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awareness of SEE issues, especially when presented in an engineering context, will motivate students to pursue engineering to solve SEE problems.

1.4.2 Environmental Education and Research in SEE

This section includes articles that argue the importance of environmental education when promoting SEE, even if in some cases engineering principles may not be included. Articles in this area also suggest alternative methods of teaching environmental education. Weber (2014) states that students can misconceive engineering as an area of study that is mainly technical, and only appropriate for those with strong mathematical and scientific backgrounds. Prior research reports that high-school students perceive engineering as a field where they cannot make a difference in the world or help solve major societal problems. The same study showed that by following lessons in environmental sustainability, students became more positive towards the possibility that their engineering studies could affect sustainable development. While sustainability is an increasingly common term and course topic at US colleges and universities, it does not seem to be a common topic in secondary curricula (Kumler, 2011). Still, even on an undergraduate level, programs have been slow to incorporate environmental sustainability within their curricula; when offered at all it is often treated as an elective. The perception of many engineering academics is that environmental sustainability is non-essential to the engineering discipline, as its multidisciplinary components (i.e., ethics, policy, sociology) are too complex to fuse with a science-based program (Weber, 2014).

Even if environmental sustainability is incorporated into an engineering program, Barrett (2006) finds about two-thirds of environmental educational systems fail to relate the issues to the students on a more local level. These educational systems can be vague, failing to take into account the dynamics of inequality of a student's demographic (Siegel, 2006). The curricula described in these two papers are consistent with what Metz et. al (2010) describes as teaching

about the environment—a general curriculum which displays statistics and images foreshadowing what the world will become if the population continues to consume in the manner it currently does in an attempt to shock individuals into better consumption habits.

In contrast to this, Metz et al. (2010) define teaching in the environment as education where the surrounding environment replicates what is taught in the classroom. An excellent example of this is the GREEN Program, which engages university students in hands-on education at functioning renewable energy facilities, including site visits and study abroad opportunities in Costa Rica, Iceland and Peru (The GREEN Program, 2014). Researchers have found that participatory action research processes, such as GREEN, is potentially empowering, liberating and consciousness-raising for individuals, as it provides critical understanding and reflection of local and social issues (MacDonald, 2012).

The study by Metz et al. (2010) compares environmental educational practices within a secondary school in a Canadian province and one within the Costa Rican public school district. With Costa Rica where over 90 percent of energy use is from sustainable energy, the curriculum in the school significantly surpassed that of the Canadian school when the study compared hours per week teaching about, in and for the environment. In both contexts, committed, motivated teachers who were aware of and used a wide variety of teaching and assessment strategies to implement environmental education were found, although the Costa Rican teachers were more specifically prepared for their subject area. It would be more difficult to employ environmental education in a school where the community is not invested in better environmental habits. Most existing teaching materials for environmental education are outdated and lacking specifics; they are vague and cannot be easily absorbed if the school does not provide the proper tools or environment to teach the students in (Yan, 2004).

We find that a majority of the research suggests that environmental education plays a vital role in promoting sustainable development; it can increase awareness of the issues and equip students with the technical, ecologic and economic knowledge to implement sustainable development in their individual lifestyles, homes, and schools (Jennings & Lund, 2000). Related to our main question, the work reviewed in this section indicates that there are significant gaps in tying engineering to the environment and in making environmental education relevant and up to date; it appears that hands-on community relevant education is the most promising approach to this. It suggests that immersing students in projects that have both engineering content and broader sustainability content may be a positive way to motivate students into engineering and into jobs that make a difference.

1.4.3   Engineering Education Integrated with Realistic Energy Projects

Barret (2006) argues that it is not enough for students to learn about or even in the environment and become armchair critics; they need to get their hands dirty and learn how to take action. This section focuses on studies in which students are engaged in energy projects that improve a school or community. Metz et al. (2010) would describe this action-oriented learning as education for the environment.   It fits into the engineering design process as a part of developing and designing a prototype or solution (Billiar, 2014). A statewide survey conducted by the Illinois Clean Energy Foundation found that the vast majority of Illinois residents, from both urban and rural areas, want to see widespread use and development of renewable energy sources such as wind and solar power (Youakim, 2005). Youakim's study analyzed a project where engineering students of Northern Illinois University assembled a 1 kW photovoltaic solar system acquired through a grant. "This project will give them a wide variety of system analysis and hands-on skills in renewable energy systems that will make them well prepared to fill a critical need in this growing industry." (Youakim, 2005, p. 10.88.5). The World Energy Project

(2013), a non-profit group that delivers sustainable energy projects to developing country schools, states that once a school begins to generate its own electricity, it is no longer dependent on power from an unreliable grid. Money that used to pay utility bills can now be reinvested in the school to upgrade facilities, buy supplies, and hire new teachers or lower school fees for families. Engineers without Borders also excels in this area, as another non-profit organization that partners university student chapters with communities around the developing world in fundamental need of energy and other various necessities (Wittig, 2013).

Collectively, the above references discuss opportunities that provide students with the experience of real-life sustainable energy projects. Though these projects are intriguing, they lack evidence that action-oriented learning increases learning outcomes, awareness or interest in using engineering to promote sustainable development. Also, all examples were implemented at the collegiate level. Thus, whether these hands-on community-based projects lead to higher interest in engineering among secondary students is an open question.

1.4.4   Problem and Project Based Learning

In this section, we review papers that study the use of hands-on, team-based projects as well as projects based on current issues in the world as an effective way to engage students in learning sustainable development and engineering. Papers of this section also include methods to employ these projects in classrooms. Billiar (2014) provided a method that infuses the engineering design process into project development in efforts to increase understanding and interest among secondary school students over three consecutive summers. Evaluation methods included observations, focus group discussions and three point scale surveys. After this 3-year study, a pre- and post-comparison of 15 teachers' ratings increased from 13 to 60 percent of teachers seeing their students' competence in the engineering design process. Similarly, the same sample of teachers' ratings increased from 20 to 87 percent in noting that their students convey

excitement about engineering. The systematic and descriptive process for curriculum development provides tools for teachers to approach the difficult task of incorporating engineering design process principles into a secondary school environment.

Oppliger (2010) finds that three things are most effective in terms of improving learning outcomes in engineering at the pre-college level. These include project-based learning, blending engineering into an existing science or math curriculum, and exposure to an engineering work environment. Also, the article reports that a continuous issue that high school educators face when developing STEM lessons is addressing problems in the world and providing developmentally appropriate content within curriculum constraints.

Under a High School Enterprise (HSE) program, Oppliger conducted a 5-year study with 12 demographically diverse schools that applied STEM learning. These schools included rural, suburban and inner-city schools from all income levels, first-generation college students and high numbers of students from ethnic groups that are traditionally under-represented in engineering. Although there were no data to support their claims, this study reports that there is much evidence that HSE student participants had an appreciation of the engineering projects and the ebbs and flows that accompany the design process. It was apparent that the HSE student body is one anticipated to enter STEM fields of study. Their project-based learning methods, as well as teachers being educated to reinforce the engineering design process, provide a foundation for the introduction of design concepts.

In regards to sustainable energy, hands-on sustainable projects play a role in inspiring students to use engineering concepts to take on energy projects in their schools and communities. Adoption of experiments on energy saving and utilizing solar energy helps participants realize the value of using environment-friendly technology (Fujihira & Osuka, 2009). In a study by

Toolin and Watson (2010), students of Montpelier High School in Vermont participated in various sustainable projects. Community experts from local businesses also played a role in contributing to the success of the projects by assisting with data collection when gathering information from the Internet was ineffective. After six years of this teaching method, results showed that the critical project-based learning experiences should include: a driving question that is relevant to a student's life in their local community, collaboration, use of technology, interdisciplinary and cross-disciplinary inquiry, extended time frame and reliable performance-based assessment. Lessons learned from this study were that the teacher should step back and let the students create a way of gathering data and learning for themselves, whether it is through the Internet or from the community; the teacher would then instead serve as a monitor, directing students to the most relevant resources.

These studies indicate that project-based learning is useful in teaching engineering at the pre-college level. When combining this with the results from the other sections, it indicates that project-based learning which incorporates SEE may be useful and motivate students to study engineering.

1.4.5   Renewable Energy Technology Education

This section covers articles that report the importance of renewable technology education to encourage the shift to sustainable development. Pavlova (2009) argues that sustainable development can be conceptualized and used to advance technology education practice.

"It has been argued that valuing the other of both human and non-human nature should be the basis for developing design projects in technology education. In this paradigm, the main aim of education should be the development of a new attitude that is oriented towards a system of social and ecological wealth, rather than the wealth of the consumer society. Only a society that unites people with new values will be capable of sustainable development. As a result, education

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should provide both an instrument for and a method of transformation for sustainable development" (Pavlova, 2009, p. 128).

Technological education is still some distance from keeping up with the shift that sustainable technology currently undertakes, yet the challenge must be met if the students' experience in technological education is to remain relevant and beneficial (McGarr, 2010). These readings question whether technology education promotes social and economic progress or profit.

Developing country areas are most in need of the transition to clean energy (United Nations, 2007). Furthermore, millions of rural communities in developing countries still lack access to safe and reliable energy; access to energy is as fundamental to human welfare as clean water, agricultural productivity, health care, education, job creation, and environmental sustainability. Rural communities in Nepal spend more than one-third of their household expenditure on energy services (Sapkota et al., 2014). The reinforcement of education is an effective way to promote renewable energy development (Bin, Wenjuan, Yan & Guangming, 2006). Unavailability of skilled technicians and mechanics has hindered the acceptance of several renewable energy technologies in many areas that users could not get proper repair and maintenance; lack of renewable energy education could, therefore, hinder not only sustainable development but also job creation (Garg & Kandpal, 1996).

In all, the articles suggest that renewable energy technology be included at all levels of education in order to create energy consciousness among the public and provide exposure to the basic concepts of their applications. Some main objectives of renewable energy education commonly described in the readings included enabling students to become aware of the nature and cause of the energy crisis, the various types of non-renewable and renewable sources of

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energy and their potential capacity, and alternative strategies towards solving the energy crisis in the future. In summary, education into renewable energy technology has the potential to lead to sustainable development, but it is vital that it be in the broader context. We hypothesize that, by providing a new outlook on how an engineer can create change, this kind of focused education will motivate students to study engineering further in order to apply their skills to sustainable development. A study by Wittig (2013) monitored learning outcomes of collegiate students within an Engineers without Borders community project. In the words of a student within the study, "Engineering should not be about the biggest building, the money, or the largest structure. For me, it is the biggest impact to the less fortunate" (p. 11).

1.5   Summary and Analysis of the Articles

Table 1 summarizes the results of the literature review; it displays the number of papers which fall into each category of a SEE element (listed in left column) within a corresponding educational environment (bottom row). Notice how seven of the 27 papers gathered have methods useful for teaching within a SEE element but are implemented at a collegiate level. Some papers fall into more than one category of SEE element or educational environment. Each study is counted only once within a category's total.

We can see that of the readings gathered, there are limited SEE articles pertaining to urban schools. Furthermore, there were only articles for realistic energy projects implemented at the collegiate level. We also see that studies that include engineering education are concentrated more within project learning and at the collegiate level. Oppliger (2010) was the only article we reviewed that compared across more than one school environment. While results could not measure whether students had a grasp of engineering concepts within the short time of the study,

the article reported positive interaction and engagement across both developing and urban school demographics for the introduction and struggle of using the engineering design process.

In regards to our central question raised in the introduction, many articles provide insight as to which methods and practices work best when implementing aspects of SEE in developing, suburban and collegiate schools. However, there is very little quantitative research on how the methods impact interest in or pursuit of a field in engineering or sustainability.

Table 1: Comparing Literature within each SEE Element and School Demographic

		Developing Country Secondary School	Urban Secondary School	Suburban Secondary School	Collegiate
8 (*25%)	**Awareness and Motivation**	Gottlieb, D. (2012) MacDonald, C. (2012) Ojala, M. (2012)	Riel, M. (2010)	Schelly, C. (2012) Fujihira, K. (2009)	*Ahn, B. (2014) *Khalaf, K. (2013)
13 (*15%)	**Environmental Education on a local perspective**	Barrett, M.J. (2006) Gottlieb, D. (2012) MacDonald, C. (2012) Metz, D. (2010) Yan, D. (2004)	Siegel, M. A. (2006)	Fujihira, K. (2009) Kumler, L. M. (2011) Pavlova, M. (2009) Schelly, C. (2012) *Toolin, R. (2010)	Jennings, P. (2000) *Weber, N. R. (2014)
3 (*100%)	**Realistic Energy Projects**	-	-	-	*GREEN Program (2014) *Wittig, Ann (2013) *Youakim, Al Kalaani (2005)
5 (*83%)	**Problem-Based Project Learning**	*Oppliger, D. (2010)	*Oppliger, D. (2010)	*Billiar, K. (2014) Fujihira, K. (2009)	*Khalaf, K. (2013) *Wittig, Ann (2013)
9 (*22%)	**Renewable Energy Technology Education**	Li, Bin. (2006) McGarr, O. (2010) Sapkota, A. (2014) Singh, D. (2002)	-	Pavlova, M. (2009) Garg, H.P. (1996) *Toolin, R. (2010)	Jennings, P. (2000) *GREEN Program (2014)
		Developing Country Secondary School	**Urban Secondary School**	**Suburban Secondary School**	**Collegiate**
	Total Articles	**11 (*9%)**	**3 (*33%)**	**7 (*29%)**	**7 (*86%)**

Source: University of Massachusetts, 2015
Notes: *Denotes articles that incorporate engineering education. Percentages of total articles that include engineering education are also listed for each category on both axes.

1.6   Directions for Future Research

Taken together, the studies above – and the gaps therein - indicate some key areas for research. The majority of papers we found were primarily qualitative in nature and focused on curriculum design. Thus, there is a need for evidence, and especially quantitative evidence, on whether implementing SEE into the curriculum impacts interest in engineering and/or sustainability and especially whether it impacts the number of students who go on to study engineering. Ideally, studies would include careful controls—for example, studies that include Project-Based-Learning with one community-based renewable energy project compared to a standard project. To the degree that SEE is effective in inspiring interest in engineering, the next step is carefully structured studies to determine which SEE elements are most impactful in increasing the number of students pursuing a career in engineering and sustainable development. In all, this suggests a longitudinal design. This inclusion of SEE could even lead to the design of widely-applicable educational tools.

There is a dearth of studies in urban schools, and, it has not been shown in any study, that what works in suburban schools may not work in urban schools. Thus, evidence on the impact of SEE in urban schools is of particular interest. Of the total 4-year undergraduate enrolment in 2012, less than 13 percent of undergraduate engineering students were Black and Hispanic, respectively; as compared to about 56 percent for white students (National Center for Science and Engineering Statistics, 2014). It would be valuable to measure if incorporating aspects of SEE would lead to more participation from under-represented minorities in STEM fields than students exposed to a traditional classroom curriculum. Studies that consider the effectiveness of specific SEE methods across demographics can additionally give insight into how SEE programs should be designed, especially for under-served students.

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A longer-term question is whether incorporating SEE education at the secondary level is likely to lead to more engineering students focused on making a significant impact in their communities. Answering such a question may require a significant longitudinal study, but may be worth it.

CHAPTER 2

HOPE FOR SUSTAINABILITY AND ENGINEERING INTEREST WITHIN URBAN SECONDARY SCHOOL PROJECTS-QUANTITATIVE EXPERIMENT

2.1   Introduction

In this experiment, we compared a project based around renewable energy technology and sustainability with another engineering project without the sustainability context in a high school science class on an urban demographic. We evaluated whether the first project would lead to more hope for sustainable development within the students and whether it would be more likely to inspire them to become the next generation of engineers to solve these issues. The two science classes completed two identical surveys of hope for sustainable development and interest in engineering before and after an engineering design project. One classroom was the experimental group that worked on constructing a paper wind turbine while the other class, being the control group, designed a balloon jet toy where the context of sustainability was withheld. Results showed that the classroom working with the wind turbine gave higher ratings between pre and post surveys while conversely, the ratings of the classroom working with the jet toy decreased between surveys.

