Understanding Young Women's Experiences of Barriers in High School Physics Education

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Abstract: This paper reports results of a qualitative study that aimed to understand how young women experience barriers in their high school physics education. The bases of the research include the longstanding issue of underrepresentation of women in physics in Canada, prevalent themes on the gender gap identified throughout physics education research, and the gap in literature that provides an explanation of young women's experiences with barriers encountered in their high school physics education. Social cognitive career theory and the concept of physics identity provide a lens through which students' experiences of barriers are described. Focus group and interview results concern students' perceptions, experiences, identity, and gender. Young women's stories reveal challenges, differences, and consequences of being a young woman in high school physics. The paper brings in student voice, practice-oriented recommendations for physics educators, and research-based knowledge for the advancement of equitable physics education.

Keywords: Physics Education, High School, Gender, Barriers, Equity, Phenomenology

Introduction

The issue of underrepresentation of women and other marginalized groups in physics is a familiar and longstanding problem common to many nations. Across the globe, statistics tell us that fewer women than men are studying physics (Natural Sciences and Engineering Research Council of Canada, 2010). For example, in the United States, women accounted for just 20% of the baccalaureate degrees earned in the fields of engineering and physics in 2010 (American Physical Society, 2015). This calls into question both the reasons for the disparity and what the consequences are for women and the field of physics.

While empirically-validated explanations for gender disparity in physics education and the physics field are numerous, as are proposed solutions and improvement initiatives (Preodi-Cross et al., 2013), fewer qualitative studies exist that represent the voices and experiences of women in physics education. This study aims to add knowledge to our preliminary understanding of women's experiences in high school physics education.

Kanny, Sax and Riggers-Piehl (2014) state that the five most prevalent themes in the literature on gender gap are: (1) background characteristics, (2) familial expectations and beliefs, (3) kindergarten to Grade 12 experiences, (4) psychological factors, and (5) perceptions of the field. Research focused on students' K-12 experience argues that the underrepresentation of women in the field of physics is related to girls encountering barriers throughout their kindergarten to Grade 12 education (Maltese & Tai, 2011; National Research Council, 2012; Sadler, Sonnert, Hazari, & Tai, 2012; Sikora & Pokropek, 2012; Tai et al., 2006). Barriers include teacher expectations and curriculum biases (Deemer et al., 2014; Haussler & Hoffmann, 2002; Murphy & Whitelegg, 2006) and the pervasive perception that the nature of the physics field is inherently masculine (Hazari & Potvin, 2005). In Canada, the highest number of young women who choose to reject physics do so at high school level (NSERC, 2010), which is of particular educational concern since those formative years have been concomitantly identified as the most likely time for young women's interests in physics to be sparked (Hazari & Potvin, 2005). To date, much of physics education research has focused on identifying the influential factors in women's physics experiences or accruing statistics to illustrate trends in representation of women in physics.

The purpose of this qualitative study was to investigate how young women physics students construct meaning of the barriers they experience in their high school education. It asked: What barriers do female high school students experience in physics education in Ontario? What meanings do female students attribute to the barriers encountered in their physics education? This paper is a novel contribution to the literature because previous work has yet to centre young women's spoken stories of experiences in high school physics education. Their stories reveal the challenges, differences, and consequences of being a young woman in the high school physics classroom. Gaining this knowledge is valuable for subsequent questioning and reconceptualizing of physics education as a more equitable space and experience for women.

Conceptual Framework

The definition of a *barrier* in this research was any factor that could negatively influence young women's ideas about what physics is or their decisions about studying physics. Social cognitive career theory (SCCT) considers contextual barriers as inhibitors of self-efficacy and intentions at times both much earlier and near to the time of developing a career plan (Lent et al., 1994; 2000). SCCT is a useful framework for this study because it connects experiences in physics education (contextual barriers) with the meaning of such experiences (used in decision-making about intentions to continue studying physics).

SCCT also suggests that learning experiences in high school physics moderate the development of students' physics identity. Physics identity is the extent to which a person feels that they are a "physics person" (Hazari, Brewe, et al., 2017, p. 96). Physics identity is comprised of four components: beliefs of competence, beliefs of performance, feelings of interest, and feelings of recognition (Hazari, Sonnert, et al., 2010). Importantly, SCCT suggests that many aspects of learning experiences influence the four components of students' physics identity. Additionally, physics identity is suggested to be a predictor of career choice, persistence, and engagement in physics (Hazari, Sonnert, et al., 2010). Therefore, physics identity is a useful concept in considering the effects of barriers on young women in high school physics education and consequently their future engagement in physics.

