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Females' Exclusion from Physics: Examining Two Deterring Factors

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Abstract

Females' low participation in post-compulsory physics education has been a major concern for researchers over the past five decades. The present study focuses attention on two major deterring factors, the *female pedagogy-sensitivity effect* and the *stereotype effect*. The objectives of this study are to uncover the constituents and meanings of these factors by (a) analyzing the perspectives of female university science students and, (b) evaluating differences in their impacts among females choosing to major in biology compared to females choosing to major in physics. The study contributes to our understanding of how these deterring effects impact on females along their educational path and particularly in their tertiary education.

Keywords: *physics education, females in science, stereotype, science education, science education pedagogy, gender imbalance*

Introduction

High-quality delivery of scientific literacy is crucial for the continuous growth of post-industrial economies and for increasing the resilience of societies worldwide. Society's need for science-savvy citizens includes government, industry and communities, all in which science-related policies and decisions are formulated routinely (DEST, 2003; International Council for Science, 2011; National Research Council, 2012; Tytler, 2007; U.S. Department of Education, 2006). Throughout the past five decades, despite extensive efforts to increase students' participation in science education, female participation has been continuously and consistently low (Hill, Corbett, & St. Rose, 2010; National Science Foundation, 2009). The steepest drop in females' participation in Science, Technology, Engineering and Mathematics (STEM) occurs at the transition into tertiary education, at which point 20% of males plan to major in engineering, computer science, or the physical sciences, compared with only about 5% cent of females (National Science Foundation, 2009). When examining the branching points of these differences, some evidence suggests that girls begin reporting less confidence in math and science in middle school and that these gender differences deepen in high school (Haussler & Hoffmann, 2002; Pajares, 2005). The worrying gap in female versus male participation in STEM fields has stimulated a lot of research over the years, suggesting various typologies of deterring factors. For example, Enman and Lupart (2000) suggested a seven-factor typology, including (a) values; (b) self-confidence; (c) perceptions of ability; (d) attributions; (e) classroom biases; (f) stereotypes of math and science as masculine domains; and, (g) peer and parental influences (p. 162). Hill et al. (2010) offered a three-factor typology comprised of the (a) social and environmental factors that shape girls' achievements and interest in math and science; (b) college environment; and, (c) continuing importance of bias, often operating at an unconscious level, as an obstacle to women's success in STEM fields (p. 27).These typologies and others suggest that the social context in which females develop their interest in sciences is a powerful multifaceted effector deterring talented females from pursuing physics education. Two of these social effectors, pedagogy and stereotype, are of particular importance as described below.

The Physics Classroom Pedagogy

A report published by the Institute of Physics drew attention to the powerful role of physics pedagogy implemented at UK state schools in making the gender imbalance in physics-related subjects worse (Institute of Physics, 2013). Pedagogy includes explicit aspects, such as contents and modes of delivery, and implicit aspects such as attitudes and motives.

With regard to the explicit aspects, studies have pointed out that the content of physics pedagogy favors boys' interests rather than girls', with overemphasis on technical aspects leaving girls uninterested (Haussler & Hoffmann, 2002; Hill et al., 2010; Hoffman, 2002). A few studies have highlighted the differences between the pedagogical needs of girls and boys. Compared with boys, girls have a stronger need to have a sense of purpose in their learning of scientific phenomena (Osborne & Collins, 2000), and perceive relevance and context in their studies (Hoffman, 2002; Krogh & Thomsen, 2005; Murphy & Whitelegg, 2006; Osborne & Collins, 2000). The literature suggests that in terms of the explicit aspects of physics pedagogy, both contents and modes of delivery are skewed in favor of boys' needs (Hoffman, 2002).

With regard to the implicit aspects of physics pedagogy, studies since the 1980s have pointed to favoritism in attitudes towards boys in the physics classroom. Boys receive more public attention in physics class than girls do. They are asked more questions and given longer answering time (Kelly, 1988). Teachers appear to have higher expectations from male physics students than from female students (Haussler & Hoffmann, 2002). This and other evidence portrays a physics classroom in which the pedagogical climate does not motivate females to succeed and does not support females' participation and contribution.

Physics Stereotype

A stereotype may be defined as "*a belief about a group of individuals*" (Kanahara, 2006, p. 311). When a stereotype is being applied, we make assumptions about an individual or ourselves under the influence of our preconceived conceptions (ibid). Although stereotypes may be socio-cultural structures, they affect individual attitudes, choices and behaviors.

