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An investigation on how operational wind turbines are used in secondary classrooms

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AN INVESTIGATION ON HOW OPERATIONAL WIND TURBINES ARE USED IN SECONDARY CLASSROOMS

An Abstract of a Thesis

Submitted

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Technology

James Smith

University of Northern Iowa

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ABSTRACT

Through a review of literature, it was found that many schools in the United States are installing operational wind turbines, but it was unclear how teachers were using them in their science, technology, engineering and mathematics (STEM) classrooms. In order to identify how these operational wind turbines were being used and to create a list of expectations for schools with operational wind turbines, this exploratory study surveyed STEM teachers from all across the United States. A stratified random sample was created using a U.S. Department of Energy database of schools with operational wind turbines. Administrators from the selected schools identified STEM teachers to complete a questionnaire. Teachers provided information about the curriculum they use to teach about wind power and energy concepts, class activities that incorporate operational wind turbines, and how they value operational wind turbines as an educational resource.

It was found that a training program for teachers in wind power and energy and operational wind turbines is a critical component to a school's plan if they expect teachers to teach about this subject. A list of activities incorporating operational wind turbines is reported in this paper as well as teachers opinions about using operational wind turbines in class. Also, a need was identified for the design of a wind turbine that is based around education and incorporates a simple, user-friendly interface and is accompanied by specific curriculum that illustrates how to teach about STEM concepts using an operational wind turbine.

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CHAPTER 1

INTRODUCTION

Due to high energy prices, uncertain resource supplies, and increased environmental concerns, wind power has emerged as a major source of energy in the Unites States' energy production. According to the American Wind Energy Association (AWEA), over the past four years, the wind industry accounted for 35% of all new electrical generation capacity, trailing only natural gas (American Wind Energy Association [AWEA], 2011).

Utility companies across the country are installing wind turbines as a result of State Renewable Portfolio Standards (RPS's). RPS's mandate utility companies to diversify their energy production portfolios by producing a specific percentage of their electricity from renewable sources by a specific date. A renewable resource is defined by the United States Department of Energy (USDOE) as an affordable energy source that can be replaced or "renewed" and does not contribute to climate change or have any major impact on the environment (U.S. Department of Energy [USDOE], 2008). Wind power will continue to develop at a fast pace because it is a renewable, affordable, efficient, and abundant resource in many parts of the United States. According to the USDOE, a national twenty percent wind scenario by 2030 is an ambitious, yet feasible goal. However, there are several challenges that must be overcome for that to happen (USDOE, 2008).

One challenge in increasing wind energy production is expanding the wind power manufacturing and service industries to a scale that would support the twenty percent by

2030 model. There is an increasing demand for technological advances in wind power manufacturing processes and advances in education and training within United States' secondary and post-secondary educational institutions.

In August 2010, the USDOE reported that while the United States has a few higher-education institutions that offer wind energy related degrees, most were two-year technical degrees. This report showed there is a need for researchers, engineers, and scientists with wind power experience and training (USDOE, 2010). Many universities across the nation are focused on either incorporating wind power concepts into existing programs or are designing new degree programs that help to prepare professionals in the wind power industry. Even with new programs being offered, there are too few students completing these programs to fill the need of the expanding energy profession.

This problem is a part of the decline of science, technology, engineering, and mathematics (STEM) related professionals for the past ten years in the United States. The number of STEM professionals is expected to continue dropping (USDOE, 2008). This shortage of STEM professionals is a direct result of insufficient college graduates from STEM programs. Part of the problem may be a lack of engaging and relevant STEM curricula in secondary schools in the United States. A recent study shows that K-12 students that have an expectation of having a science related career are three times more likely to earn a STEM degree than students without similar expectations; showing that memorable life experiences before college have strong impacts on future career plans (USDOE, 2010).

Secondary schools are focused on improving curricula by providing students with more relevant, hands-on activities that illustrate real world applications for STEM content. Many schools are starting to use wind power technology to teach about STEM concepts because it is cutting edge, relevant to technology education curriculum, and engaging for students. Andy Swapp, a technology education teacher in Milford, UT is one example of how teachers are integrating wind power into their curriculums. He led his class through wind prospecting activities. This led to the development of two operational wind turbines on the Milford School campus (Swapp, Schreuders, & Reeve, 2011, September). However, changing curriculum to involve wind power is difficult for teachers that lack the experience or technological understanding.

There are several resources made available to help teachers ease the transition into teaching wind power and energy curriculum. These include wind power and energy curriculum, educational wind project development programs, and industry and college outreach programs.

Wind power curriculum developed by Kid Wind and the National Energy Education Development Project (NEED) are valuable resources available to teachers for free on the internet. In addition, there are many suppliers that have developed wind turbine kits that students can build and experiment with. These activities serve as engaging hands-on activities that teach students about many STEM concepts.

The Wind for Schools program is another resource for students to learn about wind power issues. The USDOE's Wind Powering America initiative launched the Wind for Schools program to educate, engage, and enable communities, students, universities, and other stakeholders about how the wind industry can contribute to the United States energy production (USDOE, 2011a). This program organizes teams of professionals, community members, and college students to develop a wind turbine on several school campuses each year. Wind for Schools has installed over 70 small-scale wind turbines at secondary and post-secondary schools. College students are involved in developing the wind power project, as well as developing and implementing wind energy curricula for K-12 schools to use. Teachers and students benefit by having an operational wind turbine on their school campus, which provides them exposure to and context for STEM concepts (USDOE, 2010). Additionally, members of the community are informed about wind power issues through the development of this project.

The development of wind power and STEM curriculum is also carried out through higher education and industry outreach programs. Colleges, universities, and industry see the potential exposure and recruitment opportunities from providing meaningful opportunities to K-12 students. Many outreach programs recognize that STEM content needs to be made exciting and relevant (Kauser & Bhatia, 2011). Many of these outreach programs do this by providing K-12 schools with engaging class speakers, bringing fun and educational experiences to schools, providing relevant workshops, and facilitating equipment loan programs that provide expensive equipment for free or at low cost to schools.

More and more K-12 schools and colleges are installing wind turbines on their campuses for educational purposes or as a way to invest in a stable form of energy and become more energy independent. Wind power manufactures like Southwest

Windpower realize that there is a market for wind turbines in education. They offer school discounts on their Skystream 3.7, the same turbine used in the Wind for School program. Since school budgets are tight and energy prices keep rising, a few schools have invested in large wind turbines to save money. Federal grants and zero or low interest loans make installing a large turbine a feasible solution for reducing and stabilizing energy costs for many schools in Iowa. School turbines range in size from small wind turbines, used more for educational purposes, to the large utility scale turbines, 500 Kilowatt or larger (Galluzzo & Osterberg, 2006).

Statement of the Problem

Operational wind turbines were being installed on school campuses, but it was unclear how secondary schools could effectively use this technology to engage and teach students about wind power concepts. This study aimed to identify practical expectations for how operational wind turbines could be applied in secondary classrooms to enhance student learning and interest in science, technology, engineering and mathematics (STEM). The term practical is used to acknowledge that there are examples of exceptional wind energy curricula, but this study focuses on what the majority of schools with operational wind turbines could reasonably do.

Purpose

The practical expectations that were derived by this research added much needed information in the area of wind power and energy education, and thus has filled a gap within the wind power and energy education body of knowledge. This information is crucial for schools that have access to a wind turbine, or are designing new wind power programs, developing new educational labs, or purchasing new equipment. Also, businesses that are producing educational wind turbine kits can use this information to further market their products, to add value to their existing products, and design new products that will improve wind power education.

Statement of Need

The need for this study was based on the lack of available literature identifying how operational wind turbines could be incorporated into school curricula to enhance student learning and experiences. It has been shown that by integrating high-tech equipment into secondary STEM classrooms, student experiences are more memorable (Kreible & Salter, 2008). Memorable experiences and exposure to wind technology can have a powerful impact on students' career goals. It has been shown that students with career expectations in STEM fields are more likely to graduate with STEM degrees than students without similar expectations (USDOE, 2010). Although there are many schools that have operational turbines on-site (Galluzzo & Osterberg, 2006; USDOE, 2010) and literature identifying wind turbines as an effective piece of STEM curriculum (Swapp et al., 2011, September; USDOE, 2010), there was little information about how the majority of teachers with access to operational wind turbines were using them to teach about STEM concepts in the classroom. In addition, there was a need for identifying ways teachers could use this technology in the classroom before schools can justify a large investment such as an operational wind turbine.

Research Questions

The following are research questions answered by this study that apply to STEM teachers with access to an operational wind turbine:

1. What instructional materials do teachers use to teach about wind power and energy?
2. How satisfied are teachers with the curriculum options currently available? What improvements would they like to see?
3. How do teachers incorporate operational wind turbines into their STEM curricula?
4. Do small scale turbines (rated less than 50 kW) have comparable curricular applications to intermediate (rated between 50 and 500 kW) and large scale turbines (rated more than 500 kW)? If not, how do the three sizes of turbines differ in their curricular applications?
5. What is the relationship between teachers with prior experience and/or training in wind power and energy and their hours spent teaching about wind power and energy?
6. What value do STEM teachers place on having an operational wind turbine on site as an educational resource?
7. What is the relationship between educational value placed on operational wind turbines and time teachers have spent learning about wind power and energy concepts though training and prior experience?
8. To what extent do teachers feel that having an operational wind turbine improves student interest and engagement in STEM courses and/or wind power and energy careers?

Assumptions

The following assumptions were made during this study:

1. The survey instrument used in this study was a valid and reliable tool for gathering the information needed to answer the defined research questions.
2. Surveying STEM teachers with operational wind turbines was an appropriate research methodology that addresses the problem and purpose of this study.
3. The statistical methods were appropriate and accurate in addressing the research questions. This included meeting all statistical assumptions.
4. All schools with operational wind turbines are identified on the USDOE website (USDOE, 2010).
5. The responding sample population was equivalent and accurately reflected the total population of schools with operational wind turbines.
6. The STEM teachers working for schools that have an operational wind turbine were stakeholders in this study and provide accurate and honest feedback.
7. The results of this study are generalizable toward all schools that have sufficient wind resource.

Limitations and Delimitations

This study will be conducted in view of the following limitations:

1. The sample size was limited to the small percentage of schools in the United States that own operational wind turbines, and who are listed on USDOE's School Wind Project Locations website (USDOE, 2011d).
2. The design of this study limited responses to data useful for exploratory conclusions.

3. Data collection and analysis were limited by the questionnaire's validity and reliability and the statistical methodologies used in this study.
4. Generalizability is limited to School districts located in areas that have suitable wind speeds for wind power generation and have resources available to them to develop a wind power project.

Also, the following delimitations have been formed into this study:

1. The study only looked at STEM teachers from thirty-three schools selected through a stratified random sampling process from the population of K-12 schools owning their own operational wind turbine.
2. The subjects that provided information in this study was restricted to STEM teachers. Administrators, businesses, and other stakeholders were not looked at in this study.
3. The focus of this study was to identify practical expectations for operational wind turbines on school campuses, not to evaluate the effectiveness of curricula that includes them. This study did not make comparisons between schools using operational wind turbines within their wind power curricula and schools that do not.

Definitions of Terms

The following terms are defined to clarify their use in the context of the study:

Operational Wind Turbine: A turbine that is installed on site to the school and generating electricity. Electricity may be stored in batteries, used by facilities, or contributing to the electrical grid.

STEM: Science, Technology, Engineering, and Mathematics. For this study, STEM may be the integration of the various subject areas, or it can be any one of the four subject areas. Examples of classes classified as a STEM class within this study are physics, meteorology, geology, technology education, Project Lead the Way, Engineering by Design, career and technology education, algebra, trigonometry, calculus, etc.

Small wind turbine: Turbines that have a rated power capacity of less than 50 kilowatts (California Energy Commission, 2011).

Intermediate wind turbine: Turbines that have a rated power capacity between 50 kW and 500 kW (California Energy Commission, 2011).

Large wind turbines: Turbines that have a rated capacity above 500 kW(California Energy Commission, 2011).

School Level Administrator: Person who manages or supervises educational activities within a school building. An example of a school level administrator is a principal.

Secondary School: A school intermediate between elementary school and college. Examples include high schools, junior high schools, and middle school and may be either a public or private school.

Statement of Procedure

This study followed a survey research design that used a stratified random sample. The following is the plan of procedure that was used for this study. It includes procedural information for the sample selection, development of instrumentation, data collection, internal validity, and data analysis:

Instrumentation

This studies questionnaire (Appendix A) and cover letter (Appendix B) were developed. The researcher began this process by searching for existing instruments that could be adapted to satisfy this study's needs. The missing parts needed in this study's questionnaire were then developed by the researcher. The instrument was converted into an online questionnaire and pilot tested to improve its validity and reliability.

Sample Population Selection

The study surveyed a stratified random sample of STEM teachers that work in schools that have an operational wind turbine. To identify all the schools that have operational wind turbines, the researcher used the USDOE website which hosts a listing of all the K-12 schools in the United States that have operational wind turbines (USDOE, 2011d). This list was then stratified into three groups according to the size of their turbine. The researcher then randomly selected 11 schools from each stratified list to create a stratified random sample population of secondary school districts with operational wind turbines. The administrators from each school selected were then contacted and asked to refer a group of STEM teachers for this study. This group of STEM teachers made up the sample population for this study.

Data Collection Procedures

The researcher started to collect data by sending an email containing a cover letter and a link to the online questionnaire to each administrator selected in the sample. Administrators then forwarded on the email to each of their STEM teachers. All communications between the researcher and the participants went through the administrator in each school. This ensured confidentiality of the participants. Participants had three weeks to complete and submit the questionnaire. Two reminders were sent to participants during these three weeks to encourage participation. A final email was sent to the participants to notify them that the data collection period had ended. A letter of thanks was sent to all those who participated in the study. Further information about how to follow up with the research findings was given at that time. Data collected through the survey was downloaded, organized, and evaluated for further statistical and qualitative analysis.

Data Analysis

Once the data had been collected, it was then organized for data analysis. The researcher used Google Form which made it very simple to extract the data from the participating subjects. One advantage of using online survey software is the reduction of human error during this organization process. The quantitative data was organized into an easy to use spreadsheet. SPSS and Excel were the statistical programs used to run most statistical tests.

Qualitative data, in the form short answer and essay responses were recorded and coded according to similarities in major ideas. The researcher was able to find trends if they existed.

The following statistical methods were used to analyze the quantitative data:

1. Descriptive statistics were used to analyze the total sample population and figure a response rate.
2. The samples' individual responses for each question were analyzed using descriptive statistics. Frequencies of similar responses were given as bar charts, percentages, and in tables.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Many schools across the United States have operational wind turbines, yet it was unclear how STEM teachers in those schools were using them to enhance student learning. This research was an exploratory study that investigated how STEM teachers who have access to operational wind turbines are using them to engage and teach students about wind power concepts, and how much educational value these teachers place on having access to operational wind turbines. This chapter is a review of the literature that related to wind power and energy education at the time of this study. This literature review focused on four areas which were as follows: trends in the wind industry, STEM/wind power and energy education shortages, and studies and projects relating to secondary education and wind power and energy.

Energy education has always been of importance in both science and technology education, but it was not until the 21st century that wind power became a major energy source in the United States (International Technology Education Association [ITEA], 2007; National Research Council, 2011). As a result, there were few research articles focused on the implementation of wind power technology in secondary education. Most post-secondary articles dealing with wind power and energy education were found within the area of engineering education with few articles in the science and general education literature. Many of these articles were very technical with limited application to secondary education. Most the wind power and energy education articles were case studies of best practices or outreach successes published by post-secondary researchers.

Additionally, several government reports were used to define the current state of the wind industry and government assisted wind power and energy education programs. There was limited research available in the area of wind power and energy education. This exploratory study was valuable in providing needed research in how secondary teachers have utilized wind energy curricula.

Trends in the Wind Industry

The wind industry has been growing. Since the 1980s when Iowa became the first state to create a RPS, many state governments have been adopting RPS's to mandate public utility companies to diversify their energy portfolios with more environmentally friendly forms of energy production (Pew Center on Global Climate Change, 2007). Wind farms were being developed all across the nation to increase the amount of energy developed from renewable sources. According to the AWEA (2011), the wind industry has added more new generating capacity than any other renewable energy source, and most traditional fossil fuel energy sources as well; second only to natural gas.

In the past decade, the wind industry has seen steady growth. This has resulted in the creation of more than 80,000 jobs in the United States. According to Jeff Anthony from the AWEA, as of 2010, there are over 400 manufacturing facilities across 41 states that supply the wind industry. Due to the increase of domestic wind power manufacturing in 2011, 60% of the average turbine is supplied by companies located in the United States compared to only 25% only five years previously (Anthony, 2011). The number of wind industry jobs is expected to continue to increase as more and more wind farms are installed and new manufacturing facilities develop and established facilities grow.

In 2006, the Bush administration looked at wind energy as a way to reduce the dependence on foreign oil and to increase sustainable energy production practices in the United States. The USDOE researched if a national twenty percent wind energy scenario by the year 2030 was realistic. The USDOE concluded that it was feasible but not without overcoming several major challenges which included making dramatic changes to the utility grid to accommodate interstate electricity transmission, scaling up wind manufacturing in the United States, and improving and expanding wind energy education programs to supply a competent workforce to the wind industry (USDOE, 2008). This study showed how wind power has developed into a reliable energy source which is relatively inexpensive and competitive with other fossil fuels for energy production when all things are considered.

STEM and Wind Power and Energy Education Shortages

Within the United States, universities and K-12 schools have the responsibility to scale up its efforts to educate and prepare a competent workforce as a result of the rapidly growing wind industry. The wind industry workforce requires a wide range of specialized skills and knowledge that can only be obtained from specialty educational programs and/or on the job training (Liming & Hamilton, 2011; USDOE, 2008). The 20 Percent by 2030 report indicated a need for post-secondary institutions to develop more technical, engineering, and research programs focused on wind technology. In 2008, there were 14 programs related to wind power and energy available in the United States (USDOE). As of December 2011, there were 95 community colleges and 53 universities that offered degree programs in wind energy education and technical training showing that the number of wind energy programs has grown dramatically (USDOE, 2011b). Despite the scale-up on wind power and energy education programs, a steady decline of students pursuing STEM degrees has been a major problem for United States' educational institutions (National Science and Technology Council, 2000).

Colleges and Universities are focused on improving K-12 teaching and recruiting to fill the wind power and energy education along with other high needs STEM programs they offer. Many colleges and universities have outreach programs that aim to improve wind energy teaching practices of current K-12 teachers (Guo & Taherneyhadi, 2011; P. Higby, personal communications, January, 2012; Pecen, & Humston, 2009; Pelletier, Heymans, & Chanley, 2008; Powers et al., 2010). There is an effort to make wind energy concepts more interesting and fun for K-12 students and to help teachers become more competent to teach about this highly technical area. In addition, university and college outreach programs actively visit secondary classrooms to share information and high-tech equipment relating to STEM fields in hopes of recruiting more students into STEM careers (Fletcher, 2010; Henderson et al., 2006; P. Higby, personal communications, 2012; Kauser & Bhatia, 2011; Krieble & Salter, 2008). When speaking about Iowa State University's PhD program in Wind Energy Science, Engineering, and Policy, James McCalley, the professor leading the development of this program, stated "the key to the program is the ability to recruit highly capable domestic students to enter a PhD program"(Brennan, 2011). These studies show that colleges and universities view STEM and wind energy education as high priorities in post-secondary education. They recognize the need to increase the number of trained STEM professionals if the United States is to continue being a leader within the global economy.