Methods

This qualitative study is phenomenological in nature, aiming to investigate and describe a phenomenon as a person consciously experiences it and the meaning attributed to the experience by that person (van Manen, 1990). Specifically, it investigated how young women physics students construct meaning of the barriers they experience in their high school education. The qualitative methodology adopted for this study builds on the growing use of qualitative methods in physics education research—a traditionally quantitative research field—enabling wider research-based perspectives on women in physics education.

The following statements explain the phenomenological philosophy adopted for this research and outlines the research in terms of its methodology. The lived experience of barriers in high school physics for girls was described and supported by first-person accounts. Through the researcher's reflexivity, bracketing (setting aside biases and subjective beliefs about the phenomena being studied), and analysis of the data provided by participants, the general themes emerged from the stories shared by the participants. Lastly, interpretations, as an inevitable aspect of description, were offered about the meanings of young women experiencing barriers in physics education, specifically concerning implicit or hidden meanings of lived experience. In agreement with Finlay's (2012) ideas about description and interpretation within phenomenology, the view of description and interpretation as a continuum was adopted. This means at one pole is pure description of experience and at the other pole is interpretation of experience to ascribe meaning, and a combination of the two practices exist in between. In this phenomenological study, interpretation was used when an interpretation of context aided description.

Participants

The individuals who were recruited for this study were women who had experienced physics education in an Ontario high school less than 8 years ago. Nine women were recruited in order to explore the diverse viewpoints on their experiences in an in-depth manner. The participants were recruited through snowball sampling. Inclusion criteria required that participants had taken at least one physics course in an Ontario high school. All nine participants had done so, with the exception of one participant who expressed interest in participating and went to high school outside of Ontario. At the time of data collection the participants attended an Eastern Ontario university and were studying in a variety of different programs: physics-related, non-physics related, and non-science related.

The data were obtained through focus groups and interviews. Together, the participants attended four two-hour semi-structured focus group meetings where they retrospectively recounted and discussed their experiences in high school physics. The focus group protocol included open-ended and emerging questions to allow participants to generate their own responses. Using focus groups to understand the experience of barriers in high school physics for young women was beneficial for two main reasons. First, participants were able to share different perspectives, which stimulated discussion and introduced new ideas. Second, the participants often clarified and checked for understanding of each other's experiences, which served as validation for the points being raised as shared experiences.

In order to provide an opportunity for participants to explore their experiences at a deeper level, discuss new experiences, or discuss topics brought up in the focus group meetings, they were offered an optional one-hour, one-on-one interview. All nine participants opted to participate in the interview. One participant responded in writing to interview prompts because she was out of the country during the interview period. The empathetic interview described by Fontana and Frey (2005) was employed to avoid a stance of neutrality, which was important for the researcher to become invested in understanding the experiences being discussed. The interviewer engaged in an active and collaborative discussion about the participants' experiences (Holstein & Gubrium, 1995) during the interview.

The audio-recorded focus groups and interviews were transcribed verbatim and analyzed using a general inductive approach to allow themes to emerge. The approach involved reading of data to derive themes through descriptions and interpretations of the data made by the researcher (Strauss & Corbin, 1990) and included questioning what core meanings are evident in the text in relation to the research questions (Thomas, 2006). This was achieved by carrying out open, axial, and selective coding steps as described by Strauss and Corbin (1990). These steps involve reading the data, labeling segments of text, then categorizing the labels and reducing the categories into as few as possible. The themes most relevant to the research questions were the outcome of the analysis and are presented descriptively as the findings of the research study.

Results

Three major themes emerged from the data analysis: perceptions of physics as barriers in high school physics education, barriers influence students' election and learning of physics in high school, and gender and identity in the high school physics experience. Specific sub-themes of each major theme are presented here; when illustrated with participant words, quotations are used.

Perceptions of physics as barriers in high school physics education. The first major theme was formed from participants' defined perceptions about what physics was both before and during their first experience learning physics, which, for most participants, was in Grade 11. These were shared when participants discussed their limited prior experiences with physics phenomena, their negative perceptions of physics, and the images of physics learners they held.

