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Evaluating Student Growth in High School Science Education Through the Lens of Science Identity

Vanessa Tran
Portland State University

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Evaluating Student Growth in High School Science Education Through the Lens of Science
Identity

By

Vanessa Tran

An Undergraduate Honors Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science
in
University Honors
and
Biology

Thesis Adviser

Stephanie Wagner

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Introduction

Education has long been perceived as a means to equalize disparate groups of people socioeconomically. Leaps in education have been made to provide equal opportunity to marginalized groups, however equal representation has yet to be achieved within certain career paths. Specific to certain fields of science, technology, engineering and math (STEM), the gender gap has yet to be diminished so that women are more represented.

Although women account for roughly 50% of the workforce in the United States, women account for only 24% of jobs in STEM (Noonan, 2017). In regards to the Bachelor's degrees that women earn, women earn 20% of engineering degrees, 19% of physics degrees, and 18% of computer science degrees (American Physical Society [APS], 2015; National Center for Education Statistics [NCES], 2014). Comparatively, women are more represented within the fields of chemistry and biology, accounting for 48% of Bachelor's degrees earned in chemistry, and 60% of Bachelor's degrees earned in the biological sciences. Since 2004 the collective percentage of women earning degrees in STEM has been stagnant around 36% (Figure A, Appendix). With women in STEM earning 35% more than women in non-STEM fields, and 40% more than men in non-STEM fields, it is a wonder why women are not more represented in STEM occupations (Noonan, 2017).

Background

There are a myriad of components that factor into the choice people make in choosing a STEM career. K-12 science education has particularly evolved to better encourage students to learn science in recent years through the Framework for K-12 Science Education. Science education for high school students is an important consideration in answering how the gender gap comes to exist and what perpetuates the gender gap. Students in early and middle

adolescence are in a period of time in which they are questioning their vocational role, and forming an understanding of themselves (Erikson, 1968).

In preparing students for college and jobs post-secondary education, students are expected to exhibit their proficiency in science through standardized testing and passing their classes. However, high school students can feel added pressure to succeed in school, given the significance of standardized tests in determining their futures. In over-stressing the importance of exam scores, enjoyment and motivation for engaging with class material in a meaningful manner can be neglected (La Guardia, 2009). The importance of motivation and enjoyment is important for encouraging students to pursue science careers, otherwise studied as science identities. Past research has examined how underrepresented individuals decide to continue through the STEM pipeline into college.

Science identity has been a concept used to characterize how students are motivated to pursue STEM careers. Socioculturally, individuals who develop science identity convey competence in scientific knowledge, are recognized by others knowledgeable in the sciences, as well as self-identity as a “science person” (Carlone & Johnson, 2007). Science identity can be perceived as a discursive identity, exuded by how students engage with the subject (Brown, 2004). These interactions can be within the classroom, during an afterschool science club, or within an informal context. Students can develop their discursive identity as they interact with science teachers, or with their peers. Although there is a definitional dilemma in science identity theory, studies on science identity generally work to understand how to motivate underrepresented students to academically achieve in their science courses.

Rationale

Logically, a foundation built upon conceptual physics can ease students into learning chemistry and biology (American Association of Physics Teachers [AAPT], 2006). In adopting Physics First, science concepts are intuitively taught from a broad perspective and narrowed down to be applied to specific science subjects as students continue through the sequence. In 2005, Physics First was implemented in about 3% of U.S. public schools, with half of these schools requiring the full Physics-Chemistry-Biology (P-C-B) sequence (AAPT, 2006). The Physics First sequence is an inversion of the traditional high school science sequence where biology is the first course in a set of science requirements. Students are expected to complete and pass year-long courses in the following sequence: physics, chemistry and biology. Although the Physics First sequence is not a new concept, the placement of physics before or after chemistry has been a long-standing discussion in science education since the mid-19th century (Sheppard and Robbins, 2009).

