To Stay or Leave? A Plan for Using Phenomenology to Explore Gender and the Role of Experiential Learning in Engineering

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INTRODUCTION

Our Engineering Education Research (EER) team is working to identify and address leaks in Europe's STEM pipeline that lead to the shortfall and lack of diversity among European engineers. Our intent in this SEFI paper and presentation is threefold: (1) summarize our research plan and objectives, (2) elicit critique and advice regarding the design of the study, and (3) encourage dialogue about the use of phenomenology in EER.

At the core of our two-year Marie Curie International Incoming Fellows project, funded by the European Union, is a phenomenological research study. Broadly speaking, the study uses educational research methods derived from the social sciences as a way of building knowledge in order to increase participation and engagement in engineering. Specifically, we will use phenomenological methodologies to investigate how experiential and Problem-Based Learning (PBL) pedagogies influence gender diversity in engineering education. The study in innovative regarding: (1) the use of phenomenology in EER, (2) gender diversity in engineering, and (3) learning outcomes of PBL.

Through this study, we are attempting to address existing gaps in understanding of: why women chose to go into engineering, how they make this type of decision, and why they stay in or leave the field. Most prior research on this topic has been statistical in nature. It has tended to track *what* happens—assessing patterns of enrolment and retention—but failing to identify *why* women become interested in engineering in the first place, and what keeps them engaged in the field or compels them to leave. In other words, the *why* behind the statistics remains unclear today.

Nevertheless, prior research does suggest that experiential, Problem-Based Learning increases student engagement and many help address reasons women avoid STEM subjects [1, 2]. In response to this hypothesis, we have designed a *Phenomenological Study of How Women Experience Engineering Education: Understanding How PBL Influences Their Decisions to Join or Leave Engineering*. We are currently seeking participants in Ireland, Portugal, and Poland who represent four different segments of the engineering pipeline (high school, college, early career, and late career/CEOs). We plan to interview 24 women, including many individuals who have experienced PBL as well as some who have not, to help us understand the diversity of experiences they have had. We expect this study to generate new understandings of the effectiveness of pedagogical methods that have been designed to attract and retain more diverse groups of engineering learners as well as how individual women perceive and engage with engineering. The project is timely from a scientific point-

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of-view because phenomenology is now emerging in research on diversity in engineering education but it has not been used to study PBL.

1 BACKGROUND

1.1 Need for Engineers

The European Union faces an enormous deficit of engineers and the problem is escalating. The prolific British inventor Sir James Dyson recently asserted he was "recruiting 650 highly trained engineers and scientists," and emphasized "I could take on 2,000 if I could find them" [3]. Today in the UK, demand for STEM workers is growing 4.5 times faster than all other areas and it is probable that by 2014, the UK will need 2.4 million highly skilled STEM workers, or 775,000 more than it needs today [4].

Students' experiences at the primary, secondary, and tertiary level of education—all along the STEM pipeline—seem to influence their perceptions and subject interests. By the tertiary level, interest and enrolment in science, technology, engineering, and mathematics (STEM) is far too low to keep up with industry demand. Just 4.8% of UK undergraduates applied to study engineering or technology in 2010 [5], and the problem appears to be escalating. For instance, the number of engineering students in Ireland has been in continuous decline since 1999 [6]. In studying 200-2005 data from the whole island, researchers observed a full 1/3-drop in the number of people studying engineering over that five-year period [7]. Globally, among undergraduates who do enrol in university programmes of engineering, roughly half drop out of the major within a year).

All this leads to precarious shortfalls within the engineering professions. In 2009, Belgium had 2500 unfilled engineering positions [4]. In 2011, Germany needed 76,400 more people with engineering skills [8] and 114,000 people with STEM skills [9]. When considering all types of STEM workers (skilled and vocational), today's shortages reach: 10,100 in Italy; 18,300 in Poland; 41,800 in Spain; and 87,800 in Germany. Experts [9] have estimated that, by 2015, total shortfall will reach 380,000-700,000. Our team believes the EU must act now, or face the social and economic consequences of stalled growth.

1.2 Need for Diversity

STEM problems are more severe in the EU than in other Western economies [4], because the EU attracts fewer experts from outside and there is little between-country movement of scholars to catalyze knowledge sharing/creativity. In fact, Dyson noted, "88% of postgraduate students in Britain are from outside the EU and they are taking their technology skills back home with them".