Studies consistently expose the deeply rooted belief that girls' and women's ability to perform well in STEM is inferior to boys' and men's ability (Ambady, Shih, Kim, & Pittinsky, 2001; Hill et al., 2010; Nosek, Banaji, & Greenwald, 2002). Murphy (2000) summarized evidence suggesting that stereotypes related to "male" versus "female" domains take effect as early as primary school age. The stereotypic perception of a scientist as a male persists into adulthood and is prevalent even among adults who otherwise believe in equity and equality (Valian, 1998). These pervasive stereotypic beliefs have been shown to be transmitted inter-generationally, such that parents with strong stereotypes pass them on to their daughters (Bleeker & Jacobs, 2004; Kelly, 1988).The process by which the male scientist stereotype produces negative effects among women has been described as "stereotype threat" (Nguyen & Ryan, 2008). Stereotype threat arises in situations in which a negative stereotype is relevant to evaluating performance (Hill et al., 2010). This type of threat situation causes females to perform much worse than males in math tests (Nguyen & Ryan, 2008; Walton & Spencer, 2009). Experiments have shown that stereotype threat is commonly the default in testing situations and that females perform much better when the threat is removed (Hill et al., 2010, p. 39).

Over the centuries, many of societies' traditional beliefs regarding female versus male roles and capabilities have changed and become less significant. It seems, however, that the male physicist stereotype is still prevalent.

The evidence outlined above, regarding the deterring effects of both physics education pedagogy and the gender stereotypes, set the framework for the present study. This study aimed to obtain the perceptions of female university science students regarding the above two deterring factors, by eliciting their retrospective reflections on their paths to becoming scientists. The study put forward the following objectives:

- to uncover the constituents and meanings of the 'female pedagogy sensitivity effect' and the 'stereotype effect' through the perspectives of female university science students;
- to investigate the perceptions of females choosing to major in biology compared to females choosing to major in physics with regard to the two effects; and,
- to investigate the ways in which the 'pedagogy sensitivity effect' and the 'stereotype effect' have influenced the educational choices and paths of females choosing to major in biology compared to females choosing to major in physics.

Methods

Two basic assumptions regarding deterring factors were developed as a framework for directing the study's methods and analysis. The factors are as follows:

Deterring factor A: Female pedagogy-sensitivity effect: In order to succeed, females require a responsive pedagogy. Female students studying physics are more affected than male students by the implemented pedagogy.

Deterring factor B: The stereotype effect: The stereotype of physics as a predominantly male discipline contributes to deterring female students from studying physics.

To achieve the study's objectives, specifically designed instruments were developed and implemented among second-year female university students who were studying biology and physics. The participants' perceptions regarding the above deterring factors were obtained through a written questionnaire, an individual interview and focus group discussions.

The methodological approach consisted of a qualitative approach, using an interpretivist case study. The interpretivist case study is a method of studying social phenomena through the analysis of an individual case or small group (Merriam, 1998). Time and budget limitations constituted major determinants in developing the methodology, leading to a decision to choose a small sample size yet obtain in-depth information from each participant. Triangulation was used as a method for ensuring validity.

Participants

Six female second-year students studying science at the University of Melbourne, Australia participated in the study. Three students majored in physics, and three majored in biology. The three physics students represented 43% of the total Year 2 female physics students at the university, at that year. The total number was seven female students. The number of participants was as close as possible to the saturation point, thus ensuring that the gathered information would be reliable and valid, though limited in its generalizability (Guest, Bunce, & Johnson, 2006). An effort was made to achieve homogeneity to the extent possible. Homogeneity facilitates data saturation (Guest et. al., 2006, p.59). In the present study elements of homogeneity were present by the fact that the six students were studying at the same university, at the same year level, and in the same course. All the students were females between the ages of 20–24.

Data Collection and Analysis

The following three instruments were developed and administered: an individual written questionnaire, an individual interview, and focus group discussions. Each of the instruments was validated by science education experts from three different universities. The instruments were developed to uncover the participants' conscious as well as unconscious attitudes, reflections and perceptions regarding physics education, as they experienced them along their educational path. Conscious attitudes were obtained through the interviews and questionnaires whereas unconscious attitudes were obtained through hands-on activities during the focus groups. Two separate activities were developed for the focus groups, one aiming to elicit unconscious attitudes in regard to female-sensitive pedagogy and the other in regard to the stereotypic effect. In the first activity, the participants were asked to assemble an electric train with an alarm that goes off when a door is opened (male pedagogy) and to design a model for an alarm for an infant incubator that goes off if the temperature drops (female pedagogy). The activities elicited discussions regarding female-sensitive pedagogies versus male pedagogies. In the second activity, the participants were given an anonymous vocational guidance report of a student who clearly excelled in sciences. They were asked to provide the student career advice by requesting additional information about the student. The discussions surfaced up unconscious stereotypes that were later analyzed. In the process of analysis, the data was coded and a set of constituents were developed for describing the scope and mechanisms of each of the deterring factors.

