A literature overview of differences between engineering education and other disciplinary education.

Maartje Van den Bogaard
ECE Engineering Education Research
University of Michigan
Ann Arbor MI, USA
ORCID 0000-0002-2267-3674

Ibrahim H. Yeter
National Institute of Education
Nanyang Technological University
Singapore
ORCID 0000-0002-0175-2306

Johannes Strobel
Center for Education Research and Innovation
SRI International
Menlo Park CA, USA
ORCID 0000-0002-2124-1116

Abstract— **This work-in-progress reports on a project to establish differences between STEM education, and specifically Engineering Education, and other education fields/disciplines based on empirical observations. In this study we report on first steps towards a literature overview of such differences and on the development of an analytical framework to analyze the publications.**

Keywords — STEM, Engineering education, DBER, Literature Overview

I. Introduction

Engineering Education (EE) as part of the broader STEM education fields is generally viewed by the EE community as an area that is different from general education and other disciplinary education fields. Especially, engineering education research (EER) falls in the broader category of discipline-based education research (DBER) where the general focus has been on a specific group of students, instructors, programmes and institutions with specific goals and attributes that albeit using methods from the social sciences and the engineering and design sciences. Trailblazer in EER, Kamyar Haghighi [1], argued that the context of education and educational research may lead to different answers to similar questions as a result. Haghighi postulated that EER as a research field could be the catalyzer for solving issues pertaining to the need for well-trained engineers who are ready to face a future where technology will play an increasingly important role, while interest in and preparation for EE and careers seemed to be dwindling. Jesiek, Newswander and Borrego [2] describe how the discipline of engineering education research emerged from a need within the field of engineering education, which has been struggling with issues of quantity and quality of recruitment, enrolment, retention, diversity/inclusion and graduating newly minted engineers.

In delineating the disciplines and communities of STEM Education, especially EE and EER, members often justify the need for a specific discipline on perceived fundamental differences between STEM, engineering and other disciplines (see [3] for some summary). We believe it is fair to assume that STEM, and particularly EE, is succinctly different from other educational fields based on common sense comparisons between learning goals of programs, and consequently, curriculum attributes and a sense that somehow engineering students are different from students in other fields. Rigorous research, systematic or large-scale on testing assumptions of differences however have not been a point of departure for the emergence or validation of EE and EER as a separate area of DBER. There are some notable exceptions such as the work conducted by Graziano et al. [4], who studied differences in person/thing orientation between students in engineering and other disciplines. Also, Wai [5] looked at differences in spatial ability between students who chose STEM versus students who did not. Other notable studies include Veenstra et al. [6], which they looked at differences in first-year student success. Additionally, Schommer and Walker researched epistemological beliefs [7] where Lichtenstein et al. [8] compared the undergraduate experience of engineering majors and non-engineering majors. They found that students had a lot in common, yet indicated significant differences in the set-up of the programs. To date, there has been no attempt to look at the differences between engineering and other disciplines systematically.

The overarching research question that informs this larger research project is: *What are differences between STEM and particularly engineering as a field of education and other fields of education, if any, from the point of attributes of students, instructors, learning environment and (institutional) culture?* While this question is deliberately broad, the main intention is to describe differences in the broadest possible range of EE and non-EE fields. This work-in-progress presents the first efforts for a literature search and a comparison of an initial framework for grouping these differences to the differences reported in a sample of the literature.

II. Literature overview

Most researchers, who report differences between STEM/engineering education and other disciplines did not set out clear criteria to establish differences between disciplines. In most cases, they establish differences when checking the homogeneity of their samples, which may include students from several disciplines. In other cases, they look at how certain groups of students are impacted by certain interventions. Establishing differences between students, their learning experiences, attributes of learning environments, etc. are, as such, a bycatch of studies into something else. Such findings are – at best - unsystematically reported different parts of the publications, for instance, in result and discussion sections, rather than in the research questions, abstracts or keywords. Hence, established processes of conducting a systematic literature review [9] are not applicable, as searching through meta-data systematically in databases such as Scopus or Web of Science™ is unlikely to yield meaningful results.

In this work, the aim is to describe differences between STEM/engineering education and other disciplines' education fields in a systematic way, yet the aim is not to appraise or synthesize the research. In order to address challenges to its feasibility, we propose a scientific approach, a *literature overview* which is, according to Grant and Booth [8], *"... a generic term used for 'any summary of the literature' that attempts to survey the literature and describe its characteristics. As such, it can be used for many different types of literature review, with differing degrees of systematicity (page 99)."* The overarching aim is to give a comprehensive overview, being cognizant of the fact that it may take specific and deliberate effort to build awareness and articulate existing inherent biases in the study. A systematic search using subject headings and other meta data from bibliographic databases is limited due that disciplinary differences may not have specific terms associated, and therefore, may not be classified accordingly.