To address shortfalls in the EU and diversify perspectives, STEM programs need to attract and retain more women. Today, only 13% of Germany's engineers are female [8]. Nearby, in the UK in 2010, college applications submitted by men requesting engineering as a major outnumbered those from women by more than 7:1, in fact, only 0.58% of all college applications in the UK involved women requesting to study engineering [5]. Graduation rates reflected these inputs: from 2000-2009 men accounted for over 80% of all graduates in engineering, manufacturing and construction in the countries of Germany, Ireland, the Netherlands and Austria [10].

Such gender issues are prevalent in North America and Australia as well. In fact, "Australia and other western countries still have participation rates for women in engineering education that <u>are lower than any other field of education</u> and that have stagnated or declined for the last decade" said Mills [11, p. 139, emphasis added). In Australia in 2009, women accounted for 15.4% of engineering graduates. At that time in the US, 17.9% of engineering undergrads were female, despite the fact that women comprised 60% of the US's overall undergraduate population [12].

Mirroring enrolment problems, the situation has worsened in recent years with regard to graduation rates as well. Although 24.8% of Irish university students graduated in STEM subjects in 1999, only 22.7% did the same in 2005 [6]. Similarly, in the US the percentage of students entering engineering majors fell by 2% between 1999 and 2009 [12].

Part of the problem is that too many students drop out of engineering after they start. In Australia, for instance, 40% of all engineering majors leave before graduation. Fully half of all electrical engineering majors in Germany leave without earning engineering degrees [8].

In Australia, the drop out rate was typically higher for women than for men in the past—even in cases where they have been achieving high grades [11]. However, things have improved somewhat in this regard because today's engineering dropout rate in Australia is just 25% for women compared to 40% for men. Nevertheless, half of all female engineering graduates in Australia still leave the profession within ten years of graduating.

Our project involves talking with women at each stage of the STEM pipeline. As such, we hope to gain insight into what issues and concerns they face and have faced over time.

1.3 Addressing Problematic Factors

In a white paper for the European Schoolnet and CISCO, researchers [13] investigated gender-related patterns in France, Italy, Holland, Poland, and Great Britain. They found girls typically drop out of STEM subjects after secondary school, and this seems to result from:

- lack of role model support
- persistent stereotypes
- lack of familiarity with STEM roles
- and in some cases, perceptions of difficulty

This results in a loss of opportunity for women students and for society at large.

In analysing data that were collected at the Dublin Institute of Technology (DIT), members of our team found that opportunities for design and creativity appeared to be more important to women than men, although they lacked enough responses from women to make definitive claims [14]. Quantitative survey data were supported, however, by anecdotal comments of made by female participants in DIT's May 2013 RoboSlam workshop (Figure 1), who stated that having opportunities to create and to be artistic were considerations for them.

A case study by Jeschke *et al*. [15] posed a similar hypothesis, asserting that robotics curricula that involve Problem-Based and Project-Based Learning hold particular appeal for young women. In addition, it appears women sometimes avoid technical subjects when they see them as overly theoretical, non-experiential, or not hands-on enough [16, 17].

Fig. 1. Transition Year students building robots

Scholars in the area of 'student development' provide further support for this hypothesis. Their qualitative work has documented women's desire to learn in interpersonal, contextualized and/or connected ways [18, 19]. Other researchers claim that PBL is more inclusive and that female students are more likely to ask questions in non-competitive PBL environments [20]. Overall, it appears PBL may increase student engagement and increase interest in STEM subjects among women [1, 2]. As such, PBL seems to hold promise for attracting and retaining more women engineers and it is a major component of our current research project.

2 METHODOLOGY

Beddoes and Borrego [21] stressed the need for greater methodological and philosophical rigor in research on gender in engineering. In their analysis of the three major engineering education journals over the 14-year period from 1995-2008, these researchers identified just 88 articles on gender in engineering (57 from North America, 25 from Europe). They found 22% of all articles on gender in engineering education in special focus issues, not mainstream editions. Further, they noted that few used any form of theoretical framework, asserting that, overall, “engineering education scholarship is still characterized by a lack of explicit and consistent theoretical engagement” [21, p. 283]. In response to their claim, our EER team is working to engage rigorously with the theories underpinning phenomenology and help enrich the scholarship on engineering education.

