Cross-Cultural Training and Engineering: An Illustration Using Vietnamese Engineering Faculties' Responses to Nature of Engineering Instrument (Work in Progress)

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Abstract

Engineering faculty have advanced experiences with engineering that non-engineers do not have, but what Nature of Engineering (NOE) concepts do engineering researchers hold? For K-12 engineering education, having an informed NOE understanding is an essential part of engineering literacy. Yet for the higher education engineering community, NOE is hardly ever discussed. Understanding engineering faculties' NOE views can be a valuable contribution to current NOE research. Our project is part of a collaboration between a southwestern US higher education institute and a Vietnamese University. The cohort of Vietnamese engineering faculty is participating in training for research in environmental engineering for three months in the US. Vietnamese faculty is expected to improve their research skills at the end of the comprehensive professional development under the training of US environmental engineering researchers. Over the three months, Vietnamese faculty will search literature, learn lab skills and conduct a self-driven, lab-based research project in an environmental engineering lab. The purpose of our research is two-fold: Firstly, we will investigate what Vietnamese environmental engineering faculty say in response to the NOE instrument; secondly, the purpose of our study is to explicate the impact of a collaboration between a US university and a Vietnamese university. More specifically, our research study will identify NOE views of Vietnamese engineering faculty prior to and after training. While Nature of Engineering (NOE) views are increasingly growing stateside, it is equally important to look at the views of NOE globally. Following the Vietnamese faculty research experience with hands-on laboratory projects under US engineering research mentors, we will examine how Vietnamese engineers' NOE views have changed through interviews and open-ended written assessments. Although there are some attempts in assessing teachers' and students' NOE views, according to the authors' knowledge, there is no prior research which assessed NOE views of international engineering faculty in a higher education setting. In this work-in-progress research, we report the framework and anticipated outcomes of a pilot study on NOE understanding of Vietnamese faculty.

Keywords: Nature of Engineering, Engineering Education, Environmental Engineering, International Collaboration, NOE Instrument, Engineering Faculty

Introduction

For the last 10 years, there is a continuous increase in the number of research attempts in engineering education, and a relatively increased growth in emphasis on Nature of Engineering (NOE) research [1, 2, 3, 4, 5, 6, 7, 8]. Although still a developing area, a handful of NOE research findings demonstrate that instructors and students hold an inadequate understanding of NOE [4,6]. Nevertheless, training of teachers and students holds promise to improve learners' NOE understanding. Although there are some recommendations to place NOE instruction at the center of engineering education [2, 5, 9], it is still an emerging area, particularly in higher education.

In an effort to understand the NOE, Karatas et al. [4] made a thorough review of the literature of engineering, Hartman and Bell [3] conducted a Delphi study, and Deniz et al. [2] made a detailed review of Next Generation Science Standards (NGSS) and the K-12 Science Framework to develop a list of NOE aspects. Research comparison of the NOE items reveals many similarities among the NOE literature that NOE is the epistemology of engineering which are philosophical values and beliefs inherent to body of engineering knowledge. There was a broad consensus among the researchers about the NOE aspects for the development of NOE understanding that engineering is: subjective, creative, empirical, socially and culturally embedded. Two other important aspects are the distinction of criteria and constraints, and no universal engineering design process exists for doing engineering but all engineers follow a cyclical engineering design process. These researchers also underscored that it is important to acknowledge that engineering design is tentative and a social and collaborative field which requires teamwork. It is also important to recognize the similarities and differences between engineering and other disciplines such as science (see appendix A).

Currently, the extant NOE literature, which recently gained momentum due to the federal push in engineering education, only assesses the NOE ideas of K-12 teachers and students. While we appreciate the important contribution of the conducted research, we also underscore the necessity of understanding the NOE ideas of professional engineers (e.g. engineering researchers and higher education engineering instructors). Investigating engineering faculty's NOE views can play a significant role in contributing to our current understanding of NOE teaching and learning. Through our work-in-progress paper, we seek to understand Vietnamese engineering researchers' NOE views by assessing their NOE understanding with the NOE instrument and follow-up interviews.

