An Investigation of the Current Landscape of K-12 Engineering Education and the Potential Impact of NGSS on First Year Engineering Curricula

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Abstract - **For the first time engineering is included in a national science standards document. The Next Generation Science Standards (NGSS) incorporate engineering design as a stand-alone concept with a set of specific engineering design standards and integrate it throughout the typical science content areas (life science, physical science, and earth and space science). Over the next few years, the influence of these standards will impact students entering engineering programs because they will experience engineering design throughout their K-12 education. In this paper, we describe a research study in progress that seeks to better understand how students are prepared in high school to succeed in the first year of an engineering curriculum. Our study is focused on answering the following research questions: (1) How are students currently prepared in high school to be ready for an engineering program? (2) How is success in a first year engineering curriculum defined? What are the measures of success currently being utilized? What are the strengths and what are the challenges? (3) What impact will NGSS have on the first-year engineering curriculum? In particular, will there need to be a shift in the kinds of material included in the first year curriculum given the emphasis on engineering design at the high school level?**

Index Terms –Next Generation Science Standards, Preparatory Curriculum.

INTRODUCTION

The Next Generation Science Standards were released in April 2013 and will be implemented in K-12 schools beginning in 2014. The standards represent a shift in science, which includes significant engineering content related to the design process and the differences between science, engineering, and technology. The development of the standards was guided by the "Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas." [1] The standards are organized around disciplinary core ideas and cross cutting concepts. The cross cutting concepts are the themes that cut across all science subjects. The cross cutting concepts are: (1) patterns, (2) cause and effect: Mechanism and explanation, (3) scale, proportion, and quantity, (4) systems and systems models, (5) energy and matter: flows, cycles, and conservation, (6) structure and function, and (7) stability and change. The disciplinary core ideas are the major subject areas within science and include (1) physical sciences, (2) earth and space science, (3) life science, and (4) engineering, technology, and applications of science. Engineering was not mentioned in any science education document prior to the release of these Next Generation Science Standards.

The disciplinary core idea engineering, technology, and applications of science includes a focus on the engineering design process and links between science, engineering, and technology. The Next Generation Science Standards focus on the differences between the scientific inquiry and engineering design processes. The document highlights two major differences: (1) Scientists ask questions and engineers define problems and (2) Scientists construct explanations and engineering design solutions. Also embedded in the design process is its cyclical nature.

The Next Generation Science Standards state, "The Next Generation Science Standards (NGSS) represent a commitment to integrate engineering design into the structure of science education by raising engineering design to the same level as scientific inquiry when teaching science disciplines at all levels, from kindergarten to grade 12." [1, Appendix I, p.1]. The National Science Education Standards were published in 1996 and were the impetus for a move toward scientific inquiry and in 2013 most science teachers have a strong knowledge base of the processes involved in scientific inquiry and are incorporating them in their classrooms. The goal of incorporating engineering design to the same level as scientific inquiry is significant.

RESEARCH QUESTIONS

The focus of this paper is to begin to answer the following questions:

1. How are students currently prepared in high school to be ready for an engineering program?
2. How is success in a first year engineering curriculum defined? What are the measures of success currently being utilized? What are the strengths and what are the challenges?

3. What impact will NGSS have on the first-year engineering curriculum? In particular, will there need to be a shift in the kinds of material included in the first year curriculum given the emphasis on engineering design at the high school level?

POPULATION

In order to answer these questions we will use a convenience sample of teachers attending the STEM Education Summer Conference. Over the last five years, a team from CSU has organized the Engineering Education Summer Conference. The Engineering Education Summer Conference (EESC) has taken place at CSU under the direction of Dr. Stephen Duffy, Dr. Debbie Jackson, and Dr. Nigamanth Sridhar for the past five years. The EESC was funded by the University Transportation Center, housed in the Civil and Environmental Engineering Department in the Fenn College of Engineering. The EESC originated as a way to disseminate the successes of the Shaker Heights High School Engineering Applications course developed from the Garrett A. Morgan Technology and Transportation Education Program (GAMTTEP) grant to Mr. Joe Marencick. Mr. Marencick was instrumental in the success of the first EESC and has continued to provide support and guidance for following EESCs. The conference brings together K-12 educators and staff, university faculty, and industry professionals for a critical conversation about implementing and improving engineering education in the K-12 science and mathematics curriculum. Success seems apparent with 24 teachers from nine school districts, representing grades 2-12 attending the first EESC, 39 teachers from 14 school districts from grades 4-12 attending the second EESC in 2009, 46 teachers from 20 school districts or private/charter schools attending in 2010, and 54 teachers from 25 school districts attending in 2011. This year the EESC, renamed the STEM Education Summer Conference is supported by an NSF STEP grant, "Mathematics Achievement as a STEP for STEM Success." Through this conference and other outreach efforts, we have built a representative sample of teachers from a variety of schools (both public and private). We are also utilizing our connections with the Ohio STEM Learning Network to widen the sample of teachers throughout the state.

