From Workshop to Wind Turbines: Inspiring Middle School STEM Education

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Abstract

This initiative was the result of a grant provided by the Kansas NASA Space Grant Consortium (KSGC). Middle school teachers (grades 6-8) in western Kansas actively engaged in a workshop designed to broaden their understanding of wind energy, solar power, and the power grid, aiming to enhance their students' proficiency in science, technology, engineering, and mathematics (STEM). Through the incorporation of the Next Generation Science Standards Disciplinary Core Ideas related to earth and space science, along with the integration of the Standards for Mathematical Practice, and the practical applications of science education activities developed by the NASA Science Mission Directorate, educators delved into exploring the interconnectedness of Earth as a system and various weather phenomena. This comprehensive approach aimed to equip teachers with the knowledge and tools necessary to effectively instruct their students on the principles of renewable energy.

1. Introduction

A two-day workshop, "Wind Energy in the Land of Oz," was offered for middle school teachers in western Kansas. Experts in renewable energy provided teachers with information about science, technology, engineering, and mathematics (STEM) careers related to wind energy, engaging under-represented groups. The workshop connected to NASA efforts in the Science Mission Directorate Research [1].

This project invested in both the intellectual and material capital available to middle school teachers in as a means of expanding their knowledge of wind energy, solar power, and the power grid which can enhance their students' STEM skills and interest in not only STEM careers, but also renewable energy. By integrating the NGSS Disciplinary Core Ideas [2] of earth and space science, as well as the Standards for Mathematical Practice [3], middle school teachers explored earth as a system with an emphasis on renewable energy.

The workshop focused on earth and space science as teachers explored different models of wind power applications, as well as integrating science, data analytics, engineering, and career connections. The teacher training allowed teachers to explore the power of wind by building and testing wind turbines and then preparing their students to build and test their own wind turbines.

2. Student Targets

The imbalance of women vs. men persists in the technology industry. The problem is not only getting girls to engage with technology, but also keeping them there. According to the International Renewable Energy Agency (IRENA), the wind energy industry is largely male-dominated; women represent 21% of the wind energy workforce [4]. The 2019 National Renewable Energy Laboratory reported, "employment in the U.S. wind industry increased 32% from 2015 to 2016 – yet, in 2019, women made up only 25% of the wind energy workforce and only 13% of those were wind energy research scientists and engineers" [5]. Researchers suggest that addressing the gender gap means "encouraging women interested in wind and renewable energy careers to form and nurture professional relationships, be open to different roles and experiences, and be persistent in searching for the right opportunity" [5].

The two-day workshop and follow-up training, as well as on-going individual consultations built a network of teachers working with the university who see the promotion and use of wind energy as a tool to attract and excite middle school students into STEM careers. This project, while indirectly working with students, was designed to create an environment to support middle school girls' teachers – those who will have a long-term relationship with the girls, as well as the boys, from each of the schools involved in the project.

During the recruitment phase for the workshop, schools were targeted that served underrepresented communities in western Kansas and indicated support for women in STEM-related fields. We personally contacted all teachers who had shown an interest in including wind energy in their school curriculum or extra-curriculum.

3. STEM Alignment

The Next Generation Science Standards (NGSS) [2] for K–12 education was created through a cooperative effort led by a multi-state initiative. These standards are comprehensive in both content and practical application, organized in a cohesive manner across various disciplines and grade levels. They aim to offer students a science education that is internationally comparable. The development of these standards is grounded in the Framework for K–12 Science Education, which was crafted by the National Research Council [6].

The NGSS Disciplinary Core Ideas (DCI) [7] encompass fundamental scientific concepts integral to an NGSS curriculum, spanning four key domains: physical science, life science, earth and space science, and engineering, technology, and applications of science. These core ideas serve as the foundational content that shapes an NGSS curriculum, emphasizing key areas of factual comprehension within each scientific discipline. Rather than memorizing a multitude of isolated science concepts, DCIs assist students in building an interconnected comprehension of essential STEM ideas. This interconnected understanding equips them to make sense of real-world phenomena and devise practical solutions to various problems.

