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Chapter 45: The Link between Science & Engineering in NGSS Classrooms

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Abstract: This capstone study presents the results of literature review articles and observations of classrooms in America, looking specifically at engineering in science classes using Next Generation Science Standards (NGSS) and Science, Technology, Engineering, and Math (STEM). In Saudi Arabia the class periods are of short duration and do not apply real practical scientific application. The goal of this study was to determine if NGSS will bridge the gap between curriculum and focus on real life engineering concepts and what methods American school system **teachers** use for science classes. The evaluation of literature on current science trends, STEM, and NGSS in America indicates that when students are exposed to STEM with technology and engineering as early as Kindergarten the interest in science will increase. Findings throughout the research showed that students in K-12 who are exposed to engineering concepts will have increased achievement in math and science. The findings through my observations were quite positive; showing that when students are provided hands on materials in STEM they increase their thinking skills and became more excited with the lesson. The action research shows that STEM, NGSS, and engineering increase student interest and achievement.

Introduction

Devices, Equipment, Experiment, and Challenging minds. Those are the things that make up a scientific thinking better. Science education in the United States has had tremendous leaps and America is one of the most developed countries scientifically and technically. As a teacher, I look at the ways of teaching science and found that there are standards adopted by schools to teach students science. The latest of these methods in education is Next Generation Science Standards (NGSS). According to NGSS, science and engineering learning is combined at the same time with a focus on major concepts in science and away from the many facts associated with it.

The educational system in the Kingdom of Saudi Arabia is characterized by a short duration of the class and a lot of information in the school curriculum with few practical applications the lack of link between the curriculum and real life. My 18 years of experience in middle and high school chemistry classes has lead me to realize the need for the application of science education standards for the next generation a special solution to bridge this gap by focusing on concepts and engineering applications. I hope to advance the scientific level of students in my beloved country through a generation of learners who can benefit from his knowledge at the technical and engineering levels. The lack of link between the curriculum and real life.

Methodology

Action research and observations were selected to compare data collected at University of Central Florida BLCIS with the cultural of my teachings in Saudi Arabia to understand how to change science classes with application of engineering and NGSS.

The independent capstone project used in this action research allowed me to read research articles on STEM in American schools, Next Generation Science Standards (NGSS), K-12 curriculum, high quality education in America, teaching strategies in Science, and the vision of scientific classrooms. This also included observational research in United States schools with teachers and students. My research will help me discover how to change a stimulating environment to students and apply engineering in my science classes with NGSS. I also used observations as a method for research. I observed a third grade public school class in Orange County, Florida with Hidden Oaks Elementary. This was a public school that opened in 1991 with rougly 400 students in grades PreK-5th. But a new building was just built last year. The school offers resources, cafeteria, media center, and a playground. My academic literature research was done the fall of 2019 and continued with public school observations at Hidden Oaks Elementary school during the spring of 2020. It is my theory that it is better for students in science classes to be exposed to engineering using Next Generation Science Standards.

Article research information was taken to indicate that NGSS will prepare high school students for their college or career. I used a variety of methods in my observations such as conferences, workshops, interviews, collection of quantitative data, and note-taking. Observation of American school systems was conducted while teachers were teaching lessons to American students and volunteering my time. I was able to observe elementary students and collected information using observation and note-taking of the variety of teaching lessons and methods the American teachers use to produce the concepts on engineering in science. I also asked questions from the staff to determine answers related to my topic.

From my literature review I discovered that NGSS are aligned with the grade level, using STEM in the classroom will raise a student's interest, and that all students benefit from NGSS, STEM, and engineering with other academic areas such as math and literacy. In comparison, students in America have higher achievement with academics when they have STEM or NGSS in the science lessons but in Saudi every student learns with videos, teacher lessons, experiments and labs; they do not apply engineering skills and do not make any engineering models in science. Student's do not have the connection between real-life and science because teachers use textbook, tools, labs, and experiments. From my action research at Hidden Oaks I worked with third grade ELA students. The class had a reading area, computer area, laptop shelves, and digital board. The students were in small groups of 3-4. The research and studies are clear that in the American schools students perform better when they are with their peers with stimulating activities in Science.