In addition to colleges and universities, state governments are guiding and assisting K-12 teachers toward more effective instruction in STEM areas. In the report, "Iowa STEM Education Roadmap," the state of Iowa identifies that students are lacking STEM literacy and there is a need for improved STEM education to help prepare students for jobs in STEM related careers (Iowa Governor's STEM Advisory Council, 2011).

This idea of STEM literacy is very closely related to technological literacy. According to ITEEA, the United States and many other developed nations are dependent on technology. Yet, many citizens are ignorant about how technology works and how it has evolved. This has created a situation where the future of technological change is controlled by a minority of people that understand technology. There is a need for all United States citizens to become technologically literate if the United States is to continue to be a leader in technology innovation (ITEA, 2007; National Research Council, 2011).

The Iowa STEM Education Roadmap report outlines a strategic plan that identifies specific objectives necessary to reverse the declining academic performance of K-12 students within Iowa and the United States. These objectives include the following:

- increasing student interest in STEM fields
- increasing emphasis on STEM fields in the classroom
- improving pre-service teacher preparation programs

- educating communities in Iowa about the importance of STEM within living productive lives and developing strong economies
- improving retention of people in STEM careers
- developing a partnership with private companies
- providing all K-12 students with equal opportunities to get a quality STEM education

By implementing this strategic plan, Iowa plans to help students and communities change their perspective about STEM careers. New standards in Science, Technology and Engineering will play a large role in this new educational strategy. The state of Iowa aims to motivate teachers and students and provide them with the resources needed to understand the nature of STEM subject areas (Iowa Governor's STEM Advisory Council, 2011). In addition, the number of students pursuing careers in STEM fields will begin to increase. This includes students entering into wind power and energy programs.

Studies and Projects Relating to Wind Power and Energy

Both science and technology education subjects identify renewable energy as part of their content standards (ITEA, 2007; National Energy Education Development Project [NEED], 2012). The literature for studies and projects relating to wind power and energy is found within the fields of science, technology and engineering, and career and technological education.

The majority of articles dealing with wind power and energy education came from post-secondary institutions reporting on undergraduate and graduate student projects. Only three articles published dealt specifically with methods and content used in secondary education. Online reports developed by the United States government organizations contributed for most of the information about how operational wind turbines are being used in secondary classrooms. This next section will discuss knowledge and projects that various authors and organizations have contributed, and identify key points that relate to this study in some way. This section will start by addressing articles and reports focused only on secondary education, then both secondary education and post-secondary education, and finally post-secondary education.

Secondary Education

Andrew Swapp, a technology and engineering education teacher at Milford High School in Utah, lead a team of curriculum developers at Utah State University to publish two articles about wind energy and education. Through his research and foresight, he has identified wind technology as an important part of Technology and Engineering education. He was one of the first people to conduct and write about wind power and energy education in secondary schools.

In "Prospecting for Wind," the authors identified wind prospecting activities as an important and effective piece of any wind power and energy program. The history of wind technology, careers in wind prospecting, current wind prospecting technology, the need for future post-secondary programs in wind prospecting, the wind prospecting process, and how to teach about wind prospecting were all key concepts that were identified and described in this publication (Swapp, Schreuders, & Reeve, 2011, May).

"Wind Power: Essentials for Bringing it into the Classroom" is another article published by Swapp's team. This publication complemented "Prospecting for Wind." The author identified wind power and energy as an important component to Technology and Engineering programs due to the United States focus on diversifying its energy production efforts. This article focused on the history and evolution of the wind power industry, modern wind power technology systems and how they function, and how to teach about wind power and energy in the secondary classroom (Swapp et al., 2011, September).

The authors identified that wind power and energy concepts are highly technical and hard to understand for many people without prior experience and/or professional development training. Lack of prior experience or training in this area could be a reason why some teachers do not teach about wind power and energy. This study intended to see if there was correlation between experience and training and both how much time STEM teachers spend teaching about wind power and energy and how much teachers value their schools operational wind turbine.

"Wind Power: Essentials for Bringing it into the Classroom" provided much context and general information about the wind power industry. Also, several curriculum sources and instructional activities that teachers can use were identified. This helps secondary STEM teachers see the value of wind power and energy within K-12 STEM programs, and provides some realistic curriculum ideas for teachers to use and build on. Articles like this are needed to advance this content area within secondary schools. It will be easier for teachers without experience or training in wind power and energy to transition into this subject area if there are more resources.

A second author who has published articles relating to secondary education instructional practices in wind energy and power is Wen-Jye Shyr, a professor within the

Department of Industrial Education and Technology at the National Changua University of Education in Taiwan. Shyr has published several articles related to renewable energy education in secondary education. One of his publications deals directly with integrating wind energy laboratory experiments into a junior high classroom in Taiwan. While Shyr's research methodologies suffered from validity issues due to the use of a convenience sampling, a small sample size, and the use of statistical tests which under his circumstances had insufficient power, Shyr did provide one example of a hands-on wind power and energy related research in a secondary STEM education classroom. In addition, Shyr identified the need for more hands on activities to be used in STEM classes as a way to increase student interest in STEM fields and to develop students' STEM literacy (Shyr, 2010).

Wind power and energy curriculum developers have done a lot of work to help secondary schools teach about wind power and energy concepts. Curriculum developers have identified a need to develop and offer free teacher resources to secondary schools due to the complex and often misunderstood nature of wind power and energy and the significant economic potential behind the wind industry. According to Wind Power America, over twenty agencies have contributed to wind power and energy education by developing and providing free curriculum resources to elementary and secondary teachers (USDOE, 2011c). Two major players in this arena are KidWind Project and National Energy Education Development Project. These two wind curricula projects offer free standards based lesson plans, PowerPoint presentations, videos, design project outlines, experimentation outlines, equipment plans, and other resources that can be used by

STEM teachers and students. With all the different wind power and energy curricula out there, it would be interesting to know which ones are commonly known by STEM teachers, which ones are most used by STEM teachers, and whether or not STEM teachers think they are effective?

While the collection of wind power and energy curricula is extensive, there is a minimal curriculum that is designed to be used directly with operational wind turbines. It was worth exploring if STEM teachers were satisfied with the current wind curriculum options that they had. Also, would teachers like to see more curricula that allow students to directly use operational wind turbines in their studies about wind power and energy?

While not directly focusing on instructional methods used by STEM teachers in secondary school, "Wind Power and Iowa Schools" offered some information about schools in Iowa that have operational wind turbines. This report was developed by the Iowa Policy Project and described the efforts of ten schools in Iowa that developed wind projects as of 2006.

Galluzzo and Osterberg identified the need for schools to develop their wind power projects based on the fact that schools are continually faced with tight budgets and rising energy costs. Wind energy projects have helped schools save money, and promote energy independence and environmental responsibility. Also, the schools featured in this report indicated that the turbines added educational value. It was reported that the majority of wind turbines installed in Iowa in 2006 were intermediate to large in rated capacity.

The authors found that wind turbines and Iowa schools have proved to be a good match. Generating power from the wind has helped schools reduced their carbon footprint, provide communities and students with exposure to renewable energy sources, reduce and secure utilities costs for their future, and have provided teachers and students with opportunities to learn about wind power and energy. The development process was highlighted and it was emphasized that it's a very complicated process. For schools wanting to develop a wind turbine project, the authors found that talking with other schools that had developed their own wind project was very helpful. The most important factor in feasibility for each project was found to be the negotiations between the schools and the utility companies. Critical negations included net metering options and power purchasing rates. Cost savings was found to be the primary reason for schools to develop these ten wind turbine projects in Iowa (Galluzzo & Osterberg, 2006).

This report mentioned briefly how schools have used these turbines for educational purposes, but the explanations were very vague and short, showing a gap in educational understanding that needs further investigation. This study intended to investigate exactly how STEM teachers use operational wind turbines in their curricula. Also, some schools that had larger turbines reported little educational value of these turbines. This could have been due to teachers and students lacking access to the operational turbines, or it could be because Galluzzo and Osterberg didn't focus on educational value too much in their study. This raised a question about whether a significant difference in educational value between the different size capacities of wind turbines existed.

Both Secondary Education and Post-Secondary Education

In 2007, USDOE's Wind Powering America program launched the Wind for Schools Project. The project's three goals included:

1. engage rural K-12 students and teachers in wind energy activities
2. develop college programs that prepare college students for careers in the wind power industry
3. expose and educating rural communities to the benefits of wind energy

In a report titled "Wind for Schools: A Wind Powering America Project," a detailed description of this program was given. The program involves installing a 1.8-kW wind turbine on rural K-12 school campuses across the United States. Additionally, the program developed Wind Application Centers (WAC) at nearby State Universities. Once established, the WAC's took over the wind turbine development process for K-12 schools in their areas and provided technical assistance. Within the development process, representatives from eight different entities worked together to plan and develop each wind turbine project. These teams consisted of various professionals which included K-12 teachers and administrators, green tag marketers and sponsoring companies, local utility or electric cooperatives and many other experts that were able to add valuable information to this planning process (USDOE, 2007).

In another report titled "Wind for Schools Project Curriculum Brief," more details about how K-12 students are influenced by this program. Students are impacted when exposed to the operational wind turbine and by participating in activities designed for wind power and energy education that are fun and interesting. One important finding was that, "exposure to real-world applications can have an important impact on future career plans: a recent study shows that K-12 students with expectations for a science-related career are three time more likely to earn physical science or engineering degrees than those without similar expectations," (USDOE, 2010, p. 1).

The Wind for Schools program also had an impact on college students. College students were directly involved in the development of each wind project through their participation with the WAC. Participation in planning operational turbine projects and providing technical assistance provides post-secondary students with valuable wind power and energy experience they can use in their future careers.

According to "Wind for Schools Project Curriculum Brief," Wind for Schools supports curricula and training developed by NEED, the KidWind project (USDOE, 2010). While the aforementioned curricula are free, they do not directly involve the operational turbine. The operational wind turbine only provided a context for the lessons and activities provided by the aforementioned curricula. On the other hand, there was one activity that allowed students to work directly with the wind turbine by accessing the turbine's data acquisition technology. Students were able to recover turbine output data and other weather data for research and analysis.

The Wind for Schools Project provided strong justification for this study in identifying the operational wind turbines as a strong educational tool that motivates students to pursue wind careers. This is the only documented operational wind power application where educational value is the primary purpose. More research in this area was needed due to the fact that there was only one reported activity were students directly utilizes the operational wind turbine. This led the researcher to question if there were more opportunities for students to directly utilize operational wind turbine technology when learning about STEM concepts and how much educational value STEM teachers placed on having access to their own operational turbine. This information could be used to justify K-12 school districts investing in their own operational wind turbine. This study aimed to identify those schools that were directly using operational wind turbines and investigate how they used them. This enables all schools to maximize their schools operational wind turbine.

Post-Secondary Education

In this section of the review of literature, activities done at the post-secondary level are described. There are numerous articles relating to wind power and energy practices conducted at the post-secondary level.

Professors at University of Texas identified the need for more post-secondary wind power and energy engineering programs across the United States. These instructors developed several instructional activities for training undergraduate engineering students in wind turbine technologies and wind power integration. Lab-volt and Hampden equipment were utilized to conduct most of the learning experiments. Experiments and their level of difficulty are listed below:

1. Introduction to software/hardware	Basic
2. Fixed speed wind turbine, real power	Basic
3. Fixed speed wind turbine, reactive power	Basic
4. Turbine design, pitch control	Basic

5. Rotor resistor control, real power control — Intermediate
6. Self-excited wind turbines — Intermediate
7. Doubly-fed induction generators — Advanced

(Burnham, Campbell, Santoso, Compean, & Ramos, 2009)

This reference indicated that there was great need to expand the number of documented programs and learning activities used to train professionals in wind power and energy careers. While the activities provided in this article are post-secondary level of difficulty, some can be implemented in upper level secondary wind power and energy classes. The activities are hands on, which has been shown to be very effective for student learning and retention. However, the activities described in this article do not directly involve an operational wind turbine.

Faruk Yildiz and Keith Coogler of Sam Houston University reported on a student project that incorporated using engineering skills to design and build an educational renewable energy training unit. Students in a senior design class were challenged with a problem and worked with as a team assisted by an adviser to build a prototype and test a cost efficient, easy to build and operate, alternative energy training unit that incorporated several renewable energy sources and different electronics testing equipment. Students designed the interactive educational training units to include solar, wind, human power, passive solar air and water heating, and hydrogen fuel cell energy harvesting systems (Yildiz & Coogler, 2010).

This article indicated both the value behind student design projects and the need for more versatile training equipment to be used in renewable energy education. Yildiz and Coogler concluded that this design project was an effective project to incorporate the design process, cross curricular team cooperation, and to develop a renewable energy teaching and research training unit for students, faculty, local community colleges, secondary high/school STEM teachers, and others interested (2010).

It is common to find college students learning by problem based design projects within many engineering curricula. Wind related projects range from designing, testing, and analyzing small models of wind turbines, to designing a utility scale wind project. There are several documented cases of this happening at the post-secondary level.

Students from Frostburg State University participated in a design project where students designed and built a lab scale prototype of a wind turbine. Students used Solidworks CAD program and a rapid prototyping machine to develop multiple prototype designs. They were able to test, evaluate, and redesign their wind turbines to improve function and efficiency (Pippen & Wang, 2008).

The authors concluded that the design process had proved to be an effective learning tool for students. Further research and experimentation will take place to improve the efficiencies of these wind turbine designs and add to the wind turbine technology body of knowledge.

In 2006, two students attending University of Northern Iowa designed and built a tilt up 500 W axial flux wind turbine. In a senior design project, Praska and Al-Qassab designed, built, installed, and tested this turbine to learn more about wind power concepts. Within this article, the student documented their procedures as well as several solutions to problems that came up during the construction of this turbine. Students tested the turbine once it was functional and created a power curve to illustrate its performance. The final cost of this project was $1,419.

This design project was found to be an engaging activity for Praska and Al-Qassab. They found it challenging to overcome their lack of experience in this area and felt an indescribable sense of accomplishment once the turbine began generating electricity. The authors concluded by indicating a further need for field testing and load testing on their wind turbine. Also, they found their community to be very interested and supportive of wind technology (Pecen, Praska, & Ashraf, 2006).

Post-secondary programs are also teaching students to assess wind resource and design wind projects accordingly. In 2006, students at Arizona State University were included in a wind resource assessment projected on the Hopi reservation. Enrollment in a project based class allowed students in an engineering program at ASU to gain real world experience by conducting a wind assessment with faculty for the Hopi tribe in the mountains of Arizona. As the project moved from one phase to the next, faculty introduced concepts just in time. This was found to be a successful experience as students gained real world engineering experience, and faculty were able to teach a project oriented class while meeting ABET general program standards A-K (Henderson et al., 2006).

Students at Rowan University created the New Jersey Anemometer Loan Program. This program provided Southern New Jersey businesses access to low cost wind assessment equipment. Students specified, purchased, tested, calibrated, and installed three 20-30 meter tall anemometer towers. With this equipment, students were able to collect wind resource data and assess the feasibility of appropriate wind turbines. The article reported much interest in the anemometer loan program. There were three additional towers being purchased and a waiting list of 30 customers in 2006.

The authors concluded that there was a need for further data collection before an accurate assessment could be completed. Nonetheless, this anemometer program proved to be needed by New Jersey businesses to assess the feasibility of their wind resource. Students participating in this program had gained valuable real-world engineering experience and have met all educational objectives (Hill, Janssom, & McDevitt, 2006).

In 2005, Professors and students at the University of Northern Iowa designed and constructed a wind-hydro hybrid renewable power station. The project included six undergraduate research and design students who participated in all aspects of this design project. The project included evaluations of wind and water resource, designing an appropriate wind/hydro hybrid power station, and constructing the project. The authors concluded that this project was helpful in recruitment of students within the newly established UNI's Electrical and Information Engineering Technology Program. Enrollment had increased in past years. In addition, many people from the community had expressed interest in small scale wind energy as a result of the publicity of this project (Pecen, Fahmy, & Chalkiadakis, 2005).

Summary of the Review of Related Literature

It is evident from the literature that the wind industry is growing and will continue to grow. This trend creates a need for wind power and energy education programs to grow and develop further in both secondary and post-secondary education. Post-secondary programs have grown, but due to the increasing rate of growth of the wind industry, a higher rate of STEM literate professionals and researchers with experience in wind technologies is needed.

Studies have shown that STEM education at the secondary level needs to improve in order for the United States to remain a leader in technological innovation. There is a shortage of students entering STEM programs in the United States. Many new STEM initiatives and content standards are being developed and implemented by national and state leaders to help teachers transition into a more STEM focused, hands-on curriculum that will serve the needs of students and the United States, which is a technology-dependent country. Additionally, post-secondary institutions are assisting by providing outreach resources and training opportunities to secondary teachers.

Wind power and energy is a subject area that lends itself well to STEM curricula because it is heavy in all areas of STEM and offers a real-world connection. Many schools across the nation have or are considering installing operational wind turbines either for educational or financial reasons. Government programs and tax incentives have provided resources and support that make an operational wind turbine an affordable and reasonable option for schools and other entities that want to generate their own clean power. Additionally, many K-12 schools in the United States have adopted curricula developed by one of many wind power and energy curriculum developers.

While there are some studies that indicate that wind power and energy is starting to be taught in K-12 schools, the body of literature in this area was incomplete and had many holes. Studies relating to wind power and energy at the secondary level were few, which indicated a need for exploratory research to identify areas that needed further investigation.

CHAPTER 3

METHODOLOGY

This chapter gives a detailed, comprehensive description of the methods used during this study. Included are descriptions of the research design, population and sample, instrument, and procedures, followed by discussions of internal validity and data analysis.

Description of the Research Design

In this study, a survey research design was used. A stratified random sample of STEM teachers were surveyed via an online questionnaire. Administrators working within school districts with operational wind turbines served as research personnel by forwarding a cover letter and internet link to STEM teachers. Teachers had approximately three weeks to complete the survey online. After three weeks, the stored data was then organized and analyzed.

Description of the Population and Sample

The total population represented by this study includes all STEM teachers working for schools that have an operational wind turbine located near its school campus. Within this study, STEM teachers are any teacher that teaches science, technology, engineering, or math classes.

The USDOE manages a webpage called "School Wind Project Locations." This webpage lists all schools as of December 2011 that have developed wind turbine projects in the United States (2011d). The information given by this site includes the school, city, state, size of turbine project, and the turbines status. This information was used to generate a stratified random sample for this study.