Renewable energy and a focus on wind technologies is aligned to NASA’s mission needs in the Science Mission Directorate [1], aligned with the NASA STEM Goals 2 and 3 – Goal 2: Build a diverse future STEM workforce by engaging students in authentic learning experiences with NASA’s people, content and facilities, and Goal 3: Attract diverse groups of students to STEM through learning opportunities that spark interest and provide connections to NASA’s mission and work.

The project was intentionally aligned with the NGSS. The project involved active participation from both middle school teachers and subsequently their students in engineering and mathematical modeling. Participants were involved in a hands-on approach where they are not merely learning theoretical concepts but were actively engaged in applying engineering principles and mathematical models to real-world scenarios, in this case, related to wind energy.

The project established specific connections to the Middle School (MS) energy standards, as highlighted in Table 1. The content, activities, and learning objectives of the project were directly related to the energy standards specified for middle school education. These standards cover key concepts related to energy transfer, scientific principles, and the application of engineering solutions.

This alignment with NGSS, coupled with the focus on engineering and mathematical modeling, shows that the project was not only about conveying information but also about achieving specific educational objectives. These objectives included fostering critical thinking skills, promoting hands-on learning experiences, and instilling a deep understanding of energy concepts among both teachers and students.

The project's intentional alignment with NGSS, active engagement in engineering and mathematical modeling, and specific connections to middle school energy standards collectively contributed to a robust and targeted educational experience that goes beyond traditional classroom learning. It emphasized the practical application of science and engineering principles in the context of wind energy, aligning with contemporary educational standards and goals.

Table 1. NEXT Generation Science Standards

MS-PS3-3.	Apply scientific principles to design, construct, and test a device that either minimizes or maximizes energy transfer.
MS-PS3-5.	Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object
MS-ETS1-1.	Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
MS-ETS1-3.	Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
MS-ETS1-4.	Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved [2].

Additionally, the Standards for Mathematical Practice (SMPs) [3] outline the skills that educators in mathematics should aim to cultivate in their students. These practices are built upon significant processes and proficiencies that have enduring importance in the field of mathematics education. The mathematical practices dictate that students should encounter mathematics as a challenging, cohesive, practical, and logical subject.

The project aligns with specific Standards for Mathematical Practices outlined in Table 2. For instance, SMP 1 involves making sense of problems and persevering in solving them, which is evident as students work through challenges related to wind turbine design. SMP 4, focused on modeling with mathematics, is exercised as students use their mathematical knowledge to solve real-world problems in the context of wind energy.

These mathematical practices offer a depiction of how students should engage with and comprehend mathematics in the classroom. It is essential to seamlessly integrate these practices into every mathematics lesson, ensuring their incorporation for all students.

A wind energy project provides a valuable opportunity to involve students in a challenging and genuine learning experience. This project not only delves into the realm of renewable energy but also integrates and aligns with specific Standards for Mathematical Practices (SMPs), as illustrated in Table 2.

Table 2. Standards for Mathematical Practice

SMP 1	Make sense of problems and persevere in solving them calls for students to explain to themselves the meaning of a problem and look for entry points to its solution. This SMP focuses on students understanding problems so they can know how to begin to develop a solution strategy.
SMP 4	Model with mathematics expects student to use their knowledge of mathematics to solve real problems without previously having encountered a specific problem. Students use a variety of representations, interpret, reflect on, simplify, and make assumptions based on their mathematical knowledge to solve real-world problems.
SMP 7	Look for and make use of structure, students look for patterns and structures and can break down complex problems into either several objects or single objects [3].

Each of these SMPs make connections to real-world applications and problem-solving skills through authentic learning experiences. The wind energy project involved tangible, real-world applications of mathematical concepts. Students are not just crunching numbers in abstract exercises; instead, they are applying mathematical practices to address practical challenges related to wind energy.