Literature Review

In the first book I read; NGSS and the landscape of engineering in K-12 state science standards, I found out that Recent documents pertaining to K-12 education have fostered a connection between engineering and science education to help better prepare our students and future citizens to better meet the current and future challenges of our modern and technological society. "When looking at the increased emphasis that is being placed on engineering in the NGSS, it is important to highlight some of the main arguments behind why the addition of engineering into K-12 classrooms is beneficial to student learning. Three main arguments in favor of this are that: (1) engineering thinking helps with the development of 21st century skills in students, (2) engineering pedagogies have potential to increase student achievement in mathematics and science, and (3) engineering contexts have potential to increase student interest in STEM disciplines and careers". (Moore, et al, 2015).

The research showed that Academic standards have played a role in the educational system since the Committee of Ten set out to standardize high school education more than a century ago through recommendations that advocated that education should prepare all students to be successful in life. These recommendations led to the elementary-secondary structure of education still present in the U.S. today. "There was also an increase found in students' interest and attitudes in STEM subjects in studies that involved curriculum used as extracurricular programs such as Adventure Engineering ". (Moore, et al, 2015). In my view, adding geometry to science education fosters engineering thinking one of the most important skills of the 21st century and is a component of STEM. Further benefits of introducing engineering into the K-12 curricula are increased interest in STEM subjects and careers in STEM fields. Many recent policy documents have made the argument that the U.S. economy needs more engineering and STEM professionals, especially from underrepresented populations, if we are to remain competitive. For example, the executive report to the President of the United States entitled Prepare and Inspire: K-12 Education in Science Technology, Engineering, and Mathematics (STEM) for America's Future, states that the U.S. must prepare students with a strong STEM background in order to be competitive in a global society.

To further my action research I reviewed The NGSS for states by states article which described the development of the goal of the NGSS is to be clear about which practice students are responsible for in terms of assessment, but these practices and crosscutting concepts should occur throughout each school year. To develop a thorough understanding of scientific explanations of the world, students need sustained opportunities to work with and develop the underlying ideas and to appreciate those ideas' interconnections over a period of years rather than weeks or months. The Next Generation Science Standards (NGSS) were developed by a group of 26 states in U.S working with a writing team of 41 national experts in science education, facilitated by Archive, Inc. In addition to input from the 26 lead states. The **NGSS** reflect a multitude of contributions from many stakeholders.

" The NGSS concentrate on "a smaller set of DCIs that students should know by the time they graduate from high school, focusing on deeper understanding and applicable of content." (NGSS, 2013). Linking science to engineering and modeling is a very important part of the educational process, and it offers greater opportunities to validate scientific information and concepts. NGSS has three parts: disciplinary core ideas (DCIs) (content), science and engineering practices (SEPs), and crosscutting concepts (CCs).So, the Next Generation Science Standards (NGSS) provide an important opportunity to improve not only science education but also student achievement.So, the NGSS are intended to reflect a new vision for American science education. "The **NGSS** content is focused on preparing students for college and careers. the **NGSS** are aligned by grade level and cognitive demand with the English Language Arts and Mathematics Common Core State Standards, This allows an opportunity both for science to be a part of a child's comprehensive education and for an aligned sequence of learning in all content areas" (NGSS, 2013).