III. A Framework for Grouping Differences

As the overarching research question is deliberately broad, the first step in this project is to create a framework for grouping on the differences that were displayed in the literature. In education, the commonly discern between the micro, meso and macro levels of education [11], where the microlevel refers to the classroom level, the meso refers to the school and the macrolevel refers to national institutions. These three levels may not have enough granularity to help describe what may be found in the literature. As a start to the development of a framework that would be useful within the scope of this study, a number of book publications were examined that aimed to report overviews of comprehensive research in education. The authors or editors of such books have ostensibly put thought into the question how to best group topics that may be relevant for education. Two books that stood out were Hattie's Visible Learning [12] and Astin's What Matters In College [13]. One of the authors performed a comprehensive study into factors affecting student success [14]. The classifications were used to organize these three works and combined them in the following framework consisting of 7 overarching categories:

1. *Student attributes prior to enrolment in higher education (SPE)*. This pertains to fixed attributes at the time of enrolment in higher education (e.g., demographics, prior achievement, parental SES, career interest).
2. *Student attributes after enrolment in higher education (SAE)*. This pertains for attributes that are subject to change after enrolment (e.g., motivation, attitudes and dispositions, behaviour, metacognition).
3. *Social environment attributes (SOC).* This pertains to the student environment after enrolment. (e.g., extracurriculars, sports, peers, housing situation).
4. *Instructor attributes (IA)*. This pertains to instructors in higher education. (e.g. their training, teaching strategies, and subject matter knowledge, quality of teaching, teacher- student relationships).
5. *Curriculum attributes (CUR)*. This pertains to program attributes (e.g., number of scheduled activities, type of activities, assessment, math, reading, ethics, transversal skills, social skills).
6. *Contributions from the institute (INS)*. This pertains to institutional attributes (e.g., public/private, size, and physical, computer and other facilities available to students and teachers).
7. *Contributions from the academic discipline, culture, and workplace perceptions (DCP).*

The outcome presented in this paper is a framework for further analysis that may be used in the next phase of the research. To that end we will analyze a sample of the papers we found in the first round of our literature search and compare the topics on which engineering and other disciplines are compared with the framework presented above.

IV. Method

A. Finding and selecting sources

The main strategy to find papers was to start off with a small-scale overview of differences that one of the authors previously performed as part of a larger scientific project [14]. The papers identified in this first study were reverse snowballed through the DOI-numbers and cited references originating from the original paper were added to our database. Next these papers were screened to determine if they included elements of comparison with at least one of the STEM disciplines and another discipline.

This study included only a few additional basic criteria for inclusion, for instance, publications published in English language and from 1993 and later. The decision for this cut off year on similar ones was performed in other bibliometric EER studies including [15] and [17]. Another criterion that was included any document that has any permanence in databases that contain academic work, including the *Proquest* database with dissertations. Publications were excluded on doctoral education and in most cases publications on K-12, unless there was a clear link with higher education. Papers on MOOCs studies were not considered as this learning environment may tend to be designed for a different target audience.

B. Sampling and analysis

Based on the preliminary investigation, a total of 232 empirical studies were found from the year of 1993 until 2021. This is still an ongoing study and from the feasibility standpoint of view, a stratified random sampling technique was performed to determine 95 (41%) randomly selected studies for this paper. The stratified random sampling technique was performed through the *MS Excel* program by using the *RAND* function. After the program provided random numbers, the list of the studies was sorted to determine computer-aided numerically less valued studies from each year. According to Ackoff [15], the stratified random sampling technique provides more rigorous and accurate steps for the analysis to include representative studies from each category and comparing the sub-categories.

Figure 1 provides further detail of all studies found in the designated years. Per analysis procedure, a randomly selected process was performed to detect 22 of the 95 studies (42%) for the inter-rater reliability. After conducting the analysis, 43 studies were eliminated as they did not fit into the purpose of this work and the remaining of the studies (n=52) were considered for the investigation.

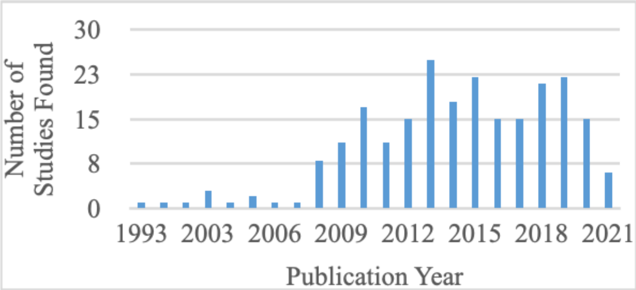

Figure 1. Number of studies found in each year from 1993 to 2021

The initial inter-rater agreement on the application of the categories in the framework was 86% and then the disagreement parts were discussed to come up for a consensus. After fully agreed, the rest of the eligible studies were analyzed. The following figure 2 provides detail on the procedure.

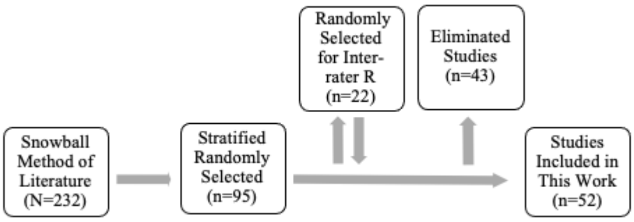

Figure 2. Procedural work on the eligible studies.