Furthermore, engaging in a wind energy project necessitates problem-solving skills. Students encounter authentic issues associated with designing, constructing, and testing wind turbines. They must apply mathematical practices to devise effective solutions, mirroring the type of problem-solving skills needed in various STEM-related fields.

Wind energy projects often involve understanding the structural components of wind turbines. SMP 7, which encourages students to look for and make use of structure, comes into play as students examine patterns and structures related to wind turbine design. They learn to break down complex problems into manageable components, enhancing their structural understanding. By integrating mathematical practices into a wind energy project, students gain a more authentic and immersive learning experience. The skills they develop are not isolated from real-world applications but are integral to the successful implementation of the project.

This wind energy project served as a conduit for students to engage in a genuine, hands-on learning experience while concurrently honing their mathematical skills in alignment with specific Standards for Mathematical Practice. This integration reinforces the practical and applicable nature of mathematical concepts in the context of renewable energy exploration.

4. Educational Workshop Schedule

To achieve the workshop goals, the middle school teacher workshop and its follow-up has four distinct phases. A teacher in-service workshop was held for two days in fall 2022 and led by trained Wind Senators who provided a hands-on wind energy experience. The training introduced 15 western Kansas teachers to wind energy, and provided teachers the opportunity to engage in interactive and interschool wind energy research. Additionally, teachers were introduced to NASA aeronautics research.

4.1. Phase 1: Recruitment

Fifteen middle school teachers from rural and high-needs districts in western Kansas were recruited to participate in the two-day workshop during fall 2022. Recruitment efforts included promotion on the university’s Science Mathematics Education Institute (SMEI) web page, emails through the Kansas State Department of Education STEM Program Manager’s listserv, as well as utilizing the College of Education’s Superintendent Network.

4.2. Phase 2: Workshop

In fall 2022, the project team facilitated a comprehensive two-day workshop with middle school teachers. The focus was on preparing teachers to educate their students about renewable energy, NASA connections, and potential career opportunities. The Kansas Energy Program contributed a wind tunnel for the workshop, along with KidWind Basic Wind Experiment kits for each participating teacher. The kits were comprised of materials designed for eight groups, with 2 to 4 students in each group. Each group autonomously constructed hubs and blade sets. To assess their designs, students utilized one of three teacher-constructed "test stations," featuring a tower, base, and generator.

During the first day of the workshop, participants began with introductions, fostering a collaborative environment. Subsequently, there was an in-depth exploration of the Kansas Standards for Earth and Space Science [2], with a particular emphasis on incorporating perspectives from NASA's Science Mission Directorate [1]. The session also featured the practical application of NASA teaching resources, specifically focusing on engineering problems related to the Earth and harnessing wind power.

Moving on to the second day, the agenda included an overview of "Energy 101: The Electric Grid" to provide participants with a comprehensive understanding of the subject matter. An engaging activity titled "Energy Enigma" from the National Energy Education Development (NEED) Project [8] followed, offering a hands-on experience as participants put on their detective hats and research clues to uncover energy facts. This cooperative learning activity approach accessed literacy and critical thinking skills as students try to conceal their own energy source while guessing the opposing teams' sources [8]. The day proceeded with the integration of Energy and Data Analytics, including guided practice sessions. Participants also had the opportunity to engage in activities within the Energy Breakout Room facilitated by the Kansas Energy Program.

The workshop featured a working lunch, accompanied by a presentation from Kansas Strong to enhance participants' insights into natural gas and oil production in Kansas. The latter part of the day was dedicated to an introduction to the KidWind Challenge [9], a hands-on initiative aimed at enhancing understanding. Practical activities included the assembly of turbines, time allocated for hands-on experimentation and testing, exploration of gear ratios and blade designs, engagement in single fan activities involving weight-lifting and electricity production, and finally, wind tunnel testing. This comprehensive schedule provided an immersive and dynamic learning experience for all teacher participants.