Limited prior experiences with physics phenomena. Considering their childhood learning memories and even early high school physics education (Grade 9 or 10), participants felt that their minimal experiences with physics and their subsequent ignorance to what physics was created a barrier to their physics learning. They reported this barrier as inhibitory to their knowledge of and comfort with physics as a science subject. It would have helped the young women feel better equipped if teachers in early high school years "[made] it really clear that *this is physics*," as they would have had a more comprehensive idea of physics rather than only as the "mysterious subject." As one participant explained, the overall perception of physics held by young women (herself included) was that "it's hard, but what the heck is it?"

Negative perceptions of physics. While some participants' perceptions of physics became more positive once they began studying it in Grade 11, all participants' perceptions prior to Grade 11 were negative in some way. Participants felt that misconceptions and negative ideas about physics were easily acquired due to the "giant question mark that physics was." In considering this issue, one participant challenged the negative perception: "It's really funny to me because nobody really knew what physics was, but everyone said that it was hard! How do you know that it's hard if you don't even know what it is?" Before starting to study physics in high school, participants viewed physics as a subject that is feared, the most difficult, "nerdy," one that everyone would struggle in, one that requires the "right" brain, dread-worthy because of scary math, and male-dominated. Some of these perceptions changed once participants began their Grade 11 physics course; however, they remained largely negative. Some examples of their perceptions during physics courses are demonstrated in these participant quotes:

> In physics you actually have to think.
> This is uncharted territory.

> No relevance to everyday life.
> It's kind of like being thrown into the deep end to learn how to swim.
> Abstract and applied.
> Science became 'mathy'.
> Difficult to grasp concepts.
> No collaborative or creative work.

These perceptions of physics were often so compelling that they negatively influenced their ideas and decisions about future physics study.

Images of physics learners. The constructed image of a physics learner, according to young women, was characterized by attributes that they did not readily associate with themselves. For example, they described physics students as "gifted," indicating that "they get it, they don't have to try hard." Further, participants' comments about physics learners demonstrated their association of attributes required for learning physics with their male peers:

> There was a perception that guys have the 'right brain' for it and girls didn't.
> I could maybe have that mindset in physics, but more likely than not, I'm not going to because I'm a girl.

Participants also described gender differences among the young women's and men's behaviours, feelings, and learning preferences in physics. They described young women as conscientious, intimidated by a class mostly comprised of men, being surprised when they performed well in physics, and not likely to continue into physics or engineering careers. In contrast, they described their male counterparts with these statements: smart, enjoying physics, spending free time reading physics news, being part of the physics club, having prior knowledge in areas helpful for physics, and that physics complemented their building and fixing interests.

Barriers influence students' election and learning of physics in high school. The second major theme is based on the findings relating to young women's decision-making about studying physics, their reactions to pedagogy, and what they identified as requirements for learning physics.

Making decisions about physics. While deciding on whether to study physics in high school, participants considered, or felt the influence of, the following factors: general interest in science, appeal of physics (e.g., fun labs, hands-on components), future preparation (e.g., university program), lack of alternative course options or electives, and other factors such as wanting to prove intelligence, or the influence of friends, parents, and teachers.

Reactions to pedagogy. Physics teachers proved to be an integral part of participants' experiences. Participants reported feeling most welcome in friendly, helpful teachers' classrooms, and less comfortable in teachers' classrooms where certain students were favoured (e.g., boys or higher performing students) or treated differently (e.g., girls being coddled and boys being pushed). Participants discussed pedagogies that they disliked, which resembled traditional teaching styles (lectures, hand-outs, sitting at desks), and pedagogies that they preferred, which resembled progressive teaching styles (investigation, videos, open discussions, real world context).

Requirements for learning physics. Participants provided insights for educators about supports they require in learning physics. Through discussions that focused on ways they felt unsupported or inhibited from learning physics, they constructed a list of supports that they felt young women require in order to successfully learn physics. These can also be considered components of successful, barrier-free physics learning, they include: conceptual understanding, comfort in class, critical thinking, problem solving, seeing the relevance of physics, and general support along the learning process.

Identity and gender in the high school physics experience. The third major theme encompassed physics identity and gender within the high school physics experience. Ideas relating to identity and gender were prevalent among all discussions indirectly and directly; this theme concerns participants' experiences with physics identity and gender as these were directly addressed. For each participant, the journey with physics identity evolved over time, and was individually unique. Participants' experiences with gender were more similar to each others' experiences than they were dissimilar, yet all participants found unique meaning to the gender-dependent influences they experienced.