In order to get equal representation from all three size categories of turbines, a stratified random sample was used. To do this, the aforementioned list of school wind projects was organized into three categories according to the size of the turbine project at their school; small, intermediate, and large. Using the randomization calculator available from http://www.randomizer.org/, the researcher generated a list of 11 schools for each category. The researcher then contacted the administrator for each school district and asked them to forward a cover letter and the online questionnaire link to all STEM teachers in their school. This group of STEM teachers made up the sample population for this study.

Description of Power Estimates

G*Power3, a statistical software program, was used to calculate all power estimates described in this section (University of Duesseldorf, 2012). The researcher estimated that seven STEM teachers per school would receive an invitation to complete the questionnaire. This would produce a sample population of 231. According to G*Power 3, a sample population of 231 would provide sufficient power to identify a medium effect size for all statistical tests applicable to this study. With an alpha level of .05, and a beta level of .80, it would take a minimum sample size of 159 to identify a medium effect size in an analysis of variance (ANOVA) statistics test comparing three groups. Also, with an alpha level of .05 and a beta level of .80, it would take a minimum sample size of 82 to identify a correlation between two variables. This indicates that a sample population of 231 people and a minimum response rate of 68% are sufficient to identify a medium effect size and make valid conclusions within this study.

Description of the Instrument

The instrument used in this study consists of an electronic cover letter and an online questionnaire sent to teachers via email. School administrators were sent an email that contained the cover letter and the online survey link, which they forwarded on to their STEM teachers. This kept participants anonymous, reduced research costs, was convenient for both the sample populations and the researcher, and made it possible to survey teachers from all parts of the United States in a timely manner.

The cover letter is a critical component in this research. It provided the participant with the following: information about this study and its objectives, clear justification as to why the help of the sampled population is needed, information about risk inherited through participation of this study, an informed consent disclaimer, and instructions for accessing the online questionnaire. The main objectives for the cover letter were to deter nonresponse and to provide informed consent for this study.

The instrument itself is a short online questionnaire which should take less than thirteen minutes to complete. The questionnaire is comprised of two sections, a demographical section and more content specific section. Most demographical questions were derived from proven instruments that have been used in previous studies. Other questions will be written clearly by the researcher. Survey questions included multiple choice, checkboxes, and a few open ended questions.

Once the questions were written, the researcher then converted the questionnaire into an online form using Google Forms. This software program enabled the researcher to send participants a link by which they could access the questionnaire. Google Forms also received, stored, and organized data into a spreadsheet as questionnaires were submitted by participants.

After the initial online questionnaire was created, the researcher conducted a pilot study. The cover letter and online survey link was sent to a pilot sample population. The pilot sample population consisted of secondary teachers representing science, technology, engineering, and mathematics subject areas, as well as professors within the Technology Department at the University of Northern Iowa. The sample population took the survey and provided feedback about the instrument.

The pilot study resulted in several corrections. A few basic corrections to spelling, grammar, and wording were made to improve the clarity and validity. Also, each qualitative question was studied found to produce applicable responses that were able to be coded by the researcher. Quantitative questions were reviewed and found to produce reasonable results.

The feedback collected from the pilot survey indicated that questions were clear and straight forward and directed toward a population that had access to an operational wind turbine.

Explanation of Procedures

The procedures that were completed in this study included developing and piloting the instrument, selecting the sample population, surveying the sample population, and performing a data analysis on the results. The following section will break each of those procedures down into a series of steps.

Instrumentation

This study required use of a questionnaire that was low cost and that allowed participants to access and submit conveniently. For these reasons, the questionnaire was made available online using Google Form. Below is the procedure that took place during the development of the questionnaire used in this study.

1. Searched for valid applicable ready-made questionnaires for use in this study.
2. Adapted, modified, and synthesized the instrument for use in this study.
3. Developed a cover letter that was designed to accompany the questionnaire.
4. Converted the questionnaire into a Google Form.
5. Pilot tested the questionnaire by administering it to a group of current and former colleagues.
6. Made revisions to the questionnaire based on the results and from the feedback provided by the pilot sample population.

Sample Population Selection

The following list lays out the step by step procedure used to build the sample population used in this study.

1. Stratified all K-12 school districts that own an operational wind turbine located close to their campus according to their turbine size. The USDOE website hosted list of all the K-12 schools that have operational wind turbines. This list of schools was sorted into groups according to their turbine's rated capacity (small, intermediate, and large).

2. Using randomizer.org, the researcher randomly generated a group of numbers that were used to identify 11 schools from each stratified list.

Data Collection Procedures

The procedure used to contact the administrators, forward an invitation and information to teachers, and to facilitate the data collection process will be identified in this section.

1. Identified sample populations' contact information by researching school websites, identifying appropriate administrators and phone numbers.
2. Contacted school level administrators by phone to request their school's participation in the study. While on the phone, the researcher discussed with the administrator the research project objectives and justification, and procedures.
3. If unable to reach administrator by phone, follow-up emails were sent explaining this study's objectives and inviting administrators to participate.
4. Soon after either phone or email communications with school administrators, the cover letter and online questionnaire link were sent via email.
5. Administrators forwarded the email onto all STEM teachers at their earliest convenience. Administrators identified the number of invited teachers via an email to the researcher. This provided the researcher with a verification of principals' participation and an accurate count for the sample population given access to the questionnaire.

6. Participants had three weeks to complete the questionnaire via the internet. Two reminders were sent on day seven and 14 to encourage participation and reduce nonresponse during those three weeks.
7. A final email was sent to administrators, which was then forwarded onto the participants to notify participants that the data collection period has ended. A letter of thanks was sent to all those who participated in the study. Further information about how to access the researcher's website followed.
8. Data collected by the online survey was then downloaded, organized, and evaluated for further statistical and qualitative analysis.

Threats to Internal Validity

This study was not without threats to internal validity. The main threats to internal validity in survey research are mortality, location, instrumentation, and instrumentation decay (Fraenkel, Wallen, & Hyun, 2012). Measures used to control these threats are identified below.

Mortality threats were present in this study. The mortality threats were limited to non-response because this study only requires participants to provide feedback once. Nonresponses are participants that failed to return a questionnaire for any reason. Even though sample selection is random, nonresponse is not random. This means that a high rate of nonresponse is detrimental to the generalizability of a study. According to Fraenkel et al. (2012) attempting to minimize the loss of subjects is the best way to reduce the mortality threat in survey research. The researcher identified the following measures which, through research, have shown to increase the response rate in survey research (Porter, 2004).

1. Have school administrators disperse the questionnaires to the participants. This increased the likelihood that participants read the cover letter. Also, this allowed the participants to see the administrators endorse this study and provided an opportunity for participants to identify a greater stake in the study.
2. Clearly communicating the importance of the study and marketing it toward participants allowed the sample population to identify the significance of the study.
3. Restricting the length of the questionnaire to approximately ten minutes, keeping the format of the questionnaire simple and easy to read, implementing online survey technology, and clearly communicating how subjects were to participate. These methods show that the researcher was focused on convenience for the participants.
4. This study incorporated multiple contacts as a means of increasing response rates. Providing three emails asking subjects to participate in the study was an effective technique used to increase the response rate in this study.
5. Within the cover letter, the researcher specifically asked subjects for their help.

Internal Validity was also threatened by locational constrains. Using an online questionnaire allowed subjects to take the survey in a location that was convenient for them. This threatens internal validity because the location cannot be standardized.

Instrumentation threats are reduced by using an online questionnaire. The online survey tool administered the questionnaire consistently for each subject. This controlled the threats associated with data collection.

This study was subject to threats due to instrument fatigue. These threats were controlled by using an online questionnaire to collect and organize the data as they were completed and submitted. Also, the researcher reduced the time and complexity of scoring by limiting the number of open ended questions.

Explanation of Data Analysis

Once the data had been collected, it was then organized for data analysis. The online survey software automatically stored and organized data submitted by the participating subjects into a spreadsheet. The researcher used SPSS and Excel statistical software programs to create visual representations of the data and to run further statistical tests. The following section will explain the procedures and statistical methods that were used to analyze the data collected in this study, and identifies how each research question was answered.

Response Rate

Mortality was the biggest threat to this study's validity. A high response rate is an indicator of a low mortality threat. According to Porter (2004) a low response rate will result in biased data, and any conclusions drawn from biased results may be erroneous. Figuring the response rate is a simple statistic calculated by dividing the number of participants that submitted questionnaires by the total sample population. While there is no standard for response rates, it is an important statistic that will need to be reported in the researcher's conclusions.

Research Question 1

Research question 1 stated "what instructional materials do teachers use to teach about wind power and energy?" Two questions from the questionnaire were used to answer this research question. They were as follows:

1. Have you used or plan to use any of the following curricula or programs to teach about wind power and energy concepts?
2. What specific wind power and energy instructional materials have you created that your students will see or use?

The first question was answered with categorical responses which were used to create a frequency bar graph and distribution statistics. The second is a qualitative question that was scored by coding responses. Responses were grouped into common themes and organized into a frequency bar chart. Between the two questionnaire items, a list of all used instructional materials was derived.

Research Question 2

Research question 2 stated "how satisfied are teachers with the curriculum options currently available? What improvements would they like to see?" Two questionnaire items were used to answer this research question. They were as follows:

1. How satisfied are you with the wind power and energy curricula currently available?
2. What improvements to wind power and energy curricula would you like to see?

The first question probed participants to respond using a six point Likert scale. Responses were organized into a table used to illustrate how teachers feel about the current curricula options in order to better identify trends.

The second question is a quantitative question that required coding to score. This question was used to identify future recommendations for curriculum development. The data from this question was coded and grouped into common themes.

Research Question 3

Research question 3 stated "how do teachers incorporate operational wind turbines into their STEM curricula?" There are three questionnaire items that addressed this question. They were as follows:

1. As a part of your class(es), how often do students directly interact with your school's operational wind turbine or any of its byproducts?
2. As a part of your class(es), how do students use your school's operational wind turbine or any of its byproducts to learn about STEM concepts?
3. As a part of your class(es), what STEM concepts are taught or reinforced through your students' interaction with your schools' operational wind turbine?

For the first question, a pie chart was used to organize the data. The second and third items are qualitative questions that required coding. The responses were analyzed and grouped into common themes.

Research Question 4

Research question 4 stated "do small scale turbines (rated less than 50 kW) have comparable curricular applications to intermediate (rated between 50 and 500 kW) and large scale turbines (rated more than 500 kW)? If not, how do the three sizes of turbines differ in their curricular applications?" Two questionnaire items were required to answer this research question. They were as follows:

1. What size wind turbine does your school have?
2. As a part of your class(es), how do students use your school's operational wind turbine or any of its byproducts to learn about STEM concepts?

To answer this question, an analysis of variance (ANOVA) test was conducted. In this ANOVA, the factor groups were the three size classes for turbines, and the dependent variable was the number of ways or curricular applications in which students directly interacted with a schools wind turbine. The ANOVA identified if there was a difference in mean scores of curricular applications between any of the three groups of turbines. The null hypothesis for this test was *there are no statistical differences between the number of curricular application between small, intermediate, and large operational turbines.* If there was a significant difference between any one of the three groups of turbines, then Tukey's HSD post hoc multiple comparisons test with a .05 alpha level could be used to determine which groupings were significantly different (Howell, 2010).

The second part of this research question could have been answered by identifying trends between the three classes of turbines in how students directly interact with their school's operational wind turbine or any of its byproducts.

Research Question 5

Research Question 5 stated "what is the relationship between teachers with prior experience and/or training in wind power and energy and their hours spent teaching about wind power and energy?" This research question required two questionnaire items to answer completely. They were as follows:

1. Approximately how many hours do your students spend learning about wind power and energy concepts in your classroom throughout the courses you teach?
2. Approximately how much time have you spent learning about wind power and energy content through training/experiences?

Pearson's product-moment coefficient with a 95% confidence interval was used to determine a correlation coefficient (Howell, 2010). The two variables involved in this correlation test were (1) how many hours students spend learning in class about wind power and energy concepts and (2) how many hours of wind power and energy training and/or experience teachers have. A Pearson's r value approaching one would indicate a strong relationship between these two variables. A scatterplot was also used to show if a linear trend was present.

<u>Research Question 6</u>

Research question 6 stated "what value do STEM teachers place on having an operational wind turbine on site as an educational resource?" One question from the questionnaire was used to answer this research question. It was as follows:

1. How valuable is your school's operational wind turbine as an educational resource in your class(es)?

This question probed participants to respond using a ten point rating scale. Responses were organized into a frequency histogram. Positive or negative skewness indicated how teachers as a whole value operational wind turbines as an educational resource.

Research Question 7

Research question 7 stated "what is the relationship between educational value placed on operational wind turbines and time teachers have spent learning about wind power and energy concepts though training and prior experience?" This question required two questions from the questionnaire to answer. They were as follows:

1. How valuable is your school's operational wind turbine as an educational resource in your class(es)?
2. Approximately how many hours have you spent learning about wind power and energy content through training/experiences?

Pearson's product-moment coefficient with a 95% confidence interval was used to determine if there was a relationship between the following two variables (Howell, 2010). The variables are (1) how much educational value teachers place on operational wind turbines and (2) how much time teachers have spent learning about wind power and energy content through training/experiences. An r value approaching one indicated a strong relationship. Also, a scatterplot was created to illustrate the relationship between these two variables.

Research Question 8

Research question 8 stated "to what extent do teachers feel that having an operational wind turbine improves student interest and engagement in STEM courses and/or wind power and energy careers?" Data from one questionnaire item was used to answer this research question. It was as follows:

1. To what degree do you personally agree or disagree with the following statement: I believe that having an operational wind turbine improves student interest and engagement in my class?

To answer research question 8, data was collected using a six point Likert scale and organized into a frequency bar graph. A mean score indicated to what extent teachers, as a whole, felt operational wind turbines improve student interest and engagement.

CHAPTER 4

RESULTS

The results from this study will be reported in this chapter. The report begins with a description of the sample population response rate, followed by a description of the data collected by this survey. This includes the following: demographics of participants, a description of how operational wind turbines are used in secondary classrooms, and final comments made by participants regarding wind power and energy.

Sample Population Response Rate

As noted in Chapter 3, the schools invited to participate were selected using a stratified random sampling process. An administrator from each of these schools was initially contacted via telephone. If an administrator was not reached, an email was sent inviting them to participate in the study. If no response was given by the administrator after three days, and third contact was made via an email message. Of the 33 school administrators that were initially invited to participate, 24 were willing to participate.

Administrators that failed to respond to the prior three contacts were dropped from the study. To reach this study's target of 33 participating schools, 11 additional schools were randomly selected to join the study; nine schools with small sized turbines, and two with intermediate sized turbines. Of the second group of schools invited to participate, five of the 11 administrators agreed to participate. Table 1 illustrates school administrators' participation for each stratified grouping. The total number of school administrators that were willing to participate in this study was 30.

Table 1

School Participation by Stratified Grouping

	Group 1 Schools		Group 2 Schools		Total Participation
Turbine Class	Participated	Non-Participative	Participated	Non-Participative	
Small (< 49 kW)	6	5	5	4	11
Intermediate (50-500 kW)	9	2	0	2	9
Large (> 500 kW)	10	1	0	0	10
Total Number of Participating Schools					30

Schools with smaller wind turbines were not as likely to participate for some reason or another. This is a trend that was observed in both the first and second groups of schools that were invited to participate. Just less than 50% were non-participative in both situations. The reason for this was not apparent to the researcher, but it merits further investigation. The researcher speculates that this response rate either has a direct relationship with schools participating in Wind for Schools or schools that through their own efforts have developed their own wind project.

The researcher divided the data collection process into two groups because there was a need to invite a second group of schools. The first group consisted of the initial schools that were quick to respond, and the second group consisted of the group of schools that were either late to respond or that were later added. Both groups had approximately three weeks to complete the survey despite being divided into two groups. During the three weeks of data collection both groups received the same reminders which followed a similar schedule.

The total number of teachers invited by the 30 participating administrators was 292 teachers; these teachers are considered this studies sample population. A total of 70 questionnaires were returned by the end of the data collection window. The response rate was 24%. This very low response rate is very normal. It has been shown that response rate trends for survey research have declined since the 1960's (Porter, 2004).

Demographics of the Participants and Schools

In this section, a description of the population that completed the questionnaire is given. This description will include the following variables: gender and race, age, teaching experience, highest educational attainment, content area specialty and grade level, school-size representation, and training or experience in wind power and energy. It should be noted that from this point, the term teachers will refer to those teachers that participated in this study.

Gender and Race

Teachers were asked to provide their gender and race by selecting the option that best described them. One hundred percent of the teachers provided their gender and race. The results from the gender and race portion of the questionnaire indicate that the majority of teachers were white males. Sixty nine percent of teachers were male, 31% were female. Of the 70 teachers, 97% were white, 1% was black, African-American, or negro, and 1% was Asian.

Age

Teachers were asked to select the range of ages which described them. One hundred percent of teachers responded to this question. The results indicate a very wide spread. Figure 1 illustrates the breakdown of teachers' ages. The smallest group was teachers 60 or more years old. Next were teachers that were 20 - 29 years old.

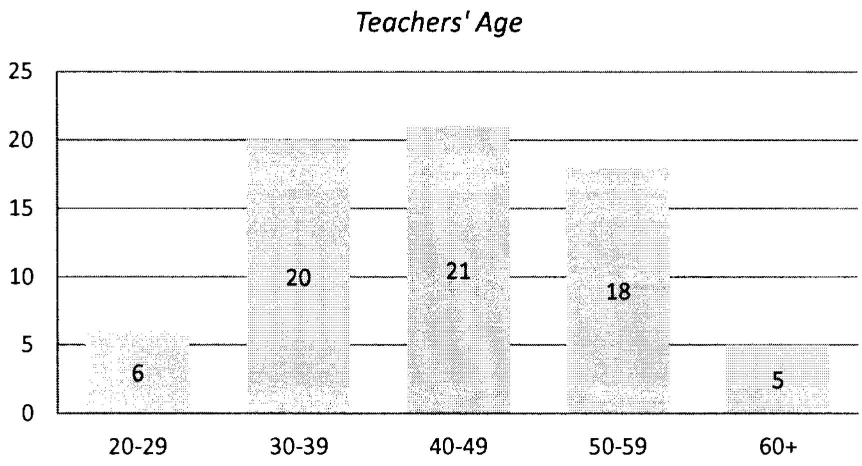

Figure 1. Age of teachers. This figure illustrates the number of teachers in each age range where the y-axis is the number of teachers and x-axis is age-range in years.

Teaching Experience

Teachers were asked to select the range of years that best described their teaching experience. The response rate for this data was 100%. The results indicate that majority of teachers participating in this study had more than ten years of teaching experience. Figure 2 shows the results from this question. The largest group of teachers taking this survey was teachers with more than 20 years of experience.

Highest Educational Attainment

Teachers were asked to select an option that best described their highest educational attainment. One hundred percent of teachers answered this question. Table 2 shows the different educational attainment options they had and the results from the question.