4.3. Phase 3: Follow-up

After the two-day workshop, teachers actively engaged their middle school students in discussions centered on renewable energy, specifically wind energy. Working in teams, middle school students explored the power of wind by designing, building, and testing their own wind turbines, in anticipation of the Kansas KidWind Challenge [8]. The project team was available to support teachers and students during this phase. Additionally, two wind tunnels and sensors were made accessible for checkout from the university.

Plans were developed to support teachers in preparing their students for the Kansas KidWind Challenge in February 2023.

5. Outcomes

Sixty-seven percent (67%) of the teachers involved in the two-day workshop were women. All teachers involved in the training have been able to articulate how to use renewable energy discussions in their middle school classrooms to promote student interest in STEM.

Approximately half (50.1%) of the middle school students in the included schools are females. Among the middle school student population, 37.5% belong to underrepresented minority groups, and 52.9% of students from participating schools face economic disadvantages. A significant proportion, 53.3%, took part in the Regional KidWind Challenge. Seven student teams attended the Regional KidWind Competition, and although they did not win, the teachers reported high engagement of students in STEM. Of those who did not attend the Regional Competition, they hosted an internal competition in their middle schools.

We surpassed our anticipated targets in female involvement, disabilities, and underrepresented demographics. The projected female participation was 47%, but the actual turnout reached 67%. There were no anticipated participants with disabilities, yet the actual number turned out to be 7%. The expected impact on 25% of students was exceeded, with the actual figure reaching 37.5%.

Informal feedback from teachers suggests that the materials purchased will be utilized over an extended period. Middle school educators, for instance, are indicating that they are integrating the acquired information into year-round programming with their students. We are providing support for the schools with a lending program of wind tunnels for classroom use.

6. Conclusion

Fifteen middle school teachers from rural schools in western Kansas participated in the two-day workshop during the fall of 2022. Workshop leaders shared information that prepared the teachers to teach about renewable energy. KidWind Basic Wind Experiment kits were provided to each teacher.

The "Wind Energy in the Land of Oz" workshop successfully addressed the critical need for expanding middle school teachers' knowledge of wind energy, solar power, and the power grid.

This workshop, aligned with the Next Generation Science Standards and NASA's STEM goals, aimed to not only enhance teachers' understanding but also to stimulate students' interest in STEM careers, particularly in the underrepresented field of renewable energy.

The project strategically focused on narrowing the gender gap in the technology and wind energy industry, acknowledging the predominance of males in this sector. By investing in teacher training and building a network to support middle school educators, the initiative aimed to create a lasting impact on students, fostering their interest in STEM fields. The recruitment process targeted schools supportive of women in STEM and aimed to increase representation from underrepresented minorities in western Kansas.

The workshop's educational schedule, divided into distinct phases, provided hands-on experiences, interactive research opportunities, and connections to NASA's aeronautics research. The alignment with the Next Generation Science Standards and Standards for Mathematical Practice ensured a comprehensive and authentic learning experience for both teachers and students.

The outcomes of the project exceeded expectations, with a significant percentage of female teachers and students actively participating. Moreover, the initiative successfully engaged underrepresented minority groups and economically disadvantaged students. The participation in the Regional KidWind Challenge, although not resulting in a win, demonstrated high student engagement in STEM activities.

Teachers are now able to engage their middle school students in discussions on renewable energy, specifically wind energy as they work with their students to explore the power of wind by designing, building, and testing their own wind turbines.

The informal feedback from teachers indicates a lasting impact, with educators incorporating the acquired knowledge into their year-round programming. Overall, the "Wind Energy in the Land of Oz" project has not only achieved its immediate goals but has also laid the groundwork for a sustained and meaningful impact on STEM education in western Kansas middle schools.

7. References

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