Literature Review

NOE research is a relatively new research agenda which is growing exponentially with the release of recent engineering reform documents [10, 11]. There are several studies investigating students' and teachers' NOE views [4, 5, 6, 7]. Karatas et al. [4], for example, conducted a study to examine first-year engineering students' NOE views through a modified version of the Views-of-Nature-Of-Science (VNOS) questionnaire [12]. The researchers found that engineering students held naive NOE views. More specifically, most students struggled to differentiate between science and engineering, and they illustrated engineering as applied science. Only a few students thought that there could be more than one solution for an

engineering design problem and solutions are tentative. In another study, Karatas, Micklos and Bodner [5] examined 6th-grade students' NOE views through students' engineer- or engineers-at-work drawings and semi-structured interviews. The study consisted of 20 students (10 male-10 female), ages 11-12 years old that were close to the intellectual national average. Data was collected from 45-minute interviews held by 2 researchers. Semi-structured interviews included questions about students' definition of engineering, the demarcation between science and engineering, and the role of engineering in society. Researchers found that most students had difficulty explaining the differences between science and engineering, and relatively few students viewed engineering design as a dynamic process. Overall, authors reported that 6th-grade students held naive NOE views.

In another strand, Deniz et al. [13] investigated the NOE views of in-service elementary teachers who participated in an engineering teacher professional development during summer 2016 in a southwestern public university. Thirty teachers from a large urban area were included in this study from different teaching experience backgrounds and all had different levels of college science courses. The data consisted of open-ended questionnaires and interviews in the beginning and end of the study. Researchers analyzed the data by using a five-point scale and the data analyses of pre and post tests concluded that professional development increased teachers' NOE scores significantly.

Similarly, Deniz et al. [14] investigated the changes in elementary teachers' engineering teaching efficacy beliefs that participated in NOE teacher professional development during summer 2016 in a southwestern public university. Thirty elementary school teachers were included in this study from different teaching experience backgrounds and all had different levels of college science courses. The data was collected by using a modified version of the STEBI [15] instrument which included 23 Likert-scale items rated from 1- strongly agree to 5-strongly disagree. Elementary teachers' efficacy beliefs increased significantly toward engineering instruction after the professional development. Authors recommended that when learners understand NOE, it would increase learners' attitudes toward engineering and engineering knowledge. Additionally, they also emphasized that understanding NOE may positively influence students' engineering career decisions. Furthermore, they also suggest that NOE and Nature Of Science (NOS) are related and complement each other, specifically addressing the demarcation aspect. As a side note, they ended with a recommendation that NOE should be explicitly taught rather than implicitly.

In another study, Marti et al. [8] organized a graduate level summer course for in-service secondary science teachers. Teachers designed solar powered water heaters or water treatment systems by using the engineering design process. The course included explicit references to NOE aspects. Researchers adopted the NOE instrument [13] and conducted pre and post assessments to investigate teachers' NOE views. Results showed that teachers held incomplete or partially informed ideas about NOE in their case studies in the beginning of the course. However, teachers' NOE views improved at the end of the course.

Other studies also indicate that students and teachers hold incomplete NOE understanding. For example, Yesilyurt et al. [16] examined NOE understanding of elementary students and reported that students held a weak understanding of NOE as stated in pre-test findings. Deniz et al. [13] assessed 30 elementary teachers' NOE beliefs and found that teachers defined engineering synonymous with science according to pre-test results. In the study conducted by Kaya et al. [6], researchers investigated pre-service teachers' NOE views and found that pre-service elementary teachers hold weak NOE knowledge like in-service teachers.

In contrast to the quantitative research conducted by Deniz et al. [13] and Kaya et al. [6], Marti et al. [7, 8] conducted qualitative case studies to assess teachers' NOE views. In examining two NOE studies [13,8], it is apparent that secondary teachers held better understanding of NOE aspects when compared to the elementary teachers, but the secondary teachers still hold partially informed NOE views at the onset. On the other hand, training helps learners to improve their NOE views. At the end of the interventions, participants improved their NOE understanding in all the studies stated above.

Overall, most of the NOE research related to engineering education show similarities in NOE aspects and assessments independent of their research methodology. Researchers underscored that understanding these NOE aspects inform engineering literacy and NOE is an essential component of engineering education. However all the current NOE research was conducted for K-12 students or teachers. We believe that there is a research gap that needs to be studied to reveal engineering faculty's NOE views. Higher education instructors' engineering views influence their engineering teaching, which, in turn, influences engineering students' future engineering perceptions. Examining higher education instructors' NOE views is important to develop engineering education further. Specifically, understanding engineering faculties' NOE perceptions can provide a framework to modify current engineering courses and may assist in embedding NOE instruction in higher education settings.