Issues of physics identity. In terms of interest, or the degree to which a student feels curious and attentive to topics in physics, the participants experienced these barriers: their interest level in physics was lower in comparison to their interest in other sciences; they felt indifferent toward physics due to the lack of knowledge about the subject; they felt nervous or dreaded taking physics because of the perceived difficulty; there was not enough laboratory time or hands-on activities; the difficulty of the material overcame any initial interest; and their interest was thwarted by not knowing the purpose or goal of learning the material in physics class. The following statement by one participant typifies these barriers:

> That ah-ha moment . . . I never ended up getting that in physics . . . I never felt like I had an end goal.

In terms of competence, or the degree to which a student believes they have the ability to understand concepts in physics, the participants experienced these barriers: a perception that learning physics was not natural and intuitive to them; believing that competence in physics would come only with a steep learning curve; lack of opportunities to discuss and "wrestle" with physics concepts; low feelings of empowerment and certainty in their ability to grasp physics concepts; general self-doubt or underestimation of personal abilities; frustration at not understanding physics concepts; feelings of helplessness after thinking they were falling behind the class in understanding; "math anxiety" and panic in problem solving tasks; not knowing how to ask for help; and operating with a fixed mind-set or entering "survival mode" when difficulty arose (e.g., learning in order to pass the next test rather than for the benefits of the learning experience).

> Okay, I guess I'm not really as good at this as I thought, I will change my plans for university. It [Grade 12 physics] really brought me down . . . did not feel good about physics at all.

In terms of performance, or the degree to which a student believes they can successfully complete physics tasks (e.g., laboratory experiments or problem solving), participants experienced these barriers: feeling defined by and being fixated on the grades they received; experiencing in physics for the first time in school that very hard work is necessary to perform well; pressures from home to achieve high grades; stressful, performance-based learning tasks; comparison between peers and the general feel of competition in the class; and behaviours of perfectionism.

> I didn't feel much like a physics student whatsoever and it was all based on my marks.
> Once my performance in physics was declining, it was challenging my entire self-perception.
> I wasn't doing well and that deterred me.

In terms of recognition, or the degree to which a student believes they are perceived by others (e.g., teachers, peers, or family) as a physics person, the participants experienced these barriers: students avoid recognition as a physics person because it compromises their social recognition; embarrassment from struggling with a physics tasks in front of peers; feelings of non-belonging in physics class; teachers' elitist view of physics and physics students; seating arrangements based on student achievement; perceived pressure on students to uphold their reputation as strong students; failure of others in students' lives to recognize students' talents and interests outside of academics; and praise only being given to students for high grades.

> I didn't feel like that was where I belonged . . . should I be in the sciences? Is this something I'm actually good at? Questioning what I believed my whole life.
> When I tell people I'm a physics student, I really have to convince them. It's like, 'Really? You seem so normal.' Thanks?

Gender-dependent influences. Factors that negatively influenced students' ideas about physics and were reported to be dependent on gender included: greater number of men than women students in physics; lack of popularity of physics among young women; increased intimidation for young women working with mostly young men as compared to working with mostly other women; perceived lower confidence among young women in physics in comparison to men; teachers' different treatment of female and male students (e.g., when offering answers in class); pressures among young women to act flirtatious or unintelligent at the risk of being seen as unattractive or intimidating to young men; perceptions of young women as less able in physics; and surprised reactions of others when young women show affinity for physics.

Summary. Issues with physics identity and gender were reported by participants as influential aspects of their experiences in high school physics education. Ultimately, barriers to students' interest, competence, performance, recognition, and gender were inhibitory to young women rooting their identities in physics, and often resulted in their rejection of further physics study.

Discussion

Barriers existed to young women in high school physics education in three main ways: students' perceptions of the field and what type of person practices physics, their personal experiences learning physics, and their experiences with gender and physics identity. The meaning that participants attribute to the barriers they encountered in their physics education ranged; for most, the negative influences lead to minimal identification with physics and rejection of the subject. The findings are consistent with SCCT's assertion that contextual barriers within the learning experiences in high school physics education moderate the development of young women's physics identities (Hazari, Sonnert, et al., 2010). Further, as the participants of this study assert with their perceptions and experiences of barriers, there remains a longstanding and unfulfilled need for educators to help mitigate barriers and foster the development of young women's physics identities (Hazari, Brewe, et al., 2017).