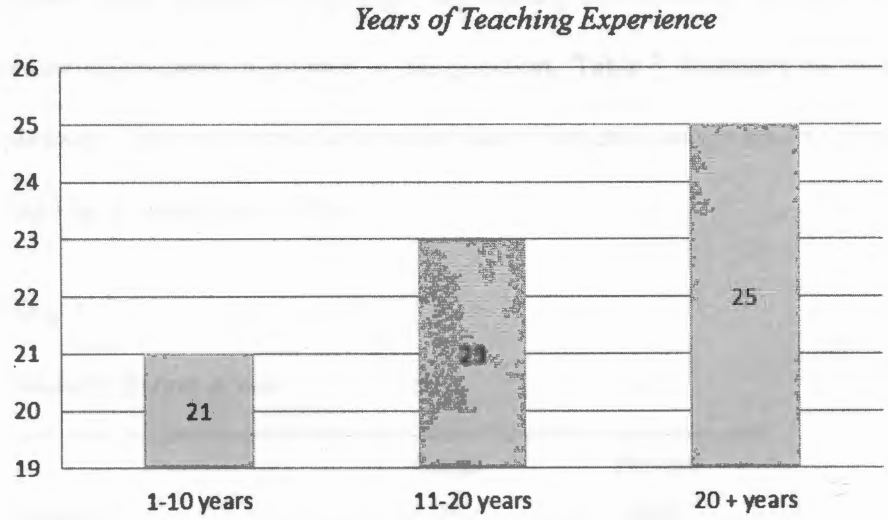

Figure 2. Years of teaching experience. This figure illustrates the number of years teachers have taught in any school. The y-axis is the count of teachers and the x-axis is the experience in range of years.

Table 2

Highest Educational Attainment

Highest Educational Attainment	Count	Percent
Bachelor's Degree	6	9%
Bachelor's + additional credits hrs	13	19%
Master's Degree	14	20%
Master's + additional credit hrs	35	50%
Other		

Content Area Specialty and Grade Level

Teachers were asked to classify themselves in one or more of the following content areas; science, technology, engineering, mathematics, or other. One hundred percent of teachers responded to this question. Table 3 illustrates the results from this question. Teachers were able to select more than one content area so percentages in Table 3 add up to more than 100%.

Table 3

Teacher Content Areas

	Count	Percent
Science	35	50%
Mathematics	22	31%
Technology	11	16%
Engineering	2	3%
Other	5	7%

Note: Teachers may select more than one, so percentages may add up to more than 100%

Teachers were asked to specify the grade level they taught. Both middle school and high school grade levels were represented in the survey with the majority being high school teachers.

School-size Representation

Teachers were asked to identify their school district, to select the best description of town's size in population that their school is located, and to state their school districts student enrollment.

The results identified that 29 different schools were represented in this study. The response rate for this data was 99%. The names of the school districts are withheld here for confidentiality reasons.

Table 4

Teacher Grade Level

	Count	Percent
Middle School	19	27%
High School	61	87%

Note: Teachers may select more than one, so percentages may add up to more than 100%

Figure 3 illustrates that about 50% of the teachers that took this survey work at schools located in towns with populations less than 5000 people. The response rate for this data was 100%.

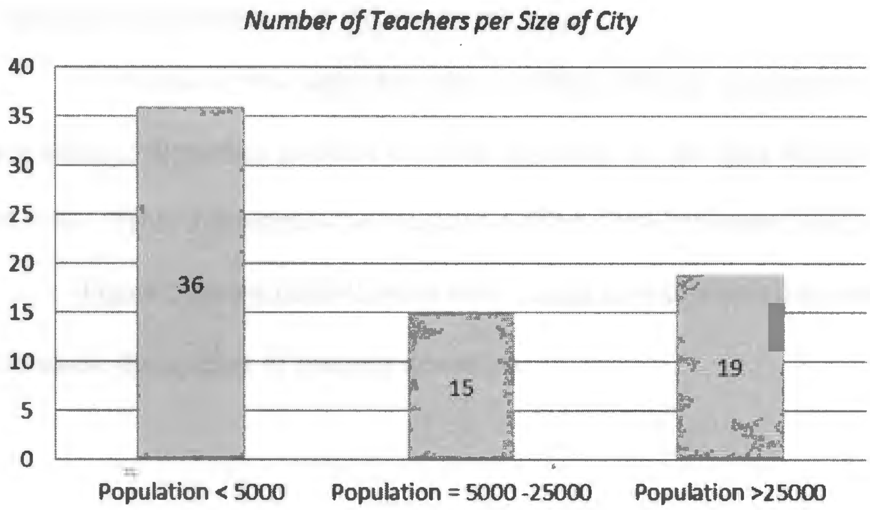

Figure 3. Number of teachers per size of city. This graph shows the count of teachers working at schools located in small, medium, and large cities. The y-axis is the number of teachers and each bar represents the size of city based on population (x-axis).

Figure 4 illustrates similar results based on school enrollment rather than population. The response rate for this data was 96%.

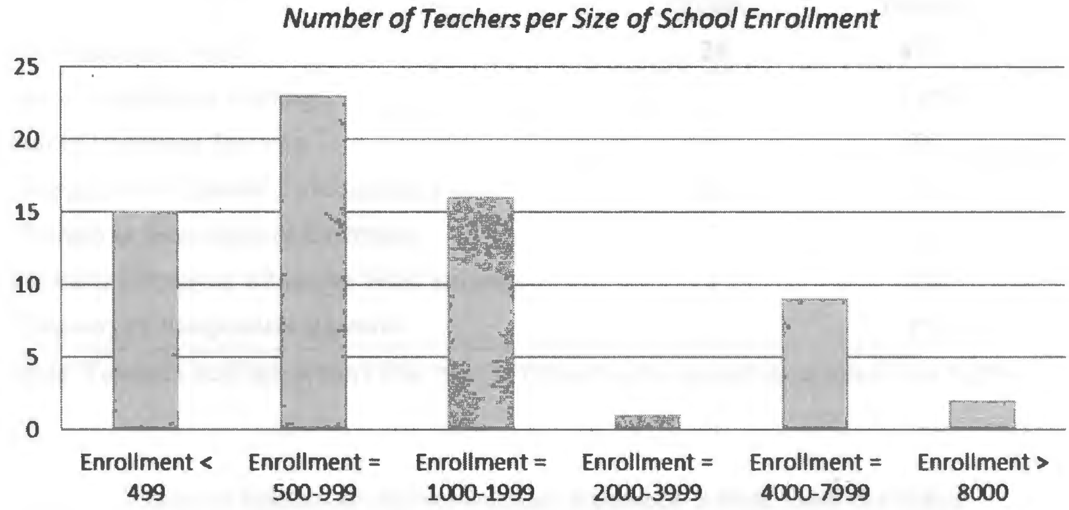

Figure 4. Number of teachers per size of school enrollment. This graph illustrates the number of teachers (y-axis) working in each of 6 size ranges of schools based on student enrollment (x-axis)

<u>Training or Experience in Wind Power and Energy</u>

Each teacher was asked how they received training or experience in wind power and energy. Sixty four teachers provided responses for this data which is a response rate of 91%. Table 5 illustrates the breakdown of how teachers responded to this question.

Figure 5 shows the following trend: as the time of training/experience of a teacher increases, the number of teachers decreases.

Table 5

How Teachers Received Training/Experience in Wind Power and Energy

	Count	Percent
No Training in Wind	28	42%
Part of Pre-service Training	7	11%
Part of In-service Training	6	9%
Through a Professional Development Class	18	27%
Through an Internship, or Externship	1	2%
Formerly Employed within the Wind Industry	1	2%
Voluntary or Independent Research	5	8%

Note: Teachers may select more than one, so percentages may add up to more than 100%

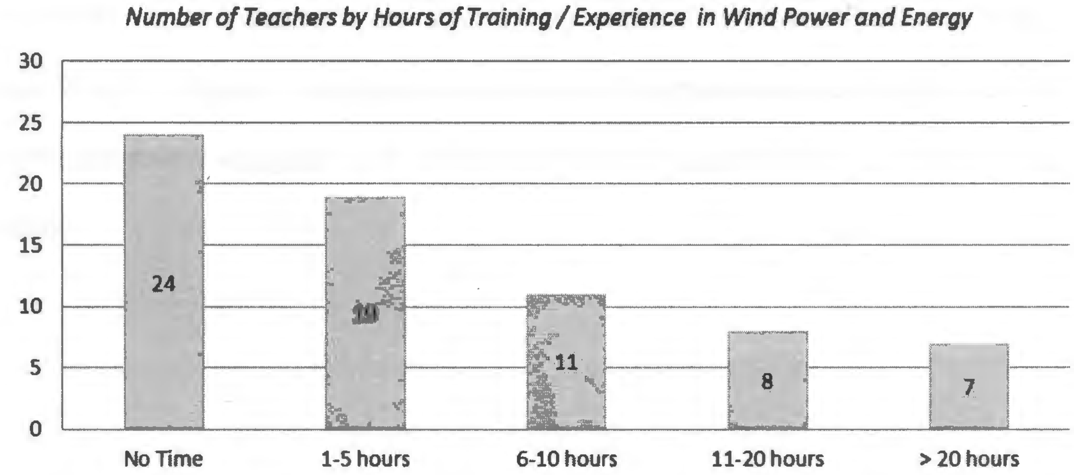

Figure 5. Number of teachers by hours of training/experience in wind power and energy. This graph groups teachers together with a similar training/experience time in hours (x-axis) and compares the total number of teachers (y-axis) for each group.

How Operational Wind Turbines are Used in Secondary Classrooms

In this section, results from the second part of this study's questionnaire will be reported. This section includes data needed to answer this study's research questions. These results will be organized in sequential order according to their order on the questionnaire.

Curriculum and Instructional Programs Used

Teachers were presented with a list of wind power and energy curricula, instructional materials, and other educational programs and were asked to identify if they had used or plan on using any of the resources listed. The response rate for this question was 70%. Figure 6 illustrates how teachers responded which shows NEED, KidWind, and Wind for Schools as the leaders in wind related curricula resources. Only one other curricular source was given aside from those listed in Figure 6. That was Alliant Energy Kids.

Frequency of Teachers using Wind Related Curricula

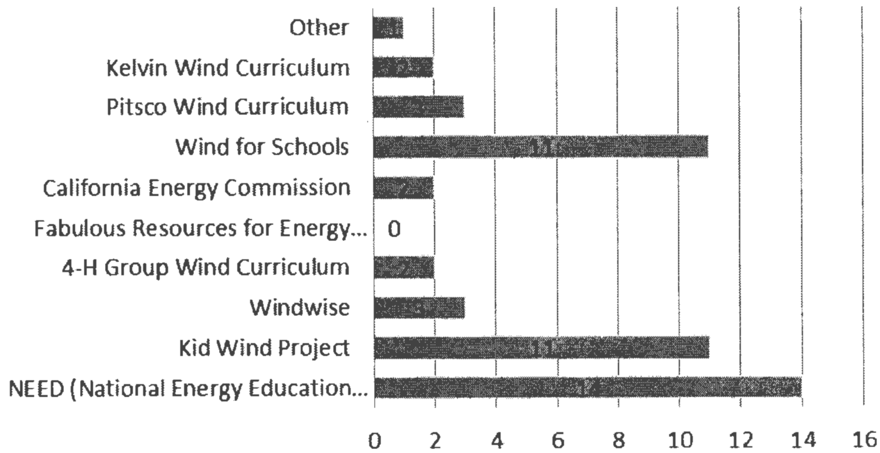

Figure 6. Frequency of teachers using wind related curricula. This graph illustrates how many teachers use the various sources of wind curricula.

Wind Curricula Developed by Teachers

In addition to curriculum and programs acquired from third party programs and curriculum developers, another question on the questionnaire asks teachers to identify all wind related instructional materials that they have created. Twenty nine percent of teachers provided specific data about instructional materials that they created. This was an open ended question, so the researcher coded and grouped similar responses together. Table 6 illustrates the results of the coding process.

Table 6

Wind Related Curriculum Developed by Teachers

Frequency	Description of curricular material
8	Activity incorporating data analysis of operational wind turbine; includes correlation between weather data and electricity generation and graphing activities
5	Unit/Lessons on wind power and energy
5	Developed wind related digital resources such as online instructions, online diagrams, flash-player animations, interactive notebooks, slideshows, web-quests
4	Design project where students designed, built, and tested efficient wind turbine blades
3	Field trip tour of on campus wind turbine, observations
3	Presentation briefing students on wind turbine technology
2	Discussions/Activities relating to Greenhouse gas savings as a result of renewable energy production
1	Presentation on wind turbine failures which leads into discussions about why they failed
1	Activities related to Units of energy: kW/H, btu, calories, etc.
1	Unit/Lesson on electromagnetism
1	Activity: Erecting a meteorological tower
1	Activity: Site selection
1	Lessons about Commercial construction and maintenance
1	Lessons about non-destructive wind turbine testing
1	Activity comparing wind and solar technology's efficiency
1	Design project: designed and constructed a wind turbine cake

Hours in Class Student Spend Learning about Wind Power and Energy

Teachers were asked to estimate the total time in hours that students spent learning about wind power and energy concepts. Figure 7 illustrates the results of this question.

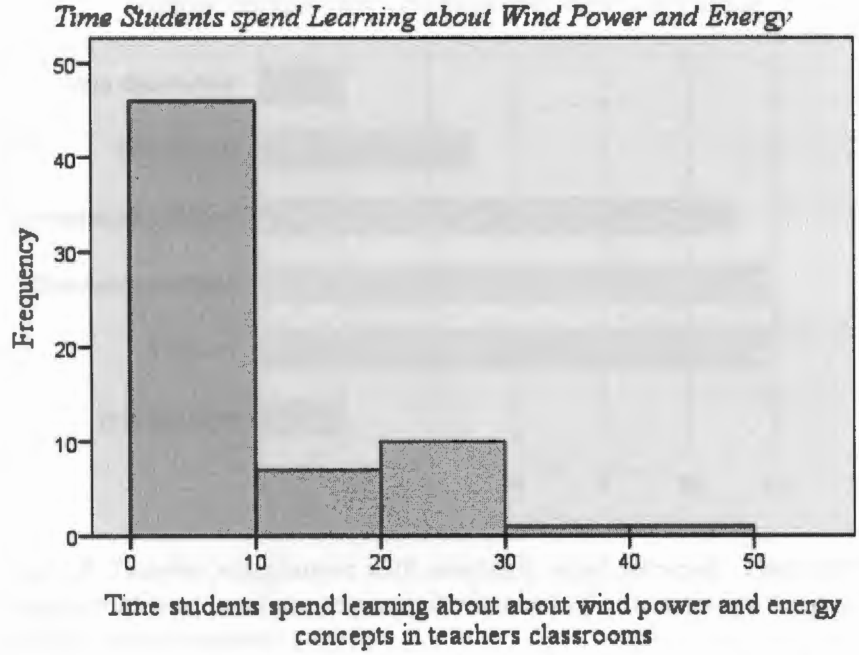

Figure 7. Time students spend learning about wind power and energy. This chart illustrates how teachers responded to the question "how many hours do students in your class spend learning about wind power and energy concepts."

Teachers' Satisfaction of Available Curriculum

Teachers were asked to indicate their satisfaction level for curriculum options currently available using a six point Likert scale. The response rate for this question was 62%. Figure 8 illustrates the results for this question. The responses were coded with one being very dissatisfied and six being very satisfied. Descriptive statistics showed a mean score of 3.25, which falls between somewhat satisfied and somewhat dissatisfied.

Teacher Satisfaction with Available Wind Curriculia

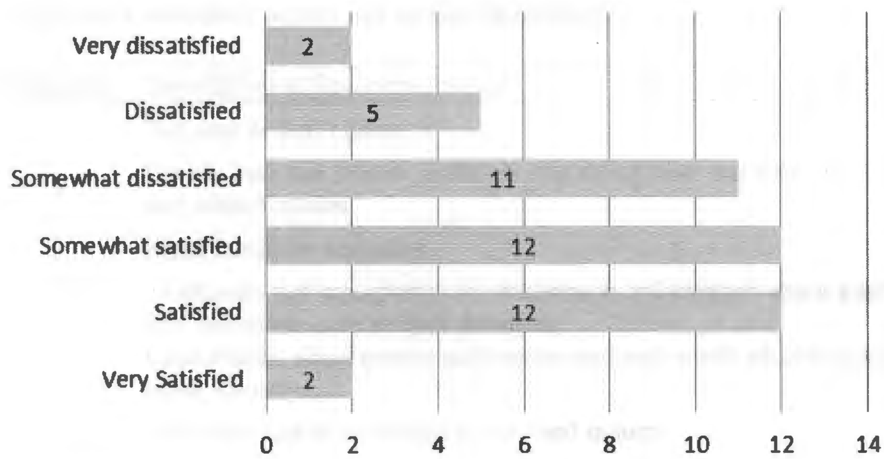

Figure 8. Teacher satisfaction with available wind curricula. This chart shows the frequency of how teachers responded when asked how satisfied they were with the available wind curricula.

Desired Wind Curricula and Resources According to Teachers

Another question in the survey asked what improvement to the available wind power and energy curriculum teachers would like to see. The researcher coded the results in order to identify trends. Forty one percent of teachers responded to this question. Of those 29 teachers, 11 responded don't know or unsure and 18 responded with at least one specific recommendation they would like to see available. Table 7 summarizes the teachers' recommendations.

Table 7

Curriculum Teachers would like to see Developed

Frequency	Description of Recommendation
11	Not sure or don't know
3	Usable data and teacher materials explaining how real-time wind data can be used, and what it means
3	More hands-on activities
3	Textbooks that incorporate comprehensive information about alternative energies and that meets core subject standards
2	Case studies about people and careers and real-world situations associated with the wind industry
1	Activities linked to careers in the wind industry
1	Low cost wind power and energy simulation software
1	Larger variety of classroom competitions
1	A program that gives school wide presentations about wind energy
1	More curricula about productivity of the wind industry and social issues related to the wind industry
1	A comprehensive Alternative Energy Curriculum that compares and contrasts the various types of alternative energies
1	More differentiation between small wind and utility scale wind applications
1	A network developed that allows STEM teachers to collaborate, share curriculum, and discuss issues related to wind power and energy.
1	Database of live wind turbine statistics from around the country that allows students to share data and contribute to a real-time wind map
1	Develop turbines at more schools
1	Better websites

Frequency Students Use Operational Wind Turbine

Within the questionnaire, teachers were asked how often their students directly interacted with their school's operational wind turbine or any of its byproducts. Ninety nine percent of teachers responded to this question. Figure 9 illustrates the breakdown of the teachers' responses and that the majority of teachers surveyed, approximately 52%, do not interact at all with operational wind turbines within their classes.