V. Results

Most studies that were analyzed included multiple categories of variables. The frequencies with which the categories occur in the studies vary a lot. The highest observed bucket categories are SPE and SAE: both categories occur 30 times in 52 studies. The categories with the fewest hits are DCP and SOC as shown in figure 3.

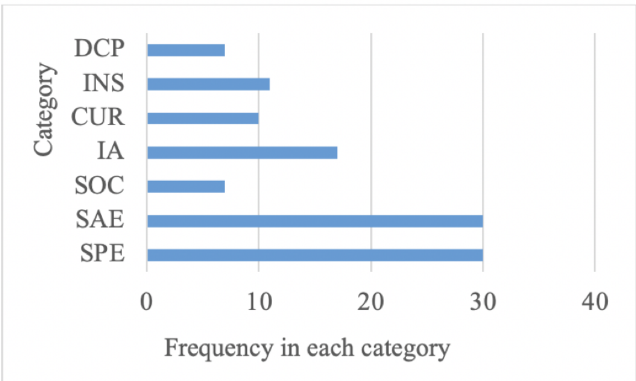

Figure 3. Frequency in each bucket category across all 52 studies.

The pre-determined seven distinctive classifications (or categories) were used as a framework to perform this study. Accordingly, the preliminary findings suggest that some of the categories may need to be redefined and operationalized further. Aligning with the initial findings, the following categories were enhanced accordingly. We did find that some of the categories have distinct dimensions and need to be refined further.

1. SPE – This mostly pertains to demographic data and prior achievement. It may also include declared major.
2. SAE – This category may hold all kinds of variables that pertain to attitudes, motivation and behaviors. A distinct other dimension pertains to performance. This may also include credits or GPA, and other measures of progress.
3. SOC – Examined studies did not include measures of the wider social environment of students. Most studies that did include a SOC variable included students' living arrangements.
4. IA – Three dimensions were found within this category. First, there are all kinds of quantitative measures, for instance, years of teaching experience. A second dimension pertains to students' perceptions of teachers, their subject-knowledge and proficiency in teaching, and the interactions the students had with them. The third dimension has to do with teachers' beliefs about teaching and learning.
5. CUR – Within CUR, two main dimensions were found, quantitative data on curriculum attributes, and student perceptions and elements of the curriculum. It is safe to assume that teachers' perceptions may be a third dimension within CUR, yet none of the studies included such explicit data
6. INS – For INS, the dimensions of quantifiable data on attributes of institutions and facilities were observed. More specifically, some of the studies included student perceptions of the facilities, their college experience or institution as a whole.
7. DCP – Very few of the studies included DCP variables. Within the current sample, it may not be feasible to discern between any distinct dimensions.

VI. Discussion and Next Steps

The 52 relevant studies were analyzed and met the study criteria for inclusion. The studies included elements of comparison with at least one of the STEM disciplines and another discipline, they have permanence in databases that contain academic work and are in the English language. The initial framework that was developed by the authors based on literature allowed to categorize all the variables included in the studies. It was established that these categories have distinct dimensions that need to be integrated in the next version of our framework.

Another finding of this study was the distribution of categories. For example, student attributes outranked the other categories by far in 52 studies. Variables that pertain to students' social environment, to dimensions of the curriculum or the institution were not included in many studies. It is well-known that student-related variables explain most variance in student success studies, however, that does not explain why studies in a wide variety of topics include mainly student-related variables. It was expected to find more counts within the DCP category, as there has been a considerable number of studies in the area of teachers' epistemological beliefs. The fact that DCP had a low occurrence is an indication that further analysis has yet be performed to cover this area of research.

Despite a very careful screening of the papers before they were added to the database, about half of the papers were not applicable when the papers were examined closely. As the study findings suggest that in many cases, papers included STEM-participants, but did not report separately on any outcomes. Instead, the STEM-participants were aggregated with students from other disciplines. In many cases, this may possibly make sense as establishing differences between groups of students is often not a research goal in itself. This finding underlines our initial point of departure that locating the type of studies that are informative to our purpose is challenging: the methods employed in literature synthesis projects would not perform well in this project. Consequently, other strategies may be needed for finding relevant papers, and although completeness is an ambition, we do not anticipate being able to claim we included every relevant work published at any point.

Overall, this study is promising in its scope and approach. This study included to locate publications that report on differences between STEM and other disciplines to establish an empirical baseline for the differences between STEM, and specifically engineering, and other disciplines. The aim is to pursue this project further. As the next following step is to examine the remaining publications and conduct snowball technique for all publications that may be found in the relevant references. Additional next step is to determine which journals have published at least two relevant papers reporting on differences between STEM and other disciplines and to go through their archives back until 1992 to find more relevant papers. Additionally, the aim to refine the framework and solicit experts for more references by setting up a Delphi-study.

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