We believe phenomenological methodologies are optimal for identifying key factors in individuals’ choices to join or leave engineering. Such work can help describe *what* happens and *how* it happens, which can inform program development.

2.1 Brief Description of Phenomenology

Creswell [22] has identified five specific strategies for use in qualitative research: phenomenology, ethnographies, narrative research, grounded theory, and case study. Today, the term ‘phenomenology’ is used to describe both a philosophy and a research method [23]. In research, phenomenology is used to study human consciousness and to investigate the way people perceive specific phenomena. Phenomenologists aim to provide both describe and interpret participants’ experiences of specified phenomena.

Because the human conscious filters all experiences of the world, phenomenologists see no distinction between what exists and what is perceived. Thus, they question the premise of objectivity, disbelieving that there is a set of objective facts or truths ‘out there waiting to be discovered’. Phenomenologists believe that understanding of the world is created by humans, stored within their minds, and informed by the sensations they experience.

As a method of conducting research, phenomenology aims to collect and understand human experiences that are stored in individual human minds. Phenomenological researchers collect individuals’ descriptions of experiences, analyse them, and use them to develop deeper understanding. Because phenomenology facilitates the study of human experience, it has also been used extensively in research on identity, health, sexuality, and psychological [24] (Smith, Flowers, & Larkin, 2009).

Feldman [25] believes organizations that assume there is an objective reality, such as NASA, may be able to benefit tremendously from analysing their own beliefs and behaviours through qualitative lenses. Feldman thinks that NASA relied too heavily on quantitative data and positivist methods, and that the organization’s failure to implement diverse ways of seeing facilitated the *Challenger* explosion. Members of the organization failed to see inter-relationships among problem solving, organizational culture, and social structures. Thus, his research identified the need to use qualitative perspectives to achieve a more holistic and accurate set of interpretations. He and other researchers [26] have called for qualitative research to be conducted *by* and *about* NASA. They think phenomenological inquiry is well suited to this task—noting that NASA studies phenomena, just as phenomenology does.

2.2 Use in Engineering Education Research

Today, phenomenology is emerging for use in EER. We have located two dissertation studies that used the method. The first, conducted in South Africa, by Karen Ilse van Heerden [27], described the phenomenon of ‘acquiring the discourse of engineering’ in college. More recently, working in the United States, Pamela Charity-Leeke [28] used phenomenology to analyse gender roles in engineering. Also in the US, Julie Martin Trenor is using phenomenology to explore how first-generation college students found their way to engineering; she reported preliminary findings in a conference paper [29].

In the past few years, a number of phenomenological engineering education studies reached the scholarly press. They include the study of engineering students’ *learning strategies* [30] and their experiences of *finishing degrees* and *entering the engineering profession* [31]. Researchers have also explored students’:

- Experiences of dissatisfaction during STEM graduate school in Taiwan [32]
- Use of textbooks during problem-solving activities [33]
- Experiences of multi-disciplinary design [34]
- Experiences using tablet PCs to teach engineering [35]

Recent work by our colleagues at DIT has applied phenomenology to generate understanding of lecturers’ experiences of:

- Curriculum design [36]

- Experience with researching nanoscience and nanotechnology [37, 38]
- Using peer-learning groups to transform teaching practices [39]

Results indicate this is a highly appropriate method to use in engineering education and that it can help educators understand and address critical problems). In addition to reviewing phenomenological studies regarding engineering education, we are also reviewing research on Problem-Based Learning as well as non-phenomenological studies of gender in engineering.

3 DESIGN

To understand how women experienced the decision-making process, we intend to conduct in-depth semi-structured interviews with women from across the European Union.

3.1 Objectives

We are conducting this study to generate new understanding of how to attract and retain diverse populations in engineering. We want to identify factors that influence women's choice of engineering as a career as well as factors that influence their decisions to leave engineering. In addition, we want to understand how to effectively teach students using PBL. In the process, we aim to build greater understanding of how to use phenomenology to study learning of technical subjects.

3.2 Sample

Our study uses a purposeful, stratified sampling. Guest, *et al*. [40] have recommended sample sizes of 5-25 for phenomenology. Reid, Flowers, and Larkin [41] suggest limiting the sample size for interpretative phenomenological analysis projects to 15. In order to provide a robust description that includes voices from many cultures and age groups, we aim to interview at least 24 women. We will include women at the high school, college, and early and late stages of their careers. We intend to include participants from Ireland, Portugal, and Poland including women who have experienced PBL as well as those who have not.