Research Questions

There are two research questions that will guide our study:

1. Do the Vietnamese engineering faculty hold NOE views that are not aligned, partially aligned, or fully aligned with the previously articulated NOE aspects?
2. To what extent, if any, do Vietnamese engineering faculty's NOE views change after engineering professional development?

We will present the methodology and strategy to assess Vietnamese engineering faculties' NOE views in this work-in-progress study.

Methods

We adapted the validated NOE instrument, developed by Deniz et al. [13]. VNOE is an open-ended questionnaire that consists of 7 questions aimed at assessing learners' NOE understanding. In the modified version of the NOE, we added three more questions to address NOE aspects missing from the questionnaire, such as the social NOE aspect, added language to force participants to provide examples for each questionnaire item, and slightly rephrased one question to make it more universal. The modified instrument, as shown in Appendix B, has not been validated.

All the questionnaire items will be translated to Vietnamese by translators. The NOE instrument will be distributed to the Vietnamese faculty when they sign the consent form. Participants will have ample time to complete the written questionnaire. This will allow participants to reflect on their NOE views in-depth and relate the responses to their current work experiences. After receiving the written responses, we will conduct a follow-up interview with the participants to elaborate on their written responses to generate as much detail as possible on their NOE views. All NOE items will be used in conjunction with individual follow-up interviews with the Vietnamese engineering research and teaching faculty with the assistance of

interpreters. Interpreters will translate the questions and the responses instantaneously. We expect each interview to last between 30-60 minutes. We are planning to conduct face-to-face or video conference interviews with the Vietnamese engineering researchers. The interviews will be audio recorded and transcribed verbatim by one researcher, and a second researcher will review the transcribed text for accuracy. If any clarification of the data will be necessary, follow-up emails will be carried out. Transcripts will be shared with the Vietnamese engineering researchers and the interpreters for confirmation and to reach higher accuracy in data.

We will conduct regular meetings to analyze the data. Predetermined NOE aspects (see Appendix A) will guide the coding of written and interview responses. After each response is scored based on the rubric (see Appendix C), authors will discuss to reach a consensus on the scoring, and final profiles of the participants will be generated by merging interview and written responses. Based on the data size, results will be reported either qualitatively as descriptive statements, or statistical paired t-test will be employed to compare pre-test and post-test NOE responses of the Vietnamese engineering faculty.

Anticipated Outcomes

This study will examine engineering faculty NOE understanding, and it will present a description of their epistemological beliefs of engineering. Our research will contribute to overall understanding of professional engineers' NOE views. We expect engineering faculty to hold informed views of engineering; however, it is just an assumption. If they do not, we will explore the effectiveness and influence of a professional development on faculty's NOE views. According to research, scientists do not always think and reflect about the philosophical values and assumptions of their work [18]. It might be the case for engineers as well. We are planning to empirically test this assumption to understand engineering faculty's NOE views.

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Appendices

Appendix A. Descriptions of Nature Of Engineering Aspects (Retrieved from

<https://peer.asee.org/assessing-high-school-science-teachers-nature-of-engineering-noe-perceptions-with-an-open-ended-noe-instrument-fundamental>)

NOE Aspect	Description
Demarcation criteria (What is engineering? What makes engineering different from other disciplines?)	<p>Engineering is systematically engaging in the practice of design to achieve solutions for specific problems. Engineers apply their understanding of the natural world (scientific knowledge) to design solutions for real world problems. This endeavor results in new technologies.</p> <p>In the K-12 context, "science" is generally taken to mean the traditional natural sciences: physics, chemistry, biology, and (more recently) earth, space, and environmental sciences...</p> <p>We use the term "engineering" in a very broad sense to mean any engagement in a systematic practice of design achieve solutions to particular human problems. Likewise, we broadly use the term "technology to include all types of human-made systems and processes-not in the limited sense often in schools that equates technology with modern</p>