A study by Wittig (2013) sought to see if problem-based learning by way of the non-profit Engineers Without Borders provided more learning outcomes than standard engineering coursework. Engineers Without Borders supports community-driven development programs worldwide by collaborating with local partners to design and implement sustainable engineering projects while creating transformative experiences and responsible leaders. An experiment was set up where students underwent several engineering projects designed to improve the living standards in rural Honduras. Learning outcomes reported significantly higher within the students that were taught under EWB methods. In the words one of the 14 students within the study,

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"Engineering should not be about the biggest building, the money, or the largest structure. For me, it is about making the biggest impact to the less fortunate" (p. 11).

We aimed to see if methods practiced within the group Engineers Without Borders can be condensed for high school students and still have similar effects. Our experiment was designed to answer the following: *Will a standard engineering project based around renewable energy technology (RET) cause a student to be more enthusiastic about pursuing engineering as a field of study than an engineering project lacking this sustainability context?*

2.2   Methods

2.2.1   Participants and Experiment Design

The subjects were junior-level high school students of an undisclosed school, ranging in age between 16 and 18. Altogether 30 students (15 in each) from two elective science classrooms participated in this study. Within two class periods, both classes worked in teams of three to construct a prototype for competition. One class prepared a paper wind turbine while the other made a balloon-powered jet toy as seen in figures 2 and 3.

Figure 2: Class 1 Wind Turbine Activity   **Figure 3:** Class 2 Jet Toy Activity

These two activities were implemented based on the following quasi-experimental design (Gall et al., 2003) to compare before and after survey results between the two groups:

Wind Turbine Activity: $R \quad O_1 \quad X \quad O_2$ (experimental group)

Jet Toy Activity: $R \quad O_3 \quad \quad O_4$ (control group)

R represents the random assignment of students within both classrooms. The quasi-independent variable, *X,* was the sustainability context behind working with the wind turbine activity, making that classroom the experimental group. The control group working with the jet toy received similar concepts within learning the engineering design process, but the sustainability background was withheld. Variables O_{1-4} are the time series measurements where identical surveys will be administered with questions on a five-point Likert scale (from 1-strongly disagree to 5-strongly agree) before and after each activity. Specifically, variables O_1 and O_3 are the pre surveys for the wind and jet toy class respectively and O_2 and O_4 are the post surveys.

2.2.2 Dependent Variables

The two surveys were designed to measure a student's interest in engineering and hope for sustainable development. Derived and validated by the work of Unfried et al. (2015), our engineering interest survey measures student's attitudes toward science, technology, engineering, and math. For purposes of this study, hope, as described by Ojala (2012), consists of three different components: goals which we wish to happen, an ability to come up with routes to get to where we want (pathway thinking), and the motivation to use these pathways (agency thinking). When we mention sustainable development specifically, we are referring to research and technology that assists with the mitigation of issues such as climate change and energy deficiency. The surveys can be seen below in Tables 1 and 2.

2.2.3 Hypothesis

$$O_1 = O_3 < O_4 < O_2$$

Our hypothesis consisted of three parts. (1) Since the classrooms are of equivalent grade levels, we hypothesize that the pre-survey results will not be significantly different between the groups. After projects and post surveys were completed (2) both groups should see an increase in engineering interest. Our final hypothesis is that (3) the students within the experimental group

will report higher levels of hope and interest as compared to those within the control group due to the sustainable development context with the wind project.

2.3 Results & Analysis

After students of both classes finished pre and post surveys, pre-test responses across students were averaged for each question when compared to the corresponding post-test question, illustrated in Figures 4 and 5. The scores for each question ran on a Likert scale ranging from 1 to 5 (strongly disagree to strongly agree); in all questions (except #2 of the hope survey) a higher value indicates higher interest in engineering or higher levels of hope.
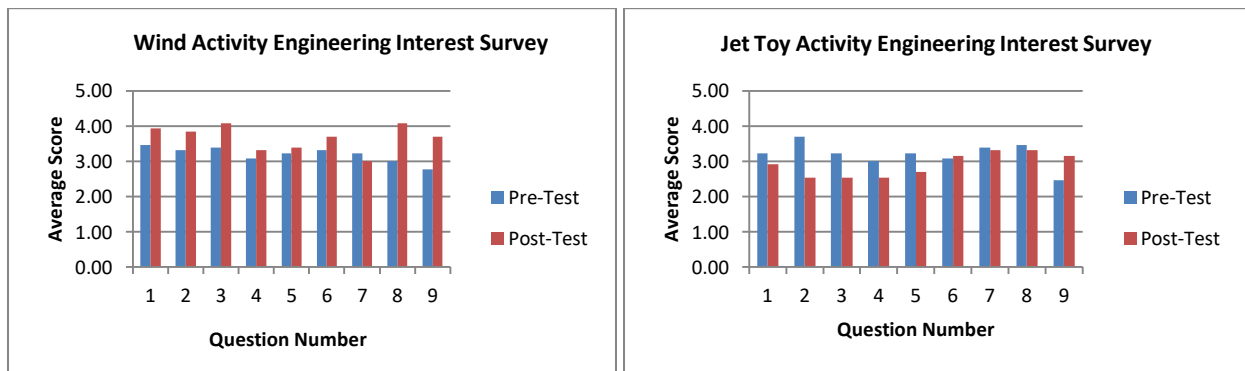
Figure 4: Results of Engineering Interest Survey between Pre and Post Test
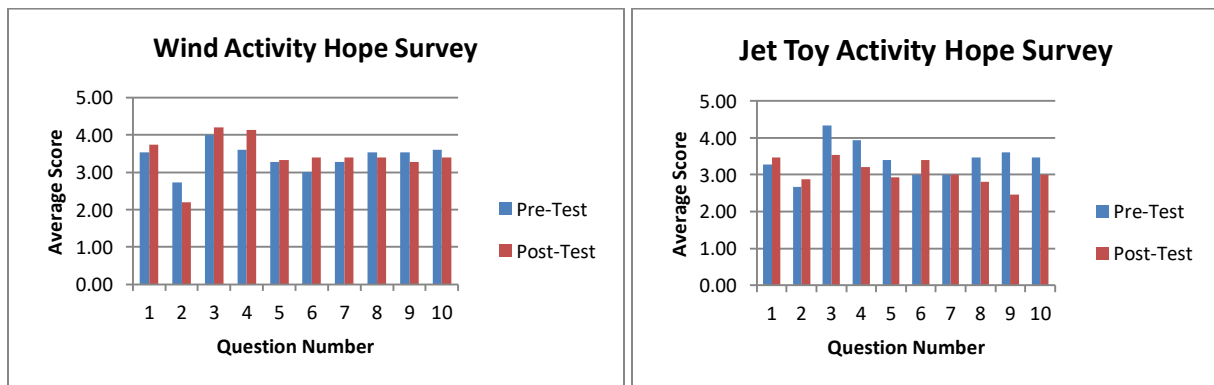
Figure 5: Results of Hope Survey between Pre and Post Test

We see that the majority of questions show an increase in hope and engineering interest after the wind activity, whereas they show a decrease after the jet toy activity. The average post-

test responses were all higher within the wind activity as compared to the jet toy. In the results of the hope survey, the changes from pre- to post- were small. In the Jet toy class, there were decreases in hope in six of the ten questions.

Tables 2 and 3 show the average differentials (post-pre) between each question for both wind turbine and jet toy activity.

Table 2: Engineering Interest Survey Questions with Differentials between Pre and Post Test Averages (Unfriedet. al, 2015)

Question Number	Wind diff	Jet Toy diff	Question
1	0.46	-0.31	I like to imagine creating new products. (creativity)
2	0.54	-1.15	I want to improve things that people use every day. (helping others)
3	0.69	-0.69	I like to building/fix things. (creativity)
4	0.23	-0.46	I am interested in what makes machines work. (curiosity)
5	0.15	-0.54	Improving and designing products/structures will be important for what I want to do in the future. (pre-determined)
6	0.38	0.08	I am curious about how electronics work. (curiosity)
7	-0.23	-0.08	I want to help solve major issues in the world. (helping others)
8	1.08	-0.15	I would like to use creativity/innovation in my future work. (creativity/pre-determined)
9	0.92	0.69	I believe I can be successful in a career in engineering. (pre-determined)

In Table 2 we see that the highest differential in the wind class was in question 8, meaning that using creativity and innovation in their future was an idea the wind activity affected most. Another notable differential was the significant decrease in the jet class's question 2 response where students would want to improve things that people use every day.

Table 3: Hope Survey Questions with Differentials between Pre and Post Test Averages (Ojala, 2012)

Question Number	Wind diff	Jet Toy diff	Question
1	0.20	0.20	Because society has confronted complex and seemingly hopeless problems before and has been able to solve them eventually' (positive reprisal).
2	-0.53	0.20	Because I do not think that sustainable development is as big of a problem or urgent as certain researchers claim (denial, reversed Likert scale).
3	0.20	-0.80	Because we as individuals can change our behavior; together we can influence sustainable development in a positive direction' (trust-self).
4	0.53	-0.73	Because I believe that research and technical solutions will contribute to the improvement of the sustainable development problem' (trust-others).
5	0.07	-0.47	Because the awareness about this problem has increased considerably during recent years' (positive reappraisal).
6	0.40	0.40	Because politicians in more and more countries take sustainable development seriously' (trust-others).
7	0.13	0.00	Because even though there is a risk that humanity will go under due to this problem, nature will survive' (positive reappraisal).
8	-0.13	-0.67	Because as long as there are people who are active in environmental organizations there is a possibility that sustainable development issues will be solved' (trust-others).
9	-0.27	-1.13	Because I know that there are a number of things that I myself can do to contribute to the improvement of the sustainable development problem' (trust-self).
10	-0.20	-0.47	Because I try to focus on positive news about sustainable development in the media' (positive reappraisal).

Note that question 2 assessed denial of sustainable development issues, meaning high denial would equate to low hope and vice versa; to translate this among the other questions which assessed hope, we reversed the Likert scale for all responses (Ex: a student reporting 5, strong denial, on question 2 would be reported as 1). Question 9 ("because I know that there are a number of things that I myself can do to contribute to the improvement of the sustainable development problem") showed a considerable decrease after the jet toy activity, meaning

average hope for an individual student assisting with the issues of sustainable development decreased.

The hope survey contained ten questions each falling into one of four categories: positive reprisal, trust self, trust others, and denial. Figure 6 shows the results for each activity based upon these categories. For the one question in the denial category, we would look for a decrease between surveys instead of an increase, ensuring that the projects presented would cause rise to the awareness of the issues within sustainable development.
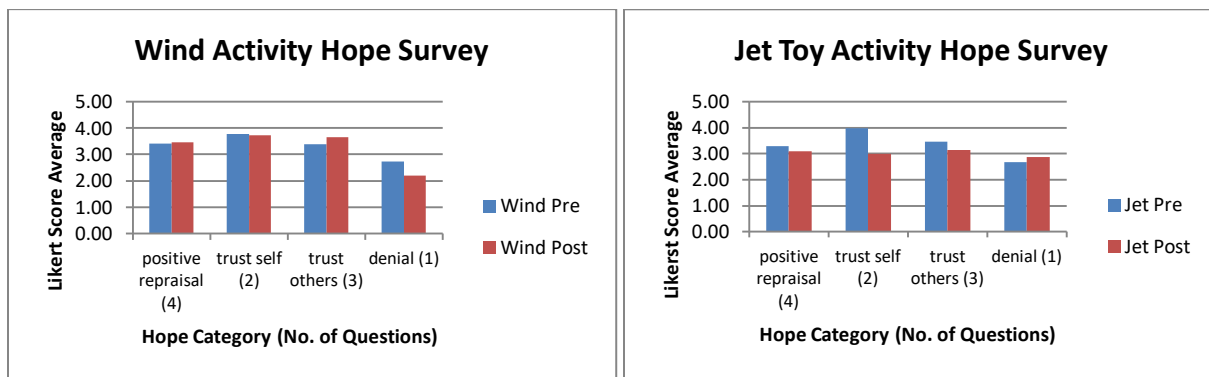
Figure 6: Scores for Categories of Hope in Wind and Jet Toy Activity

When categorized like this, we see fairly small changes after the wind activity, except, surprisingly, in the "trust others" category; and a decrease in denial as expected. After the jet toy activity, hope decreased in all three categories and denial increased.

The engineering interest survey also contained four categories: creativity, helping others, curiosity, and pre-determined. Figure 7 shows how each classroom's averaged scored within these categories.
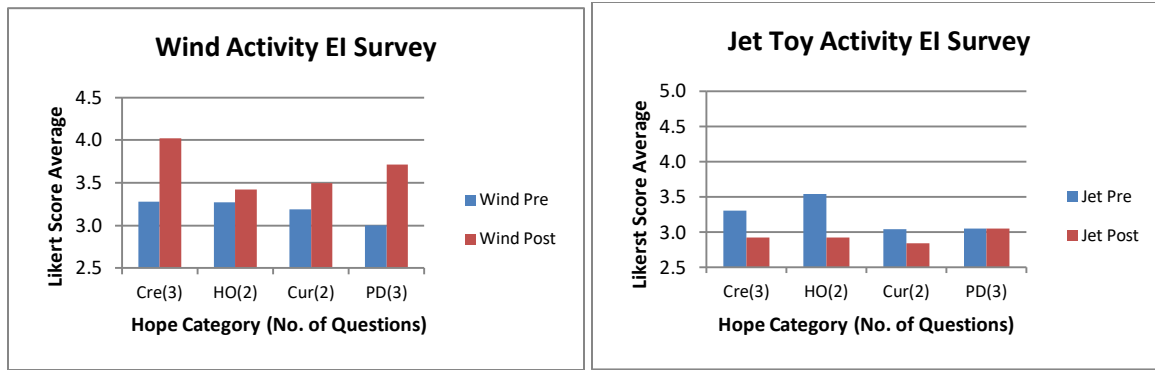
Figure 7: Scores for categories of engineering interest in wind and jet toy activity. Cre: creativity, HO: helping others, Cur: curiosity, PD: pre-determined

Here we see that interest increased in all four categories within the wind activity and decreased in all categories within the jet toy except the pre-determined category, where interest remained the same.

To check for significant differences between the two controls, we ran a hypothesis test based upon the 5% level of confidence criterion. First, we averaged the results over all participants for each question within each control. In Tables 3 and 4, we show a statistical analysis of t-test for the two pre-surveys displaying the results for hope on the left and engineering on the right. We present the mean and variance of the t-test, where the mean can be interpreted as the average level of hope or interest in engineering within that classroom on a five-point scale. The variance tells us how far all responses vary from the mean. Based on the hypothesis that the difference in the means between both activities is 0, the p-value at the bottom is the level of significance between the two populations. We would accept the null hypothesis (no significant change) if $p > 0.05$, and conversely, reject the null hypothesis if $p < 0.05$

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Table 4: Two Sample T-test assuming unequal variances for wind and jet toy activity pre survey (all responses)

Pre-Test Hope	Wind	Jet Toy		Pre-Test Engineering Interest	Wind	Jet Toy
Mean	3.4067	3.4133		Mean	3.2000	3.1852
Variance	1.0885	1.3045		Variance	1.2806	1.2863
Obeservations	150	150		Obeservations	135	135
Hypothesized Mean Difference	0			Hypothesized Mean Difference	0	
P (T<=) two-tail	0.9579			P (T<=) two-tail	0.9145	

We see that the means for both surveys were almost identical between groups; the resulting p-values show high probabilities of students of both groups reporting similar answers.

