

MINDING THE GENDER GAP: ASSOCIATING GENDER UNDER-REPRESENTATION WITH FEMALE STUDENTS' RESEARCH MOTIVATIONS

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Abstract - Imbalance in male and female graduate enrolments highlights the need to review gender representation in STEM disciplines. This study examines research motivations as a reason for low female participation in engineering and computer science graduate studies. Interpretive content analysis is used to analyze and compare research focus of female and male graduate students, and results indicate a tendency for research undertaken by females to encompass a higher degree of communal contribution. This suggests that female student researchers tend to take on an agentic role in wanting their research work to leave a social impact and by association are less inclined to engage in "research for the sake of research". It is hoped that this study will generate more in-depth discussion and exploration to encourage researchers of both genders to examine their research motivations in order to achieve diverse participation and representation within STEM research.

Keywords - Higher Education; Gender Representation; STEM; Research Motivations

I. INTRODUCTION

Over the past two decades, participation of female students in graduate study programs has increased quite dramatically. Surveys of 2016 (Okahana& Zhou, 2017) indicate that 55.9% of graduate students in the USA comprised female students, which is an astonishing upsurge compared with the low figure of 6% recorded in 1960.

Nevertheless, this trend does not unequivocally mean female student researchers are overall well represented in all study disciplines. When compared with male enrolment in graduate schools, far fewer female students are engaged in science, technology, engineering and mathematics (STEM) subjects. More research focused on identifying trends and reasons for under-representation of female graduate students is therefore much needed in order to fully comprehend and address this phenomenon.

II. ISSUES IN GENDER REPRESENTATION STUDIES

Researchers, educators and policy planners interested in gender representation find that male students are generally more incentivized to pursue and perform well in STEM related studies whilst female students are encouraged to enter fields such as education, social sciences, business or law. A critical review of related literature on female under-representation in STEM studies reveals enduring themes on gender gap theories. These include issues of gender stereotyping, efficacy about ability, and motivations underlying choices of study and prospective career.

While much attention and discussion have evolved around the first two themes (i.e., gender stereotyping

and efficacy beliefs), much less is focused on deliberating motivations underlying female students' decision to *not want to* engage in certain STEM research or study disciplines. This study is undertaken on the premise that an examination of research motivations of female graduate students can shed light on why these students are not keen to select or engage in certain STEM studies or research, namely Engineering and Computer Science.

2.1. Motivations underlying STEM engagement

To gain a clearer understanding of gendered preferences in female students' research goals, we review current studies exploring themes of achievement motivation and goal orientation. A study by Diekman et al. (2017) sought to find out whether male and female students held different beliefs concerning graduate school enrolment and examined the extent to which motives and goals affected students' interest in pursuing STEM related studies. Their study showed female students possessed a much stronger communal goal orientation compared to their male counterparts. Diekman et al. also highlighted the notion that goal congruity, i.e., a concept that aligns study goals with goals of altruism and social impact, is present as a strong determinant for female students to initiate and sustain interest in STEM study programs.

Evidence from the literature shows female student researchers generally do not usually regard STEM studies to be supportive of communal and social impact goals, particularly in research on engineering and computer science. A comprehensive review of female roles in STEM disciplines (Meiksins et al. 2017) discovered that engineering and computer science were not perceived by females

as fields in which they could “pursue their desire to work with people and to resolve social problems and make the world a better place” (p311).

This finding supports earlier surveys (Stout, Grunberg & Ito, 2016) that indicated university students generally perceived engineering, math and physics offered far fewer opportunities for communal contribution and hence this could account for why female students were less interested in pursuing these disciplines. Godwin et al. (2016) presented similar conclusions in their surveys across 50 USA universities; they pointed out that in general female students placed high significance on aligning their studies with not only altruistic communal value but also agency belief, i.e., the belief that what they learn and their contribution of research efforts will *enable them* to improve the community they live in and ultimately the world.

2.2. Motivations underlying female students' research engagement

The literature points to valid reasons for us to believe that female students who embrace altruistic values would choose to focus their studies or conduct research on issues that befit their goals of serving society and contributing to community at large. Studies by Stout, Grunberg and Ito (2016) and Godwin et al. (2016) provide some of this evidence but their studies surveyed college students or undergraduates, and not graduate students and their research interests. Nevertheless, such studies provide a basis for us to assume that the inclination towards aligning studies or research with altruistic goals will be similarly embraced by female student researchers in science graduate programs. The current study therefore aims to elucidate female students' research focus by examining their graduate research aims or goals see if the research work they select to undertake actually embraces communal or agentic goals.

This current state of knowledge gives rise to the following research issues, namely (i) do female student researchers select research focus areas that have communal goals and social impact value; and (ii) is there a difference between male and female students' research motivations, viewed from the perspective of a desire for their research work to embrace communal goals and leave a social impact on the community.