There was also an increase found in students' interest and attitudes in STEM subjects in studies that involved curriculum used as extracurricular programs such as Adventure Engineering During my action research I also studied the National Research Council guide to implementing the next generation science standards, and

I found out that NGSS present a vision of science and engineering learning designed to bring these subjects alive for all students, emphasizing the satisfaction of pursuing compelling

questions and the joy of discovery and invention. "Next Generation Science Standards (NGSS) describe a new vision for science learning and teaching that is catalyzing improvements in science classrooms across the United States. Successful implementation of the NGSS will ensure that all K-12 students have high-quality opportunities to learn science. identifies some overarching principles that should guide the planning and implementation process" (NGSS, 2015).

Creating a classroom environment and teaching staff is one of the most important factors contributing to the application of any teaching method. The National Research Council guide found that Apply NGSS in classrooms will be a major undertaking will require changes to science education. I found that in this book The NGSS offer a vision of science classrooms where students learn the core ideas and crosscutting concepts of science through engagement in the practices of science and engineering. "resource and mentor teachers should help classroom teachers understand and adopt the new vision for science learning and instruction through incremental and continuing changes to instruction. They should provide teachers with the curriculum resources needed to support this vision" (NGSS, 2015).

In Instructional research in the NGSS, McNeil showed that Successful implementation of reform efforts, such as the Next Generation Science Standards requires attention to multiple levels of the education system and various stakeholders involved. School principals are responsible for leading sweeping instructional reforms resulting in new roles to support changes to classroom instruction. It is my view that training school leaders and science teachers on the standards of science education for the next generation is important before they are applied in schools. The focus on science practices provides as (NGSS) a vision for teaching and learning that cannot be realized without sufficient support for teachers.

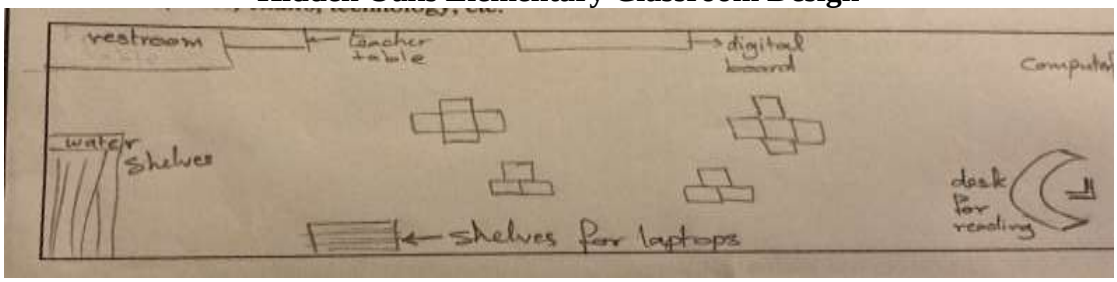
OCPS Observations for Immersion

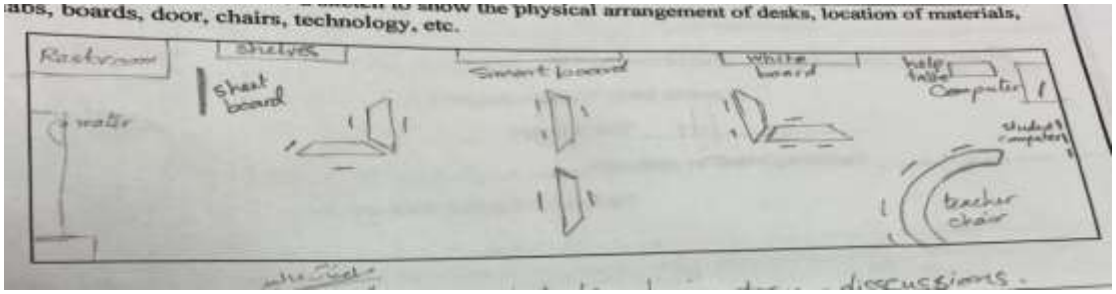
Hidden Oaks Elementary is the OCPS School that I observed at with 443 students. The school is a public school where any child in the zip code can attend. They serve children from PreK-5th grade with mostly students who are still learning English or have disabilities. So the teachers focus many lessons on helping children learn to read and write. The school is also a center for ESE students which means that they offer many services to students with disabilities. I also learned that they have clubs for students like art, chores, and student council. The school has been around since 1991 and received an Energy Star Award for their achievements. Their mission is to be the top producer of successful students in the nation. They focus on the following goals- Intense Focus on Student Achievement, High-Performing and Dedicated Team, Safe Learning and Working Environment, Efficient Operations, and Sustained Community Engagement. The teachers are involved with PTA (parent-teacher association) which I was able to volunteer and observe at meetings. The principal at Hidden Oaks says she is "committed to excellence" and the teachers work hard to make school a place for parents, teachers, and students to work together on education. The OCPS Science curriculum follows FLDOE Next Generation Sunshine State Standards in Science including embedded Florida Standards