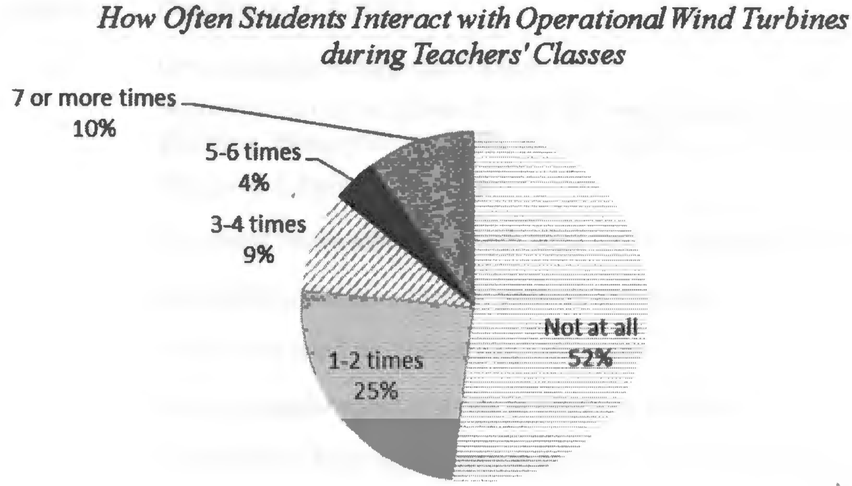

Figure 9. How often students interact with operational wind turbines during teachers' classes. This pie chart illustrates the percentage of teachers that responded according to the key when asked how often their students use operational wind turbines or any of its byproducts.

<u>Activities that Allow Students to Use Operational Wind Turbines</u>

Also, teachers were asked how students use their school's operational wind turbine or any of its byproducts to learn about STEM concepts. This was an open ended question. Responses that were provided were coded and analyzed for trends. Fifty one percent of teachers responded to this question. However, of the 36 teachers that responded, only 13 provided specific information about how their students use an operational wind turbine. The rest responded not at all, none, or don't know. Table 8 illustrates the results of the 13 teachers that responded.

Table 8

How Students Use Operational Wind Turbines in the Classroom

Frequency	Description of Activity
23	Do not use the turbine, don't know
9	Worked with data acquired through the wind turbine's software which includes graphing, interpretation of data, fit to a regression curve, averaged datasets
2	Observed it during a field trip
2	Discussed issues associated with wind turbine including energy transfer
2	Studied how turbines operate: controls and outputs
1	Studied the wind turbines ecological impacts
1	Studied angular speed and rate in electrical systems
1	Study how turbine can be used as an alternative energy source
1	Use power-curve data from manufacture and historical wind data to project payback period from a large wind turbine
1	Calculated income generated by turbine
1	Calculated greenhouse gas savings
1	Converted units of energy to different forms
1	Used in calculations to determine the amount of energy needed to create a net-0 electrical waste.
1	Studied the electrical grid and how the turbine is connected
1	Troubleshoot problems that arise with the wind turbine
1	Brainstorm and try to solve problems associated with the turbine
1	Redesign parts that fail on our turbine and contact the manufacturer
1	Use energy to run greenhouse fans and lights
1	Use historical data to test accuracy of a computer model that predicts the output of a small turbine
1	Study the engineering behind a wind turbine structure

Concepts Reinforced by Activities Incorporating Operational Wind Turbines

Teachers were also asked what STEM concepts are taught or reinforced through students' interactions with the wind turbine. 19% of teachers responded by providing the science, technology, engineering, and math concepts that were reinforced by student activities that incorporated the operational wind turbine. Table 9 provides a comprehensive listing of STEM concepts that teachers were able to reinforce using an operational wind turbine.

Table 9

Concepts Reinforced Through Student Activities Involving Wind Turbine

Graphing	Power-curve
Data interpretation	Technological impacts on society
Averaging	Technological impacts on the environment
Wind speed to power ratios	Sustainability
Regression and prediction	Efficiency
Angular velocity	Application of technology: energy and power system
Conversion of units of power/energy	Systems : inputs and outputs
Power	Design process
Energy	Electricity
Thrust and Drag	Generators
Energy conversion	Economics
Alternative energy forms	

Number of Student Activities that Incorporate Operational Wind Turbines

Using the data from the previous question, the researcher was able to determine the number of student activities that incorporated an operational wind turbine given by each teacher. Figure 10 illustrates the frequency of teachers according to the number of curricular applications given.

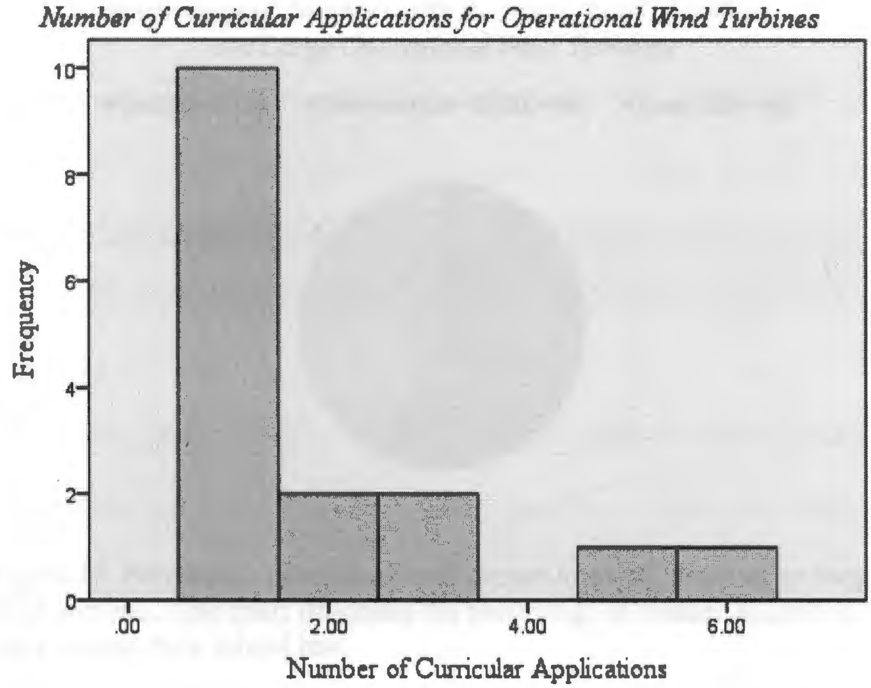

Figure 10. Number of curricular applications for operational wind turbines. This chart illustrates the frequency of teachers according to the number of ways their students use operational wind turbines or any of its byproducts to learn about STEM concepts."

Sizes of School Wind Turbines

One item on the questionnaire asked teachers to identify the size of wind turbine located on their school campus. The response rate for this question was 98%. The researcher found it surprising that 51% of the teachers responded "don't know." One of this study's research questions requires this information, so the researcher used the school's name identified by each teacher to look up the turbine size information from the USDOE's webpage (USDOE, 2011d). Figure 11 illustrates the percentages of teachers in each size classification. Table 10 is a cross tabulation of size of turbine and number of student activities involving the operational wind turbine according to teachers.

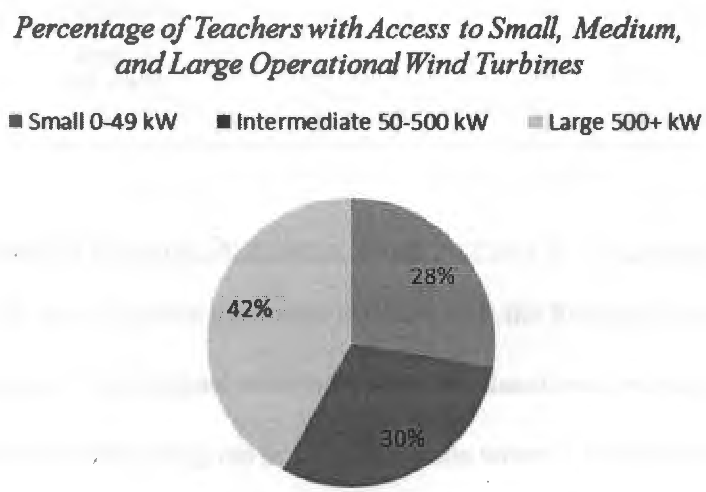

Figure 11. Percentage of teachers with access to small, medium, or large operational wind turbines. This chart illustrates the percentage of teacher according to the size of wind turbine their school has.

Table 10

Crosstabulation: Turbine Size and Number of Wind Turbine Curricular Applications

		Number of Curricular Applications					Total
		1	2	3	5	6	
Turbine Size	Small 0-49 kW	4	1	1	0	1	7
	Medium 50-500 kW	3	0	0	0	0	3
	Large 500 + kW	3	1	1	1	0	6
Total		10	2	2	1	1	16

Value Teachers Place on Operational Wind Turbines as Educational Resources

The questionnaire prompted teachers with the following question: How valuable is your schools' operational wind turbine as an educational resource in your classes? Teachers responded using ten point rating scale where 1 = no educational value and 10 = high educational value. The response rate was 93%. Figure 12 illustrates how teachers responded.

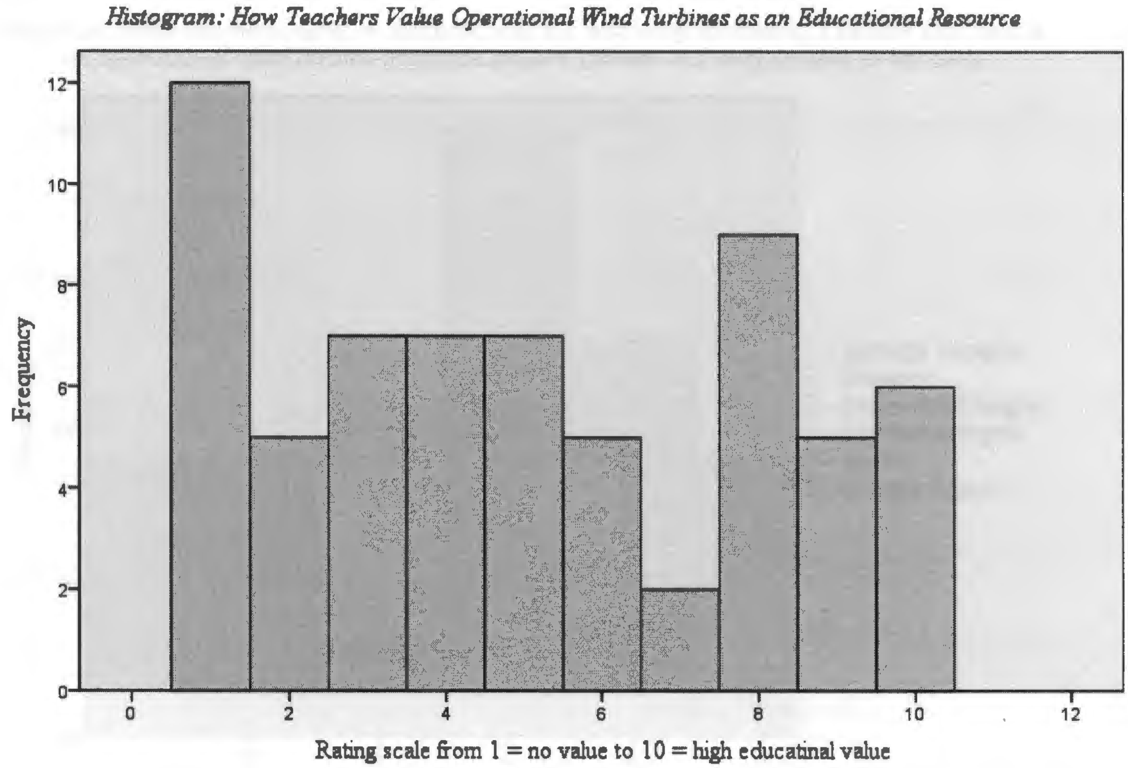

Figure 12. How teachers value operational wind turbines as an educational resourse. Figure 12 illustrates the frequencies of teachers communicating their value judgement using a rating scale 1-10 where 1 = no educational value and 10 = high educational value.

<u>Extent Teachers feel Operational Wind Turbines Improve Student Interest and Engagement</u>

Teachers were asked "what degree do you personally agree or disagree with the following statement: I believe that having an operational wind turbine improves student interest and engagement in my class." Ninety percent of teachers responded. Teachers were able to respond using a six point Likert scale. The results for this question are illustrated in Figure 13.

Degree to which teachers agree or disagree with the following statement: I believe that having an operational wind turbine improves student interest and engagement in my class

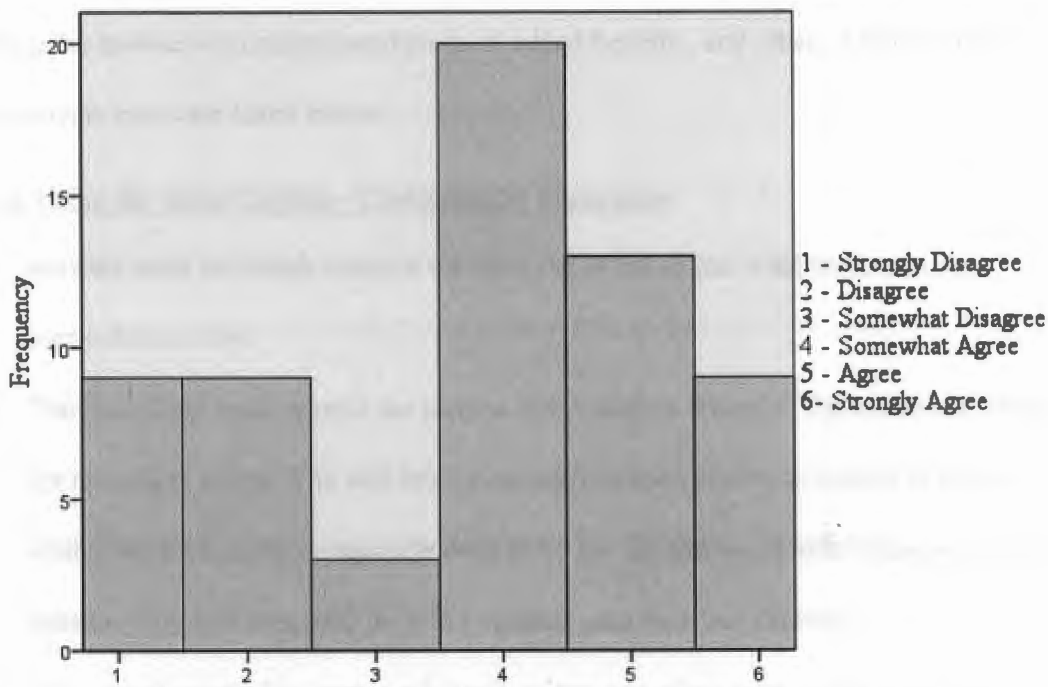

Figure 13. The degree to which teachers personally agree or disagree with the following statement: I believe that having an operational wind turbine improves students' interest and engagement in my class. This chart illustrates the number of teachers that selected each of the responses shown above.

<u>Final Comments Made by Teachers Regarding Wind Power and Energy Education</u>

The final question on the survey offered teachers an opportunity to share any final comments, concerns, or recommendations related to the use of operational wind turbines being used within STEM classes. Out of the 70 teachers that participated, 20 teachers took this opportunity to share their thoughts.

The researcher analyzed the feedback given by teachers and identified common themes. These themes identified include currently not using the turbine with complaints or frustrations, teachers just getting started learning about how to use a turbine, need more time, resources, and training in order to utilize the turbine, positive experiences using the turbine with recommendations or added benefits, and other. A listing of the comments made are listed below.

Not Using the Wind Turbine - Complaints or Frustration

- answers were left blank because we have not included our wind turbine in our curriculum to date
- The consultant used to erect the turbine is not student-friendly. The turbine is off-line for months at a time. The unit has a poor performance record, is located at a very visible location and consequently does more for the anti-wind folks because it rarely runs the way it is supposed to. It is a running joke with our students.
- Since wind energy has been a relatively minor part of my curriculum in the past, it has not been utilized as much as it could be.
- Our turbine is no longer functional
- I do not have access to call up production statistics, and in a 40 minute class period you are not going to the turbine. If you did go to the turbine what would you dare to do? Can't go up into the turbine, too much liability.
- Just looking at the turbines is not enough. There ought to be more to actually DO with them.

Need More Time, Resources, and Training

- We really need planning and preparation time to build solid curriculum at the high school level. Most of what I see is for lower grades. Do you have references of most current plans? Schools need to be able to share data live and reliable. We need time to learn how to use the resource that is available. The potential is great for it to be a learning tool.

- I believe that the wind turbine has potential to be used as a beneficial educational tool in my classes. However, without having any training I feel that the time it would take me to teach myself about wind turbines and the time to develop lesson plans is too great for me to use wind turbines or wind energy as a teaching tool in my classroom at this point in time.
- I wish I had more time to prepare a unit on our wind turbine. It would be beneficial having more support from a tech department in displaying real-time data from our operational turbine.

Teachers Just Getting Started

- This is my first year teaching. Due to course requirements for seventh graders I have not had a class with them this year. Wind turbines do not apply to any of the other courses I am teaching this semester.
- Our turbine is not fully operational yet. In my class, students have explored alternative energy cars (electric/hybrids), to see if they are cost effective. I would like to do the same with the turbine once it is fully operational and I get the data and training.
- Our Wind Turbine is hopefully going to save our school 80% of our electricity bill
- excited to get to really start using it

- I really don't use the wind turbines in my curriculum. We learn about other types of energy, but haven't included the wind turbines in our curriculum. We have only had the wind turbines for one year.
- I have only started to investigate methods to teach classes about wind power.
- I am just starting with my seventh grade technology class to teach one section of wind power for the 2012-2013 school year.

Positive Experience and Recommendations

- An operational turbine takes the fear or mystery out of wind power. The students get familiar with the technology and are more likely to use it when they get older. It will seem like a normal part of life and not an anomaly. It should even pay for its self and bring $$ back to your program
- The fact we have an actual wind turbine at our school makes learning about it that much more interesting to the students. They can actually see it running and see the actual output for the day.
- I think our turbine is valuable to demonstrate that our community can shift to alternative energy, even though I personally only use the turbine or its data specifically in a few lessons throughout the year. The 8th grade teacher uses it more during her Energy unit, and the tech teacher teaches an entire wind power unit, so it does get used in our building.

Other

- Anxious to see the importance placed on wind energy in the Next Generation standards

CHAPTER 5

CONCLUSIONS

In this chapter, conclusions will be reported regarding the sample population, and each research question.

Sample Population

This section will identify conclusions based on the results of the demographics portion of the survey. Discussions about various demographics as they relate to education, survey research, and wind power and energy will take place.

The results indicate that STEM teachers that participated were predominantly white males. It is important to note that while this study's sample population is not representative of race and gender in the United States, the sample population does identify a current trends in the STEM education field, as well as in STEM professions (Chubin, May, & Babco, 2005; Digman, 2012; George, Neale, Van Horne, & Malcom, 2001; National Science and Technology Council, 2000; USDOE, 2008).