We then checked for a significant difference between the two groups after their engineering activities in Tables 5 and 6.

Table 5: Two sample T-test assuming unequal variances for wind and jet toy activity post survey (all)

Post-Test Hope	Wind	Jet Toy		Post-Test Engineering Interest	Wind	Jet Toy
Mean	3.4467	3.0667		Mean	3.6667	2.9185
Variance	1.0273	1.9687		Variance	0.9403	2.0903
Obeservations	150	150		Obeservations	135	135
Hypothesized Mean Difference	0			Hypothesized Mean Difference	0	
P (T<=) two-tail	0.0760			P (T<=) two-tail	1.16E-06	

When looking at the overall difference from pre to post within both surveys, both the engineering interest survey gave a significant difference with a significantly low p-value of as compared to the hope survey with about 7.6%. That is, there is evidence that the wind activity had a significantly different impact on students' interest in engineering, but not on hope.

Table 6: T-test for wind and jet toy activity post surveys (results for each individual question)

Hope Post Test				Engineering Interest Post Test		
Question	p value	Accept or reject null hypothesis		Question	p value	accept or reject null hypothesis
1	0.505638	-		1	0.044499	reject
2	0.142235	-		2	0.005564	reject
3	0.15319	-		3	0.004153	reject
4	0.015011	reject		4	0.127442	-
5	0.38123	-		5	0.140928	-
6	1	-		6	0.264806	-
7	0.419382	-		7	0.562398	-
8	0.173327	-		8	0.145808	-
9	0.045716	reject		9	0.189019	-
10	0.407992	-				

When viewing each question individually, the hope survey saw significance in questions 4 and 9 (trust in self and others category questions). For the individual questions within the engineering interest post-survey, the first three questions saw significance (helping others and creativity category questions). Of course, this was a small study with 15 students in each control.

In Figures 8 and 9, question averages for both activities were placed on a scatter plot and a line of best fit was used to estimate an overall classroom response for engineering interest and hope in both classrooms.
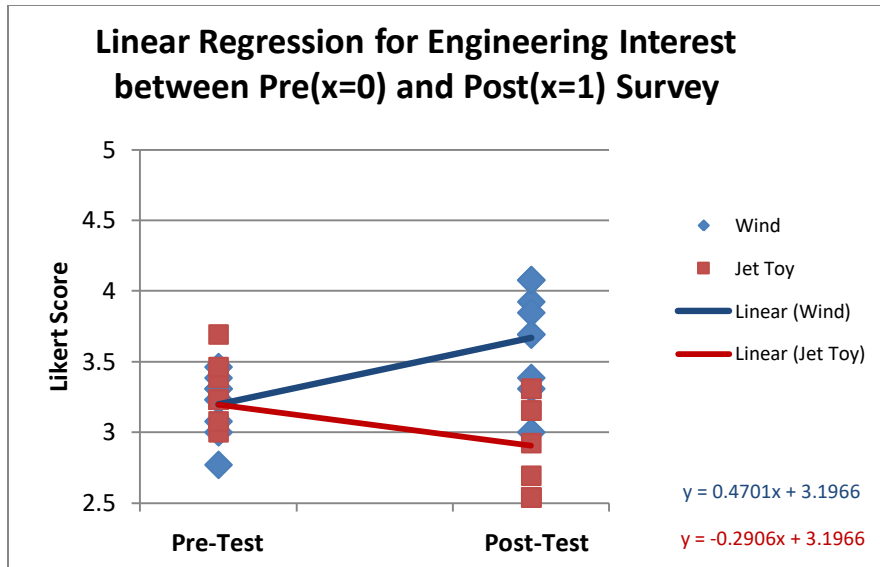
Figure 8: Comparison of Linear Regressions of both activities' Engineering Interest Survey
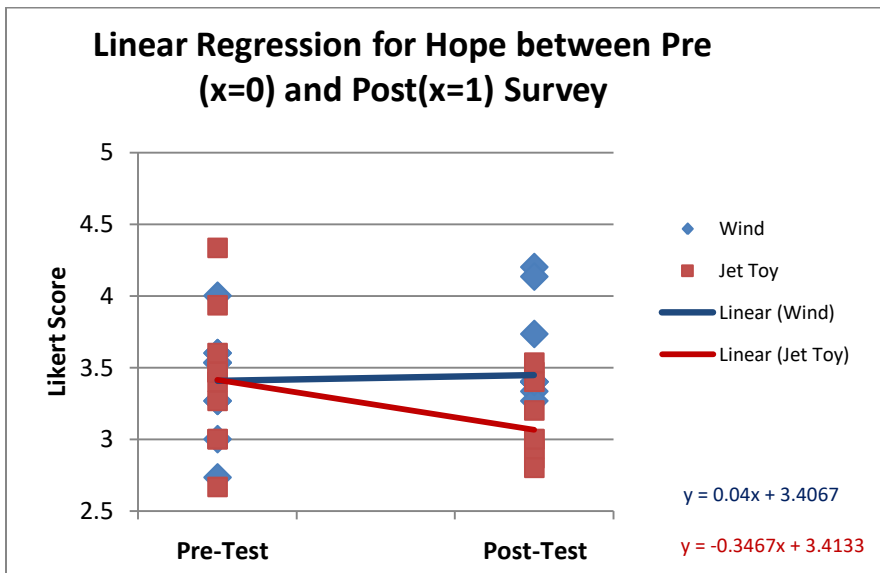
Figure 9: Comparison of Linear Regressions of both activities' Hope Survey

The regression line of the engineering interest survey showed an increase in interest after the wind turbine activity and a decrease after the jet toy activity. With the Likert scale ranging from 1 to 5, average interest in engineering started at about 3.20 in both classes. Following their respective projects, the wind class's average increased to about 3.67 while the jet toy class decreased to nearly 2.91. Similar trends show within the hope survey, with regression lines

showing a slight increase between pre and post-test in the wind activity and a decrease in the jet toy activity. Where both classes started with a hope average at about 3.41, hope slightly increased to 3.45 in the wind class, and the jet toy class's average dropped to 3.07.

2.4   Conclusion

We investigated whether a project within the context of broader societal concerns would lead students to have an increase in hope and an increase in interest in engineering. Our results are mixed and bring up new questions. We found that the activity containing sustainability context did tend to lead to higher hope and higher interest in engineering, while the non-context activity tended to lead to decreases in both. When looking at the overall surveys, the results were only significantly different between the groups within the engineering interest post-survey. When looking question by question as to whether the results in the context group were different from the non-context group, we found significant differences in two out of ten in the hope survey and three out of ten in the engineering survey. Since there was such a significant difference between the overall means of control and experimental engineering interest post survey, we would expect to see significant differences between more of the individual questions. Due to all surveys being anonymous, it would be impossible to trace this inconsistency.

Directions for further research include using a larger random population to compare data with similar projects that run over a longer time span. The decrease in both hope and engineering interest after the jet toy activity was an unforeseen result. Qualitative methods of research including observations within the activity and post student interviews could explain phenomena like this in future research.

CHAPTER 3

LOOKING DEEPER INTO HOPE AND INTEREST IN ENGINEERING – QUANTITATIVE EXPERIMENTS

There have been numerous studies aimed at increasing the number of underrepresented minorities within the STEM field. This study adds to the literature, addressing three questions in the context of urban schools: *(1) Does hands-on sustainable energy curriculum cause students to be more enthusiastic about pursuing engineering as a field of study? (2) Does the societal context cause students to be more hopeful of sustainable development? (3) Are these two variables related; is an increase in hope associated with an increase in engineering interest?* We present a sustainable energy curriculum grounded in past literature; then use it to evaluate our questions with first-year secondary school students from an urban vocational school. We used pre- and post- surveys around a weeklong sustainable energy curriculum in two shop classes. We found increases in both hope and engineering interest independently, as well as moderate correlations between hope and engineering interest for both classes. We encourage the use of adaptive project and problem-based curriculum in urban demographic school settings. Future research involves investigating which factors outside of curricula encourage or impede STEM participation.

3.1 Introduction

In this paper, we investigate the idea that lessons that are grounded in critical societal contexts may increase engagement of minorities within STEM. Research has indicated that tying STEM to its social relevance is likely to increase retention among URMs (Freeman et al., 2014; Walker & Sherman, 2017); we hypothesize that it will increase recruitment as well. To test this, we created a curriculum based on the real world implications of renewable energy technology and sustainable development. We focused our research on two vocational shop classes in an

urban secondary school, testing for changes in attitudes toward sustainable development and an interest in engineering before and after the hands-on activity.

First, we review the literature on methods that have proven to increase STEM engagement of URM's. Next, we describe the methods to design our curriculum; we used qualitative methods prior to the study and practices from past literature to best fit the curriculum into our participant's current preferred ways of learning. We then describe the curriculum's timeline as it was implemented in our study. The next section explains the design of the study and the surveys used to collect data. Then, we analyze the results of the data with various combinations of variables, looking at different ways our curriculum did (or did not) answer our questions. Lastly, we summarize our findings and state future areas of research.

3.2 Literature Review

As compared to their White and Asian counterparts, African Americans and Latinos are less likely to complete either undergraduate or postgraduate degrees (Cook & Cordova, 2007). According to the National Science Foundation (2015), underrepresented minorities (URM's) accounted for nearly 29% of the U.S. population in 2014, yet of those enrolled in undergraduate and post-graduate STEM disciplines, URM's were 16% and 11% respectively. The inability to recruit and retain minorities and women in STEM has been described by Myers and Pavel (2011) as 'leaks' in the scientific pipeline.

Many previous studies have investigated the effect of integrating project-based learning into secondary school curriculum. A three-year pre-post study by Billiar (2014) provided and evaluated a method that incorporates the engineering design process into K-12 project-based curriculum development in efforts to increase interest and enrollment in STEM. Upon conclusion, 15 teachers saw a 13% to 60% increase in student engineering competence and a

20% to 87% increase in engineering interest over three consecutive summers. Similarly, a three-year study conducted by Han et. Al (2016) introduced 528 students of STEM high schools and 2688 students of non-STEM high schools to project-based learning methods in the same region where 71% of the participant were Hispanic, at-risk, or a combination of the two. The findings of this study showed a significant increase (α=0.5) on academic achievement via a latent growth model with linear regression slopes ranging from 4.56 to 6.39 on a 20-point scale between the groups over the three years.

Engineering presented in the societal context of problem-based learning (PBL) has the ability to increase interest in the field once students are made aware of the impact they could have in the world. A study by Wittig (2013) examined learning outcomes of collegiate students within an Engineers without Borders international community project; upon conclusion one of the student participants stated: "Engineering should not be about the biggest building, the money, or the largest structure; for me, it is about making the biggest impact to the less fortunate" (p. 11). Another example lies within the Female Recruits Explore Engineering (FREE) program which serves as a bridge for engineering professionals to work with high school URM female college students (Reyes, 2016). A study by Bystydzienski et al. (2015) reported that more than half of the participants that year (n=131) considered a career in an engineering field; furthermore, girls who completed the program experienced an increase in interest for engineering and pursued STEM-related education in college.

Ojala (2012) investigated the correlation of hope concerning sustainable development (in regards to climate change) and pro-environmental behavior through questionnaire studies. Results showed that hope could be used as a motivational force. However, there is no literature regarding how hands-on projects involving societal context affects hope for sustainability.

Problem-based learning practices in engineering are well-known to have positive outcomes on academic achievement at the collegiate level (Polanco et al., 2004; Hsieh & Knight, 2008; Yadav et al., 2011). However, few studies focus on other outcomes such as interest in engineering or societal issues, specifically prior to higher education. As a unique approach to invoke secondary student's curiosity in learning sustainable development and engineering as a future field of study, Kaikai and Baker (2016) suggest the use of a combination of team-based, hands-on projects in addition to projects based on current issues in the world.

3.3 Curriculum Design

Before constructing our curriculum, we followed a validated model for training design. Instructional system development, sometimes referred to as ADDIE (analysis, design, development, implementation, and evaluation), is defined by Clark (2015) as the iterative and systematic process for creating learning experience that develop and enhance skills and knowledge. Within the context of our curriculum development, we defined this as a bottom-up approach to lesson planning: making a curriculum based on how the students currently learn rather than assuming what methods would produce better learning outcomes and implementing a predetermined curriculum. We then used past literature along with this data to construct a curriculum suitable for the time allotted.

The participants for this study were first-year students at an urban vocational high school, which accommodates over 1,600 students; among these about 57% are Hispanic, and 27% are African American. We used the robotics and information technology shop classes, which had 17 and 16 students in each respectively. At the beginning of the study, these students were in their last two months of their 180-day school year.

3.3.1   Initial Qualitative Assessment

Five months before the study, we collected the following observations to better assist in designing the experiment. Three days a week, we observed existing teaching methods within the robotics and information technology shop classrooms, observing robotics in the morning and information technology in the afternoons. Pitts and Miller (2007) argue that the most crucial initial steps researchers should take in the field are developing a rapport with their participants prior to the study.

The instructors summarized the objectives of the first year classes:

Robotics:

"Each student, upon successful completion of the two semesters of freshman curriculum, should have a thorough understanding of basic robotics with Lego NTX-G and Parallax Basic Stamp robot programming. HTML and JavaScript are introduced. Electronics will also be introduced which includes: basic electrical circuits, Ohm's Law, DC circuit analysis for series, parallel and combination circuits, the use of basic diagrams and schematics, the manipulation of a handheld digital multimeter for circuit measurements of voltage, current and resistance, and soldering skills. Basic electronic simulation utilizing LTSPICE is introduced."

Information Technology:

"There is much flexibility in the work I give during shop week. Mainly the goal is for students to have an understanding of various careers within IT and the roles within. We would use classroom laptops for students to research that. They would look up current the work software technicians do on the apps and devices they use today and email what they find in a report. We have an activity where we teach coding iterations through the

algorithms of a Rubix cube. Java, C++, web pages through notepad, coding through the command window, etc."

Classrooms observations indicated many similarities between the two shop classes. Both used multimedia modes of presentation; a smart board projected goals for the week and task for the day for the students to reference. Both classrooms used assigned laptops throughout the day when not working on shop projects. The purposes of the laptops included taking notes, collecting data, emailing assignments, researching, coding software, etc. Seating arrangements benefitted the demonstrative to group work teaching style both classrooms commonly utilized. Specifically, the robotics classroom had three long tables students sat around, enabling the instructor to demonstrate projects on each table before the students broke off either individually or into groups. The information technology classroom used a U- shaped table seating style allowing the teacher to walk about the center of the horseshoe and make demonstrations that all could see.

3.3.2 Curriculum Literature Review

Two of the key challenges for educators, curricula developers, and training designers are (1) constructing a lesson plan that is effective across all students in the classroom, and (2) finding measures of learning outcomes (apart from test scores) to evaluate lesson plans. Student abilities, interests, and backgrounds can vary widely; a student's level of development, as well as personal interests and experiences, should be considered while choosing a particular teaching strategy so that they can accomplish their individual goals (Rutmann & Kipper, 2011). This issue, in turn, calls for a combination of multiple methods of instruction to adapt to the various ways in which a student best processes information and can get the most out of education (Cheng et al., 2015).

3.3.3 Curriculum Development

We were able to form a curriculum from the aforementioned classroom observations along with some methods developed from past literature. For hands-on problem-based learning, we used the solar town kit and mini wind turbine kit of KidWind (2016). Because it has been proven that competition used as a strategy encourages student learning (Corres & Ruiz, 2016), we cluster them into groups. Specifically, students were put into groups of three to four and instructed to act as a team (or company) that wants to sell their renewable energy product to investors (their teachers, in this case). Throughout their week-long project, we implemented a point system so each group could see their progress as their projects developed.