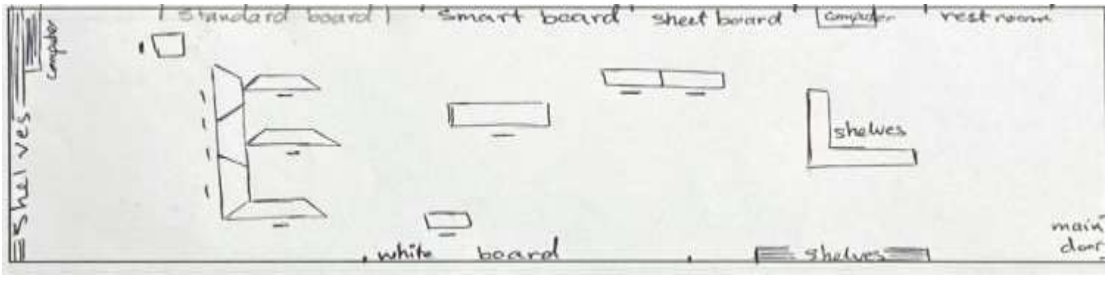
I noticed that the classrooms challenges for students where the students are independent thinker and problem solver. They are helping each student develop an enthusiasm for Learning and the skills to become a creative independent thinker and problem solver. They also use a technology program called Destiny where the students and families can check out books and academic support materials directly from their computers. This is a good program because it allows families that want to work on STEM at home to find

materials that they can use. The families like the free materials since buying things for STEM can be costly. I also got to view the American art class which was very beautiful and have a lot of material which help students to think and draw clearly. After the students finished their drawing the teacher asked him (or her) to discuss the drawing for a friend in the class. I noticed that all the classes that I visit the teachers start the class with explaining the standards and discuss the topic. They read it to the student's for the student's know what they learn today, the standards are the same for each grade level but different levels from easy to hard. I think having the standards is an easy way to organize the lesson and day for any subject not just in science. They also use many different level of thinking about one standard. For example, when learning weather with special education it is different than with 5th grade regular. Teachers also use simple strategies in special education such as small groups, visual support, some of the student's need devices to communicate or work. I am looking for how to apply these strategies and standards with lower level classes and how to deal with a student that has special needs or lower skills? This is something I am planning to explore more when I return home. Below are some diagram of the classrooms I observed and the computer labs.

Hidden Oaks Elementary Classroom Design







In my observations I learned about a variety of teaching methods and strategies such as route strategy. The students are working on reading, writing, and computers. During computers students use a program called i-ready and work on different levels. I-ready allows the children to complete reading activities based on their current level of reading so that children who are better readers are given more difficult text and those that cannot read are given phonics

lessons. The schools in Orange County use a lot of technology based programs to teach lessons. Each student has their own computer where they learn on different levels. They have been doing this since Kindergarten. I believe it's best to focus on the main ideas and from what I see the teachers in American focus on the standards.