	computational and communications devices. Technologies result when engineers apply their understanding of natural world and of human behavior to design ways to satisfy human needs and wants. (NRC, 2012, pp. 11-12)
Engineering design process	<p>The core idea of engineering design includes three component ideas (NGSS Lead States, 2013): Define, Design, and Optimize</p> <p>A. <u>Define</u>: Defining and delimiting engineering problems involves stating the problem to be solved as clearly as possible in terms of criteria for success and constraints or limits.</p> <p>B. <u>Develop Solutions</u>: Developing solutions to engineering problems begin with generating a number of possible solutions. These potential solutions are then evaluated to assess which ones best meet the criteria and constraints of the problem.</p> <p>C. <u>Optimize</u>: Optimizing the design solution involves a process in which solutions are systematically tested and refined and the final design is improved by trading off less important features for those that are more important.</p>
Empirical basis	Engineers optimize their design solutions and compare alternative solutions based on evidence obtained from test data. They use assumptions to produce simplified models that does not contain the variables that the problem are insensitive to.
Tentativeness	Phases of engineering design process do not always follow in order, any more than do the “steps” of scientific inquiry. At any phase, a problem solver can redefine the problem or generate new solutions to replace an idea that is just not working out.
Creativity	Creativity and imagination of engineers play a major role during the engineering design process. The role of creativity and imagination is not limited to any specific phase of the engineering design process.

Subjectivity	There is no unique solution to an engineering design problem. While there can be many solutions to the same problem, some of these solutions may be more suited to meet the criteria and constraints of the problem.
Social aspects of engineering	Engineering is not a solitary pursuit. Engineering design solutions are constructed through social negotiation. Despite their individual differences, members of an engineering community share common understandings, traditions, and values. This social dimension enhances the quality of engineering design solutions.
Social and cultural embeddedness	Engineering is a human activity. There is a continued interaction between engineering and society. Sociocultural factors influence the engineering design process, and in turn, engineering influences the society. These social and cultural factors include social composition, religion, worldview, political, and economic factors.

Appendix B. Nature of Engineering Questionnaire Items

- What, in your view, is engineering? What makes engineering different from other disciplines (e.g., science, philosophy, religion)? Illustrate your answer with an example.
- How do you define the work of an engineer? What do engineers do? Illustrate your answer with examples from your own work.
- What is an engineering design process? Give examples of steps in the design process.
- Do engineers follow the steps of the engineering design process in a linear format?
 - If yes, explain why. Give an example to defend your position.
 - If no, explain why. Give an example to defend your position.
- After engineers have developed an engineering design does the design ever change?
 - If you believe that engineering designs do not change, explain why. Defend your answer with examples.
 - If you believe that engineering designs do change, explain why. Defend your answer with examples.
- Does engineering design require testing?
 - If yes, explain why. Give an example to defend your position.
 - If no, explain why. Give an example to defend your position.
- Do engineers use their creativity and imagination during the engineering design process? If yes, then at which stages of the engineering design process do you believe that engineers use their creativity and imagination: identifying the problem; developing the design conceptually; constructing the design, testing the design; refining the design?
 - Please explain why engineers use creativity and imagination. Provide examples if appropriate.

- If you believe that engineers do not use creativity and imagination, please explain why. Provide examples if appropriate.
- How do engineers do their work? Do they work alone or in groups?
 - If alone, explain why. Give an example to defend your position.
 - If in groups, explain why. Give an example to defend your position.
- Some claim that engineering is infused with social and cultural values. That is, engineering reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that engineering is universal. That is, engineering transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.
 - If you believe that engineering reflects social and cultural values, explain why and how. Defend your answer with examples.
 - If you believe that engineering is universal, explain why and how. Defend your answer with examples.
- There is a variety of mobile phones commercially available in the market (e.g. iPhone, Galaxy, Huawei Mate, Nokia). Can there be a single best design for a smartphone?
 - If you believe that there is a single best design for a smartphone, please explain why.
 - If you believe that there is not a single best design for a smartphone, please explain why.

Appendix C. NOE Aspects Scoring Rubric (Retrieved from <https://peer.asee.org/board-98-high-school-science-teachers-views-of-nature-of-engineering-and-application-of-engineering-design-practices-work-in-progress>)

Description	Point
No answer, incomprehensible or irrelevant answer, or an answer could not be categorized	0 points
An answer that is not aligned with the description of NOE aspect	1 point
An answer that is partially aligned with the description of NOE aspect	2 points
An answer that is fully aligned with the description of NOE aspect	3 points
An answer that is fully aligned with the description of NOE aspect. The view is well-articulated and/supported with relevant example(s)	4 points