Physics First is not readily embraced across the nation. Physics courses has a reputation of being academically difficult, and requiring an understanding of high-level math (Neuschatz & McFarling, 2003). However, when physics courses focus on the conceptual aspect of physics with little math integration, there is no significant difference in understanding of physics based on grade level or the level of math education achieved (O'Brien & Thompson, 2009). Physics First advocates endorse the sequence due to the development of problem solving skills that are beneficial for math and subsequent science classes in a student's academic career (Goodman & Etkina, 2008; Glasser, 2012).

Enforcing Physics First can be helpful in generating the next generation of scientists in terms of bettering understanding of science. Currently Physics First discourse primarily focuses

on how course arrangement affects academic achievement. Although students have academically benefited from the sequence, less is known about the identity development generated by the course arrangement. Test scores were not found to be a salient factor in the identification of science with girls (K-12 science education), indicating need in understanding how to empower girls in their pursuit of a STEM career (Tan, Barton, Kang, & O’Neill, 2013). Concerning Physics First, understanding whether a shift in science curricula influences how science identity is developed is important in considering how to create a more equitable experience for students.

Purpose of Study

The purpose of this study is to evaluate a high school science sequence as to examine how the sequence may encourage science identity formation. The Physics First sequence is nationally known in the U.S. to improve student competence in learning science, however, the indirect effects of Physics First in terms of developing science identity has not been lengthily discussed aside from anecdotal evidence.

Research Questions

1. Are gender gaps diminished in schools with Physics First?
2. What differs in the development of science identity between males and females?
3. Does science identity development differ based on science discipline of physics and biology between males and females?

Summary of Methods

To better understand how science identity forms through Physics First, pre- and post-surveys are collected by the Beaverton School District, in Patterns Physics and NGSS Biology courses. Specifically, the Colorado Learning Attitudes about Science Survey (CLASS) is

distributed among students. The responses to statements specifically relating to science identity are analyzed for statistical significance in this study.

Literature Review

Science identity and Perseverance in Science

According to the Late Modern approach to identity, the development of identity is reflexive and negotiable (Giddens, 1991). People must invest in developing their own identity, as it is not entirely determined by the socioeconomic status and gender in which a person is born into. Relating to science identity development, the same concept can be applied in terms of becoming a person who is recognized, and self-identifies as a science person. Students can become a science person, however, there is a need among students to want to identify as a science person, and believe that they can become a science person for development to occur. For that reason, importance is put on how students perceive themselves in relation to science/scientists. Where self-concept is the realistic person a student believes they can aspire to become, self-concept and interests guide students in behaving in science classrooms and interacting with science in a way that fosters the development of science identity (Krogh & Andersen, 2012).

Self-efficacy is a quality of self-concept that is pertinent to science identity. Males and females construct self-efficacy in science differently. Bandura's description of self-efficacy details the complexity of self-efficacy development (Sawtelle, Brewes, & Kramer, 2012). Specifically, there are four means of developing self-efficacy: mastery experiences (completing a specific task successfully), vicarious learning experiences (discerning how successful a person can complete a task by first observing someone else's success in a task), social persuasion experiences (verbal affirmation) and physiological state (dependent on a person's stress levels,

mood, etc.). Through evaluating surveys of students, Sawtelle et al. found that vicarious learning experiences was the best predictor of academic achievement in women, whereas social persuasion and mastery experiences were not as effective predictors for women. Contrastingly, academic achievement in males was best predicted by positive rezones to mastery experiences.

Recognizing oneself as capable in science is important in persisting towards a science-related career. Recent research suggests that students who choose not to enter a STEM field and whose favorite classes in school are STEM courses, do so because they do not find it realistic to develop a desirable identity in higher education with STEM (Homegaard, Madsen & Ulriksen; 2014). It is important to acknowledge that the development of self-concept also includes social influences. Students that decide pursue their science interests tend to have their science identities validated by their parents, peers and teachers through expectations, support, and positive experiences with science (Krogh & Andersen, 2012). The role of encouragement can build a student's self-concept to pursue science careers.