IV. RESULTS AND DISCUSSION

4.1. Female students' research motivations

The analysis in Table 1 showed that the selected female students' research topics displayed focal interests that had explicitly stated communal goals. The social impact of these goals are expressed in the stated aims and quite often, indicated in the thesis titles and also in the Introduction sections.

III. METHODOLOGY

The qualitative methodology adopted for this study is interpretive content analysis (Krippendorf, 2004) of graduate theses, presented as the research works of 10 female student researchers and 10 male student researchers. This approach to content analysis differs from the conventional method. Interpretive content analysis involves procedures of comparing and contrasting themes derived from key concepts. This analysis is accompanied by interpretation of content while taking into consideration relevant underlying contexts.

A key contribution to interpretive data analysis is the role of researcher's self-awareness and reflexivity with regard to purposive data collection and analysis. Within the context of this study, the researcher strives to comprehend the relationships among selected data source (female students), valid data (female students' thesis topics and study aims) and corresponding research questions (identification of stated or implied communal or agency goals).

3.1. Sampling and data collection

The student researchers in this study were 10 female and 10 male students enrolled in a graduate writing class offered at a prominent university in Asia. The full enrolment was 35, which meant female students made up 28% of the gender representation of this study cohort. The researcher was the writing teacher tasked with guiding graduate students to develop critical discourse skills for writing a thesis. The 10 female students were selected based on their enrolment and interest in conducting research in two male-predominant study disciplines, i.e., Engineering and Computer Science.

3.2. Data analysis

Students' works were examined to determine the orientation or thrust of their research goals. For each student's work, the researcher examined first the thesis title and then the stated aims of the study. These data were collated and key concepts were presented under headings of discipline, title, stated aims (see Table 1). To arrive at higher reliability in coding, a second co-researcher was asked to review the table and then articulate her perceptions concerning these studies' possible or potential contributions to community. Table 2 depicts thesis topics and aims of both male and female student researchers enrolled in the same program of studies, i.e., engineering and computer science.

Discipline	Thesis title	Stated aims (communal goals or agentic roles)
Engineering	Material management for aircraft maintenance	improves efficiency and timely maintenance leading to higher air safety measures
	Forecasting system of marine beach water quality	Delivers daily beach water quality forecasts, to enhance protection of public health and efficient utilization of marine beach resources
	Public-private-people-partnership (4P) model for new infrastructure construction	Improves disaster management and targets future sustainable development
Computer Science	Social recommendation system based on sentiment similarity	satisfies online users' psychological preferences and enhances overall social networking experience
	Facial recognition online apps design	improves facial recognition software for enhanced surveillance networks
	Virtual assistants with artificial intelligence	facilitates virtual assistant models to provide users with timely, useful and relevant responses
	E-commerce and network architecture	builds task-oriented dialogue systems for improved online shopping experience
	Deep reinforcement learning for efficacy	supports the execution of business training and decisions in effective and efficient ways
	Virtual museums based on Halogens and Vuforia	enhances virtual museum experience of visitors
	Cybersecurity in blockchains: threats and counter-measures	reinforces higher awareness of risks and improved preventive measures

Table 1: Female students' research orientations

Research topics chosen by female student researchers show varying levels of communal contributions and opportunities that are likely to leave a social impact on various stakeholders. This expectancy in their research to have social impact can be realized as a driver that enhances these female student researchers' interest and motivation. As can be seen in Table 1, research work in Engineering studies embrace communal goals, whether stated explicitly or implicitly. These goals relate to improved life quality resulting from more efficient air safety measures, beneficial use of natural resources and more sustainable disaster management. It can be said that the female student researchers have their stakeholders' interests at heart and in mind when they formulate their research approach, outcomes or deliverables.

It is expected that an exploratory review of Computer Science research focus by females will display similar communal goals or social impacts on communities. From Table 1, we can see that research topics are once again chosen and similarly framed with pragmatic aims (e.g., enhancing online users' social networking, shopping or virtual museum experiences) or an improved sense of quality of life or work (i.e., satisfying psychological preferences, supporting business decision making, or reinforcing higher awareness of risks and need for preventive measures).

4.2. Gender comparison: reviewing male students' research motivations

By comparison, based on Table 2 below, male student researchers' topics appear to have minimal association to stakeholders' benefits or communal contribution.