Our methods were framed around the inclusion of the four Felder and Solomon (2014) modality pairs (active/reflective, sensing/intuitive, visual/verbal, and sequential/global) for better learning outcomes throughout the time the curriculum was implemented. Each modality pair consists of two teaching methods that contradict each other, so we separate these modalities into two groups; active and passive. The difference between passive and active training in education as described by McManus (2001) can be expressed as two paradigms of learning. Passive training focuses on the content in which the instructor presents; a pre-made curriculum or lesson plan is developed for all students to benefit from. Active learning can be an inclusive term, containing many models of instruction that allow students to be responsible for their own learning. We grouped the modalities into two separate teaching styles below in Table 7 to better integrate into our curriculum.

Table 7: Felder and Solomon (2014) modalities groups into two teaching styles

Modality	Definition	Classroom Integration
Teaching Style A (Active)		
Active	Learning by discussing, physically applying, or explaining to others	Working in small groups
Intuitive	Learning by discovering possibilities and relationships without structure	Hands on projects where concepts are discovered by trial and error
Verbal	Learning by hearing or explaining class material (peer learning inclusive)	Less written information to encourage learning though spoken communication
Global	Learning in large, abstract jumps	Informal Lesson Plans
Teaching Style B (Passive)		
Reflective	Learning through thinking through and understanding concepts independently	Independent work with time to reflect upon notes
Sensing	Learning concepts through organized steps and retention through repetition	Traditional textbook chapter readings and "plug and chug" problems
Visual	Learning through pictures, diagrams, films demonstrations, etc.	Handouts, visual aids within textbooks
Sequential	Learning in linear, logical steps	Traditional textbook instruction

We notice the teaching style A modalities benefited group work and B worked for more independent, traditional school work. Michel et al. (2009) describes how active learning incorporates many methods and techniques, some of which include: pausing in lectures for students to consolidate their notes, interspersing short writing exercises in class, facilitating small-group discussions within the larger class, incorporating survey instruments, and student self-assessment exercises into the course. Since our curriculum was framed around project-based learning, we aimed to match methods to those of teaching style A throughout the curriculum. To also better assist with curriculum development, Auster and Wylie (2006) offer four dimensions

that are critical to creating a systematic approach to promote active learning in the classroom: (1) context setting, (2) class preparation, (3) class delivery, and (4) continuous improvement. Context setting pertains to creating an open and relaxed environment for learning within the classroom. Class preparation involves planning a thoughtful, creative, yet adjustable lesson before the class session. Class delivery refers to the implementation of the planned lesson in the classroom; what if students are introverted and unresponsive? How else can we encourage student participation? Continuous improvement entails seeking curriculum assessment and using feedback (surveys, faculty observation) concerning the teacher's implemented approach.

3.3.4 Description of Curriculum and Implementation

The curriculum was scheduled in the same week for both classrooms. To start the school day, an hour and a half of instruction was implemented in the robotics shop class immediately followed by the same lesson in the information technology class. The five days were broken down as follows:

Monday

- Introduction to sustainable development: With the use of the classroom smartboard, we projected various photos of climate change, global warming, the carbon cycle, renewable and non-renewable energies, efficiency, etc. With each photo, groups would receive points for participation and/or prior knowledge of the subjects. Students also used their laptops to research what technologies provide electricity for their city's grid, and which sustainable projects are in place or being planned.

Tuesday

- Introduction to circuits and renewable energy projects: With a prior understanding of Ohm's law and concepts of series and parallel circuit connections, the students practiced

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various combinations or circuits. This included switches, different loads (lights, motors, water pumps, soundboards, etc.), and power sources (wind energy, solar, battery packs).

Wednesday-Thursday

- Construct houses: Students now were left with the task of designing a house that utilizes a switch that can make their house change from receiving electricity solely from the battery pack to some combination of renewable energy when wind or sunlight is present. The flip of the switch would represent integrating renewable into the house's power mix.

Friday

- Conclusion and post discussion: The last day is when the students finished up their houses. After a brief presentation to their peers, their instructors would then test for electrical performance (if the switch worked and how many loads were powered), design creativity, circuit complexity, oral presentation (understanding of concepts), and involvement of teammates.

Figure 10: Example Student Projects

3.4 Study Design

We use our curriculum to test whether the context of a lesson had an effect on (1) a student's sense of hope for sustainable development and (2) interest in engineering. We designed and applied two pre and post surveys, anonymously tracking pre and post responses.

3.4.1 Survey Development

The surveys were designed to measure two areas: a student's interest in engineering, and a student's hope for sustainable development. All questions were answered on a five-point Likert scale from strongly disagree (1) to strongly agree (5). We used a pre-existing engineering interest survey derived and validated by Unfried et. al (2015). It measures students' attitudes toward science, technology, engineering, and math.

Similarly, we used a pre-existing survey regarding hope for sustainable development. For purposes of this study, hope, as described by Ojala (2012), consists of three different components: goals which we wish to have to happen, an ability to come up with routes to get to where we want (pathway thinking), and the motivation to use these pathways (agency thinking). We define sustainable development as referring to research and technology that assists with the mitigation of issues such as climate change and energy deficiency. The surveys can be seen below in Tables 8 and 9.

Table 8: Engineering Interest Survey Questions (Unfriedet. al, 2015)

Question Number	Question
1	I like to imagine creating new products.
2	I want to improve things that people use every day.
3	I like to building/fix things.
4	I am interested in what makes machines work.
5	Improving and designing products/structures will be important for what I want to do in the future.
6	I am curious about how electronics work.
7	I want to help solve major issues in the world.
8	I would like to use creativity/innovation in my future work.
9	I believe I can be successful in a career in engineering.

Table 9: Hope Survey Questions (Ojala, 2012)

Question Number	Question (To be read with the leading: I feel hope for future sustainable development…)
1	..because society has confronted complex and seemingly hopeless problems before and has been able to solve them eventually.
2	..because I do not think that sustainable development is as big of a problem or urgent as certain researchers claim (denial, reversed Likert scale).
3	..because we as individuals can change our behavior; together we can influence sustainable development in a positive direction.
4	..because I believe that research and technical solutions will contribute to the improvement of the sustainable development problem.
5	..because the awareness about this problem has increased considerably during recent years.
6	..because politicians in more and more countries take sustainable development seriously.
7	..because even though there is a risk that humanity will go under due to this problem, nature will survive.
8	..because as long as there are people who are active in environmental organizations there is a possibility that sustainable development issues will be solved.
9	..because I know that there are a number of things that I myself can do to contribute to the improvement of the sustainable development problem.
10	..because I try to focus on positive news about sustainable development in the media.

3.4.2 Variables and Experiment Design

Our two independent variables were the Robotics and Information Technology classes. The dependent variables were the two surveys that were administered to both shop classes before and after the curriculum delivery; these resulted in eight possible combinations of surveys to analyze.

Combination	Class Type	Survey Type	Pre/Post Test
1	Robotics	Hope	Pre
2	Robotics	Hope	Post
3	Robotics	Engineering Interest	Pre
4	Robotics	Engineering Interest	Post
5	Information Technology	Hope	Pre
6	Information Technology	Hope	Post
7	Information Technology	Engineering Interest	Pre
8	Information Technology	Engineering Interest	Post

Figure 11: Combinations of Survey Data

Note we did not have a control group in this study. In a previous experiment, we had a hands-on project without the sustainability context, but this vocational school already does that. For our analysis, we hypothesized that the levels of hope and engineering interest between the two classrooms would be similar initially, and then increases in those same areas after the treatment. We tested whether there was a correlation between an individual student's interest in engineering and hope for sustainable development.

3.5   Results & Analysis

Recall our initial questions inquiring if our sustainable energy curriculum would improve student's hope for sustainable development, improve student's interest in engineering, and if we would see a relation in change between hope and engineering interest. We present our results in three sections: group means, individual difference scores, and hope & engineering interest correlation.

3.5.1   Group Means

In this section, we investigate whether there was an increase in hope for sustainable development and interest in engineering for both classes as a whole after implementation of our curriculum. We averaged the Likert scores of all questions for each individual student's survey and call this a Likert average score (ex: within the Rob/EI/Pre combination, one student reported a Likert average of 3.6). We then took all the individual Likert averages, averaged them again within each of the eight combinations, and referred to this as a group mean. To test whether the difference in group means between Robotics and Information Technology students were significant, we also ran four separate Welch-Aspin tests (two-sample t-test with the assumption of unequal population variances). Type one error alpha levels were set to 0.05. These group means are plotted in the figure below.
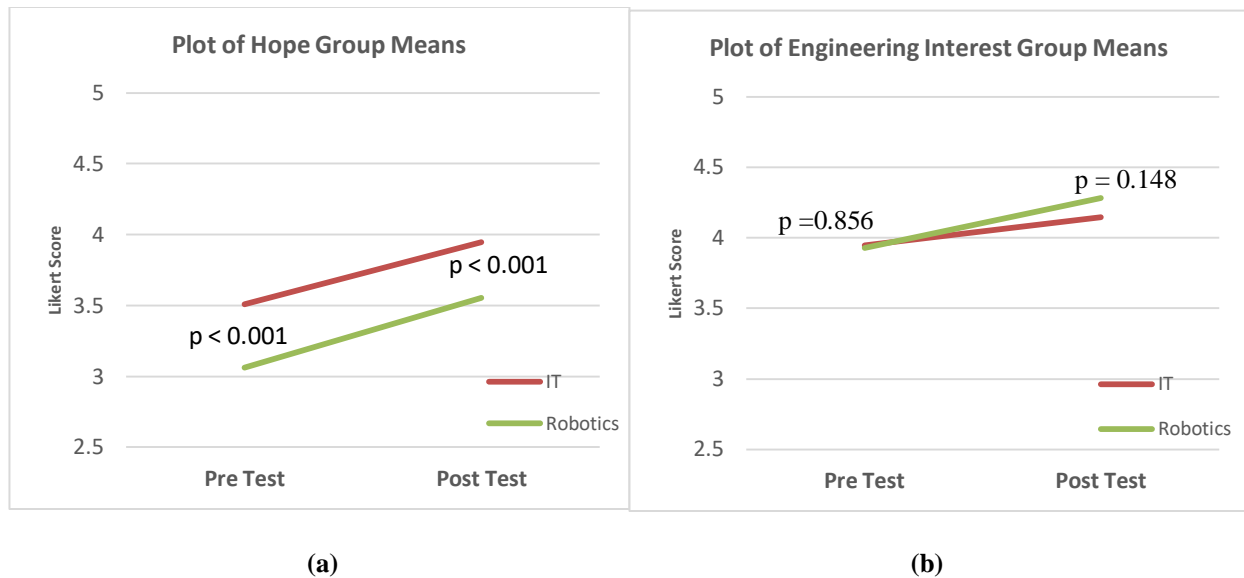
Figure 12: Overall Classroom (a) Hope and (b) Engineering Interest Group Means from Pre to Post Test

When considering grouped means, as hypothesized we see increases in hope and engineering interest for both classrooms. When analyzing the increasing trends between the two classes in Figure 12a we see that the classes started out different in the hope survey, with a significant difference between the robotics and IT classes in both the pre-test ($p< 0.001$) and post-test ($p< 0.001$) of the hope survey. Alternatively, in Figure 12b, there was no significance between the classrooms in the pre-test ($p=0.865$) or the post-test ($p=0.148$) of the engineering interest survey. We hypothesize the slightly more significant increase in engineering interest of the robotics class may be due to the fact that the curriculum was hands-on; students of the robotics shop class are more engaged with hands-on building activities than those in IT, who are more engaged in programming.

Next, we combine group means of the two classrooms to see the trends from pre to post in all students.

<center>(a)   (b)</center>
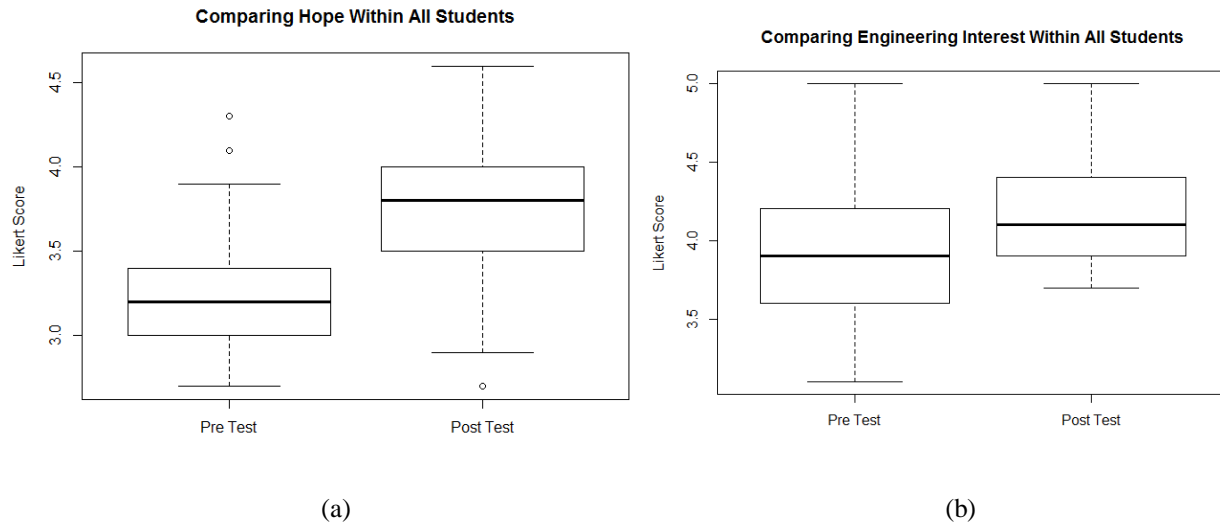
Figure 13: Box plots of (a) Hope and (b) Engineering Interest Pre and Post Test for all (N=33) students

When using a visual box plot representation for both classrooms combined, we see increases from pre to post for both hope and engineering interest surveys. Within the hope survey, the average means increased by 0.446 and the average mean within the engineering interest survey increased by 0.278. Sample variance decreased by 0.146 and 0.045 for overall hope and engineering interest survey averages respectfully. Increases in hope and interest in engineering both were significant with p-values of .00001 and 0.01 respectively.

