



ISSN: 2147-611X

International Journal of Education in Mathematics, Science and Technology (IJEMST)

www.ijemst.com

Culture, Identity, and Motivation in Engineering Education

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To cite this article:

Shelley, M., & Purzer, S. (2018). Culture, identity, and motivation in engineering education. *International Journal of Education in Mathematics, Science and Technology (IJEMST)*, 6(3), I-IV. DOI: 10.18404/ijemst.428160

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Article Info

Article History

Received:
07 July 2017

Accepted:
12 January 2018

Keywords

STEM
Engineering education
Student achievement

Abstract

The collection of papers in this special issue examine student learning and experiences in the engineering component of STEM (science, technology, engineering, and mathematics). This editors' essay provides an overview of each of the articles included in this special issue and their contributions to the expanding research on engineering education. Two main themes emerge: (1) how self-efficacy beliefs, interest, study strategies, and academic performance are manifested when learning engineering, and (2) the experiences of unique groups in engineering and contexts within which students acquire knowledge about key elements of engineering. Implications are discussed for faculty professional development; how best to create, evaluate, and use measurement instruments; the use of contemporary methods in both qualitative and quantitative analyses of student learning about and experiences with engineering; and the need to "speak truth to power" to influence policy decisions about workforce development and to encourage better-informed student career choices.

Introduction

Engineering impacts every sector of a modern society, ranging from transportation, construction, and manufacturing to healthcare, energy, and communication. Hence, improving engineering education through research has benefits beyond those who are influenced directly. The timing of this special issue is also noteworthy as we approach the year 2020—a critical era for engineering as 2020 is the year that the National Academy of Engineering in the United States predicted would see a critical turn in the technological and innovation landscape fueled by globalization (NAE, 2004, 2005). The NAE reports articulate that the engineers of 2020 would need knowledge, skills, and abilities beyond technical knowledge while highlighting that engineering education is highly linked to a country's economic progress and well-being. Yet, many authors report the need for caution in addressing engineering education given the limited public understanding of the engineering profession and of its impact on society (Cunningham, Lachapelle, & Lindgren-Streicher, 2005; Davis & Gibbon, 2002; Wulf, 1999), the declining interest of youth in pursuing careers in engineering (Becker, 2010; NAE, 2008), and lack of diversity in the engineering workforce (Sadler, Sonnert, Hazari, & Tai, 2012; Sherriff & Binkley, 1997).

One of the motivators of research in engineering education has been the need to diversify the engineering workforce and attract students into engineering. Another motivator of research is advancing student learning and enriching their experiences when they finally decide to pursue engineering. However, attracting students into engineering and diversifying the demographic make-up of the engineering workforce has been an uphill challenge especially in Western countries such as the United States and Europe. Scholars in more recent studies argue that achieving equity necessitates the examination of culture, identity, and motivation—not just at the university level but also at early stages of education as children start to develop agency, efficacy, and disciplinary identities.

Themes of This Special Issue

This special issue brings together a variety of studies and scholars in an effort to exemplify how the disciplinary cultures shape students' experiences, how they form their disciplinary identities, and how their self-efficacy and agency develop as they learn engineering. The seven papers selected for this special issue present diverse vantage points on the circumstances that influence students. While painting a collective picture of the manifestation of culture, identity, and motivation in relationship to learning engineering, the papers also center around two distinct themes: (1) self-efficacy, academic performance, and student study strategies and (2) unique groups and contexts.

Four articles examine the manifestation of student academic performance, self-efficacy, and study strategies, and explore the development of identity and changes in student interest and attitudes. Three articles in this special issue examine the educational experiences of non-traditional, often marginalized groups in engineering in a variety of contexts such as higher education institutions, K-12 classrooms, and museums.