When focusing solely on how social interactions influence student decisions to enter STEM post-secondary education, Aschenbacher, Li and Roth discerned that the social interactions and experiences that students have within a science context is quite impactful in shaping their persistence or loss of interest in science. Particularly, students who lost interest in science: attended schools where the science programs were lacking; did not feel that their identities aligned with the identity of what they perceived a scientist to be; did not participate in extracurricular science activities to practice their knowledge; had other priorities outside of pursuing science careers; and did not have the encouragement to persist in their science courses (Aschenbacher et al., 2009). Similarly, Krogh and Andersen found that social relationship,

recognition, and family alongside knowledge, excitement/challenge to be the most important in personal values that motivated students in pursuing science in their future (2012).

Science Perceived as for Certain Type of People

Science can be perceived as a culture in which students immerse themselves within the science classroom (Emdin and Lee, 2012). Students communicate their ideas with science terminology, they use equipment particular to science, and they interact with one another as a group of scientists. Therefore, a social hierarchy can be constructed in the science classroom when individuals, who understand science, use science language to exclude others from the “elite social status” and as a result discourage other students from learning science and feeling included within a community of learners. Social distance, especially when apparent, discourages students from feeling solidarity in their science identity and or a part of their peer group, creating reason to lose interest in science. When observing students in the middle school science classroom, students were less responsive when the teacher reinforced the exclusivity of science through unfamiliar science language and creating an environment where students felt alienated when uncomfortable with the material (Olitsky, 2007). Students may lose interest in science, because they find group membership unattainable.

People can construct attitudes about who does science from a young age. When examining how school children enact science as an activity in contrast to science as an inhabited identity, Archer et. al (2010) note that 10/11 year olds construct attitudes about science that are gendered. Although both boys and girls both perceived science as a subject everybody could do science did have gender boundaries in which boys had an active role in perpetuating. In interviews with the boys, some boys voiced opinions that girls were not naturally interested in, or confident in doing science. Girls on the other hand, indicated that science was an unattractive

identity to them due to the stereotypical representations of scientists as “eccentric” and “wild haired”, which they did not want to be associated with. Based on thesis studies, altering the way in which scientists are perceived is important to establishing who does science.

Cultivating Attractive Identities for Women in Science

Past research on how to engage women in science education, is focused on providing students with different learning experiences (e.g., informal, after school science clubs and science camps) but particularly, through engaging all students through gender-inclusive curriculum. Including more science inquiry throughout curricula has been discussed as important in student participation (Carlone, 2004). Students who conduct their own experiments and produce their own results may trust their own findings more than being told the information by the teacher, and also gives students an idea of what being a scientist is. Incorporating more investigative practices in physics science curriculum may work towards gender-inclusion in the physics classroom.

However, by acting as a participant-observer in an active physics classroom, and coding attitudes female students have during and near the end of the physics course, Carlone (2004) found mixed results in terms of the course encouraging female students to transition from doing science to being scientists. A lot of the girls who took the course were preoccupied with gaining the credit from the course to bolster their transcripts for college applications. Their academic identities, in terms of being good students, took precedence over their desire to learn the material. They were less concerned about building a science identity and even though they were frustrated at the difficulties provided in the active physics course, the students just accepted learning physics as only for those with the natural capacity.

Learning physics can become more meaningful to students when they perceive their course as a means to acquire an identity in which they deem attractive. Basu, Barton, Clairmont and Locke (2009) conducted a case study in which two students developed and expressed agency through engagement in their physics course. Although the students did not enter the course with interest in physics as a career, they leveraged the use of science to expand or maintain their identities. One student exhibited her interests in becoming a lawyer through developing and leading an interactive lesson plan for her peers that debated how objects are drawn to black holes. Through engaging in physics in a manner that interested her, she became more open to science as a career path. The other student was able to shape his social identity through engaging in robotics outside of school. This student relied on his personal resources to further his interests in the use of robotics in the military, and in doing so, cultivated a status as a robotics expert among his peers. Recognition from others, alongside his developing knowledge of robotics and computer science, instilled confidence and pride in him within the realm of science. In both cases, having the opportunity to shape their identities were important to both students in participating in science concept to pursue science careers.