The ages of participants in this study were somewhat abnormal. There appeared to be a low number of participating teachers from age 20-29 and 60 and older. It was expected that these two age classifications would have the fewest number of participants due to graduation and retirement trends. Despite these considerations, there seems to be a lack of participation from the younger group. There are many reasons why this could be. This data could indicate a lack of young teachers entering STEM teaching areas. This would be very concerning. However, a better explanation might be that younger teachers do not have as much time to take the survey and the fact that younger teachers are less experienced, and have not had much training in research practices. It is reasonable as the first few years of teaching are the hardest and busiest due to the steep learning curve of the teaching profession, a new school, a new subject area, and many other things. Also, research has shown that younger, less educated populations are less likely to participate in survey research (Porter, 2004). More coursework and projects focused on research is likely to improve one's willingness to participate in research. This low number of young teachers could also indicate a lack of interest or training in wind power and energy by younger teachers. This is possible due to the lack of wind power and energy content presented in teacher preparation programs.

Figure 2 illustrated the frequency of teachers by their years of teaching experience. The data showed a slight trend that teachers with more teaching experience were more likely to participate in this study. This trend parallels that of teachers' age which is no surprise. This data could also indicate a trend that older teachers with more experience are more interested in wind energy than less experienced teachers with the assumption that teachers with interests in wind power and energy are more likely to complete this studies survey than those without interest.

Teachers' highest educational attainment also paralleled age and teaching experience. It is reasonable to belief that a study containing a majority of more experienced teachers would also have a majority of teachers with at least a master's degree. Table 3 shows the breakdown of teachers according to their content areas. The largest two groups of teachers were science and math. The lack of technology and engineering teachers surveyed is concerning. This could be an indication of a declining trend in the number of technology and engineering programs offered in K-12 schools. Technology and Engineering courses are more career and technical in nature and may offer the best opportunity to incorporate an operational wind turbine into a class.

There was also a shortage of middle school representation in this survey. This is concerning as kids in their middle ages are developing their identities and interests. These middle level years may offer the best opportunity for teachers to excite and lead students toward STEM careers.

The higher rate of high school representation could be an indication that wind energy and power concepts are more technical in nature and may be a better fit for a more mature and advanced student.

Another strong trend that was identified in the results of this study was the large majority of school housing operational wind turbines located in rural areas with low student enrollment. This is no surprise as the Midwest region which is predominantly rural, has the best wind resource in the United States. Also, the Wind for Schools program primarily focuses on developing operational wind turbines in rural area school districts.

It is promising to see evidence that smaller school districts are able to overcome the high upfront costs associated with installing operational wind turbines. It might be worth looking into if large urban areas in the United States will permit schools to develop an operational wind turbine within city limits. There are some cities that restrict residential zones from installing wind turbines inside city limits due to unwanted noise, safety risks, shadow flicker, and other things.

The last area of demographics which will be discussed identify trends in teacher training in wind power and energy. Table 5 shows that 42% of teachers that work at schools with an operational wind turbine have no training in wind power and energy. This is very concerning. Despite the large growth of the wind industry and the popularity of wind energy in the United States, this data shows that very few teachers actually have training to teach about wind power and energy concepts. It may be too early to see a large effect from the outreach and professional development opportunities offered to today's pre-service and in-service teachers. It may be worth watching to see how fast these training opportunities diffuse into the current teacher workforce and if teachers are taking advantage of them.

One surprising statistic observed was that only 9% of teachers have received any sort of in-service training. An event such as the installation of a wind turbine catches a lot of attention from students, teachers, and community members. The researcher expected more schools to take that opportunity to teach lessons on alternative energy, wind energy and power, and sustainability. It would be interesting to study a school that took this opportunity and provided its teachers with that training to study the effects of that training compared to other schools that offer none.

Figure 5, which illustrates how much time teachers have taken to learn about wind power and energy through training and other experiences shows that there are some teachers, approximately 10%, that have dedicated significant amounts of time to learn wind power and energy. It would be unrealistic to believe that everyone should get that kind of training, but there is a need to provide all teachers with some training, especially if they work at a school with an operational wind turbine.

How Operational Wind Turbine are Used in Secondary Classrooms

In this section, the researcher will discuss the results of the second portion of the questionnaire. For each research question, applicable data will be analyzed and conclusions reported.

It is important to note that the response rate for questionnaire items related to how operational wind turbines are used in secondary classrooms is significantly less than questions relating to teachers demographical information. The researcher speculates that many teachers did not respond to questions specifically dealing with wind power and energy issues because they may not teach about it. Figure 14 illustrates the results of a questionnaire item which asked teachers to identify how they include wind power and energy concepts into their curriculum. This chart shows that 33% of teachers indicated that they do not include wind power and energy concepts into their curriculum. After this question, the response rate dropped off dramatically.

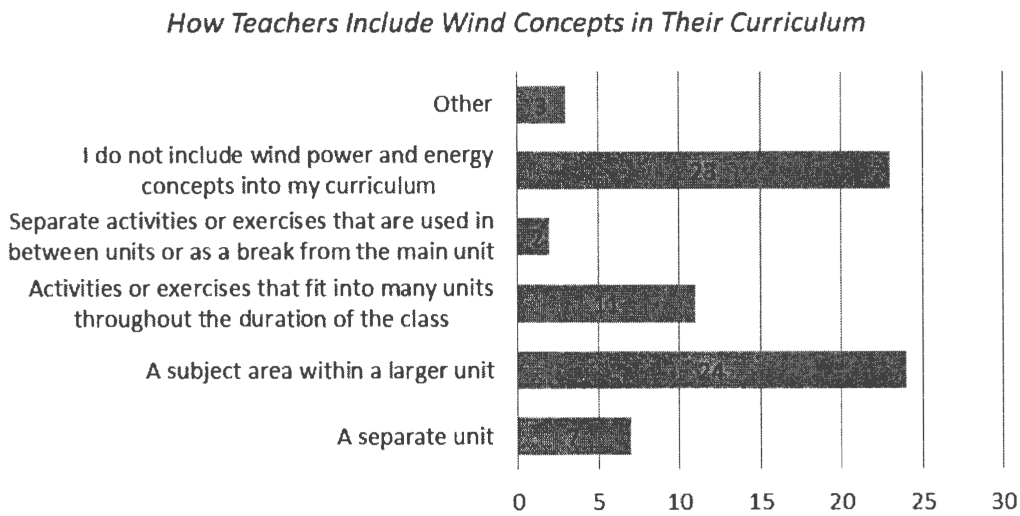

Figure 14. How teachers include wind concepts in their curriculum. This graph illustrates the number of teachers that organize wind related concepts into their curriulum according to the various methods identified on the y-axis.

<u>Research Question 1</u>

Research question 1 stated "what instructional materials do teachers use to teach about wind power and energy? To answer this question the researcher collected data that indicates from what curricular sources teacher get their wind power and energy curriculum and what curricular resources teachers have created.

Figure 6 illustrated that NEED, KidWind, and Wind for Schools were the most popular wind energy curricular sources. Each of these three curricular sources accounted for more than all others combined. NEED and Kidwind are free and very comprehensive which may explain why they are so popular. Also, Wind for Schools offers opportunities for a select number of rural schools across the United States to develop a wind turbine project using their highly structured model.

Only one other curricular material was identified by teachers. Alliant Energy Kids is a free curriculum developed and distributed by a public Midwest based utility company. There are a number of these small curricula developed by a number of different groups which include utility companies, non-profit organizations, and college outreach programs, so the researcher was surprised that teachers did not provide more curricula in addition to the ones that were listed.

The results from this question could indicate that the curricula and programs listed in Figure 6 identify a limited number of wind power and energy resources used by teachers. However, the researcher speculates that the questionnaire item did not prompt teachers directly enough to encourage them to share more information about the curriculum they use. Another possibility could be that teachers use bits and pieces of specific curriculum that they did not feel it was worth identifying. Whatever the reason, there may be some value in identifying all the curricular resources. If someone was able to identify all the wind power and energy curricula available, organize it, and create a system to effectively share it with anyone, teachers would be able to be more efficient with their time and have a better understanding about what resources are out there. Nonetheless, the data collected clearly indicates that NEED, KidWind, and Wind for Schools are three major contributors of wind power and energy resources. Also, it's important to note that the researcher did not discover any curricula developed by wind turbine manufacturers.

The second part of this answer was derived from a questionnaire item that asked teachers to identify all wind related instructional materials that they have created. This was an open ended question, so the researcher coded similar responses together. Table 6 illustrates several themes and identifies several curriculum ideas.

Table 6 illustrates a need for curriculum developers to create and distribute standards based curriculum that lays out activities where students can retrieve, use, and interpret data from wind turbines to illustrate STEM concepts. There were a couple items in Table 6 that incorporated wind turbine technology. Developing curriculum that is applicable with all the different brands and models of wind turbines could be difficult. Also, to develop curriculum resource that applies to all four areas of STEM would be a challenge. This information might identify education as a market for wind turbine manufacturers.

Another trend observed is the number of curricular items that are being recreating either by other teachers or by curriculum developers. This may indicate that teachers are not familiar with wind related curriculum that is available online. Another possibility is that wind curriculum that has been developed by groups such as NEED and KidWind do not apply well across subject areas. There may be a need for math specific wind curriculum, and science specific wind curriculum, etc. Teachers are recreating wind turbine blade design labs. This trend might be a result of the high cost per student for similar lab kits designed and manufactured by KidWind, Kelvin, Pitsco, and other companies. If this is a trend, it could show a need for curriculum that guides teachers to developing model wind turbine kits from common items found in their local hardware store. At any rate, the reproduction of already available materials illustrates a need for better communication between curriculum developers and teachers.

It is reasonable to believe that an online forum that facilitated teacher collaboration and curriculum sharing might be successful. This would allow teachers to use their time more efficiently. Digital multimedia created by teachers could be shared. It might also provide teachers with additional resources and ideas that would in turn improve their instruction and resources.

The last trend observed is how some activities go way above and beyond what is reasonable for most schools. For example, not all school programs will be able to install meteorological towers and redesign failed parts on a wind turbine. Teacher will only be able to teach these specific competencies if they themselves have had extensive training and expertise in wind power and energy technology.

Research Question 2

Research question 2 stated "how satisfied are teachers with the curriculum options currently available? What improvements would they like to see?" Teachers were asked to indicate their satisfaction level for curriculum options currently available using a six point Likert scale. Figure 8 illustrated the results for this question. From the results that there was not a large group of teachers that were very dissatisfied or very satisfied indicating that the majority of teachers feel that there is some okay curriculum out there, but not anything really great. The responses were coded with one being very dissatisfied and six being very satisfied. Descriptive statistics showed a mean score of 3.25. This score would have fallen somewhere between somewhat satisfied and somewhat dissatisfied. Again this indicates that the group of teachers as a whole did not feel strongly about the curriculum in one direction or the other, but generally felt neutral with the wind curriculum that is available.

Since the answer to the first part of question 2 was not a solid satisfied or better, it is important to identify what then do teachers need or want? Another question in the survey asked what improvement to the available wind power and energy curriculum teachers would like to see. This was an open ended question, so the researcher coded the results to identify trends in the responses given by teachers. Eighteen or 25% of teachers responded by providing recommendations for what they would like to see available. Table 7 shows the results of teachers' responses.

There were several trends identified through grouping similar ideas together. These trends will be identified and discussed in the following section.

The biggest trend observed was that 16% of teachers surveyed do not have any recommendation for curriculum they would like to see. This could be because they have not put much thought or do not spend much time teaching about wind power and energy. Many teachers responded by saying not sure, suggestions are welcome. This illustrates that teachers need training and resources to learn more about wind power and energy concepts. This was no surprise as wind science and technology are very complex and require much expertise. This identifies a need for curriculum developers to create an easy to use standards-based guidebook that illustrates how wind data can be recovered, imported into a database, how analysis tools can help teachers and students understand what the data means, and explain the relationship between wind power and energy and the STEM concepts teachers are expected to teach.

Many teachers like textbooks and feel there is a need for new and improved wind power and energy textbooks that use an integrative STEM approach. This shows that teachers would like to have the information presented to them in a more organized format. With wind power and energy being such a dynamic content area, the researcher believes that textbooks may not be the best medium for presenting this information in most content areas, but it may be the medium that many teachers feel most comfortable with. There may be a better way to organize information about wind power and energy.

More dynamic in nature and online, web based classroom environments, such as blackboard, offer many advantages for educating today's students. Many of the wind resources are available online. Also, electronic files are easier and least expensive to distribute to the masses. However, many classrooms may not have the resources to accommodate digital curriculum.

Teachers indicated that they want wider variety of resources relating to wind power and energy. Resources focused on both residential and utility scale wind, social and environmental effects of wind power, and information on careers and case studies related to wind industry. Much work needs to be done to prepare a library of digital curricular materials such as these.

Some recommendations indicate that there is a need for more curricula that focus on social and environmental impacts of the wind industry and wind technology. National standards for science and technology identify the need for students to understand technology's relationship with societies and how it impacts the way cultures live (USDOE, 2012; ITEA, 2007; National Research Council, 2011). Wind power and energy provides an avenue for students to study how an industry is created, the rate at which it was diffused into our current energy production infrastructure, and how it has changed and will continue to change the way people live.

Another trend is the need for a guide for teachers that lack the knowledge to retrieve, use, and interpret weather and energy production data. Also, there is a need to collaborate with others to find answers to problems teachers encounter. The data shows a need for collaboration and networking among wind power and energy educators. An online forum or database could allow teachers and students to see energy production statistics from other parts of the country, to interact and ask questions, share curriculum, and communicate with other people with similar problems.

Research Question 3

Research question 3 stated "how do teachers incorporate operational wind turbines into their STEM curricula?" Question 3 is answered in two parts. First, how frequently do students use their schools operational wind turbine or it's byproducts, and second, what are the activities that students are doing with operational wind turbines.

Figure 9 illustrated teachers' responses to the question, "How often do student interact with you schools operational wind turbine or any of its byproducts within your classes." Of the majority of teachers surveyed, approximately 52%, don't do anything with operational wind turbines within their classes. The vast majority of teachers indicated that they don't use the operational wind turbine at all. This indicates that only 33 teachers will be able to provide useful information about this question and other questions relating to operational wind turbines. Also, it indicates that most teachers don't see the advantages of using a wind turbine as a context for learning their subject matter.

The second part of this answer identifies how students use their school's operational wind turbine or any of its byproducts to learn about STEM concepts. 13 Teachers identified specific activities which involve students and an operational wind turbine. Those results are shown in Table 8.

Table 8 illustrates that the majority of teachers do not use the wind turbine in their classes. The researcher observed science, math, technology, and engineering concepts taught using activities that incorporate the operational wind turbine. It was also observed that many of the activities would require at least some, if not much training in wind power and energy to be able to understand and teach to secondary students.

One significant trend identified was several responses indicating that students were acquiring data from the wind turbine data acquisition software, analyzing it using statistical tools, and interpreting it. Nine different teachers reported this activity in one form or another. Some teacher's followed up with additional analysis like fitting the data to a regression curve, projecting a payback period, calculating average energy produced, calculated cost savings for the school, calculated $CO2$ emissions savings, and calculated the size of turbine needed to create a net-zero electrical system.

Table 9 also provides a listing of STEM concepts that teachers were able to reinforce using an operational wind turbine.

In conclusion, while there were few teachers that provided specific activities, the list of activities reported in Table 8 is a great start. More research needs to be done to further explain those activities and more activities could be developed.

Research Question 4

Research question 4 stated "do small scale turbines have comparable curricular applications to intermediate and large scale turbines? If not, how do the three sizes of turbines differ in their curricular applications?" Research question 4 required an ANOVA to answer. The factor groups for the ANOVA were the three classes of operational wind turbines, which are identified in Figure 11, and the dependent variable was the number of ways students interact with the turbine and or its byproducts, which is identified in Figure 10. The null hypothesis for this test was "there are no statistical differences between the number of curricular application between small, intermediate, and large operational turbines." Table 11 shows the results of the ANOVA which fails to reject the null hypothesis. This is identified by a significance level greater than .05. This indicates that the mean scores of the dependent variable, number of ways students are using the operational wind turbines, when compared across the three factor groups, which were schools classified by the size of wind turbine they had, were similar, or did not have a significantly different number of applications. In other words, small, intermediate, and large wind turbines have comparable curricular applications when used to reinforce STEM concepts in secondary school.

Table 11

ANOVA: Number of Curricular Applications for 3 Classes of Wind Turbines

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.247	2	1.624	.626	.550
Within Groups	33.690	13	2.592		
Total	36.938	15			

Although the number of teachers in each group was too small to determine an effect, there is no reason to believe that by including more teachers in this survey, that the results would be any different. The number of curricular applications seems to have more of a direct relationship with the amount of training that teachers have.

Research Question 5

Research question 5 stated "what is the relationship between teachers with prior experience and/or training in wind power and energy and their hours spent teaching about wind power and energy? To answer this research question, the researcher looked for a correlation between the number of hours students spent in class learning about wind power and energy concepts and the number of hours teachers have spent learning about wind power and energy through training, prior experience, or personal research. Using Pearson's product-moment coefficient with a 95% confidence interval and with n=65, the researcher determined the correlation coefficient to be r-value = .338 with a p-value = .006. This is a significant correlation between variable one and two with a moderate effect size (r^2 = .114).

Figure 15 illustrates this strong correlation between hours teachers spend learning about wind related concepts and time their students spend learning about it.

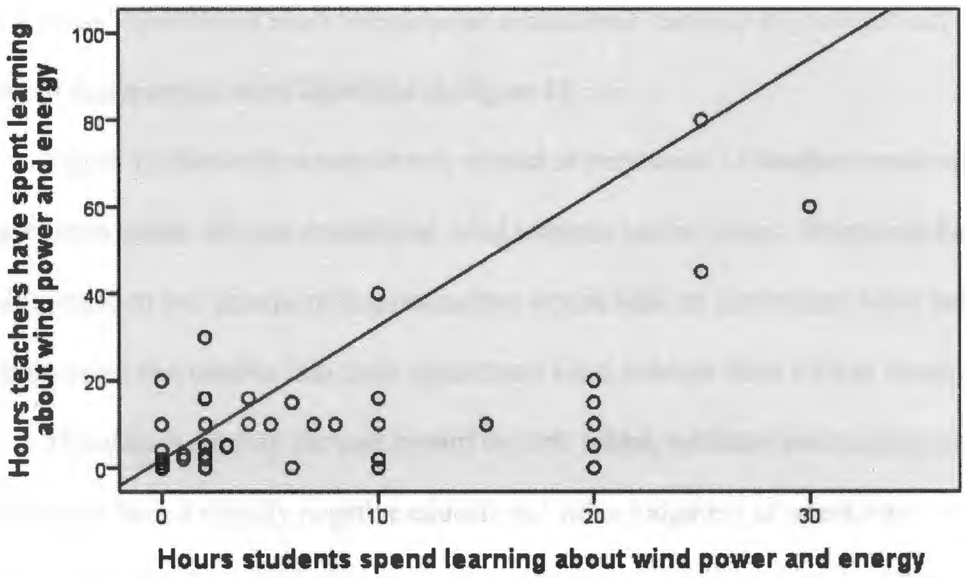

Figure 15. Scatterplot: Hours teachers have spent learning about wind power and energy and hours students spend learning about wind power and energy. This graph illustrates that there may be a strong positive correlation between these two variables.