Results

The analysis revealed that five constituents describe the scope of *Deterring factor A: Female pedagogy-sensitivity effect* and four constituents describe the scope of *Deterring factor B: The stereotype effect.* These constituents and relevant evidence are presented below.

Deterring Factor A: Female Pedagogy-Sensitivity Effect

Constituent 1. Females need to understand the meanings behind what they are taught and not merely the operational aspects. Deterrent pedagogy includes over-emphasis on calculations or technical aspects devoid of meaning and of big ideas.

Both groups of physics-majors and biology- majors referred to the fundamental role of meaning-making in physics as a prerequisite for learning. The biology group expressed an ongoing frustration with not being able to make such meanings and therefore not being able to study physics. In contrast, the physics-majors group spoke about the importance of solving exercises as a means for developing a deeper understanding of physics, once the big ideas have been understood. One physics-major respondent described the ways in which physics informed her math education, as follows: "*Rather than math helped with physics I thought physics helped with math. I remember getting things in algebra, in physics classes*". Through physics she was able to understand fundamental concepts. Once she understood these concepts, the algebra equations became clear to her as well. Unlike the biology-majors, the physics-majors found physics applications in nature to be obvious. One participant described how her challenge was to move beyond observing applications of physics in the natural world toward developing a deeper understanding. The mathematical calculations assisted her in deconstructing the observed phenomena and thus in gaining a better understanding.

The evidence indicates that the physics-majors and biology-majors differ in regard to meaning-making in physics education. Only females who understood the underlying meanings have chosen to continue studying physics.

Constituent 2. Females seek to understand the relationship and relevance of physics to real-life problems.

The evidence suggests that female-sensitive physics pedagogy needs to explicitly address the relevance of the studied topics to real-life issues. Both groups expressed the need for relevance. Although the two groups were similar with regard to the need, they differed with regard to its fulfillment. Whereas biology-majors expressed difficulty in perceiving the relevance, physics-majors expressed a deep understanding regarding the relevance of physics to real life. One physics-major described her intuitive understanding as follows: "*Physics is such an intuitive subject. You come into contact with it every day. Driving a car or even touching something*". The gap between the two groups suggests that only females who understood the relevance of physics to real-life problems chose physics for their post-compulsory education.

Constituent 3. A female-oriented pedagogy needs to emphasize the relevance of physics to personal growth or to personalize science in other ways.

The participants expressed a need to feel a personal sense of purpose in their studies of physics. While biology-majors could not see how they may grow and contribute in physics, the physics-majors expressed personal excitement about their developing ability to explain how things work. One participant expressed this feeling as follows: "*The fact that I really like about physics was that I could explain things in nature, whatever it was I could say to my parents, hey that's how this works*". Among the biology-majors, the physics pedagogy failed to elicit these personal affective responses toward the subject.

Constituent 4. Females require concrete examples for understanding.

Biology-majors described a pedagogical approach that failed to provide concrete examples. For the physics-majors this need has been fulfilled. All the students expressed the importance of such examples in order to understand physics at school. The difference between the two groups suggests that the students who chose to major in physics were either taught by teachers who used concrete examples or, alternatively, were capable of generating concrete examples by other means. The evidence suggests that the use of concrete examples in physics classes is a prerequisite for female-sensitive pedagogy.

Constituent 5. School physics pedagogy is more appealing to boys; boys find the teaching of physics at school more interesting than girls do.

The biology-majors clearly expressed the opinion that high school physics pedagogy was attuned to boys' needs. Physics classes were portrayed as a boys playground from which girls were excluded. Contrarily, the physics-majors who participated in physics classes took no notice whatsoever of the females' exclusion. These few self-selected females seemed to have had a deep interest in physics that had overridden the pedagogical and social exclusion aspects of the learning. The evidence suggests that the pedagogy's orientation toward boys not only reduces most females' interest in physics but also may be operating to create a social environment conducive to anti-female stereotype.

Deterring Factor B: The Stereotype Effect

Constituent 1. Models of physicists are males, and physics is perceived as a male occupation.

Neither group had any images of physicists as females. Both groups pointed to the media as one possible explanation for the lack. The groups' discussions elicited new awareness among the participants. We observed a major difference between the groups in their responses to their new awareness. The biology-majors associated this lack with the "serious" or "hard" nature of physics. The lack of female models was justified by their own stereotypes regarding the subject. In contrast, the physics-majors were surprised about the lack of female models. For them this lack was not justifiable and was not accompanied by a stereotypic rationale. Unlike the biology-majors, who conformed to the stereotypic effect and used it as justification, the physics-majors' new awareness triggered them to discuss the stereotypic effect as a possible deterrent.