Methods

District Demographics

The Beaverton School District (BSD) is situated within the metro-Portland area, and is the third largest school district in the state of Oregon. In the 2016-2017 school year, 40,806 students were enrolled in the school district. A total of 53 schools are included in the BSD, six of which are traditional high schools. 12,288 students attended traditional Beaverton high schools within the 2016-2017 academic year. The six high schools in addition to four alternative schools in the school district implement the Physics First sequence.

District demographics for the 2016-2017 academic year was as follows: 51.3% of the students are students of color - Hispanic/Latino students make up 25% of the student population, Asian students make up 15% of the population, multiracial students are 7% of the population, Black/African American students are 3% of the population, and Pacific Islanders are 1% of the population. Caucasian students make up 49% of the student population. 51.3% of the students are male and 48.7% are female. These demographics have been fairly consistent over the last two years.

Intervention

Physics First. The state of Oregon requires students to complete three credits of high school science, two of which are laboratory-based. School districts within the state have the freedom to choose the academic path of their students by requiring specific science courses to be completed. Since the 2012-2013 school year, the BSD has required high school students to complete the Physics First sequence, alternatively titled the Physics-Chemistry-Biology (P-C-B) sequence, or the Cornerstone to Capstone (C-to-C) program (American Physical Society (APS), 2009). Students are required to complete and pass year-long courses in the following sequence: physics, chemistry and biology. The Physics First sequence is an inversion of the high school science sequence that requires students to complete biology first (previously implemented in the BSD). Although Physics First is not a new concept, the placement of physics before or after chemistry has been a long-standing discussion since the mid-19th century (Sheppard and Robbins, 2009).

Logically, a foundation built upon conceptual physics can ease students into learning chemistry and biology (AAPT, 2006). In adopting Physics First, science concepts are intuitively taught from a broad perspective and narrowed down to be applied to specific science subjects as

students continue through the sequence. The BSD requires students to complete the entire P-C-B sequence and encourages high school students to complete another science course during their senior year. The sequence, based on past data in the district, has been indicated to be the most effective in preparing students for college and the work force (“Beaverton Schools Push Reforms with Reduced Funds”, 2012). In contrast, a majority of schools putting physics at the beginning of the science sequence do not require students to complete the entire P-C-B sequence (APS, 2009).

The Next Generation Science Standards. The state of Oregon officially adopted the Next Generation Science Standards (NGSS) in 2014, with the goal of full implementation throughout the state by the 2018-2019 academic school year. Three dimensions are a focus of the NGSS: science and engineering practices, crosscutting concepts, and disciplinary core ideas. The standards encourage inquiry-based learning, and practical applications of science that mimics the skill set of scientists (A Framework for K-12 Science Education, 2012). Students are encouraged to see the relevance of course content and to make real-world connections through the integration of phenomena-based projects in class.

Patterns Physics. The freshman physics course in the BSD is titled “Patterns Physics”, derived from a “Patterns in Nature” unit created by Bradford Hill. Throughout the course students grow in critical thinking skills through utilizing personal experiences to support their inquiry and predictions. Particular importance is placed upon identifying mathematical patterns in nature that is not reliant on formula memorization (Hill, 2013). The physics curriculum is sorted into 7 units: inquiry and patterns, energy and engineering, interaction and forces, energy transfer, waves and sound, light and waves, and electricity and magnetism.