This research suggests that by providing more training opportunities to teachers, more students will develop a better understanding about wind power and energy and become more wind power and energy literate. This is not surprising as wind power and energy concepts are complex. Further research needs to look at what kind of training, experiences, and/or personal research provides the best results and is it feasible for schools to emulate that training program.

Research Question 6

Research question 6 stated "what value do STEM teachers place on having an operational wind turbine on site as an educational resource?" Research Question 6 looks at the results of the following question that was directed to teachers: How valuable is your schools' operational wind turbine as an educational resource in your classes? The results of this question were identified in Figure 12.

Figure 12 illustrates a very evenly spread of responses. 12 teachers made up the largest group which felt that operational wind turbines had no value. There may be a possible trend of two groups of responses. One which feels an operational wind turbine has little value and another that feels operational wind turbines have a lot of value.

This data is slightly skewed toward the left, which indicates that teachers as a whole group have a slightly negative educational value judgment of operational wind turbines. This negative view of operational wind turbines could be a result of the complexity of content and equipment associated with an operational wind turbine and teachers inability to utilize the turbine as an educational resource. This indicates that more needs to be done to simplify and make wind turbine interfaces more user friendly in addition to providing more information about how to use them for educational purposes.

Research Question 7

Research Question 7 stated "what is the relationship between educational value placed on operational wind turbines and time teachers have spent learning about wind power and energy concepts though training and prior experience?" To answer this research question, the researcher looked for a correlation between educational value placed on the wind turbines by teachers and the number of hours teachers have spent learning about wind power and energy concepts though training, prior experience, and personal research. Using Pearson's product-moment coefficient with a 95% confidence interval and with n=64, the researcher determined the correlation coefficient to be r-value = .270 with a p-value = .031 with a moderate effect size ($r^2 = .073$).

Also, Figure 16 shows a scatterplot representing the aforementioned variables. This chart illustrates that there may be a strong correlation between the time teachers spend learning about wind power and energy and how much they value the operational wind turbine at their school.

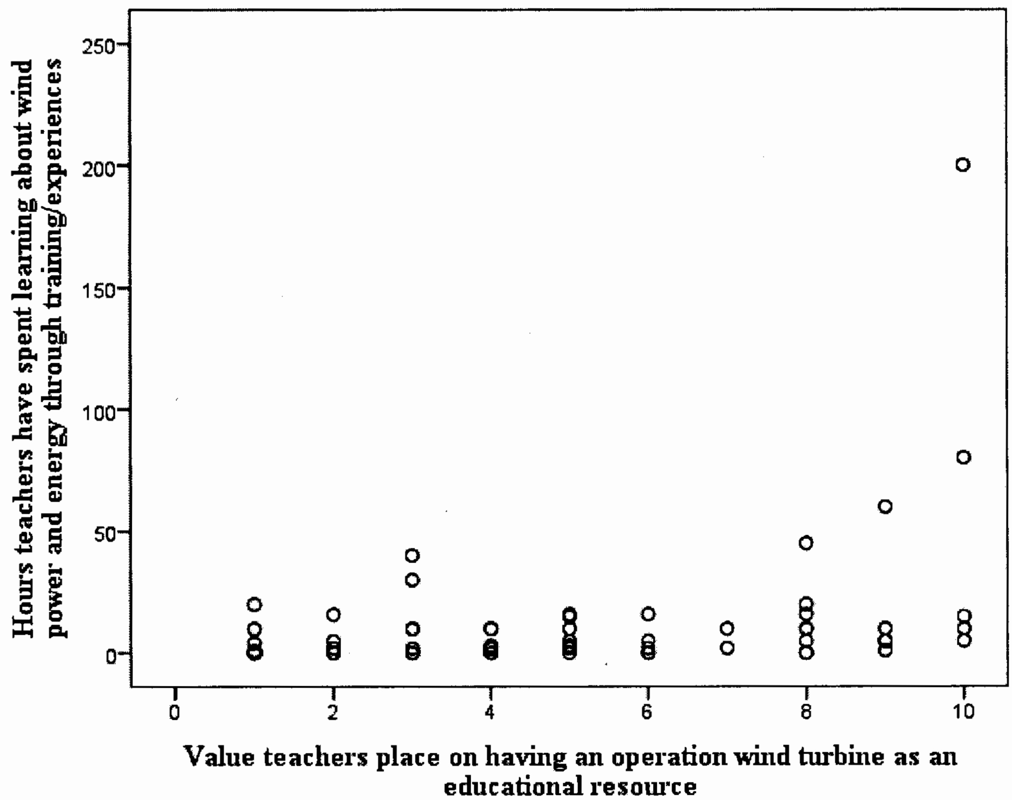

Figure 16. Scatterplot: Time Students will Spend Learning about Wind Power and Energy Concepts and Value Teachers place on their Schools Operational Wind Turbine. This chart illustrates that there is a strong positive correlation between these two variables.

The researcher hypothesized there may be a strong regression model that could be used to identify the strength of the relationship between the two aforementioned variables. The researcher conducted a test of linear regression. Table 12 illustrates the result of the linear regression which indicates that there is a significant difference between the different factor groups. A significance level of .000 indicates that this is a strong difference.

Table 12

ANOVA: Educational Value Teachers Place on an Operational Wind Turbine

	Sum of Squares	df	Mean Square	F	Sig.
Regression	113.578	1	113.578	14.875	.000
Residual	473.406	62	7.636		
Total	586.984	63			

Table 13 also illustrates the results of the regression analysis. It illustrates that according to this regression model, the mean for teachers having no wind power and energy training feel that operational wind turbines have a value of 3.274 on a 10 point rating scale, 1 being no value. For every five hours of training, experience, or personal research a teacher receives, the educational value of operational wind turbines increases by .793. This regression analysis identifies that training accounts for 20% of the various factors influencing how teachers value operational wind turbines which is a very large percentage.

This research suggests that schools must provide teachers with wind power and energy training opportunities if teachers are expected to use and to value their schools operational wind turbine as an educational resource.

Table 13

Regression Analysis: Coefficients of Operational Wind Turbines value by Teachers Depending on Time Spent Learning about Wind Power and Energy

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	3.274	.562		5.823	.000
Time teachers have spent learning about wind power and energy	.793	.206	.440	3.857	.000

Research Question 8

Research question 8 stated "to what extent do teachers feel that having an operational wind turbine improves student interest and engagement in STEM courses and/or wind power and energy careers?" Teachers were asked "to what degree do you personally agree or disagree with the following statement: I believe that having an operational wind turbine improves student interest and engagement in my class." Figure 13 illustrates the results to this question.

The wide spread of this data indicates that teachers don't agree about this. The researcher wonders why there is a difference in opinion between these two groups and what is the make-up of these two groups. It could be that the teachers that disagree do not have the appropriate training and vice versa.

Table 14 illustrates a crosstabulation between time teachers have spent learning about wind power and energy and the degree that teachers feel operational wind turbines improve student interest and engagement. This crosstabulation illustrates a weak trend that may indicate that teachers with more training believe operational wind turbines have a positive influence on student interest and engagement.

A Pearson's Correlation test was used to identify the relationship between the coded time that teachers have spent learning about wind power in the form of additional training, experience, or personal research and the degree that teachers feel operational wind turbines improve student interest and engagement. This results of this correlation identified a significant r-value of .324 with p-value = .01 with n = 62. This indicates that with more training, teachers may be able to utilize the wind turbine in more effective ways which can increase student interest and engagement.

Table 14

Crosstabulation of Time Teachers have Spent Learning about Wind Power and Energy and the Degree that Teachers Believe that Operational Wind Turbines Improve Student Interest and Engagement

		To what degree teachers believe that operational wind turbines increase student interest and engagement						Total
		1	2	3	4	5	6	
Time teachers have spent learning about wind power and energy	0 hrs	4	5	2	6	2	0	19
	1-5 hrs	1	2	0	9	4	1	17
	6-10 hrs	1	0	0	3	5	2	11
	11-20 hrs	2	1	1	0	2	2	8
	20 + hrs	1	1	0	1	0	4	7
Total		9	9	3	19	13	9	62

Additional Comments made by Teachers about Wind Power and Energy Education

The section in the survey offered teachers an opportunity to share any final comments, concerns, or recommendations related to the use of operational wind turbines being used within STEM classes. 20 teachers shared their thoughts.

The researcher analyzed the responses given by teachers and identified common themes. The themes identified include currently not using the turbine with complaints or frustrations, teachers just getting started learning about how to use a turbine, need more time, resources, and training in order to utilize the turbine, positive experiences using the turbine with recommendations or added benefits, and other. Conclusions about each theme are given in this section.

Not Using the Wind Turbine - Complaints or Frustration

There were six responses that were given by teachers that aligned with this theme. Of the five themes identified, this was the second largest category, second to teachers new to teaching about wind power and energy. Some teachers tended to have negative attitudes toward wind turbines being used in education due to past experiences or frustrations. Other just indicated that they did not use the turbines.

The responses indicating complaints or frustration seem to have resulted from minimal preparation, training, or faulty equipment. One question that arises is "are schools implementing an educational system that informs and trains teachers how to use an operational wind turbine?" Maybe some schools have implemented better systems than others resulting in better teacher attitudes and experiences. There seems to be a need for more training during the construction period so that teachers can identify the benefits of having a wind turbine located on campus other than the cost savings the school experiences.

Also, are there trends indicating why some schools have trouble with faulty equipment and others do not. Which manufacturers, contractors, and consultants provide good service and products to schools? It would be interesting to investigate what resources schools have for repair and maintenance of wind turbines and are there obvious trends that indicate why some schools have problems and some do not. These are questions which would be helpful in preventing situation where teachers are frustrated for one reason or another.

Need More Time, Resources, and Training

There were three responses that identified a want or motivation to incorporate them into their curriculum, but indicated that there was some barrier preventing them from doing so. Barriers included lack of time, training, and support from administration. Responses included in this theme indicate that teachers see the potential for educational value, but the resources are not there yet. Teachers need more resources as indicated in research question 2.

Teachers Just Getting Started

There were seven responses indicating that teachers were just getting started. This reinforces that teaching about wind power and energy is a new trend. This indicates that more and more teachers will be addressing the need to produce students with energy literacy in the future. There needs to be systems and resources available to teachers can transition easily into teaching about wind power and energy.

Positive Experience and Recommendations

It was surprising to only get three responses that identify further advantages of having an operational wind turbine located at their school. The responses in this theme indicate additional benefits that students and community members receive due to their utilization of the operational wind turbine. Teachers identified that using an operational wind turbine improve students technological literacy, it saves money, makes learning more interesting, and serves as a symbol of change for students and the community.

Other

There was one response that did not fit with any other theme. This response points out a trend that has been occurring relating to national standards and guidelines. The United States' national science standards and technology and engineering standards are currently being revised and there could be added emphasis on energy and specifically wind power and energy. The response below indicates that teachers are thinking about incorporating more energy related content into their curriculum. This might be a result of recent reports released about next generation science standards and energy literacy guidelines (USDOE, 2012; National Research Council, 2011).

Summary, Conclusions, and Recommendations

The initial problem addressed by this study was that operational wind turbines are being installed on school campuses, but it is unclear how secondary schools can effectively use this technology to engage and teach students about wind power concepts. This study aimed to identify practical expectations for how operational wind turbines can be applied in secondary classrooms to enhance student learning and interest in science, technology, engineering and mathematics (STEM) classrooms. By answering this study's eight research questions, the researcher is able to identify some basic expectations that teachers and schools can have for operational wind turbines located on school campuses.

One of the first questions teachers might ask when considering teaching about wind power and energy is what resources are available for teachers. The most comprehensive list of wind power and energy curriculum is found on the USDOE website under the curricula and teaching materials tab located at http://www.windpoweringamerica.gov/schools_teaching_materials.asp. From this listing of curricula, this survey found NEED and KidWind to be the most popular curricular resources. Also, it was found that Wind for Schools is a program that has had a great impact on secondary schools as it accounts for a large percentage of schools with operational wind turbines. There are other curricular resources out there, but they are not as widely utilized and not commonly known by the majority of STEM teachers.

Despite there being so many wind power and energy curricular options, with some being very extensive, this study determined that teachers are very neutral in terms of their satisfaction level for their current curricular options. Teachers want more comprehensive information, more variety of tools for students to use, more hands-on activities, and better ways to collaborate with other wind power and energy educators and experts in the field. It is reasonable to believe that many teachers don't know about all the online resources available. Evidence that teachers are recreating curriculum that is already available online for free was collected during this study. One very likely possibility is that there is a disconnect between teachers and curriculum developers which makes it difficult for teachers to know what's out there for curricular resources. A teacher needs to really spend some time to sort through all the curricula available. A great place to start is on the aforementioned USDOE website.

One major trend identified in this study was the need for a curricular guide that walks teachers through all the potential learning opportunities that an operational wind turbine presents. Several teachers indicated that they have developed activities for students to collect weather and turbine output data. Many teachers are unable to identify how a wind turbine might be applicable to their class. A curriculum developed by a wind turbine manufacturer was never mention by teachers in this study which leads one to believe that this does not exist. These examples illustrates the need for an operational wind turbine curricular guide that takes the guess work out of teaching STEM concepts using an operational wind turbine. A guide that identifies standards based lessons and activities for each of the STEM subject areas.

Initially the researcher speculated that smaller turbines offered greater educational opportunities than larger turbines simply because they are smaller and more approachable. However, this study determined that to be a false assumption. This study found that there are no significant differences in the number of curricular applications between large, intermediate, and small wind turbines. However, this may change if wind turbine manufacturers would design and build a wind turbine specifically designed for educational use. A user-friendly and robust control panel with lots of measurement tools and safety features could create an effective educational environment. As of right now, wind turbines are designed to generate power and to log data and aside from quality issues, one has just as much educational value as another.

Teachers surveyed in this study had very mixed opinions about how valuable the operational wind turbines are. There was an extremely wide spread on the responses given by teachers in regard to the educational value of their schools operational wind turbine. It was found that a direct relationship exists between the time teachers spent learning about wind power and energy and how much educational value they place on operational wind turbines. This indicates that schools interested in developing a wind turbine project should also develop a good training program for teachers that may be expected to utilize an operational wind turbine in the classroom. Currently, there are several alternative energy workshops that introduce wind energy concepts, as well as workshops designed specifically to allow people to build an operational wind turbine.

Wind turbine technology is complicated and requires formal training outside personal research. Several teachers indicated within this study that they do not feel comfortable working with an operational wind turbine and/or they do not have the skills necessary for incorporating them into their classes. Also, in several responses indicated that it was lack of training and understanding that has prevented them from teaching about wind power and energy in their classes. It is essential that if schools have an operational wind turbine, and if they want teachers to utilize them in an educational way, that these schools provide training opportunities for its teachers.

After talking with principal and reading teachers' responses, it is evident that there is a lot of frustration and fear about installing a wind turbine. First, it has a high initial cost for the turbine and installation, and it is somewhat difficult to get all parties involved to work together. During the literature review, the researcher learned how Wind for Schools has organized this planning process to make planning and development more streamline. One report read during the literature review indicated that consultants can provide an expertise that may help to ease through the process, but one teacher complained that the consultant was not student/teacher friendly. This indicates the importance of asking around and getting referrals. There are more and more schools that have gone through the installation process that can help shed some light on these problems (Galluzzo & Osterberg, 2006).

Despite the frustrations and concerns, there were several teachers that indicated many benefits of having an operational wind turbine as an educational resource. However, like stated before, it is unclear how teachers can utilize this technology to teach about STEM concepts. One goal of this study was to get teachers to identify the different ways they have used their operational wind turbine. The following list identifies lessons and activities developed and/or used by teachers that allow students to interact with operational wind turbines and some of its byproducts.

- Observe it during a field trip
- Observe and discussed energy transfer
- Study the wind turbines ecological impacts
- Study angular speed and rate in electrical systems
- Study how wind turbines are used as an alternative energy source
- Graph data acquired though the turbine software

- Interpret the data acquired through the turbine's software
- Fit data acquired from the wind turbine software to a regression curve
- Average datasets
- Use power-curve data from manufacture and historical wind data to project payback period from a large wind turbine
- Calculate money saved by turbine assuming it was paid for
- Calculate the savings of greenhouse gas emissions
- Convert units of energy to different forms
- Calculate the amount of energy needed to create a net-0 electrical waste.
- Study the electrical grid and how the turbine is connected
- Study how turbines operate: controls and outputs
- Troubleshoot problems that arise with the wind turbine
- Brainstorm and try to solve problems associated with the turbine
- Redesign parts that fail on our turbine and contact the manufacturer
- Use energy to run greenhouse fans and lights
- Use historical data to test accuracy of a computer model that predicts the output of a small turbine
- Study the engineering behind a wind turbine structure

Also identified were science, technology, engineering, and mathematics concepts that were reinforced during these activities. Table 9 identifies those concepts.

The final question answered by this research indicated that teachers had mixed opinions about an operational wind turbines potential to increase student interest and engagement in their classes. Some teachers strongly agreed and some strongly disagreed with this idea. There are certainly many variables that could have impacted these responses, but no conclusions can be made about them without further research.

Throughout this study, several research ideas surfaced that may merit further investigation. First, a need was identified for further development of curricular resources associated with wind power and energy, specifically curricular materials that help teachers integrate operational wind turbines into a classroom. Another research opportunity would be the development of an educational operational wind turbine. It would be interesting to take a turbine designed specifically for educational applications and compare the effects it has on a student population when compared with a standard wind turbine.

The final and possibly most significant finding in this study was the effects associated with a teacher's wind power and energy training, experience, and personal research. This study merits an investigation on schools with positive experiences with wind turbine installation and wind power and energy training opportunities for teachers to identify a model for others to follow. It was shown that it is just as crucial that schools develop a training program for teachers and a maintenance program as it is to develop and install the wind turbine itself.

With the wind industry growing at a rapid pace and an increasing need for more STEM professionals here in the United States, K-12 schools should be looking at wind power and energy curriculum as a means to excite and engage students about STEM fields. This study has identified several reasonable expectations that schools can have in regard to how their operational wind turbine can be better utilized as an educational resource.

REFERENCES

American Wind Energy Association. (2011, August 4). *Industry Statistics*. Retrieved January 31, 2012, from www.awea.org/learnabout/industry_stats/index.cfm

Anthony, Jeff. (2011). *U.S. Manufacturing of Wind Turbines and Turbine Components* [PowerPoint slides]. Retrieved from http://www.awea.org/_cs_upload/events/9989_1.pdf

Brennan, K. (2011, September 30). Iowa State Receives Multi-million Dollar Grant to Develop New PhD Program in Wind Energy Science, Engineering, and Policy. *Iowa State College of Engineering: News*. Facebook. Retrieved from http://news.engineering.iastate.edu/2011/09/30/iowa-state-receives-multi-million-dollar-grant-to-develop-new-phd-program-in-wind-energy-science-engineering-and-policy/

Burnham, D. J., Campbell, J. C., Santoso, S., Compean, A., & Ramos J. (2009). Developing Wind-Power Simulations and Laboratory Experiments for Courses in Renewable-Energy Systems. Proceedings from ASEE 2009: *American Society of Engineering Education 2009 Annual Conference*. Austin, TX. Retrieved from http://search.asee.org/search/fetch?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F19%2FAC%25202009Full443.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

California Energy Commission. (2011). *Overview of Wind Energy in California*. Retrieved from http://www.energy.ca.gov/wind/overview.html

Chubin, D., May, G., & Babco, E. (2005). Diversifying the Engineering Workforce. *Journal of Engineering Education, 94* (1), 73-86.