3.5.2 Individual Difference Scores

By anonymously distributing codes to each student, we were able to trace student pre and post responses. Recall that we have two different surveys and two different classrooms, which resulted in four pre/post plots.
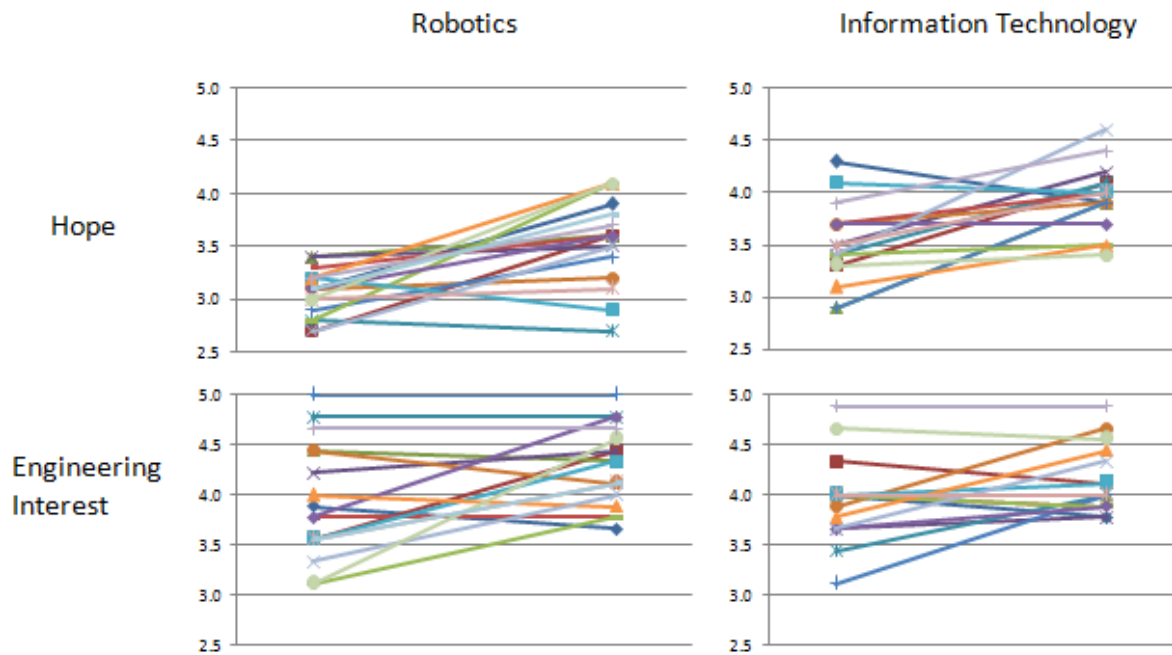
Figure 14: Each Student's Likert Average from Pre to Post Survey for all four cases

The ends of each line segment represent the pre and post averages of all questions on that survey; again, we define these as Likert averages. For example, a line within the top left plot shows the Likert average for one of the 17 Robotics student's hope survey from pre to post. We use these plots to view the pre to post trends for a survey type within a classroom; therefore, each line is independent of each other between plots. We see increases for more than half of participants across all plots. Considering these students were enrolled in technical shop classes, we believe that many would already have had an interest for engineering prior to this study. However, engineering interest decreased for over a quarter of our participants.

Table 10: Percentage of all Student's Increases and Decreases in Hope and Engineering Interest

N=33	% Increase	% Decrease	% No Change
Hope	85%	12%	3%
Engineering Interest	52%	27%	21%

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From the table, we see that the curriculum was more effective at increasing hope than engineering interest, perhaps because these students already have an interest in engineering or a technical field of study seeing as how they were enrolled in a technical shop class of a vocational school.

Next, we looked for significance within each of the four combinations of class and survey type. We conducted a one sample t-test for the student's individual difference scores (post-survey Likert average minus pre-survey Likert average).

Table 11: One sample t-test for both surveys in both classrooms at a 0.05 alpha level

Class and Survey Type	Mean Diff Score	P-value	Confidence Interval	Cohen's D
Robotics Hope	0.494	0.0003	(0.266, 0.722)	1.11
IT Hope	0.438	0.0013	(0.200, 0.675)	0.98
Robotics Eng. Interest	0.365	0.0086	(0.106, 0.623)	0.73
IT Eng. Interest	0.213	0.0438	(0.007, 0.418)	0.55

From the table not only do we see positive difference scores in all four categories, but we also see significance across all of them as well. However, interest in engineering within the information technology shop class was close to not rejecting the null hypothesis.

3.5.3   Hope & Engineering Interest Correlation

In this section, we test to see if a student's change in hope and engineering interest is related through a linear regression test and test of correlation.
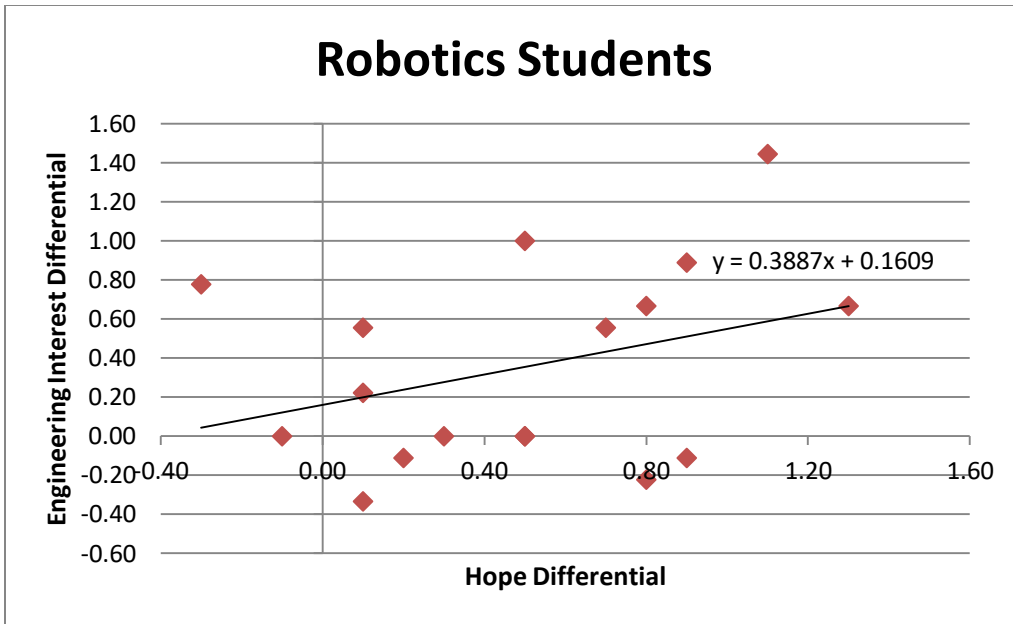
Figure 15: Robotics Students: Hope Post-Pre Differentials vs Engineering Interest Post-Pre Differentials
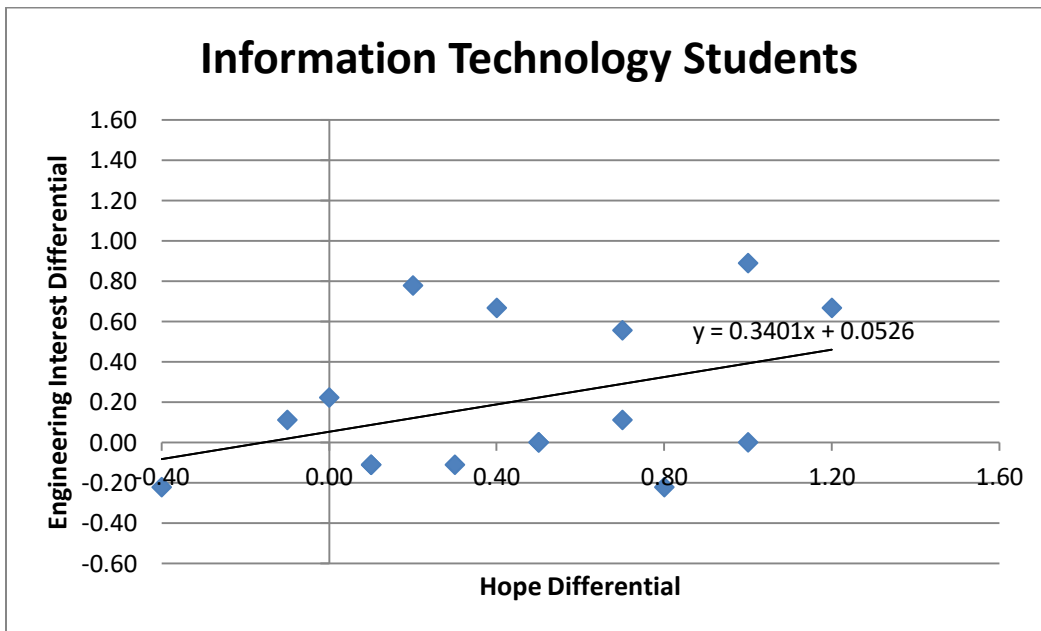
Figure 16: Information Technology Students: Hope Post-Pre Differentials vs Engineering Interest Post-Pre Differentials

By seeing the 58% of points within the first quadrant for both plots, we know that the majority of students saw increases in both hope and engineering interest between pre and post surveys. Conversely, only one student reported decreases in both engineering interest and hope between the two plots. Through both linear regression lines, we see moderate slopes, which tell us that, within our sample, if a student's hope increased throughout the curriculum, then their interest in engineering is likely to also have increased. Similarly, in table 12 below we see moderate correlation coefficients for both classes individually and combined.

Table 12: Correlation Coefficients

Class Type	N	r Coefficient	r^2
Robotics	17	0.341	0.116
Info Tech	16	0.404	0.163
Both Combined	33	0.369	0.136

3.6   Conclusion

Overall, the hands-on sustainable energy curriculum proved to increase hope and engineering interest within both classes. Incorporating these into urban secondary school classrooms could improve the enrollment and retention of URM's in STEM fields. There is also a moderate correlation in hope and engineering interest for both shop classrooms, implying that one may be causal of the other.

We do take note of some potential threats to internal validity. Students in vocational schools usually have career interest and goals predetermined which could cause the curriculum to have no effect. We chose students in their first year to best control for this; as a result, only three students reported the same levels of engineering interest before and after the curriculum. Having students working in groups throughout the curriculum could also threaten independence; i.e., their peers rather than the curriculum could have influenced a student's survey results. Also, with

the curriculum developed delivered by the researchers in a short period, we do not know if these same results would hold over a more extended period with their regular instructor.

Although the community itself was within a low-income urban area, the vocational secondary school has the resources to ensure their students inevitably pursue successful careers whether or not they be in STEM or sustainability. We aim to see next if we would have similar results in a school that lacks this level of resources and support. Future research would include using non-vocational, more at risk, urban high school students as participants. To justify our results, we would also see results compared to that of a teaching style B (traditional, passive independent school work) as a control group to not focus on the content of the curriculum, but rather the way it is delivered. More in-depth qualitative research would also be of benefit; there underlies more to the student's success in this experiment than the curriculum and prior experience with hands-on projects. We aim to explore the specific factors that recruit and retain urban students into sustainable energy/STEM fields at a secondary level.

CHAPTER 4

QUALITATIVE STUDY-INTEGRATION OF SEE AND CAREER DEVELOPMENT CURRICULUM TO INCREASE SELF-EFFICACY AND HOPE FOR AFFECTING WORLD CHANGE

4.1 Introduction

Many studies assess curriculum content to investigate the impact on the number of underrepresented pre-college students that go on to study STEM fields. However, this overlooks many factors that can support or hinder students' decision-making. We performed a qualitative study to investigate a wider range of factors, in conjunction with a renewable energy education grant. Our study took place at an urban high school that is one of Massachusetts' most struggling schools in terms of academic achievement and improvement. The grant supported the development of an engineering elective with a focus on sustainable energy education (SEE), the inclusion of career development curriculum, and a real-life, hands-on project run with a solar contractor. This contractor participated in lessons within the elective class as well. The elective ran for five months in the spring semester. The hands-on project included an eight-week paid summer internship program where the students designed solar charging stations and installed a hybrid solar/wind-powered LED signboard. Twenty-two students participated in the overall project, with a majority of Latino and African-American heritage.

We adapted Lent et al. (1994) Social Cognitive Career Theory theoretical framework and supporting literature to develop a set of research questions, pertaining explicitly to students at urban schools. We looked at three causes – experiential learning, competence level, and the SEE curriculum – and investigated how these impacted two intermediate dependent variables - their hope for world change and self-efficacy in pursuing STEM fields. Also, we asked what outcomes the students anticipate when pursuing their respective career paths.

Our methods included an observation protocol during the elective course and interviews with nine students following the conclusion of the eight-week summer internship program. The key finding was the central importance of personal relationships with peers, instructors, and family members on both self-efficacy within STEM fields and on hopes for changing their communities.

4.2 Literature Review

We break this review of literature into three subsections. First, we investigate common themes relating to the disparity of underrepresented minorities in STEM related fields. Second, we look into a focus on student competency as a solution, in the following section. Finally, we also examine the theoretical framework Social Cognitive Career Theory and studies that have adapted it for their respective research inquires.

4.2.1 Factors Contributing to the Lack of URM's in STEM

The underrepresentation of racial minorities in STEM disciplines is a national concern. Goal theory suggests that students' motivation and achievement-based behaviors can be understood by considering the habits they take on while engaged in academic work (Dweck & Leggett, 1988, Urdan, 1997). Also, goal theory provides a practical structure from which to help better understand issues of underrepresentation (Hernandez et al., 2013). One common factor in the literature to explain underrepresentation of minorities is lack of motivation. To remedy this misrepresentation, Wolters (2004) proposes the use of motivation, learning strategies, and seeing achievement as goal structures; his study involved 525 suburban junior high school students and investigated how different elements of achievement goal theory were related to each other and students' motivation, cognitive engagement, and achievement in mathematics. His results show that adaptive structure and orientation are related to outcomes in all areas.

Years of tedious mathematical coursework may not be appealing to an urban secondary school student and could seem even more intimidating to pursue at a higher level. Chen et al. (2016) noted the importance of educators understanding students' perception of academic and professional development within STEM courses, for motivational purposes. Amarnani et al. (2016) used a time-lagged survey design, the results of which emphasized the involvement of parental engagement as it can even indirectly influence self-esteem and the pursuance STEM careers. MacPhee et al. (2013) used a longitudinal study within a mentoring program to examine academic self-efficacy and performance among STEM majors who are underrepresented in education and the work field. These 'STEM-minority' groups included women, specific ethnic minorities, and low socioeconomic status individuals. Their results found increases in academic self-efficacy for students with STEM-minority status and women by both ethnicity and socioeconomic status. The correlation of findings at the program's completion for students with single versus double 'STEM-minority status' call for attention to the complex relationship between social disadvantage, academic self-efficacy, and academic performance.

Kennedy and Odell (2014) define necessary attributes of STEM programs designed to engage all students. They suggest curricula that engage students in STEM should offer instructional strategies that challenge students to innovate and invent; teachers must be able to offer standard-based technical STEM projects that use innovative instructional tools in efforts to promote applied and collaborative learning. Furthermore, the authors propose that STEM be delivered in an interdisciplinary manner to become a meta-discipline. Palmer et al. (2011) used qualitative interview methods to assess factors contributing to the retention and persistence of students of color in STEM education at a predominantly white institution. Key factors included peer group support, involvement in STEM-related activities, and intense preparation in high school.

One of the most prominent issues in U.S. education is the achievement gap (Ladson-Billings, 2006); it refers to the inconsistencies in standardized test scores between Black, Latina/o, and recent immigrants as compared to White students. However, Ladson-Billings implies that the focus needs to be on the education debt that has accumulated over time. This debt is composed of historical, economic, sociopolitical, and moral components. Herman and Golan (1993) investigated the influence that standardized testing has on teaching and learning in upper elementary classrooms, as well as the difference between the impact of testing on the low-socioeconomic status and high-socioeconomic status classrooms. Their findings reported that teachers feeling pressure from school administration, parents, and media to improve test scores. Teachers admit that they adjust their curriculum to match subjects where students performed more poorly on a past test. They also report spending substantial time focusing on testing. Results show that these practices were more substantial in schools serving disadvantaged students.

In essence, we identified the following as main factors that contribute to the lack of URMs in STEM fields. Concerns are a *lack of* the following aspects:

- Support: where information and motivation of STEM post-secondary schools or careers are low due to sparse secondary school counseling for higher education or students being first of their families and peers to pursue STEM fields.

- Self-efficacy: where the individual student is doubtful of being able to succeed with STEM as a field of study or a career

- Socio-Economic Status: where there is a correlation between students with low test scores and low socio-economic status

- Engagement in Practical Projects (problem-project based learning): where students are not exposed to the practical work done in STEM fields

- Preparation for Higher Education and Professionalism: where there is a lack of preparation of higher education academic and social transitions or skills for careers

- Lack of School Resources: where faculty to assist with preparation for post-secondary education or careers are scarce or non-existent within a vast population of students

Rather than a lacking factor, another threat to URM STEM participation is the excessive focus on standardized testing, where the focus is targeted on preparation to achieve school-wide average scores on a statewide standardized test. Lee (2015) measured achievement gaps caused by standardized testing and suggested methods linking student's skillset potential to academic expectations. We discuss similar solutions suggested by literature in the following section.