Course academic learning targets are as follows, as indicated on the course syllabus:

1. I can find patterns in nature and use them to predict future results or understand past events.
2. I can find and use patterns in energy conservation and transformation to explain and make predictions about how interactions between objects will affect the objects.
3. I can find and use patterns in forces to understand and make predictions about the motion of objects and forces they experience.
4. I can find and use patterns in energy transfer and transformation to explain and make predictions about how interactions between objects will affect the objects.
5. I can find and use patterns in waves to understand and make predictions about the motion of waves and how the waves will interact with other waves or objects.
6. I can find and use patterns in light to understand and make predictions about how light waves will interact with other light waves or objects.
7. I can find and use patterns in electricity and magnetism to understand and make predictions about how electromagnetism behaves and interacts with objects.
8. I can utilize and communicate a variety of problem solving techniques to make correct predictions about how the world changes. (Experiments/labs)
9. I can explain and apply the engineering process as an iterative and productive means of problem solving.

NGSS Biology. Generally, students are expected to complete a year of biology during their 11th or 12th year of school. However, students are able to complete the biology requirement earlier as sophomores so long as they complete the chemistry requirement. Units of the course are: molecules to cells, cells to organisms, heredity, ecology matter and energy,

ecological interactions, and evolution. The biology curriculum involves the following learning targets:

1. I can explain how molecules are organized into cells.
2. I can explain how cells are organized into organisms.
3. I can explain how genetic variation arises and how characteristics are passed on from one generation to the next.
4. I can explain how energy flows and matter cycles in ecosystems.
5. I can explain how ecosystems respond to disturbance and interactions.
6. I can explain that all life is related and that populations change over time.
7. I can use the inquiry process as a controlled and data-driven means to investigate scientific questions.
8. I can use the engineering design process as an iterative and productive means of problem solving.

Instrumentation

The Colorado Learning Attitudes about Science Survey (CLASS). The Physics Department of the University of Colorado in Boulder developed the survey to understand the attitudinal shifts of students from novice-like thinking, to expert-like thinking. Each survey has a list of statements in which responses on the survey are based on a 5-point Likert scale, where 1 is strongly disagrees and 5 is strongly agrees. Responses closer to the 5 will generally reflect more expert-like thinking. Although the survey was created to survey physics students, the statements are intentionally worded to be applicable to other science subjects and to students at different learning levels (Adams, Perkins, Podolefsky, Dubson, Finkelstein, & Wieman; 2006).

Science Identity Evaluation with CLASS. The Colorado Learning Attitudes about Science Survey has been distributed to students biannually since the 2013-2014 academic year in the Beaverton School District - the pre-survey distributed about a month into the school year, and the post-survey distributed in May. In administering the surveys, the school district can better understand how students have responded to curricula reform. Two types of CLASS surveys are used in this study to better understand how students shift science identity: CLASS specified to physics and CLASS specified to biology. These two surveys primarily differ in the specificity of the statements to the respective subject; however the same themes are found in both surveys pertaining to problem solving difficulty and effort, interest generated by the course, and real world connections.

With the intent of determining how the Physics First sequence may cultivate science identity, attitude statements reflective of science identity are evaluated from the survey. Two categories of statements can be indicative of science identity: real world connections and interest generated by the course; and self-efficacy shown through problem solving confidence (Krogh and Andersen, 2013).

Table 1: Physics and biology statements from CLASS pertinent to science identity. Statements 1-6 are relevant to real-world connections and interest generated by the course, whereas statements 7-9 regard self-efficacy.

Statement Number	Physics CLASS Statement	Biology CLASS Statement
1	Learning physics changes my ideas about how the world works	Learning biology changes my ideas about how the natural world works

2	Reasoning skills used to understand physics can be helpful to me in my everyday life	Reasoning skills used to understand biology can be helpful to my everyday life
3	The subject of physics has little relation to what I experience in the real world	The subject of biology has little relation to what I experience in the real world
4	To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed	To understand biology, I sometimes think about my personal experiences and relate them to the topic being analyzed
5	I think about the physics I experience in everyday life	I think about the biology I experience in everyday life
6	When studying physics, I relate the important information to what I already know rather than just memorizing it the way it is presented	When studying biology, I relate the important information to what I already know rather than just memorizing it the way it is presented
7	If I get stuck on a physics problem, there is no chance I'll figure it out on my own	If I get stuck on a biology problem, there is no chance I'll figure it out on my own
8	If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally!) to come up with it	If I don't remember a particular approach needed for a question on an exam, there's nothing much I can do (legally!) to come up with it
9	If I get stuck on a physics problem I usually try to figure out a different way that works	If I get stuck on answering a biology question on my first try, I usually try to figure out a different way that works