During my studies I spoke with an OCPS veteran who had been a teacher for over 20 years and she shared BioInteractive, a website which is a fully interactive simulation that can ask students to collect data, complete experiments, and respond to questions. It is like a virtual lab that uses animations, illustrations, and videos to teach. In my opinion the virtual lab at bio interactive is an engaging way to teach the scientific standards to students. They can use real world applications for scientific discoveries. The labs are so interactive making the student feels the excitement that I plan to use them in my classroom when I return. It is these types of classroom activities that will increase thinking skills, student interest and achievement. Like i-ready as a teacher I can set up the labs based on student's skills. Students who are struggling with engineering concepts can be provided labs that are easier for them and those that are advanced in their skills can be given more difficult labs to complete online.

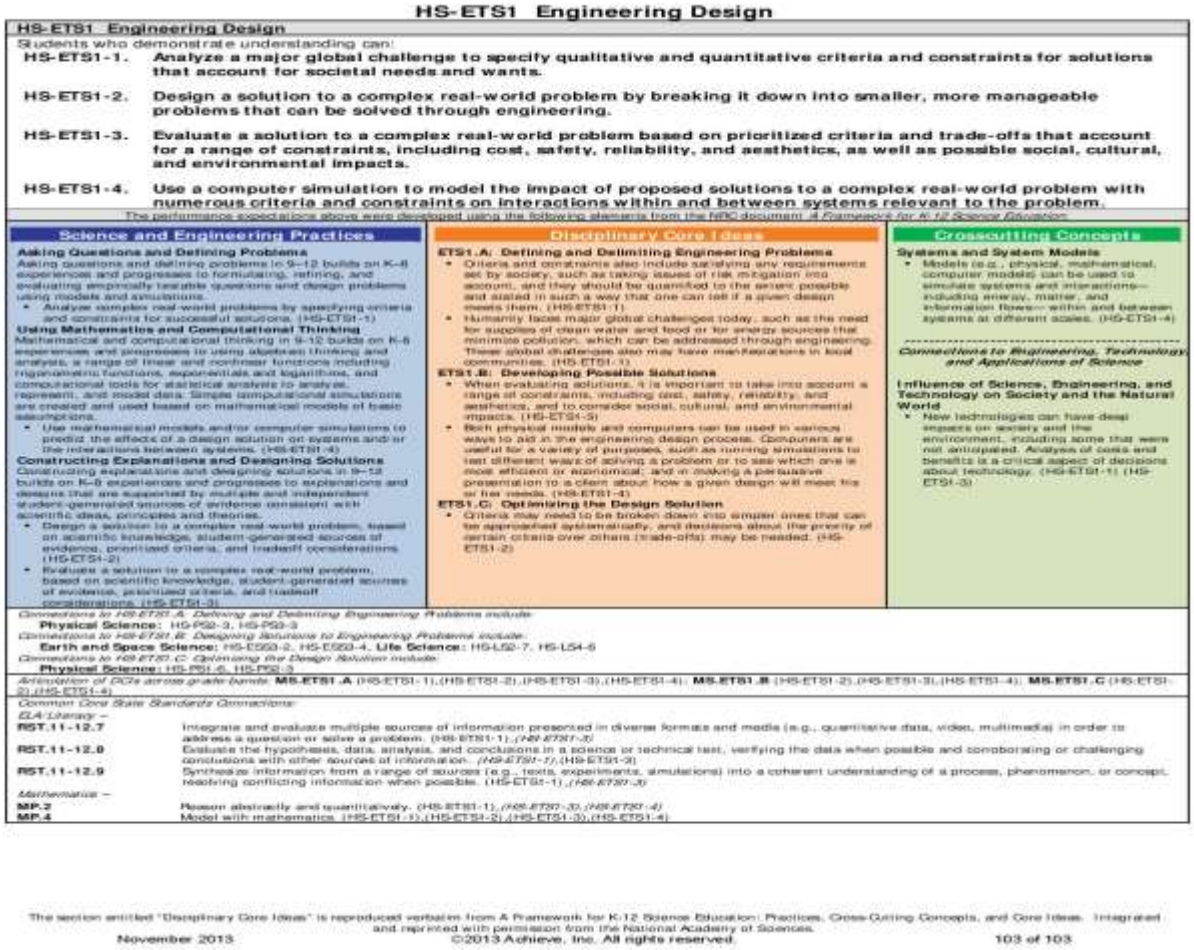
I believe that having access to the STEM fields is essential if we want a nation where our future leaders have the ability to understand and solve the complex challenges of today and tomorrow. STEM engages with active exploration to the scientific process through hands-on experiences. If we implement more scientific instruction in KSA it will also improve abilities in literacy, language-learning and critical thinking skills. While I was in the Orange County schools, I learned about how OCPS received a 25 million dollar grant to award teachers who demonstrate improving student achievement in STEM. The purpose of the grant is to increase student achievement into the main K-12 curriculum with a variety of activities. The schools are using STEM challenges in the classrooms where students are asked to complete a specific STEM activity at home following specific guidelines. They are then asked to bring the project into class to compete against classmates, then the school, and then they move onto the district for a final winner. Here is a sample of one of the challenges: **We challenge you to**….design and build a car that can travel the farthest distance under the power of a balloon. The cars will be tested on a