4.2.2 Remedy to the Lack of URM's in STEM: Competency

Kaplan and Midgley (1997) define competence as the connected pieces of knowledge, skills, and attitudes that can be used to solve a problem adequately. Taconis et al. (2004) similarly argue that competence should address not only knowledge but also expertise. They propose that these should be developed in an integrated way since each is sufficient for professional behavior separately. Lizzio and Wilson (2004) see competence as the ability to display different combinations of knowledge and skill sets regardless of job contexts. With competence equating to a culmination of attributes, it does not seem appropriate to label one with high or low competence. Instead, this study focused on qualitatively determining the various degrees of competence.

Wampold et al. (1998) used an assessment strategy to gauge the effects of curriculum reform on the competence of university chemistry students. This method used a combination of

qualitative sociological research methods and oral examinations conducted by 25 university

faculty. Observations noted in this study included: curriculum evaluation, attendance,

attentiveness, and participation. We drew from these methods when evaluating competence

through observation in our own study.

4.2.3   Theoretical Framework

Social Cognitive Career Theory (SCCT) is derived from Bandura's (1977) Social

Cognitive Theory, which argues that individuals learn by observing other individuals' behavior,

then choose to mimic that behavior depending on the perceived benefits and risk that are

associated with the behavior. An individual's cognition of that observed behavior, along with the

individual's environment, all contribute to overall learning. Lent et al. (1994) integrated this

framework into the field of career development for young adults, making Social Cognitive

Career Theory.

Figure 17: Lent et. al (1994) Social Cognitive Career Theory Framework

Their conceptual map posits that a person's personal inputs (an individual's race,

ethnicity, gender) and background contextual affordances (influential people, opportunities, and

experiences) feed into their learning experiences. These then lead to affect their self-efficacy and

outcome expectations. Self-efficacy is one's self-belief in completing a task whereas outcome

expectations are the beliefs in the outcome of that task (can I do this? vs. if I do this, what will

happen?). These then lead to a person's career interest and decision making. The arrows in the graph indicate a relation between variables. However, a study by Lent, et al. (2008) showed that the original model is not bi-directional (i.e., one's self-efficacy does not affect their learning experience). SCCT provides a useful explanatory framework with a wide range of generalization that many studies have thus far tested prediction and criterion variables. Lent et al. (2006) describe SCCT as a relatively recent framework that explains three correlated aspects of career development: (1) how basic academic and career interests are developed, (2) how educational and career choices are made, and (3) how academic and career success is obtained. These are directly relevant to this study.

Many studies have utilized and adapted this framework to their own research. Chakraverty & Tail (2013), in a qualitative study, focused on the rationale within SCCT that shows personal inputs, such as parental influence, have an effect on children's early science interest. They adapted the SCCT model to reflect solely on parental occupation as the primary contributor to a child's choice of profession.
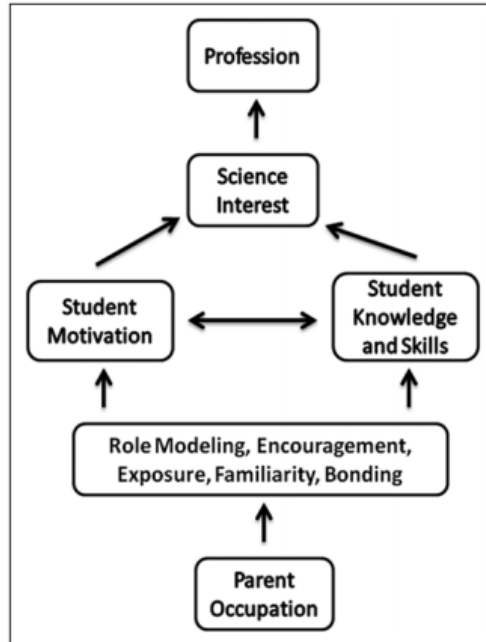
Figure 18: Chakraverty & Tail (2013) SCCT framework with focus on student's parental occupation leading to students chosen profession. Adapted from Lent et. al (1994)

Their findings via 17 interviewees indicate that not only parental occupations can affect children's science interest but also indirect association through familiarity with parental philosophies can be causative as well.

Wang (2013) draws upon the SCCT and higher education literature to test an adapted conceptual framework for understanding the entrance into STEM majors by recent high school graduates attending 4-year institutions, using quantitative methods. The conceptual model involves SCCT and past literature on factors of college students' academic choices and outcomes. In this model, a student's intent to major in STEM is affected by their 12th-grade math achievement, exposure to math and science courses, as well as math self-efficacy beliefs; all of which are subject to the influence of uphill contributors such as achievement in and attitudes toward math in previous years.
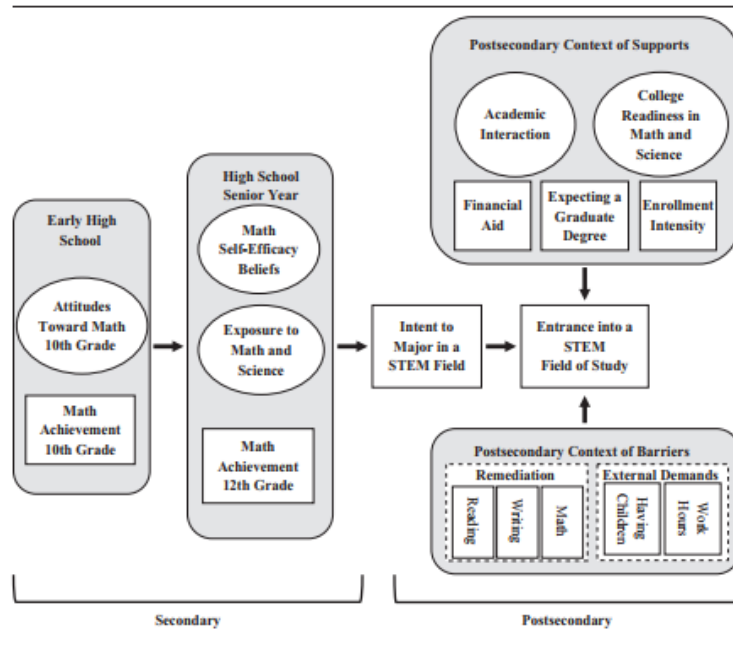
Figure 19: Wang (2013) SCCT framework with focus on secondary and post-secondary contributors leading to students chosen field of study. Adapted from Lent et. al (1994)

Results suggest that choosing a STEM major is directly influenced by a pre-determined intention of choosing STEM, high school math achievement, and initial postsecondary experiences (such as academic interaction and research experience). Dika et al. (2016) used an SCCT framework to examine interest in engineering of 200 low-income middle and high students of a material science engineering club in Puerto Rico.
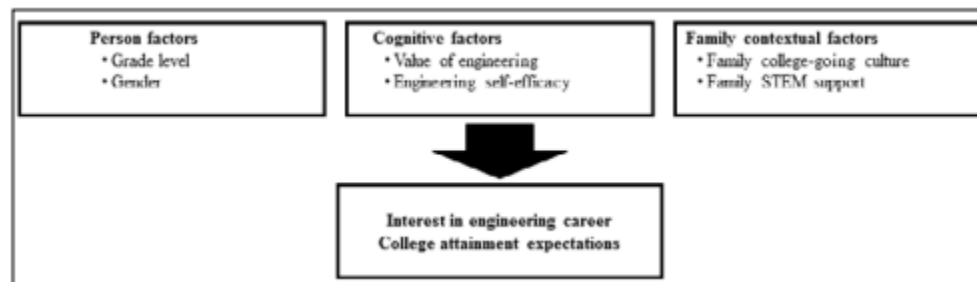
Figure 20: Dika et. al (2016) SCCT framework with focus on student's personal background affordances and cognitive factors leading to students interest in engineering. Adapted from Lent et. al (1994)

Their questionnaire data demonstrated that the perceived value of engineering is useful, but found the most influential factor to be parent's expectations and education. Several other quantitative studies have also used in SCCT frameworks through mathematical models to connect STEM interest to students of different ethnicities and socioeconomic statuses within predominantly white and historically black institutions (Lent et. al, 2013; Lent et. al, 2005; da Silva & Chiu, 2013; Garriot et. al, 2013).

4.3   Study Design

The purpose of this applied research was to add to the existing knowledge about the factors that contribute to the under-representation of URM students in STEM (Quinn, 2002). We utilized qualitative methods to investigate the relation between a student's hope and competence in his/her STEM classes and activities. We relied on an explanatory case study design to identify the causal links in real life interventions that may be too complex for experimental or surveying methods (Baker & Jack, 2008; Yin, 2003). Our sources of data are from participant observations within the classroom and interviews from students following their summer paid internship.

4.3.1   Conceptual Framework

Our contribution within SCCT is the connection between competence and hope for sustainable development (Ojala, 2012) leading to students' interest and career goals. Bandura (1977) defines self-efficacy as one's belief that one will accomplish a goal or succeed at a task. In this framework, *hope* will serve as a specific subset of self-efficacy; i.e. a student's hope for affecting world change. For this study, we construct our conceptual framework following Miles and Huberman (1994), who define it as a system of assumptions, concepts, and beliefs that guide and support the research plan. Specifically, the conceptual framework "lays out the key factors, constructs, or variables, and presumes relationships among them" (p. 440). Camp (2001)

similarly describes a conceptual framework as a structure of what has been learned to best explain the natural progression of a phenomenon that is being studied.
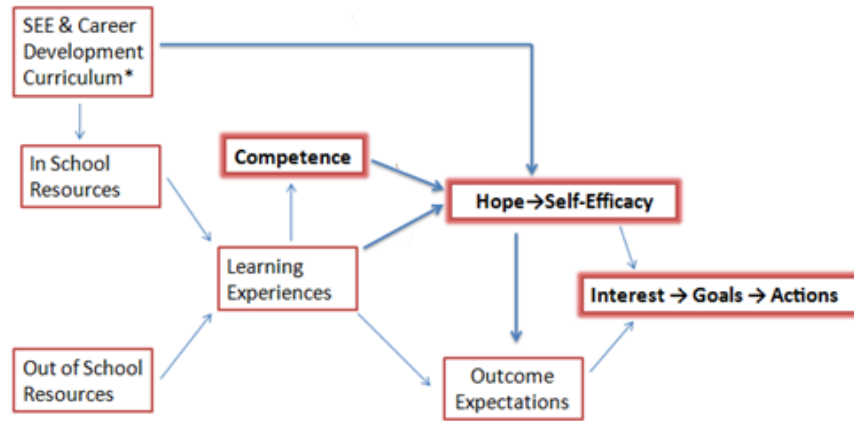
Figure 21: Conceptual Map Adapted from Lent et. al, 1994.

For this new SCCT model, we adopted the former SCCT to apply specifically to a secondary school student with the contribution of the constructs of competence and hope. We defined competence as a student's knowledge, skill sets, and attitude in STEM and sustainability (Kaplan & Midgley (1997); Taconis et al., 2004). Hope is defined as a subset of self-efficacy (a student's self-belief that they can achieve something (Bandura, 1977)), meaning specifically belief in affecting world change. We included SEE and Career Development Curriculum as an essential part of in-School Resources that the classroom received. Upstream contributors, such as competence and learning experiences, influence a URM student's hope. Out-of-school factors like socio-economic status and family support may affect access to learning experiences negatively or positively. In-school resources, such as peers, teachers, extra counseling, and curriculum content, could similarly affect a student's learning experience. We added hope to indicate that it may lead to a student's decision making about post-secondary school. In addition, we included competence as a contributor to infer that a student's level thereof can influence a student's hope for his/herself to be able to affect sustainable development.

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4.3.2 Methodology

At the beginning of the school's semester, we conducted in-class observations to gather field notes for data analysis. We began with a broad, daily preliminary observation protocol where we looked for behaviors and listened for dialogue contributing to an individual's self-efficacy, hope, and competence. Levels of competence were subjectively determined, in the sense that they are not to be solely determined by grades, but by levels of understanding of the curriculum content throughout the semester (at the discretion of the researchers and comments from the classroom instructor). Some indicators we looked for included student participation, engagement, interaction, and attentiveness (Wampold et. al, 1998).

The summer internship immediately started following the end of the student's school year. Twenty-two students worked on three group projects throughout the eight weeks, as follows:

1. KidWind Mini Wind Turbine and Solar Houses wiring (groups of two)

2. Solar Charging Stations (groups of four-five)

3. Solar/Wind Hybrid System to power an LED Signboard on the side of their school:

   - Project Manager (1 student)- Oversaw entire project and logistics

   - Installation Crew (7)- Hands on cutting of pipes and sheet metal as well as mounting outdoors

   - Engineering (4): Solved electrical, mechanical, and all other design problems and gave measurements and instruction to installation and IT teams

   - Information Technology(4)- Handled electrical and software work indoors

   - Marketing (3)- Worked to design labels for solar charging stations and signboard project. Coordinated and invited friends, family, school administration, and local district and community leaders to presentation last day of the program

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- Purchasing (3)- Kept inventory of all materials and purchases and replaced where needed.

The contractor was the primary manager of the second and third activities above. The spring elective instructor was also present for support. 60% of the students in the class were of Latino heritage followed by African American students at 27%, then the remaining were Caucasian students. All but five students were graduated seniors at the beginning of the summer and over 18. There were five women in the program. Interviews were conducted with nine participants three months following their summer internship program.

4.4 Results & Analysis

4.4.1 Emergent Results

4.4.1.1 *Peer influence in classroom*

Through observations in the classroom elective, we found peer influence to be strong. Students self-selected into tables that were maintained for the entire semester. Students who shared a table exhibited similar behaviors to each other.

Table 13: Spring Elective Classroom Observation Coding by Student

	Self-E	A*	B	C	Hope	D	E	Comp.	F	G	H
Table A											
Xa1				+			-				
Xa2		-	-	-			-		-		-
Xa3		-	-	-			-		-		-
Xa4			+	+		+			-		-
Table B											
Xb1		+		+							
Xb2		+		+			+			+	
Xb3		-	-	-			-		-		-
Table C											
Xc1		-	-	-			-		-		-
Xc2		-	-	-			-				-
Xc3		-	-	-			-		-		-
Table D											
Xd1		+	+	+			+		+		+
Xd2		+	+	+			+			+	+
Xd3		+							+		
Xd4		+	+	+			+		+	+	+
Xd5		+					+				+
Xd6		+	+	+		+	+			+	+
Xd7		+		+					+		+
Xd8		+	+	+		+	+		+	+	+
Table E											
Xe1		+	+	+					+	+	+
Xe2			+	+					+	+	

*Self-Efficacy indicators: A-Motivation, B-Participation, C-Peer Influence. Hope Indicators: D-Verbal, E-Attentiveness. Competence Indicators: F-Knowledge, G-Skillsets, H-Attitude. The "+" and "-" symbols denote observation of a positive and negative behavior, respectively, for each student within a given category.

The classroom contained five student tables, denoted **Table A**-**E**. Each "Xij" represents student j at table i. Some examples of positive behavior would be if a student would raise their hand or willingly participate three or more times on a given day; that student would receive a "+" mark within the "B" column for participation. Conversely, they would receive a "-" mark if they conducted three or more behaviors which conveyed transparent lack of interest in class material (i.e. use of cellular device, disruptive talking, turning their backs on the lesson, or having their

heads down to rest). The students sitting at **Table A** were often distracted or disruptive, and seldom engaged with class discussion. Students of **Table B,** were generally quieter and worked independently. They would make eye contact with the instructor but almost never participate spontaneously. Students of **Table C** were at risk of not graduating altogether, rarely showing up to class. Students of **Table D** had the most work ethic, also sat closest to their instructor. They were always engaged with material, discussions, and group work. **Table E**, with only two students, worked mostly independently, and engaged in class discussion most next to those of **Table D**. Students of **Table D** and **Table E** were typically the only students engaged with the contractor and similarly, the contractor would mainly engage with them.