Data Analysis

To compare how Physics First contributes to collective science identity shifts in males and females, responses to science identity statements as reflected in Table 1 are evaluated. As to follow the identity shift of a single cohort of students, pre- and post-surveys are examined for physics 2014-2015 and biology 2016-2017. Survey responses to statement number 3 and 7 are flipped, so that novice-like attitudes are consistently reflected by scores of 1 and 2; and expert-like responses are reflected by a score of 4 and 5 on the Likert scale.

In observing shifts made in response to each statement in Table 1, the responses to each statement (categorized by male or female) is averaged to represent how each sex shift in science identity. The percent shift compares how the total group, males only, and women only shift in science identity based on their attitudes before and after completing their science course.

To check whether the significance of shifts is statistically significant, four total t-tests were conducted: pre- and post-responses of only males, pre-and post-responses of only females. Prior to each t-test, a f-test preceded each test to check for equal variance. The two-tailed p-value determined the significance of each shift, with statistical significance being $p < 0.05$.

Results

Attitudinal Shifts Post-Physics Instruction

Table 2. Average shifts of males and female attitudes, and correlating p-value of each shift in physics. The asterisk (*) indicates statistical significance where $p < 0.05$.

Statement Number	Statement	Females Only		Males Only	
		Percent shift (%)	p-value	Percent shift (%)	p-value

1	Learning physics changes my ideas about how the world works	-5%	0.0000456*	4%	0.209
2	Reasoning skills used to understand physics can be helpful to me in my everyday life	-7%	0.0312*	-7%	0.027*
3	The subject of physics has little relation to what I experience in the real world	-1%	0.716	-7%	0.106
4	To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed	-12%	0.00773*	-7%	0.134
5	I think about the physics I experience in everyday life	1%	0.795	5%	0.386
6	When studying physics, I relate the important information to what I already know rather than just memorizing it the way it is presented	-8%	0.00558*	3%	0.386
7	If I get stuck on a physics problem, there is no chance I'll figure it out on my own	0%	0.897	3%	0.517
8	If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally!) to come up with it	5%	0.347	10%	0.0867

9	If I get stuck on a physics problem I usually try to figure out a different way that works	-6%	0.0527	-6%	0.0366*
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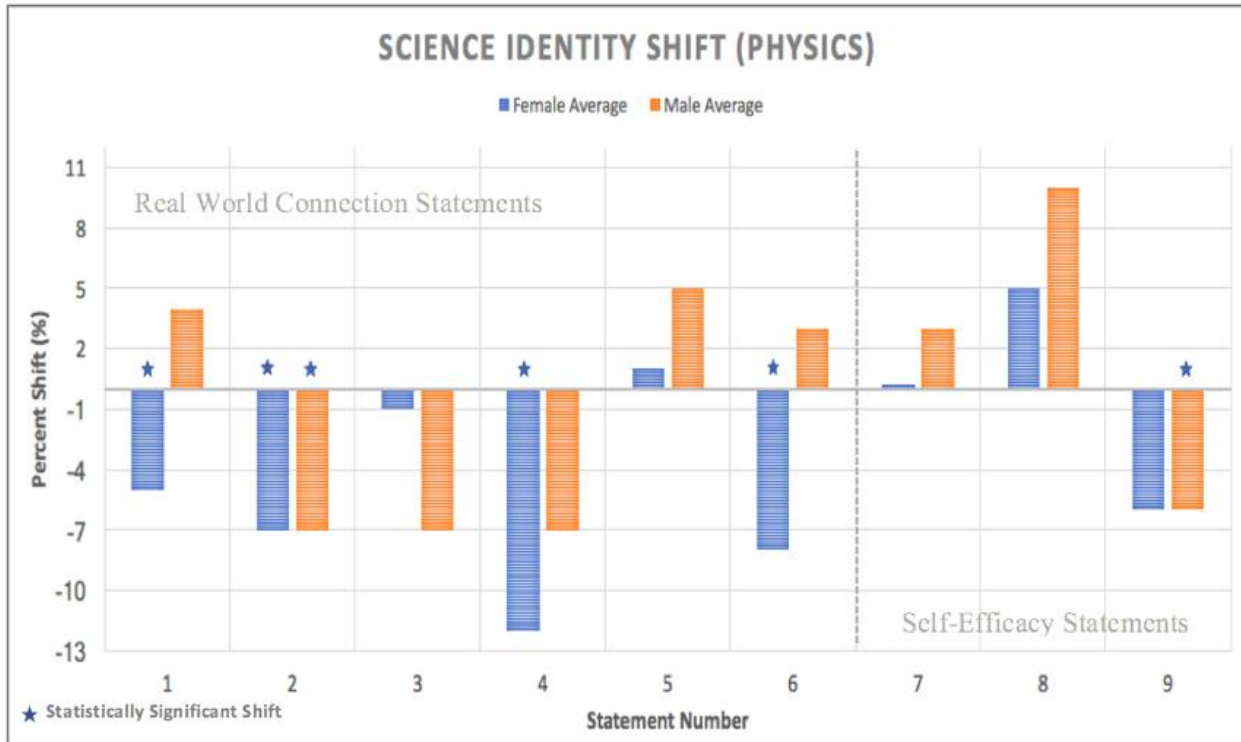