Self-efficacy, Academic Performance, and Student Study Strategies

In “*Relationship of Mathematics Self-efficacy and Competence with Behaviors and Attitudes of Engineering Students with Poor Mathematics Preparation*,” Morán-Soto and Benson examine factors that influence engineering students’ decisions to pursue and complete an engineering major. Their research specifically focuses on mathematics, which is a gateway subject to high-level engineering coursework. They examined the relationship between student mathematics self-efficacy and performance in mathematics courses through a mixed-methods study. They found mismatches between students’ mathematics self-efficacy beliefs and mathematics competence levels. Interestingly, the discrepancies between the self-efficacy beliefs and competence levels explained students’ study strategies. Students who spent extra time working and seeking extra help reported that their self-efficacy beliefs are in alignment with their competence levels. In contrast, students who procrastinated and put little effort into improving their competence reported self-efficacy beliefs that were not in congruence with their competence levels and externalized their poor performance. Despite varying mathematics competence levels, the interviewed participants reported relatively high mathematics self-efficacy and reported their persistence to continue taking mathematics courses required for their major even after failing their first college mathematics course.

Similar to self-efficacy, interest and attitudes are strong predictors of engagement and persistence. In “*An Instrument for Examining Elementary Engineering Student Interests and Attitudes*,” Lachapelle and Brennan argued for the need to develop an instrument designed to assess children’s interest and attitudes in engineering. Their article presents validity evidence for the Engineering Interest and Attitudes (EIA) survey as a pretest and posttest to measure changes in student interests and attitudes after participating in engineering activities, programs, and curricula. Such instruments designed specifically for engineering are necessary to understand and evaluate interventions and programs regarding their impact on student interest and attitudes.

In “*Exploring Academic Performance Paths and Student Learning Strategies in a Large Foundational Engineering Course*,” Grohs, Knight, Young, and Soledad examined learning strategies of second-year engineering students in a statics course. Cluster analysis identified groups exhibiting distinct performance paths, and the most important differences across those clusters were found in how students spent time rather than the total time they spent studying. The strategy of solving problems independently was used significantly more often by the highest-performing students. Unsuccessful students spent less time in independent problem-solving and more time solving problems with peers. This study is another example showing that how students study—as opposed to how much they study or how high their self-efficacy beliefs are—is important in shaping their academic success.

In “*Engineering Identity Development: A Review of the Higher Education Literature*,” Rodriguez, Lu, and Barlette analyzed the body of research on identity development in engineering and STEM. They identified 88 articles focused on engineering identity development in higher education. While research in engineering identity has increased over the last decade, it has been conducted primarily with qualitative methods and has focused on the learning contexts and experiences of women and underrepresented racial/ethnic minorities with less focus on men, international, or graduate students. The authors concluded that research on undergraduate engineering identity development should expand beyond qualitative methods and study a variety of academic communities such as mathematics, science, and engineering education. This extensive review of the literature reminds us that studying the identity development of a variety of groups within an institution including majority groups is as important as studying the experiences of minority groups based on gender and ethnicity to form a comprehensive view of minority students’ experiences.

Unique Groups and Contexts

When it comes to identity and agency development, it is also important to examine different agents at work in different educational contexts. The next three articles in this special issue examine such unique groups and contexts such as students who transition from two-year colleges to four-year universities, elementary students learning engineering in urban schools, and young girls playing with their parents when learning engineering, with critical insights suggesting the existence of bias even when all participants in these situations are well-intended.

In *“From Deficit Thinking to Counter Storying: A Narrative Inquiry of Nontraditional Student Experience within Undergraduate Engineering Education,”* Minichiello focused on the experiences of nontraditional undergraduate engineering students through narrative inquiry research. The research participants were enrolled in a two-year engineering transfer program offered in the evenings, via synchronous broadcast distance instruction. These students first attended two-year programs at regional campuses near their local communities, and later transitioned to the four-year university campus located in another city away from these communities. Their study presents personal, social, and institutional tensions arising from instances of thinking of themselves as deficient and underprepared through a narrative inquiry of the participants’ lived and told stories. Despite deep, personal reactions to the bias they experienced, participants overcame perceptions of personal deficiency to pursue and achieve their goal of becoming engineers. Moreover, participant counter stories further revealed ways in which their unique life experiences alternately served to enhance and deepen their engineering education.