Recommendations for physics educators were developed in response to the findings, which are presented as aids to teachers and the physics education research community in developing physics education that is supportive to young women's success in and continuation of physics.

Improving young women's perceptions of physics. Barriers to young women's physics education included their ideas of what physics is and images of who studies it. Biased perceptions are historically and culturally-rooted in socially-associated "masculine" and "scientific" constructs (Hazari & Potvin, 2005). To mitigate bias and the perception barrier, improvements must begin at a social and cultural level. Participant recommendations for physics educators include: (a) provide early experiences exploring physics phenomena in formal and informal education settings; (b) define physics; (c) point out to students when they are engaged with physics topics; (d) invite women role models into classrooms and discuss diverse career opportunities in physics; (e) identify and correct misconceptions about (or in a topic of) physics; (f) frame learning physics as possible for all students and provide individualized support; and (g) encourage a team learning environment in physics classrooms.

What young women identify as their learning needs in high school physics, and ways to support these. A particularly valuable aspect of this study's contribution to literature is student voices, which are underrepresented in physics education literature. The women identified their needs for successful and continued physics learning as: (a) support in conceptual understanding (e.g., videos for visualization and alternative explanation methods); (b) feeling comfortable in class (e.g., "no stupid questions" classroom environment); (c) development of critical thinking and problem solving skills (e.g., teaching students to recognize known and unknown information, or to ask "is this realistically possible" for solutions such as with negative time); (d) seeing the relevance of physics (e.g., social relevance via laboratory experiments); and (e) access to general support in learning (e.g., offering students diverse opportunities to show learning). If these supports for physics learning are lacking, students' likelihood of learning physics successfully is low, as confirmed by the participants' lived experiences.

Recommendations for fostering physics identity. Physics identity as a predictor of career choice, persistence, and engagement in physics (Hazari, Sonnert, et al., 2010) is an essential aspect of a student that requires development. Its four components—interest, competence, performance, and recognition—can contribute to the degree to which young women feel that they are a physics person, or the extent that physics is part of who they are. Most women in this study lacked well-developed physics identities but identified ways in which it can be fostered.

In terms of fostering young women's physics interest and demystifying physics, key practice recommendations for educators include providing a purpose and goal for learning physics, and making applications of physics to the human body, other subjects, or the real world.

To foster physics competence, students should be given opportunities to practice applying physics concepts and be allowed to discuss and wrestle with ideas among peers. The women felt it is most critical for teachers to take the time to develop students' ability to think conceptually. Once conceptual understanding falls behind, women described diminished interest, confidence, and competence in physics.

Similarly, once women's performance declined in the slightest, their beliefs of competence were challenged, and they questioned their abilities and interest in physics. As such, deemphasizing the importance of grades, decreasing stress and competition in the classroom, avoiding performance-based learning tasks, and instead offering a wide variety of performance opportunities (e.g., lab activities, projects) are recommended to support their performance beliefs.

To foster young women's recognition as physics people, young women should be embraced as multi-dimensional people. For example, physics interest and social interest should not be judged as incompatible aspects of a young woman's identity. Teachers can help by not segregating students by physics ability (verbally or physically), and avoiding glorifying physics and physics students above others, which only creates an elitist illusion and a seemingly unattainable standard for students.

Overall, all four aspects of physics identity—interest, competence, performance, and recognition—should be supported in order for young women to have a chance to root their identities in physics.

Conclusion

Young women in high school physics education encountered barriers that negatively influenced their perceptions, experiences, identities, and gender in relation to physics. The consequences young women attribute to encountering these barriers include rejecting the subject and the field as part of their future. This research makes two main contributions to the physics education research community. First, it helps address the qualitative research gap in literature on women's experiences in secondary physics education by offering a rich understanding of young women's experiences with barriers through the study of their voices and recollections. Second, it suggests practice-oriented recommendations for physics educators to adopt in their teaching, which were developed from young women's stated needs. The author intends these contributions to be useful to physics teachers, researchers, and the wider community to improve our potential to provide physics education that is equitable and aimed at meeting students' needs, to ultimately increase women's opportunities to pursue physics.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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