Figure 1. Positive and negative shifts in expert-like attitudes post-physics instruction.

Attitudinal shifts regarding real world connection statements. Statistical tests indicate more significance in female attitudinal shifts concerning responses to real world connection statements compared to males. Generally, females reacted to the statements with more novice-like attitudes. Regarding real world connection statements, females responded with negative shifts to statements 1, 2, 3, 4, and 6 (Figure 1). Shifts among females to statements 1, 2, 4 and 6 are of statistical significance (Table 2). One positive shift toward an expert-like attitude occurred in response to statement 5, although with no statistical significance (Figure 1).

Among males, one shift (the shift for statement number 2) showed statistical significance to real world connection statements (Table 2). The statements showed equal number of shifts toward expert-like attitudes as novice-like attitudes. Statements 1, 5, and 6 elicited positive shifts; whereas shifts to statements 2, 3, and 4 were more novice-like in attitude (Figure 1).

Attitudinal shifts regarding self-efficacy statements. Shifts in responses to self-efficacy statements among females were mixed. Among women, there was no shift to statement number 7, an expert-like shift to statement number 8, and a novice-like shift in attitude to statement number 9 (Figure 1). No self-efficacy shift to Patterns Physics showed statistical significance among females (Table 2). On the contrary, among men, one shift in response to self-efficacy statements showed statistical significance - a negative shift in attitude to statement 9 (Table 2). Otherwise, males responded with more expert-like shifts to self-efficacy statements (statement 7 and 8).

Attitudinal Shifts Post-Biology Instruction

Table 3: Average overall shifts of males and female attitudes, and correlating p-value of each shift in biology. The asterisk (*) indicates statistical significance where $p < 0.05$.

Statement Number	Statement	Females Only		Males Only	
		Percent shift (%)	p-value	Percent shift (%)	p-value
1	Learning biology changes my ideas about how the natural world works	6%	0.2459	6%	0.554
2	Reasoning skills used to understand biology can be helpful to my everyday life	6%	0.55	7%	0.708