In *“Just Put It Together to Make No Commotion: Re-imagining Urban Elementary Students’ Participation in Engineering Design Practices,”* Wright, Wendell, and Paugh examined cultural norms and teacher expectations in an elementary classroom. Their findings suggest that students conceptualized urban engineering learning environments as spaces for risk management. This notion of managing risks informed the students’ participation in collaborative decision-making and in the ways in which they viewed themselves as doers of engineering. However, this form of risk-averse participation created a tension between disciplinary practices expected in engineering design and the teacher’s need to manage a classroom in an urban school. The authors argue for the need to develop methodologies and frameworks that provide opportunities to uncover these conflicts and the potential risks that students need to take as they participate in engineering design practices.

In *“Exploring Moments of Agency for Girls During an Engineering Activity,”* Svarovsky, Wagner, and Cardella examine parent-child interactions, specifically focused on moments when girls express agency during an engineering design process. They followed these interactions during a museum exhibit that engages visitors in engineering design activity. In their study, children expressed agency and led interactions by directing, proposing design ideas, and asking questions. However, young women tended to direct their mothers more than they directed their fathers, suggesting differences in parent-child interactions should be considered to support girls’ agency in engineering activities.

Summary

In summary, this special issue brings together seven articles that provide a wide range of conceptual, methodological, and situational perspectives on how culture, identity, and motivation intersect with learning and engagement. Together, these papers argue for two critical points. First, these papers collectively suggest that beyond students’ cognitive abilities, many other considerations—such as culture, identity, and motivation—play important roles in the education of students. In addition, these papers show that learning occurs in many places: higher education institutions, K-12 classrooms, and child-parent interactions in informal settings such as museums. Second, the papers in this special issue illustrate mismatches between student abilities and perceptions, between student abilities and educator expectations, and between individual identities and institutional identities. A limited understanding of such discrepancies had perhaps been one of the reasons for slow progress in increasing student interest and success in engineering.

Conclusions

A number of lessons learned can be gleaned from this research. These articles suggest that it is imprudent to lump students into an undifferentiated mass summarized by just a set of mean scores. Instead, it is essential to examine sources of variation in student performance that are based on a mix of demographics, motivational differences, and other key variables that distinguish one student’s foundation for learning engineering principles from that of another student. That perspective provides part of the agenda for future research in the area of engineering education specifically and STEM education at all levels more generally.

A related conclusion regarding future research is that we will need to develop and apply measurement instruments and research methods that are sufficiently sensitive to handle the magnitude and full range of individual variation, to provide more valid and useful inferences about students’ performance and experiences. Both qualitative and quantitative research methods as well as their mixing are appropriate for teasing out the specifics of individuation within the broader context of systemic and structural differences in how students learn and differences in the

resources available to their families, instructors, and institutions. On the quantitative side, multilevel (mixed) models provide a well-developed approach that nests individual student traits within higher-level metrics. Qualitative methods are essential, particularly in the absence of the extensive and detailed data needed about student individual characteristics and institutional characteristics for multilevel statistical modeling, but more importantly to provide the rich context for understanding how students understand the process of learning and how best to improve outcomes of student success, equity, and workforce development.

The implications of this work for teaching will need to be embedded in teacher and faculty professional development to promote increased awareness of educators in their interactions and expectations based on cultural norms and gender roles. In addition, the education and training of education administrators, recruitment staff, academic counselors, and parents must recognize that efforts would have limited success if data are lumped without a recognition of variation among students. Professional development efforts can be informed by enhanced knowledge of what motivates students and how individual students react differently to the same instructional activities. Administrators could benefit from knowing what mix of formal and informal education may be optimal for students' ability to process and comprehend the complexities of engineering design and analysis. The process of "speaking truth to power" is essential to inform those who establish education policies and funding levels that they need to be mindful of the compelling lessons learned from studies such as these about how to encourage educators, students, and parents to ensure the best possible circumstances for developing a deep understanding of what engineering education contributes to societal growth and a more equitable future. Students must be provided with the resources and support mechanisms that will make it possible for them to succeed at as high a level as possible and thereby become more productive contributing members of their chosen profession.

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