Constituent 2. It is perceived that physicists work alone, or physics is a lonely occupation; to do physics you do not need social skills.

The biology-majors perceived physicists as working alone interacting with their computers. The physics-majors objected to this view altogether and emphasized the collaborative nature of research. One physics-major did, however, mention her difficulty in socializing with non-physics people. The evidence suggests that while the physics-majors feel comfortable socializing and collaborating within their area of interest, the biology students feel estranged from physics and physicists. They perceive the physicists as a secluded and non-engaging group.

Constituent 3. It is perceived that physics is for "nerds".

Both groups acknowledge the "nerdy" and anti-social stereotype of physicists.

Constituent 4. Female physicists are expected to appear masculine.

All the inputs by the biology-majors were limited to the male image of physics, with no mentioning of female physicists. It seemed as though these females were not aware that female physicists existed. Contrarily, the physics-majors discussed extensively how their participation in physics exposed them to ongoing stereotypic pressures by their peers. These pressures included expectations regarding the dress code, behavior and expression of ideas. One participant described frustration about the fact that art students can come to lectures wearing high heels, whereas she felt pressured by her peers "*not to dress like a woman*". She described how a post in one of the social media deterred her from wearing heels, by cynically commenting on the heels worn by another female physicist. The strong message that emerges from these females' reflections was that a female who wishes to participate in physics education is expected by her male peers to behave and appear as a male. The females in the study expressed feelings of being personally hurt by these attitudes.

Discussion

Previous research regarding females' deterrence from physics identified a range of discrete variables causing the effect. The present study grouped some of the more influential effectors under two organizing themes entitled 'female pedagogy sensitivity effect' and the 'stereotype effect'. The aim of the study was to develop an in-depth examination regarding the operating mechanisms and their influences on females along their educational path. By comparing two groups of females, one in the "soft science" and one in the "hard science," new insights were gained regarding intricate differences that exist within the sciences themselves. This approach elicited new insights and allowed for fine tuning of some of the effects that were previously discussed more generally in the literature.

The Female Pedagogy Sensitivity Effect

Overall, the developed constituents appear to be successful in highlighting the pedagogical aspects that are lacking in the physics classroom. The evidence suggests that females are more sensitive than males to the following aspects of the physics pedagogy: addressing the underlying meanings, addressing the relationship and relevance of physics to real-life problems, supporting development of a sense of relevance to personal growth, and providing concrete examples as a means for understanding. These pedagogies form the hard-core of female-sensitive pedagogy.

The findings indicate that the physics-majors females differed from the biology-majors in the degree to which each of the above pedagogical needs were met. While the biology-majors expressed frustration in regard to their needs not being addressed, the physics-majors expressed satisfaction in this regard. Some implicit information provided by the physics-majors suggests that many of their pedagogical needs were met through self-education out-of-school and through their innate abilities to construct meanings which enabled them to bridge their schools' pedagogical gaps.

The Physics Stereotype Effect

Our evidence suggests that the stereotype effect, as reflected in the participants' responses, is comprised of models of physicists are males and physics is a male occupation; physics is a lonely occupation and does not require social skills; physics is for "nerds"; and, female physicists are expected to appear masculine. This set of stereotypes form the hard-core of this factor's deterrence effect. The physics stereotype effect emerged in the study as a multilayered and multifaceted phenomenon, which includes not only perceptions, values and attitudes but social sanctions as well. It seems to be operating through different mechanisms at different stages of females' education. All the participants were subjected to the stereotypic effect. It is profound and entrenched.

The findings revealed the exertion of social sanctions by male peers in tertiary physics classes. The occurrence of overt attacks against feminine students (as reflected in the Internet post described above) conveys a punitive outcome for choosing physics. It is not surprising that out of the total cohort of science education students (approximately 6,500 science undergraduates per year) at the University of Melbourne, there were only seven females studying Year 2 physics. These very few females who "*have not gotten the message so far*" were being subjected to gender de-validation by their male peers. The message conveyed was that femininity and physics are not an acceptable match. Such peer pressure has not been reported so far in the literature and this information could be helpful in planning educational interventions.

The high homogeneity within the groups and lack of homogeneity between the groups in regard to the two factors support their constituents' explanatory capacity, in terms of both concurrent validity and content validity.

The Study's Implications

The insights provided by this study into the pedagogies and mechanisms of deterrence may provide educationists with practical pedagogical tools for supporting female physics students. The insights provided in regard to the stereotypic effect call for addressing the problem at every level of the education system and particularly at the so far overlooked tertiary level. Future research is required for developing a better understanding regarding differences in females' experiences within the various science disciplines.

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