4.4.2   Rapport with Instructor

With the majority of instruction being lecture-based, it was difficult to infer from observations whether students felt a sense of hope regarding affecting world change. Self-Efficacy was more transparent through their actions. In the beginning of the semester, the class material seemed to be too rudimentary and non-engaging for all students. Lessons presented by the contractor, however, were too difficult and intimidating. For both instructors, lecture-based material (PowerPoint slides and instructor presentation), whether on renewable energy or career development, was an immediate gateway to distraction for this class. In an interview after the summer program, a student recalled:

> "This class is easy for the most part and [I] really cares for us. Has [Contractor] worked with kids like us before? They're smart but can't teach that well." (Another student speaking on the difficulty of the course) "Kind of in the middle [Contractor] is most confusing, he moves too fast"

Regardless of curricular content or difficulty of concepts, engagement was more apparent with an instructor the students had built a rapport with (Pitts& Miller-Day, 2007).

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4.4.3 Lack of Interest in Sustainability and Engineering

Within interviews, we asked each student whether they valued income, passion, social impact, or a combination of these three within their dream career, and asked them to mark this within a three-way Venn diagram (shown in Figure 22). In addition, we asked where they would place a sustainability and/or engineering career in the same diagram. The figure below superimposes the nine students' (P1-9) pairs of responses and differentiates them through color codes. For example, P1 wants to work in public health and sees this career at the intersection of all three aspects. By contrast, they see a career in sustainability and engineering as having a positive social impact and making money, but this participant does not feel passionate about this career choice.
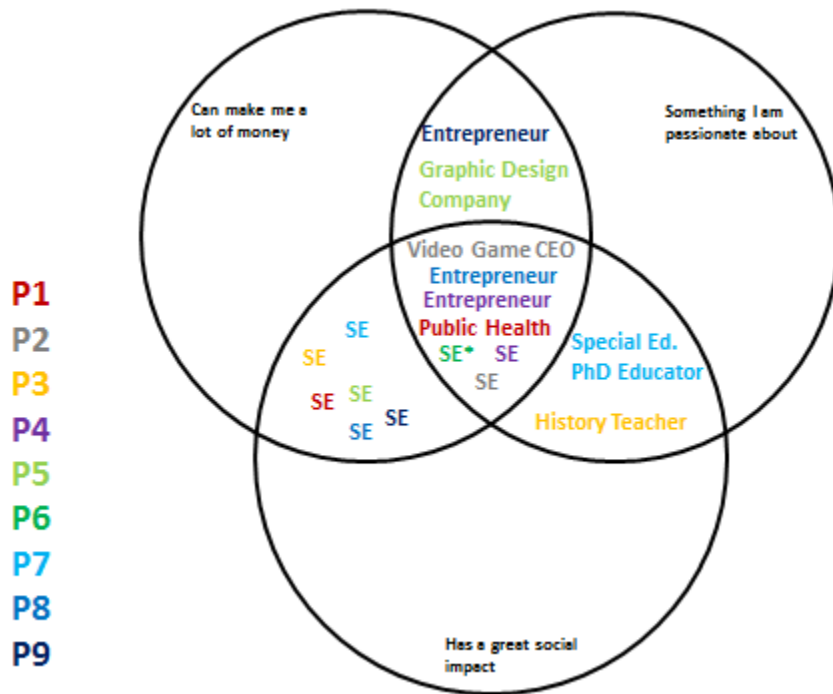
Figure 22: Participants' Intended and Sustainability/Engineering Career Values. The intended career are represented as written; SE represents a career involving sustainability, engineering, or a combination of the two; P6 is only on the chart once as their intended career is an SE career, a solar contractor)

A majority of participants were not interested in sustainability or a STEM career. This can be seen in the diagram, since six participants put SE at the intersection of money and impact,

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but not passion. These participants, like the majority of the 22 who were enrolled in the program, were graduated seniors at the point of the summer program and their career plans determined prior. We also note student disconnect with the project as a potential contribution to these results. With only one technically experienced contractor supervising them, students often performed a task wrong then had to get the contractor's attention and repeat the task frequently. This tedious frustration not only set the projects back but widened the gap between students who rose to the task and those who fell back.

4.5 Research Question Findings

Recall that we sought to investigate how experiential learning, competence level, and the SEE curriculum influenced URM student's attitudes and career choices within STEM related fields and sustainability. Here we discuss how the results from the observations and interviews reported above relate to our research questions. Specifically, we discuss what most impacted hope, self-efficacy, and anticipated outcomes.

4.5.1 Hope

Students were asked whether they hoped to affect change on a local (family, community, city) or a larger (state, country, globally) scale. Their hopes centered on changing conditions within their own communities. These hopes were often influenced directly by peers or the circumstances they grew up in:

"…because I'm coming from being raised and the Boys and Girls Club that's a community I would want to give back to, like, if it wasn't for them, I wouldn't be where I am today and of course my family… If it [entrepreneur career] does go globally. That's good and that's great but as of now, I'm just gonna take care of home."

Students observed to be highly academically and culturally competent were skeptical of the possibility of world change due to politics and the environment in which they grew up.

> "… Because just as in this city, and from what I see in the news, as a country, I don't feel like impact is really valued…like I said, the reason why sustainability isn't really a thing when it's needed is because of just some greedy people. So if everyone else doesn't care, then why should I care?"

4.5.2 Self-Efficacy

Rapport with instructors is a strong contributor for student's work ethic within the classroom and often leading to career interest.

> "…if the teacher and we don't get along, like I would just hate being there and I wouldn't want to do the work."

Conversely:

> "[Engineering Elective Instructor] had the main effect of my history class… she would give me websites or tell me to go to another teacher to help…she just encouraged you to do a lot."

This participant went on to study secondary education at their local community college with aspirations of teaching history. Students also often spoke of their families driving their academic motivation.

> "…I want something that can provide for my family. My family has been working hard for the entire lives and I feel I should be able to provide in some way or another…"

The rigor of the summer internship did have various effects, from deepening students' understanding of sustainability to discouraging them from the field altogether. One student highlighted how the lack of inclusiveness within the project contributed to them not wanting to pursue engineering:

"…[peer head of IT team] was kind of just doing everything…just pretty much took over and I just cut wires where I needed to cut wires and drilled holes where I was needed, but yeah I really didn't understand too much about what's going on. [Contractor] would always be working with him and we were just kind of like his lackeys."

Later in the interview, this participant went on to say they wanted to own their own business for the purpose of not working under anyone else:

"…because I would just feel less motivated if, kind of like in the summer I felt like I was working for somebody and I didn't really get to have much my own opinions and thoughts on things just did what I was told, didn't really understand things and even if I did, it wouldn't mean anything. So I figure that's what me working an engineering job would be like."

4.5.3 Outcome Expectations

Students anticipate adversity while attaining their goals and see themselves overcoming those hardships through the support of family, mentors, and peers.

"What would have allowed me to fail would be lack of support from my peers and my communities that I was a part of if I didn't have as much as support as I did throughout high school…I wouldn't have been able to succeed as much as I have."

In addition, many see roadblocks or failures deriving from lack of their own self-motivation.

"I feel like I do have a motivation problem. Like, I lose motivation quick, if I'm not seeing a clear, like if I can't paint the outcome of my future in my head…"

4.6 Conclusion

Many themes were identified in this study that may be relevant for STEM curriculum design and delivery to secondary students of underrepresented urban populations. We find that student's relationships heavily influence their career aspirations, particularly strong family influence and

meaningful relationships with instructors (Moore, 2006). Curricular content within the grant and hands-on projects was successful in opening some students' minds to new concepts and technical experiences. On the other hand, our student sample were graduating seniors with their career choices largely chosen prior to starting the study. In addition, a negative perception of sustainability caused by social media and various biased news outlets caused hopelessness for sustainable development. The spring elective was not a perfect match in terms of rigor in comparison with the summer project; the summer projects were extremely ambitious for students of this little experience. Recall from figure 2 that a majority of participants did not find passion in a career involving sustainability and/or engineering.

4.6.1 Recommendations

Our findings indicate that social justice training for STEM educators, especially for those of different socioeconomic class and cultural background, may be warranted (Finkel, 2018). While we found only limited evidence for the efficacy of the hands-on project (in contrast to suggestions by Zimmerman et al. (2018) and Cappella et al. (2018)), a study over a more extended period with a younger sample might be more likely to show pre-post effects. Within SEE, it is not only vital to teach the various problem-solving methods and mathematical concepts, but it is just as vital to instill a sense of understanding and practicality to empower the next generation to take action within these issues.

CHAPTER 5

SUMMARY

5.1 Contributions

Overall, in our efforts to promote SEE, we found a lack of studies within urban secondary schools via our first essay. In our second and third essays, our quantitative studies within this school demographic found that student projects involving SEE positively affect student's hope for sustainable development and interest in engineering; we also found a moderate correlation between the two. A contribution stems from our framework for developing curricula, which makes a clear distinction between an active and passive learning style, and the specific learning modalities within each. In our fourth and final essay, we found that relationships with family, peers, and instructors to be the determining factors in choosing career choices and hope for world change. Developing our curriculum, quantitative assessments, and interview protocol through prior observations of the classroom setting was an effective method to create a study best suitable for our specific sample. We define this contribution as a 'bottom up' approach, where new questions and discoveries could be cultivated through a series of studies would build upon one another.

5.2 Future Work

We suggest longitudinal research that explores the effect of trainings for instructors of underrepresented populations in efforts to bring an understanding towards social injustices within the communities they teach. Furthermore, we also promote long-term career decision mixed methods studies which integrate SEE curriculum and out of school programs (i.e. afterschool, summer, field trips) to enhance the experiences and conceptual understanding behind the impact sustainable technology can potentially have locally and globally.

REFERENCES

Ahn, B. (Januray 2014). Creating an instrument to measure leadership, change, and synthesis in engineering undergraduates. *Journal of Engineering Education, American Society of Engineering Education, 103*(1), 115-136. doi:10.1002/jee.20036

Ahuja, D., & Tatsutani, M. (2009). Sustainable energy for developing countries. SAPI EN. S. Surveys and Perspectives Integrating Environment and Society, (2.1).

Amarnani, R. K., Garcia, P. R. J. M., Restubog, S. L. D., Bordia, P., & Bordia, S. (2016). Do You Think I'm Worth It? The Self-Verifying Role of Parental Engagement in Career Adaptability and Career Persistence Among STEM Students. Journal of Career Assessment, 1069072716679925.

Auster, E. R., & Wylie, K. K. (2006). Creating active learning in the classroom: A systematic approach. Journal of Management Education, 30, 333–354.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. Psychological Review, 84, 191-215.

Barrett, M.J. (2006). Education for the environment: Action competence, becoming, and story. *Environmental Education Research, 12*(3-4), 503-511.

Baxter, P., & Jack, S. (2008). Qualitative Case Study Methodology: Study Design and Implementation for Novice Researchers . *The Qualitative Report*, *13*(4), 544-559. Retrieved from http://nsuworks.nova.edu/tqr/vol13/iss4/2 June 4, 2017.

Billiar, K. (2014). Teaching by STEM design. Advances in Engineering Education, American Society for Engineering Education, 4(1).

Borrego, M. (2014). Systematical literature reviews in engineering education and other developing interdisciplinary fields. *Journal of Engineering Education, American Society of Engineering Education, 103*(1), 45-76. doi:10.1002/jee.20038

Bystydzienski, J. M., Eisenhart, M., &Bruning, M. (2015). High School Is Not Too Late: Developing Girls' Interest and Engagement in Engineering Careers. *The Career Development Quarterly*, *63*(1), 88-95.

Camp, W. G. (2001). Formulating and evaluating theoretical frameworks for career and technical education research. Journal of Vocational Educational Research, 26(1), 27-39.

Carpi, A., Ronan, D. M., Falconer, H. M., & Lents, N. H. (2017). Cultivating minority scientists: Undergraduate research increases self-efficacy and career ambitions for underrepresented students in STEM. Journal of Research in Science Teaching, 54(2), 169-194.

Cappella, E., J., S. H., Kieffer, M. J., & Yates, M. (2018). Classroom Practices and Academic Outcomes in Urban Afterschool Programs: Alleviating Social-Behavioral Risk. Journal of Emotional and Behavioral Disorders, 26(1), 42–51. https://doi.org/10.1177/1063426617739254.

Chakraverty, D., & Tai, R. H. (2013). Parental occupation inspiring science interest: Perspectives from physical scientists. *Bulletin of Science, Technology & Society*, 33, 44–52.

Chen, Y. H., Tau, A., Zastavker, Y. V., Stolk, J. D., Dillon, A., & Gross, M. D. (2016). Understanding students' perception of academic and professional relevance in STEM courses.In Frontiers in Education Conference (FIE), 2016 IEEE (pp. 1-5).IEEE.

Cheng, L. C., Chu, H. C., &Shiue, B. M. (2015). An Innovative Approach for Assisting Teachers in Improving Instructional Strategies via Analyzing Historical Assessment Data of Students. *International Journal of Distance Education Technologies (IJDET)*, *13*(4), 40-61.

Clark, D. (2015). Why Instructional System Design and ADDIE? Retrieved May 02, 2016, from http://www.nwlink.com/~donclark/hrd/sat1.html

Cook, B. J., &Córdova, D. I. (2007). Minorities in higher education twenty-second annual status report: 2007 supplement.

Corres, J. M., & Ruiz, C. (2016). Competition oriented learning experience in electronics: Robot fabrication from scratch. In *2016 IEEE Global Engineering Education Conference (EDUCON)* (pp. 62-65). IEEE.

da Silva Cardoso, E., Dutta, A., & Chiu, C. (2013). Social-cognitive predictors of STEM career interests and goal persistence in college students with disabilities from racial and ethnic minority backgrounds. *Rehabilitation Research, Policy, and Education*, **27**, 271–284.

Debertin, D. L., & Goetz, S. J. (1994). Differences in rural and urban schools: Issues for policymakers. *Lexington, KY: University of Kentucky, College of Agriculture, Department of Agricultural Economics.*

Dika, S. L., Alvarez, J., Santos, J., & Suárez, O. M. (2016). A Social Cognitive Approach to Understanding Engineering Career Interest and Expectations among Underrepresented Students in School-Based Clubs. *Journal of STEM Education: Innovations and Research*, *17*(1), 31.

Dweck, C. S., & Leggett, E. L. (1988). A social-cognitive approach to motivation and personality. Psychological review, 95(2), 256.

Eisenman, L. T., Pell, M. M., Poudel, B. B., & Pleet-Odle, A. M. (2015). "I Think I'm Reaching My Potential" Students' Self-Determination Experiences in an Inclusive High School. Career Development and Transition for Exceptional Individuals, 38(2), 101-112.

Felder, R. M. &Soloman, B. A. (2014). Learning styles and strategies. Retrieved May 3, 2016, from http://www4.ncsu.edu/unity/lockers/users/f/felder/public/ILSdir/styles.htm

Finkel, L. (2018). Infusing Social Justice into the Science Classroom: Building a Social Justice Movement in Science Education. Educational Foundations, 31.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., &Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410-8415.

Fujihira, K., & Osuka, K. (2009). An educational methodology for sustainable development. *ICROS-SICE International Joint Conference 2009, ICCAS-SICE 2009, August 18, 2009 - August 21,* 4266-4271.

Gall, M. D, Gall, J. P, & Borg, W. R. (2003). Educational Research: An Introduction (7th edition). Boston, MA: Taxonomy of Research Designs.

Garg, H.P.Kandpal, T.C. (1996) Renewable energy education: challenges and problems in developing countries. Ctr for Energy Studies, Indian Inst of Tech, Hauz Khas New Delhi 110 016, India Source: *Renewable Energy*, v 9, n 1-4, p 1188-1193, Sep-Dec 1996.