linoleum surface (in the hallways at school). You will blow up the balloon, place the front of the car behind the starting line and release the balloon. The distance the car moves from the starting line (measured to the front of the car) will be the recorded distance. Below are the supplies that you can use to build your Balloon Car in addition to any sticking supplies like glue and tape.

This is the exact activities that I want to promote in the Saudi classrooms and share with teachers at home. OCPS challenge exposes students to engineering concepts where they build and design a car. They are also using the methods of STEM with having to solve ways to make the car move. I believe this will change our current issues in Saudi Arabia science classrooms and create a more stimulating environment for students to apply engineering skills.

During my studies in America I learned about how the teachers in American schools are using STEM NGSS standards so that their students have the ability to think critically, analyze, and solve complex problems. Students in KSA need scientific skills to succeed since more jobs will require skills in science, technology, engineering, and mathematics (STEM). I was able

to learn and understand how to use the NGGS standards I plan to teach my students to develop their understanding of the physical sciences, life and earth and space science also. This include developing and using models, planning and conducting investigations, analyzing and interpreting data, using mathematical and computational thinking, and constructing explanations; and to use these practices to demonstrate understanding of the core ideas. I am also going to have my students demonstrate understanding of several engineering practices including design and evaluation. Students will now be able to define a problem, developing possible solutions, and create designs. Each of the NGSS standards has a connection to engineering integrate traditional science content with engineering through a practice. The real-world science allows me to have more engaging and relevant lessons for my beloved KSA students. Below is an example lesson plan that I was introduced to using NGSS standards that I could share with other science teachers:



HS-ETS1 Engineering Design

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Students who demonstrate understanding can:

HS-ETS1-1. **Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.**

HS-ETS1-2. **Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.**

HS-ETS1-3. **Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.**

HS-ETS1-4. **Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems

Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.

- Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1)

Using Mathematics and Computational Thinking

Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (HS-ETS1-4)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories.

- Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2)
- Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3)

Disciplinary Core Ideas

ETS1.A: Defining and Delimiting Engineering Problems

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1)
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1)

ETS1.B: Developing Possible Solutions

- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)
- Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)

ETS1.C: Optimizing the Design Solution

- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)

Crosscutting Concepts

Systems and System Models

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-ETS1-4)

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

- New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) (HS-ETS1-3)

Connections to HS-ETS1.A: Defining and Delimiting Engineering Problems include:

Physical Science: HS-PS2-3, HS-PS3-3

Connections to HS-ETS1.B: Designing Solutions to Engineering Problems include:

Earth and Space Science: HS-ESS3-2, HS-ESS3-4. **Life Science:** HS-LS2-7, HS-LS4-6