3.3 Research Questions

Our overarching research questions are: What is it like (for women) to decide to go into engineering? What is it like to experience hands-on Problem-Based Learning pedagogies? What is it like to experience learning pedagogies that are not hands on? What is it like to decide to leave the field of engineering? With these overarching questions in mind, we will develop a more specific schedule of interview questions that we will follow loosely, in a give-and-take dialogue with each of our participants. Through exploring meanings of women's experiences in engineering, our research team aims to understand unique experiences as well as commonalities.

3.4 Data Collection

Descriptions of experience provide data for phenomenological studies. Written responses, such as essays and journal entries can prove useful [42], but most phenomenological researchers collect using semi-structured of open-ended interviews [43, 44]. Some phenomenological researchers also conduct focus group sessions in order to gather data. Whatever the format, participants' accounts must be gathered in a way that provides verbatim, detailed transcripts for the research team to study and analyse.

In this type of research, participants are conceptualized as co-researchers and are asked to reflect on their experiences. Interviewers develop a dialogue with each participant—gathering data that will help reveal key meanings about the individual's experiences. The interviewer may guide participants into deep reflections that help them identify underlying emotions. This approach stands in contrast to structured interview approaches and those that take an interrogative or challenging stance. Interviews are open-ended and characterized by a sense of curiosity. The interviewer serves as a sort of facilitator, working to elicit deep, rich, and personally meaningful accounts from each participant.

In past experience, our research team has found that participants frequently drift from describing their *experience* to providing *reflections* on their experience or *opinions* formed from experience. Learning to turn the dialogue back to accounts of experience, and to avoid rational analysis of the events during the interview, presents a challenge to novice interviewers. Nevertheless, these techniques are at the core of Moustakas' [44, 45] approach, described in more detail below.

3.5 Analytical Methods

Hermeneutic phenomenologists believe that all phenomena are embedded and experienced with meaning. They seek to describe and interpret the everyday lived experience of their participants—or the underlying but invisible text of life regarding their actions, behaviors, intentions, and experiences. Van Manen (1990) has identified a range of activities related to this type of research, which include:

- Determining a specific phenomenon to study
- Investigating events as they are *lived* (in contrast to how people *conceptualize* them)
- Identifying themes that are central to the experience as described by participants
- Describing the phenomenon using a narrative format
- Maintaining connection to the original question and its purpose
- Synthesizing findings so that the parts and the whole harmonize

In a prior study [39], our team implemented the highly structured approach to phenomenology defined by Moustakas [44, 45] that was recommended by Creswell [22]. In that study, we built understanding of how phenomenology could be used effectively in technical fields like engineering. In this context, conceptions of objectivity, reality, and epistemology differ from the social sciences, which birthed phenomenology. As such, we seek to help bridge the gap, translating the language of phenomenology so that it is easier for engineers to use and understand.

Following our earlier model, in this study we plan to have multiple researchers analyse data independently, working with one transcript at a time. During initial analyses, we will identify descriptions of experience, discard opinions and reflections, and work to distil the descriptions into a list of invariant (non-repetitive, non-overlapping) meaning units depicting the individual participant's experiences as recommended by Moustakas [44].

We will then label each meaning unit after determining if the specific unit in question is 'textural' or 'structural'. To us, textural descriptions involve *what* was experienced whereas structural descriptions involve *how* it was experienced. Following this work, we intend to develop a composite *textural* description as well as a composite *structural* description for the group. Then we will work to synthesize the two into a composite *textural-structural* description for the whole group, in an effort to convey the essence of deciding to join, stay in, or leave engineering.

In contrast to Moustakas [44], van Manen [45]does not offer a procedural system but rather constructs the procedure and allows it to emerge in the course of conducting the research. Before commencing work, we will consider critiques of Moustakas and investigate methods for Interpretative Phenomenological Analysis (IPA) recently proffered by Smith, Flowers, and Larkin [24].

4 SUMMARY

In this paper we have provided a brief overview of our design in order to gather feedback from SEFI conference goers. We have explained our rationale for the study and provided a detailed description of the need for such work. We hope that the research we are about to conduct will contribute to the field of EER and help improve the way we teach engineers and who we attract to the field.

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