Discipline	Thesis title	Stated aims (communal goals or agentic roles)
Engineering	Adaptive finite element analysis for 2D elastostatic problems	presents automatic adaptive refinement procedure for finite element analysis to obtain solutions of prescribed accuracy
	Temperature distribution in highway bridges	predicts temperature distribution based on heat transfer theory to develop finite element models for different structural components of highway bridges

	Online real-time monitoring system for geotechnical application	designs new sensorarray for validating and calibrating accelerations and displacements measured
	Behaviour and design of tubular structural members under concentrated bearing loads	Evaluates applicability of design provisions for cold-formed high strength steel and concrete-filled tubular structural members under concentrated bearing loads, leading to new Direct Strength Method
	Cell-based dynamic traffic assignment models: formulations and properties	Improves accuracy of dynamic traffic modelling by encapsulating network version of cell transmission model
Computer Science	Interference lithography	signals breakthrough in holographic lithography for distributed grating fabrication
	Linear time algorithm on suffix array construction	constructs suffix arrays in linear time and space for induced sorting using d-critical substrings
	Adaptive image encryption for reversible data hiding	develops multi-sensor data fusion algorithms, leading to higher maximum embedding rate
	Detecting XSS attacks using machine learning method	Extends application of advanced machine learning algorithms in deep/extreme learning machine for classification of XSS webpages
	Fluent parameter server design for distributed machine learning	supports flexible consistency models, elastic scalability and fault tolerance for efficient machine learning

Table 2: Gender comparison of research orientations

The thrust of male student-researchers' studies is more noticeably targeted at improved research outcomes which take the forms of more rigorous methods, more detailed analysis framework or higher prescribed accuracy. The goals found in male students' studies appear to be "research for the sake of research", with no immediate association as to what or how a stakeholder or user community can benefit from these studies' outcomes. For comparison, we reviewed the two studies in computer science by female and male students that focused on cybersecurity. The female student's study on blockchain security was aimed at reinforcing users' awareness of risks in these transactions and also improving preventive measures they could adopt. In contrast, the male student's work on detecting XSS attacks was intended to improve application of machine learning and the classification of cross-site scripting (or XSS) websites, with no mention of users affected by these attacks or consideration of their need for improved cybersecurity.

In some cases, gendered attitudes reflected in the form of goals or expectations are internalized, to the extent that the learners may themselves be unaware of this role congruity or association with their research intents or interests. In the comparison

between genders (Tables 1 and 2), a noteworthy point is while male student researchers may also have engaged in research work that potentially have a communal goal orientation, this goal is very often not explicitly stated in the title or study aims.

4.3. Communal goal motivations

While goals related to communal and agency benefits are generally pursued by both genders, evidence from literature shows that females tend to endorse communal goals to a higher degree, compared to male student-researchers (Diekman et al. 2017). Gender differences reflected in attitude and orientation (i.e., social compassion and traditional morality) are largely consistent over time and across cultures, as indicated in cross-temporal (Eagly et al. 2004) and cross-nation studies (Else-Quest et al. 2010).

Female under-representation in higher education research for engineering and computer science majors is clearly a phenomenon worthy of concern, and for good reasons. The National Academy of Engineering 2017 website (cited in Reinking and Martin, 2018, p150) tells it as it is: "...despite an increase in female participation in many traditionally male-dominated professions such as medicine and law, women remain grossly under-represented in

engineering... Diversity of thought is crucial to creativity, and by leaving women out of the process of innovation we lose a key component of diversity and risk stifling innovation." In 2015, the United States Agency for International Development (USAID) points out that a current global concern is to ensure females are trained to develop appreciation for STEM, especially in fields of study where there is continued and significant female under-representation (Cummings, 2015).

At the same time, a related concern is that the emphasis on communal contribution that is so valued by female researchers should in turn be given higher prominence in the training and mentoring of all students, male as well as female. Indeed, this study goes so far as to advocate that male researchers should, like their female counterparts, view communal goal and social impact as a significant and integral aspect of their research focus.

V. CONCLUSION AND IMPLICATIONS

This study is a preliminary effort as it reviews the works of a small sample of graduate students. It nevertheless serves to indicate that there is a need for more extensive research that can lead to more informed understanding of researcher motivations to enable the fostering of more equal gender representation in STEM higher education.

There is also the need for scholars to employ more diverse theoretical lenses and methodological approaches to fully comprehend the interactional dynamics that drive this gendered representation. Some exemplary work in this area includes reviews and meta-analyses (Okahana & Zhou, 2017; Meiksins et al. 2017, 2018), case studies (Christie et al. 2017, Cheryan et al. 2017), relational studies on retention or withdrawal (Ma & Liu 2018), and impact studies on development of STEM aspirations and expectations (Boucher et al. 2017; Buse, Bilimoria & Perelli, 2013; Sassler, Michelmore & Smith, 2017).

By better integrating and acknowledging communal opportunities, the stereotypic perceptions of study fields of engineering and computer science could gradually change to make these areas of study more inclusive and more engaging to scholars of not merely one, but both genders. It is hoped that this realization of the association between female students' selection of disciplinary study and research motivations will generate more in-depth discussion on how to stimulate female student-researchers' engagement into fields where they are currently under-represented. Some scholars advocate a solution to this under-representation by raising awareness of the association and often perceived misalignment between STEM related research and communal goal orientations through universities'

orientation programs that focus on helping female students make more informed choices based on gendered values and research motivations. Inevitably, there should also be more proactive efforts in transforming the landscape of STEM research to increasingly reflect an orientation that embraces meaningful communal goals and widespread social impact in the researcher efforts of both female and male students.

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