Connections to HS-ETS1.C: Optimizing the Design Solution include:

Physical Science: HS-PS1-6, HS-PS2-3

Articulation of DCIs across grade-bands: **MS.ETS1.A** (HS-ETS1-1),(HS-ETS1-2),(HS-ETS1-3),(HS-ETS1-4); **MS.ETS1.B** (HS-ETS1-2),(HS-ETS1-3),(HS-ETS1-4); **MS.ETS1.C** (HS-ETS1-2),(HS-ETS1-4)

Common Core State Standards Connections:

ELA/Literacy –

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ETS1-1),*(HS-ETS1-3)*

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. *(HS-ETS1-1)*,(HS-ETS1-3)

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-1),*(HS-ETS1-3)*

Mathematics –

MP.2 Reason abstractly and quantitatively. (HS-ETS1-1),*(HS-ETS1-2),(HS-ETS1-4)*

MP.4 Model with mathematics. (HS-ETS1-1),(HS-ETS1-2),(HS-ETS1-3),(HS-ETS1-4)

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Results

There was also an increase found in students' interest and attitudes in STEM subjects in studies that involved curriculum used as extracurricular programs such as Adventure Engineering. Adding geometry to science education fosters engineering thinking one of the most important skills of the 21st century and is a component of STEM. Further benefits of

introducing engineering into the K-12 curricula are increased interest in STEM subjects and careers in STEM fields. In comparison, students in America have higher achievement with academics when they have STEM or NGSS in the science lessons but in Saudi every student learns with videos, teacher lessons, experiments and labs; they do not apply engineering skills and do not make any engineering models in science. showing that when students are provided hands on materials in STEM they increase their thinking skills and became more excited with the lesson. The action research shows that STEM, NGSS, and engineering increase student interest and achievement.

Conclusion

Devices, Equipment, Experiment, and Challenging minds. Those are the things that make up a scientific thinking better. Science education in the United States has had tremendous leaps and America is one of the most developed countries scientifically and technically. The need for the application of science education standards for the next generation a special solution to bridge this gap by focusing on concepts and engineering applications. In conclusion to advance the scientific level of students in my beloved country through a generation of learners who can benefit from his knowledge at the technical and engineering levels we will link between the curriculum and real life to have better forward thinkers in Saudi and students in K-12 will have increased achievement in math and science

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I was in the BLCSI Newsletter for my work in America and the program.

Norah Mohammad S Alahmri

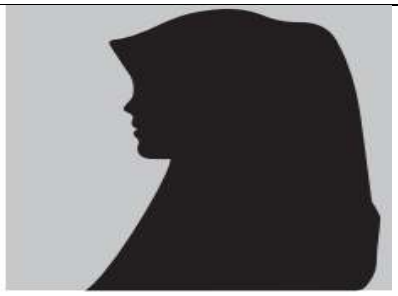
ELEMENTARY SCHOOL - SCIENCE

BIOGRAPHY

Norah Mohammad S Alahmri is from Riyadh, Saudi Arabia and has 18 years of teaching experience. She works at the elementary school level, and focuses on Science.

SUMMARY OF ACCOMPLISHMENTS

Norah is from the Aseer Education Department in the Kingdom of Saudi Arabia. She obtained a master's degree in curricula and methods of teaching science. She worked in high school teaching for 15 years and in training and teaching talented students for two years in elementary school.



Norah is on her way to becoming a pioneer in education in the Kingdom of Saudi Arabia. She started the program with some hesitation on the type of work required, but she is completing tasks above what is required, and writes in academic language. She also has a clear understanding of scientific research. Norah is passionate about finding ways to bridge the gap between science and technology by STEM and methods of acquiring scientific concepts. She is very interested in studying the standards of science education for the next generation (NGSS) and how to apply them in the classroom. This is a new trend in the methods of teaching science.