Garriott, P. O., Flores, L. Y., & Martens, M. P. (2013). Predicting the math/science career goals of low-income prospective first-generation college students. *Journal of Counseling Psychology*, 60, 200–209.

Goodnough, K., & Cashion, M. (2006). Exploring Problem-based Learning in the Context of High School Science: Design and Implementation Issues. *School Science and Mathematics*, *106*(7), 280-295.

Gottlieb, D., Vigoda-Gadot, E., Haim, A., & Kissinger, M. (2012). The ecological footprint as an educational tool for sustainability: A case study analysis in an israeli public high school. *International Journal of Educational Development, 32*(1), 193-200.

Han, S., Capraro, R. M., &Capraro, M. M. (2016). How science, technology, engineering, and mathematics project based learning affects high-need students in the US. *Learning and Individual Differences*, *51*, 157-166.

Herman, J. L., & Golan, S. (1993). The effects of standardized testing on teaching and schools. Educational measurement: Issues and practice, 12(4), 20-25.

Hernandez, P. R., Schultz, P., Estrada, M., Woodcock, A., & Chance, R. C. (2013).Sustaining optimal motivation: A longitudinal analysis of interventions to broaden participation of underrepresented students in STEM. Journal of educational psychology, 105(1), 89.

Hsieh, C., & Knight, L. (2008). Problem-based learning for engineering students: An evidence-based comparative study. *The Journal of Academic Librarianship*, *34*(1), 25-30.

Jennings, P., & Lund, C. (2000). Renewable energy education for sustainable development. *Renewable Energy, 22*(1-3), 113-118. doi:10.1016/S0960-1481(00)00028-8

Kaikai, M., & Baker, E. (2016). Engineering for Sustainable Energy Education within Suburban, Urban and Developing Secondary Schools. *Journal of Education for Sustainable Development*, *10*(1), 88-100.

Kaplan, A., &Midgley, C. (1997). The effect of achievement goals: Does level of perceived academic competence make a difference?. *Contemporary educational psychology*, *22*(4), 415-435.

Kennedy, T. J., & Odell, M. R. L. (2014).Engaging Students in STEM Education. Science Education International, 25(3), 246-258.

Khalaf, K. (2013). Engineering design EDUCATION: When, what, and HOW. *Advances in Engineering Education, American Society for Engineering Education,*

Kidwind. (2016). Retrieved December 02, 2016, from http://www.kidwind.org/

Kumler, L. M. (2011). Students of action? A comparative investigation of secondary science and social studies students' action repertoires in a land use context. *Journal of Environmental Education, 42*(1), 14-29.

Ladson-Billings, G. (2006). From the achievement gap to the education debt: Understanding achievement in US schools. Educational researcher, 35(7), 3-12.

Lee, J. (2015). Educational testing: Measuring and remedying achievement gaps. Emerging Trends in the Social and Behavioral Sciences: An Interdisciplinary, Searchable, and Linkable Resource, 1-14.

Lee, M., & Bong, M. (2016). In their own words: Reasons underlying the achievement striving of students in schools. Journal of Educational Psychology, 108(2), 274.

Lent, R. W., Brown, S. & Hackett, G. (2006). Social cognitive career theory. In J. H. Greenhaus& G. A. Callanan (Eds.), *Encyclopedia of career development* (pp. 751-754). Thousand Oaks, CA: SAGE Publications Ltd.

Lent, R. W., Brown, S. D., & Hackett, G. (1994).Toward a unifying social cognitive theory of career and academic interest, choice, and performance. Journal of vocational behavior, 45(1), 79-122.

Lent, R. W., Brown, S. D., Sheu, H. B., Schmidt, J., Brenner, B. R., Gloster, C. S., Treistman, D. (2005). Social cognitive predictors of academic interests and goals in engineering: Utility for women and students at historically black universities. *Journal of Counseling Psychology*, *52*(1), 84.

Lent, R. W., Sheu, H. B., Singley, D., Schmidt, J. A., Schmidt, L. C., &Gloster, C. S. (2008). Longitudinal relations of self-efficacy to outcome expectations, interests, and major choice goals in engineering students. Journal of Vocational Behavior, 73(2), 328-335.

Lent, R. W., Miller, M. J., & Smith, P. E. (2013). Social cognitive predictors of adjustment to engineering majors across gender and race/ethnicity. Journal of Vocational Behavior, 83, 22–30.

Lent, R., Brown, S. & Hackett, G. (2006). Social cognitive career theory. In J. H. Greenhaus& G. A. Callanan (Eds.), *Encyclopedia of career development* (pp. 751-754). Thousand Oaks, CA: SAGE Publications Ltd.

Li, Bin. Dong, Wenjuan; Xiong, Yan; Chen, Guangming (2006). *Integrating renewable energy education into national high educational system*. Source: *ISES Solar World Congress 2007, ISES 2007*, v 4, p 3005-3008, 2007, ISES Solar World Congress 2007, ISES 2007.

Lizzio, A. & Wilson, K. (2004). Action learning in higher education: an investigation of its potential to develop professional capability. Studies in Higher Education, 29, 469-488.

Lochmiller, C. R., Huggins, K. S., & Acker-Hocevar, M. A. (2012).Preparing leaders for math and science: Three alternatives to traditional preparation. Planning and Changing, 43(1/2), 198.

London, M. (1983). Toward a theory of career motivation. Academy of management review, 8(4), 620-630.

MacDonald, C. (2012). Understanding participatory action research: A qualitative research methodology option. *Canadian Journal of Action Research, 13*(2), 34-50.

MacPhee, D., Farro, S., &Canetto, S. S. (2013). Academic self-efficacy and performance of underrepresented STEM majors: Gender, ethnic, and social class patterns. Analyses of Social Issues and Public Policy, 13(1), 347-369.

McGarr, O. (2010). Education for sustainable development in technology education in irish schools: A curriculum analysis. *International Journal of Technology and Design Education, 20*(3), 317-332. doi:10.1007/s10798-009-9087-7

McManus, D. A. (2001). The two paradigms of education and the peer review of teaching. *Journal of Geoscience Education*, *49*(5), 423-434.

Means, B., Wang, H., Wei, X., Iwatani, E., & Peters, V. (2018). Broadening participation in STEM college majors: Effects of attending a STEM-focused high school. AERA Open, 4(4), 2332858418806305.

Metz, D., McMillan, B., Maxwell, M., & Tetrault, A. (2010). Securing the place of educating for sustainable development within existing curriculum frameworks: A reflective analysis. *Canadian Journal of Environmental Education, 15*, 150-169.

Michel, N., Cater, J. J., & Varela, O. (2009). Active versus passive teaching styles: An empirical study of student learning outcomes. *Human Resource Development Quarterly*, *20*(4), 397-418.

Miles, M. B., & Huberman, A. M. (1994). Qualitative data analysis: An expanded source book (2nd ed.). Newbury Park, CA: Sage.

Moore, J. L. (2006). A qualitative investigation of African American males' career trajectory in engineering: Implications for teachers, school counselors, and parents. Teachers College Record, 108(2), 246.

Myers, C. B., & Pavel, D. M. (2011). Underrepresented students in STEM: The transition from undergraduate to graduate programs. Journal of Diversity in Higher Education, 4(2), 90. National Center for Science and Engineering Statistics (2014). National Science Foundation. *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2013*. Special Report NSF 13-304. Arlington, VA. Available at http://www.nsf.gov/statistics/wmpd/2013/tables.cfm.

National Science Foundation, National Center for Science and Engineering Statistics. (201. *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2015*. Special Report NSF 15-311. Arlington, VA. Available at http://www.nsf.gov/statistics/wmpd/. Accessed December 20, 2016.

Ojala, M. (2012). Hope and climate change: The importance of hope for environmental engagement among young people. *Environmental Education Research, 18*(5), 625-642.

Oppliger, D. (2010). High School Enterprise: Introducing engineering design in a high school team environment. Kampe, Jean. Source: *ASEE Annual Conference and Exposition, Conference* Proceedings, 2010, 2010 ASEE Annual Conference and Exposition.

Palmer, R. T., Maramba, D. C., &Dancy, T. E. (2011). A qualitative investigation of factors promoting the retention and persistence of students of color in STEM. The Journal of Negro Education, 491-504.

Pavlova, M. (2009). Conceptualisation of technology education within the paradigm of sustainable development. *International Journal of Technology and Design Education, 19*(2), 109-132. doi:10.1007/s10798-008-9073-5.

Petersen, S. L., Erenrich, E. S., Levine, D. L., Vigoreaux, J., & Gile, K. (2018). Multi-institutional study of GRE scores as predictors of STEM PhD degree completion: GRE gets a low mark. PloS one, 13(10), e0206570.

Pitts, M. J., & Miller-Day, M. (2007). Upward turning points and positive rapport-development across time in researcher—participant relationships. *Qualitative Research*, 7(2), 177-201.

Polanco, R., Calderón, P., & Delgado, F. (2004). Effects of a problem-based learning program on engineering students' academic achievements in a Mexican university 1. *Innovations in Education and Teaching International*, *41*(2), 145-155.

Quinn, P. M. (2002). Qualitative research and evaluation methods. *California EU: Sage Publications Inc*.

Reyes, A. (2016). *Increasing the STEM Self Efficacy in Underrepresented Minority Middle School Resource Guide* (Doctoral dissertation, California State University, Northridge).

Riel, M. (2007). *Understanding Action Research, Center For Collaborative Action Research*. Pepperdine University. 2007. Accessed online on September 15th, 2014 from http://cadres.pepperdine.edu /ccar/define.html

Rutmann, T., & Kipper, R. (2011). Teaching strategies for direct and indirect instruction in teaching engineering. In *Interactive Collaborative Learning (ICL), 2011 14th International Conference on* (pp. 107-114). IEEE.

Saldaña, J. (2016). Ethnotheatre: Research from page to stage. Routledge.

Sapkota, A. Lu, Z., Yang, H., Wang, J. (2014). Role of renewable energy technologies in rural communities' adaptation to climate change in Nepal. *Renewable Energy, 68,* 793-800.

Sari, U., Alıcı, M., & Şen, Ö. F. (2018). The Effect of STEM Instruction on Attitude, Career Perception and Career Interest in a Problem-based Learning Environment and Student Opinions. Electronic Journal of Science Education, 22(1).

Saw, G., Chang, C. N., & Chan, H. Y. (2018). Cross-sectional and longitudinal disparities in STEM career aspirations at the intersection of gender, race/ethnicity, and socioeconomic status. Educational Researcher, 47(8), 525-531.

Schelly, C., Cross, J. E., Franzen, W., Hall, P., & Reeve, S. (2012). How to go green: Creating a conservation culture in a public high school through education, modeling, and communication. *Journal of Environmental Education, 43*(3), 143-161.

Shoffner, M. E., Newsome, D. W., Barrio Minton, C. A., & Wachter Morris, C. A. (2015). Young adolescents' outcome expectations: A qualitative study. Journal of Career Development, 42(2), 102-116. DOI: 10.1177/0894845314544033.

Siegel, M. A. (2006). High school students' decision making about sustainability. *Environmental Education Research, 12*(2), 201-215.

Singh, D (2002). The Influence of Renewable Energy Technology on the Learning of Science at Myeka High School in rural KwaZulu Natal. *Physica Scripta,* 1.

Taconis, R., Van der Plas, P., & Van der Sanden, J. (2004). The development of professional competencies by educational assistants in school-based teacher education. European Journal of Teacher Education, 27, 215-240.

The GREEN Program. (2014). Global Renewable Energy Education Network. The Story. Retrieved from http://thegreenprogram.com/#about-us-real

Toolin, R., & Watson, A. (2010). Students for sustainable energy. *Science Teacher, 77*(4), 27-31.

U.S. Census Bureau. (2014). *Urban and rural classification*. Retrieved from https://www.census.gov/geo/reference/urban-rural.html

Unfried, A., Faber, M., Stanhope, D. S., &Wiebe, E. (2015). The Development and Validation of a Measure of Student Attitudes Toward Science, Technology, Engineering, and Math (S-STEM). *Journal of Psychoeducational Assessment*, 0734282915571160.

United Nations. (2007). The united nations development agenda: Development for all. Retrieved February 12th, 2016 from http://www.un.org/esa/devagenda/UNDA1.pdf.

Urdan, T. C. (1997). Examining the relations among early adolescent students' goals and friends' orientation toward effort and achievement in school. Contemporary Educational Psychology, 22(2), 165-191.

Wampold, B. E., Wright, J. C., Williams, P. H., Millar, S. B., Koscuik, S. A., &Penberthy, D. L. (1998). A novel strategy for assessing the effects of curriculum reform on student competence. *J. Chem. Educ*, *75*(8), 986.

Walker, L. H., & Sherman, H. J. (2017). Common Core and STEM Opportunities. *The Mathematics Enthusiast*, *14*(1), 413-434.

Wampold, B. E., Wright, J. C., Williams, P. H., Millar, S. B., Koscuik, S. A., &Penberthy, D. L. (1998). A novel strategy for assessing the effects of curriculum reform on student competence. *J. Chem. Educ*, *75*(8), 986.

Wang, X. (2013). Why students choose STEM majors: Motivation, high school learning, and postsecondary context of support. *American Educational Research Journal*, *50*(5), 1081-1121.

Wang, X. (2013). Why students choose STEM majors: Motivation, high school learning, and postsecondary context of support. American Educational Research Journal, 50(5), 1081-1121.

Watson, D. (2011). "Urban, but not too urban": Unpacking teachers' desires to teach urban students. Journal of Teacher Education, 62(1), 23-34.

Weber, N. R. (2014). First-year students' environmental awareness and understanding of environmental sustainability through a life cycle assessment module. *Journal of Engineering Education, American Society of Engineering Education, 103*(1), 154-182. doi:10.1002/jee.20032

Wittig, A. (2013). Implementing Problem Based Learning through Engineers Without Boarders Student Projects. *Advances in Engineering Education, American Society for Engineering Education.*Volume 1.

Wolters, C. A. (2004). Advancing Achievement Goal Theory: Using Goal Structures and Goal Orientations to Predict Students' Motivation, Cognition, and Achievement. Journal of educational psychology, 96(2), 236.

World Energy Project. (2013). Energy for education. Retrieved from worldenergyproject.org. Accessed January 23, 2014.

World Health Organization, W. H. O. (2014). Global health observatory (GHO), urban population growth. Retrieved from http://www.who.int/gho/urban_health/situation_trends/urban_population_growth_text/en/

Yadav, A., Subedi, D., Lundeberg, M. A., & Bunting, C. F. (2011). Problem-based learning: Influence on students' learning in an electrical engineering course. *Journal of Engineering Education*, *100*(2), 253.

Yan, D. (2004). Exploration, innovation, participation, and practice: A preliminary probe of high school environmental education. *Chinese Education and Society, 37*(4), 85-91.

Yerdelen, S., Kahraman, N., & Taş, Y. (2016). Low Socioeconomic Status Students' STEM Career Interest in Relation to Gender, Grade Level, and STEM Attitude. Journal of Turkish Science Education (TUSED), 13.

Yin, R. K. (2003). Case Study Research: design and methods, Thousand Oaks, 3.

Youakim, Al Kalaani (2005). *A solar system project to promote renewable energy education* (Northern Illinois University, Technology Department) Source: ASEE Annual Conference and Exposition, Conference Proceedings, p 12857-12861, 2005.

Zimmerman, M. A., Eisman, A. B., Reischl, T. M., Morrel-Samuels, S., Stoddard, S., Miller, A. L., ... & Rupp, L. (2018). Youth Empowerment Solutions: Evaluation of an after-school program to engage middle school students in community change. Health Education & Behavior, 45(1), 20-31.