Digman, L. (2012). *Recruiting Under-represented Minorities into STEM* [PowerPoint slides]. Unpublished presentation, Department of Energy Education, University of Northern Iowa, Cedar Falls, IA.

Fletcher, R. (2010). Using an Alternative Energy Summer Camp for High School Students as a University Outreach Program for the Recruitment of Future Engineering Students: A Two Year Study. Proceedings from ASEE 2010: *American Society of Engineering Education 2010 Annual Conference*. Louisville, KY. Retrieved from http://search.asee.org/search/fetch;jsessionid=1jkdvtfb1jqdu?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F32%2FAC%25202010Full1219.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

Fraenkel, J., Wallen, N., & Hyun, H. (2012). *Design and Evaluate: Research in education.* New York, NY: McGraw-Hill.

Galluzzo, T., & Osterberg, D. (2006). *Wind Power and Iowa Schools.* Iowa Policy Project. Retrieved from http://iowapolicyproject.org/2006docs/060307-WindySchools.pdf

George, Y., Neale, D., Van Horne, V., & Malcom, S. (2001). *In Pursuit of a Diverse Science, Technology, Engineering, and Mathematics Workforce: Recommended research priorities to enhance participation by underrepresented minorities.* Retrieved from http://ehrweb.aaas.org/mge/Reports/Report1/AGEP/?downloadURL=true&loId=EB79A2C2-3280-4404-AAF3-0D5D3F8A9D6D#ExecSummary

Guo, L, & Taherneyhadi, M. (2011). Emerging Technology Institute – Training Middle and High School Teachers in Alternative Energy. Proceedings from ASEE 2011: *American Society of Engineering Education 2011 Annual Conference.* Vancouver, BC. Retrieved from http://search.asee.org/search/fetch;jsessionid=2i5fnndqd7vh9?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2FAC2011%2FASEE_AC2011_270.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

Henderson, M., Rogers, B., Grondin, R., Roberts, C., Danielson, S., & Sundararajn, R. (2006). Using a Wind Power Assessment Project on the Hopi Reservation as a problem-based learning experience. Proceedings from ASEE 2006: *American Society of Engineering Education 2006 Annual Conference.* Chicago, IL. Retrieved from http://search.asee.org/search/fetch?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F12%2F2006Full318.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

Hill, B., Jansson, P., & McDevitt, R. (2006). Renewable Energy Resource Assessment: New Jersey Winds. Proceedings from ASEE 2006: *American Society of Engineering Education 2006 Annual Conference.* Chicago, IL. Retrieved from http://search.asee.org/search/fetch?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F12%2F2006Full485.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

Howell, D. (2010). *Statistical Methods for Psychology.* Belmont, CA: Cengage Wadsworth Learning.

International Technology Education Association (2007). *Standards for technological literacy: content for the study of technology.* (3 ed.). Reston, VA: International Technology Education Association.

Iowa Governor's STEM Advisory Council. (2011). *A Strategic Plan for Science, Technology, Engineering and Mathematics (STEM) Education.* Retrieved from http://www.iowamathscience.org/sites/default/files/2011stemeducationroadmap_finalrc51.pdf

Kauser, J. & Bhatia, K. (2011). Engineers on Wheels. Proceedings from ASEE 2011: *American Society of Engineering Education 2011 Annual Conference.* Vancouver, BC. Retrieved from http://search.asee.org/search/fetch?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2FAC2011%2FASEE_AC2011_1323.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

Krieble, K. & Salter, C. (2008). Promoting Science via an Equipment Loan Outreach Program. *The Physics Teacher, 46,* 296-299.

Liming, D, & Hamilton, J. (2011). Careers in Wind Energy. *Occupational Outlook Quarterly*, 54 (4), 12-19. Retrieved from http://www.eric.ed.gov/PDFS/EJ912039.pdf

National Energy Education Development Project. (2012). *About NEED.* Retrieved from http://www.need.org/About-NEED

National Research Council. (2011). *A framework for k-12 science education: Practices, crosscutting concepts, and core ideas.* Washington DC: The National Academy for Sciences. Retrieved from http://www.nd.edu/~nismec/articles/framework-science%20standards.pdf

National Science and Technology Council. (2000). *Ensuring a Strong U.S. Scientific, Technical and Engineering Workforce in the 21st Century.* Retrieved from http://www.whitehouse.gov/sites/default/files/microsites/ostp/workforcerpt.pdf

Pecen, R., Fahmy, M., & Chalkiadakis, F. (2005). Design and Construction of A Hydro Wind Hybrid Renewable Power Station in Iowa Hickory Hills State Park. Proceedings from ASEE 2005: *American Society of Engineering Education 2005 Annual Conference.* Portland, OR. Retrieved from http://search.asee.org/search/fetch?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F29%2FAC%25202005Paper1410.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

Pecen, R. & Humston, J. (2009). MSETI-AREA: Math-Science-Engineering-Technology in Iowa on Applied Renewable Energy Areas. Proceedings from ASEE 2009: *American Society of Engineering Education 2009 Annual Conference*. Austin, TX. Retrieved from http://www.asee.org/search/proceedings?search=MSETI+and+pecen&commit=Search

Pecen, R., Praska, F., & Al-Quassab, A. (2006). Design and Implementation of an Educational Axial Flux Wind Turbine/Generator. Proceedings from ASEE 2006: *American Society of Engineering Education 2006 Annual Conference*. Chicago, IL. Retrieved from http://search.asee.org/search/fetch?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F12%2F2006Full1476.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

Pelletier, M., Heymans, L., Chanley, P. (2008). Professional Development Institutes on Alternative Energy. Proceedings from ASEE 2008: *American Society of Engineering Education 2008 Annual Conference*. Pittsburg, PA. Retrieved from http://search.asee.org/search/fetch?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F17%2FAC%25202008Full1235.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

Pew Center on Global Climate Change. (2007). *States with Renewable Portfolio Standards*. Retrieved from http://www.pewclimate.org/node/1303

Pippen, J. & Wang, J. (2008). Research and Design on Wind Turbines. Proceedings from ASEE 2008: *American Society of Engineering Education 2008 Annual Conference*. Pittsburg, PA. Retrieved from http://search.asee.org/search/fetch?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F17%2FAC%25202008Full1645.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

Porter, S. (2004). Raising Response Rates: What Works? *New Directions for Institutional Research*, *121*, 5-21.

Powers, S., Brydges, B., DeWaters, J., Small, M. M., St.Lawrence-Lewis, G. G., & Turner, P. (2010). K-12 Teacher Professional Development Effectively Offered by STEM faculty from a Research University. Proceedings from ASEE 2010: *American Society of Engineering Education 2010 Annual Conference*. Louisville, KY. Retrieved from http://search.asee.org/search/fetch?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F32%2FAC%25202010Full177.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

Shyr, W.-J. (2010). Integrating Laboratory Activity into a Junior High School Classroom. *IEEE Transactions on Education, 53*(1), 32-37.

Swapp, A., Schreuders, P., & Reeve, E. (2011, May). Prospecting for Wind. *Technology and Engineering Teacher*, *70* (8), 19-24. Retrieved from http://web.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=3b4e7f30-bfe6-4264-8255-55643ec75dc3%40sessionmgr110&vid=2&hid=125

Swapp, A., Schreuders, P., & Reeve, E. (2011, September). Introducing Wind Power: Essentials for Bring it into the Classroom. *Tech Directions,* 13-19. Retrieved from http://d27vj430nutdmd.cloudfront.net/6340/79383/79383.7.pdf

U.S. Department of Energy. (2007). *Wind for schools: A wind powering America project*. Retrieved from website: http://www.nrel.gov/docs/fy09osti/45684.pdf

U.S. Department of Energy. (2008). *20 Percent Windpower by 2030*. Retrieved from http://www.20percentwind.org/20percent_wind_energy_report_revOct08.pdf

U.S. Department of Energy. (2010). *Wind for Schools Project Curriculum Brief.* Retrieved from http://www.windpoweringamerica.gov/pdfs/schools/wind_for_schools_curriculum_brief.pdf

U.S. Department of Energy. (2011a). *Wind for Schools Pilot Project Results*. Retrieved from http://www.windpoweringamerica.gov/schools_model.asp

U.S. Department of Energy. (2011b). *Wind Energy Education Training Programs*. Retrieved from http://www.windpoweringamerica.gov/schools/education/education_training.asp

U.S. Department of Energy. (2011c). *Wind Energy Curricula and Teaching Materials*. Retrieved from http://www.windpoweringamerica.gov/schools_teaching_materials.asp

U.S. Department of Energy. (2011d). *School Wind Project Locations*. Retrieved from website: http://www.windpoweringamerica.gov/schools/projects.asp

U.S. Department of Energy. (2012). *Energy Literacy: Essential principles and fundamental concepts for energy education*. Retrieved from website: http://www1.eere.energy.gov/education/pdfs/energy_literacy_1_1_low_res.pdf

University of Dusseldorf. (2012). G*Power3. Retrieved from http://www.psycho.uni-duesseldorf.de/abteilungen/aap/gpower3/download-and-register

Yildiz, F. & Coogler, K. (2010). Students Built Educational Renewable Energy Training Units. Proceedings from ASEE 2010: *American Society of Engineering Education 2010 Annual Conference*. Louisville, KY. Retrieved from http://search.asee.org/search/fetch?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F32%2FAC%25202010Full1256.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

APPENDIX A

QUESTIONNAIRE

Questionnaire: An Investigation on How Operational Wind Turbines are Used in Secondary Classrooms

Thank you for participating in this survey. For your convenience, this questionnaire is designed to be fast and easy to complete. Please allow yourself about 10 minutes to complete this questionnaire. Answer each question with as much detail as you can. Your time and cooperation is greatly appreciated.

Continue »

Questionnaire: An Investigation on How Operational Wind Turbines are Used in Secondary Classrooms

Part 1: Demographics

This section of the survey gathers data regarding you as an individual, a professional, your training, and your school. Thanks for your participation.

1. Are you ...

- Male
- Female

2. What is your age? Select the answer that best describes your age

- 20-29
- 30-39
- 40-49
- 50-59
- 60+

3. What is your race? Check one or more boxes to indicate what you consider yourself to be

- White
- Black, African Am., or Negro
- Spanish, Hispanic, or Latino
- American Indian or Alaska Native
- Asian Indian
- Chinese
- Filipino
- Japanese
- Korean
- Vietnamese
- Other Asian
- Native Hawaiian
- Guamanian or Chamorro
- Samoan
- Other Pacific Islander
- Other:

4. How many years have you been a teacher, either at your current school or some other school? Select the answer that best describes your teaching experience

- Less than 2
- 2-5
- 6-10
- 11-20
- More than 20

5. Describe your highest educational attainment.

- Bachelor's degree
- Bachelor's + some graduate credit hours
- Master's degree
- Master's + additional credit hours
- Other:

6. What grade(s) will you teach this school year? Select all that apply

- Middle School (grades 6-8)
- High School (grades 9-12)

7. Do you consider yourself to be a ...Select all that apply

- Science Teacher
- Technology Teacher
- Engineering Teacher
- Mathematics Teacher
- Other:

8. What is the name of your school district?

9. Which of the following best describes where your school building is located? Is it ...

- in a town of less than 5,000 people
- in a town of 5,000 to 24,999 people
- in a city or urban area of 25,000 people or more
- Don't know / Not sure
- Other:

10. What is the approximate enrollment of your school district? Enter the approximation as a whole number (Example: 3,500)

11. Which of the following best describes your training/experience in the wind power and energy subject area?

- Part of my pre-service training
- Part of an in-service training
- Part of my professional development
- Part of an internship or externship with a wind company
- I was employed by a wind company prior to teaching
- Other:

12. Approximately how much time have you spent learning about wind power and energy content through training/experiences? Enter the approximation of hours as a whole number (Example: 10)

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Questionnaire: An Investigation on How Operational Wind Turbines are Used in Secondary Classrooms

Part 2: How Operational Wind Turbines are Used in Secondary Classrooms

For this set of questions, please think about the courses in which you may be teaching using wind power and energy resources during the 2012-2013 school year.

13. There are a number of ways wind power and energy concepts may be included in a curriculum. Which of the following best describes how you include wind power and energy concepts into your curriculum, if at all?

- A separate unit
- A subject area within a larger unit
- Activities or exercises that fit into many units throughout the duration of the class
- Separate activities or exercises that are used in between units or as a break from the main unit
- I do not include wind power and energy concepts into my curriculum
- Other:

14. About how often do you plan to teach wind power and energy concepts in any class?

- Not at all in any class
- Once or twice per course
- About once per month
- Once per week
- Most every day
- Don't know

15. Approximately how many hours do your students spend learning about wind power and energy concepts in your classroom throughout the courses you teach? Enter the approximation of hours as a whole number (Example: 35)

16. In what class(es) will you teach about wind power and energy concepts this year? Please include both the grade and subject for each class in the blanks below. Use the following format for each class entry: GRADE(S) - SUBJECT / COURSE (Example: Grade 7 - Technology Education / Applied Technology)

17. Have you used or plan to use any of the following materials to teach wind power and energy concepts? Select all that apply

- Textbooks/Curriculum guides
- Computers
- iPads or tablets
- Internet/Online resources for students
- Activity books
- Project kits
- Videos/Television programs
- Competitions
- Field Trips
- Guest speakers
- Other:

18. Have you used or plan to use any of the following developed curricula or programs to teach wind power and energy concepts? Select all that apply

- NEED (National Energy Education Development Project
- Kid Wind Project
- Windwise
- 4-H Group Wind Curriculum
- Fabulous Resources for Energy Education developed by University of Northern Iowa
- California Energy Commission
- Wind for Schools
- Pitsco Wind Curriculum
- Kelvin Wind Curriculum
- Other:

19. What specific wind power and energy instructional materials have you created that your students will see or use? Write down anything that you think applies.

20. How satisfied are you with the wind power and energy curricula currently available?

- Very Satisfied
- Satisfied
- Somewhat satisfied
- Somewhat dissatisfied
- Dissatisfied
- Very dissatisfied

21. What improvements to wind power and energy curricula would you like to see?

22. Have you experienced any of the following barriers to teaching wind power and energy concepts in your classes? Select all that apply

- I have not experienced any barriers
- I do not have the knowledge or training to teach about wind power and energy
- I do not have the class time
- I do not have enough preparation time
- I do not have enough resources or funding
- Wind power and energy concepts are unrelated to my subject area
- My school setting in not conducive to teaching about wind power and energy
- Education about wind power and energy is not appropriate for the grade level I teach
- I am not interested in teaching about wind power and energy
- Other:

23. What size is your school's operational wind turbine? An operational wind turbine is a full functioning wind turbine that generates electricity from the wind. Turbines are sized by manufacturers according to the power produced at optimal wind-speeds in Kilowatts (kW)

- 49 kW or less (small)
- 50-500 kW (intermediate)
- 501 kW or larger (large)
- I don't know

24. As a part of your class(es), how often do students directly interact with your school's operational wind turbine or any of its byproducts? Byproducts might include, but not limited to, electricity, power generation data, shadow flicker, etc...

- Not at all
- 1-2 times
- 3-4 times
- 5-6 times
- 7 or more times

25. As a part of your class(es), how do students use your school's operational wind turbine or any of its byproducts to learn about STEM concepts? Specifically list all activities that apply, or say not at all if they don't use your schools wind turbine as a part of your class.

26. As a part of your class(es), what STEM concepts are taught or reinforced through your students' interaction with your schools' operational wind turbine? List all concepts that apply (Example: wind turbine power curve)

27. Have you experienced any of the following barriers when incorporating your school's operational wind turbine into your class(es)? Select all that apply

- I have not experienced any barriers
- I do not have the knowledge or training to work with an operational wind turbine
- I do not feel comfortable working with an operational wind turbine
- I do not have the class time
- I do not have enough preparation time
- I do not have enough resources or funding
- An operational wind turbine is unrelated to my subject area
- My school administrators do not allow my students near the operational wind turbine
- Using an operational wind turbine is not appropriate for the grade level I teach
- I am not interested in using an operational wind turbine
- Other:

28. How valuable is your school's operational wind turbine as an educational resource in your class(es)?

	1	2	3	4	5	6	7	8	9	10	
No educational value											High in educational value

29. To what degree do you personally agree or disagree with the following statement? I believe that having an operational wind turbine improves student interest and engagement in my class.

- Strongly disagree
- Disagree
- Somewhat disagree
- Somewhat agree
- Agree
- Strongly agree

30. Do you have any final comments, concerns, or recommendations related to the use of operational wind turbines within STEM classes?

« Back Continue »

Questionnaire: An Investigation on How Operational Wind Turbines are Used in Secondary Classrooms

End of Survey

Please click "SUBMIT" if you have completely finished this questionnaire. If you have not yet completed the questionnaire, click "BACK" to navigate to the previous page(s). Thank you for your participation in this study. Your input will greatly benefit this research. If you are interested in learning more about this study and how operational wind turbines are used in secondary education, visit the following website: https://sites.google.com/site/windturbinesinschool/ Conclusions for this study will take time to develop and will be made available on this website on November 16th. Thanks again for your contributions.

« Back | Submit

APPENDIX B

COVER LETTER FOR THE QUESTIONNAIRE

Dear Teacher:

Your school has been selected to participate in a study looking at how operational wind turbines are used to reinforce STEM concepts. In other words, because your school has developed its own wind turbine project, my team is interested in learning more about how you are using your school's operational wind turbine within your classroom. Wind has proven to be an affordable and reliable energy source and a great context for STEM education. Yet there are few curricular resources that detail how operational wind turbines can be used to create engaging experiences for students.

My goal is to compile a list of practical activities and educational advantages or disadvantages for different kinds of turbines that you and other teachers can use to improve student learning and experiences in STEM classes. However, to do this, I need your help.

I need you to complete a short and simple questionnaire. Below is a link that will take you directly to the online questionnaire. This questionnaire has been designed to be fast (takes approximately 10 minutes) and easy to use (mostly multiple choice and check boxes with a couple open ended questions), and all questionnaire responses are submitted anonymously. It should also be noted that your participation is strictly voluntary, and any information provided will only be used by the researcher for the purposes of this study.

Please take a few minutes to complete this survey. Thank you for your time.

Sincerely,

James Smith

Graduate Student: University of Northern Iowa

ONLINE SURVEY LINK:

https://docs.google.com/spreadsheet/viewform?fromEmail=true&formkey=dFhTX1VIcz
Y5UmpmUi1JU2p6R1QzMGc6MQ