Online surveys will be administered during the STEM Education Summer Conference. These surveys will also be emailed to current teachers from a database of former students and through the Ohio STEM Learning Network. Participants will be asked if they are willing to participate in follow up interviews. A random sample of willing participants will be contacting to elaborate on their survey responses through a structured interview.

DATA COLLECTION AND INSTRUMENTS

In answering the three research questions both quantitative and qualitative measures will be utilized. An education and an engineering faculty member will analyze all data. This dual analysis and mixed methods design will facilitate a more complete analysis.

Research Question: How are students currently prepared in high school to be ready for an engineering program?
As previously mentioned the researchers are in contact with K-12 teachers throughout the state of Ohio. As a first step to designing a valid and reliable survey, the researchers will email 12-15 teachers in a variety of school districts how they are currently preparing students for engineering careers. The results of this question will serve as the basis for designing a survey to be sent to all teachers across Ohio. The results of this survey will be analyzed quantitatively. After the online survey is analyzed the results will be used to develop questions for semi-structured interviews. The interviews will be recorded, transcribed, and analyzed using traditional coding mechanisms.

Research Question: How is success in a first year engineering curriculum defined? What are the measures of success currently being utilized? What are the strengths and what are the challenges?
The researchers will begin to answer this question through a review of the related literature since 2000. The search will include engineering and education databases in an effort to ensure a complete and thorough review. The specific search will be for research studies about first year engineering curricula and success in these courses. Each research study will be read and the measures of success, strengths of the study, and limitations of the studies will be listed. After the list is created and studies are read by both the engineering and education faculty members the frequency for the measures will be figured and the strengths and limitations will be coded and organized into themes. This information will be reported to the engineering education and first year engineering communities along with the results of the other research questions.

Research Question: How is success in a first year engineering curriculum defined? What are the measures of success currently being utilized? What are the strengths and what are the challenges?
This question requires a thorough review of NGSS. All engineering concepts within the standards will be listed. This list will be condensed using qualitative analysis procedures including coding and creating themes. The results of this analysis will be compared to the first year engineering course at CSU as well as the ABET standards. This comparison will yield information about the alignment of NGSS to introductory engineering courses. The researchers will also use the comparison to make recommendations based on the alignment of the high school and college standards and curricula for future engineering courses.

DISCUSSION AND IMPLICATIONS

The answers to these research questions will provide important information for engineering educators, in particular, those creating first year engineering courses. The NGSS is the first national standards document that includes engineering and the ramifications of this for K-12 and for higher education are vast.

The level of preparation a student entering the first year engineering program has the potential to shift significantly given the emphasis on engineering in the NGSS. Such a shift in preparation levels will necessitate a shift in how the first year curriculum is designed and delivered. Our research study will provide a strong research base for the community involved in designing and delivering the first year curriculum in engineering programs.

Table 1: Methods and Instruments for Data Collection and Analysis

Research Questions	Methods	Analysis
1. How are students currently prepared in high school to be ready for an engineering program?	Online survey distributed to over 200 teachers Random sample of willing participants will be interviewed	Surveys will be analyzed quantitatively Interview questions will be designed based on the survey results Interview responses will be analyzed qualitatively
2. How is success in a first year engineering curriculum defined? What are the measures of success currently being utilized? What are the strengths and what are the challenges?	Thorough review of current (since 2000) engineering education literature Research studies will be collected and analyzed for instruments used and their strengths and weaknesses	Data from research studies will be analyzed qualitatively for patterns of frequency as well as documented strengths and challenges of current measures
3. What impact will NGSS have on the first-year engineering curriculum? In particular, will their need to be a shift in the kinds of material included in the first year curriculum given the emphasis on engineering design at the high school level?	NGSS engineering standards within core concepts and separate from core concepts will be collected and analyzed	Content analysis of NGSS specific to engineering standards Compare the results of the content analysis to the *Introduction to Engineering Design* Course at CSU as well as the ABET standards

REFERENCES

1. *A Framework for K-12 Science Education*, © 2012, National Academy of Sciences.