3	The subject of biology has little relation to what I experience in the real world	7%	0.329	-2%	0.901
4	To understand biology, I sometimes think about my personal experiences and relate them to the topic being analyzed	-8%	0.0312*	-10%	0.0478*
5	I think about the biology I experience in everyday life	11%	0.106	9%	0.239
6	When studying biology, I relate the important information to what I already know rather than just memorizing it the way it is presented	4%	0.521	6%	0.278
7	If I get stuck on a biology problem, there is no chance I'll figure it out on my own	-2%	0.0572	-11%	0.0864
8	If I don't remember a particular approach needed for a question on an exam, there's nothing much I can do (legally!) to come up with it	-2%	0.0142*	-11%	0.169
9	If I get stuck on answering a biology question on my first try, I usually try to figure out a different way that works	-2%	0.688	-2%	0.252

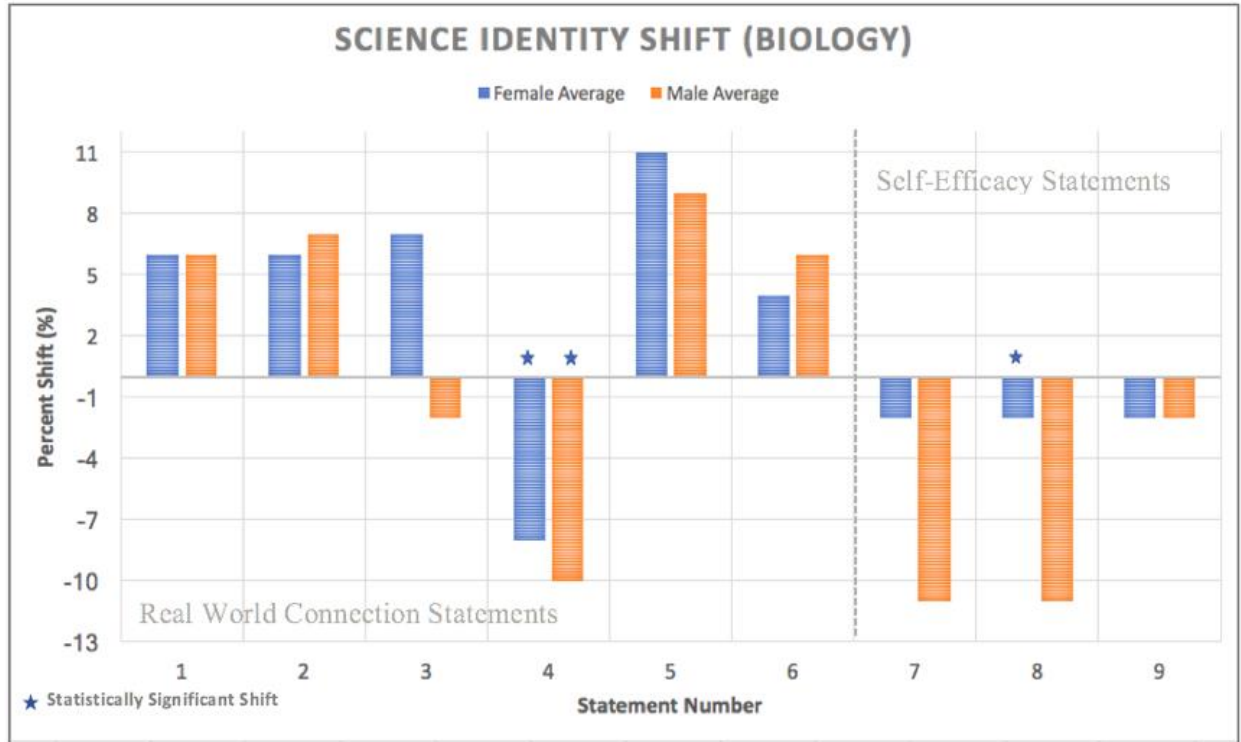


Figure 2. Positive and negative shifts in expert-like attitudes post-biology instruction.

Attitudinal shifts regarding real world connection statements. Of the six real world connection statements, females shifted toward expert-like attitudes with five of the statements (statements 1, 2, 3, 5 and 6). None of the positive shifts were of statistical significance, but the novice-like shift in attitude to statement 4 deemed significant. Males and females had similar shifts in attitude for all real-world connection statements, with the exception of shifts concerning statement 3. Males shifted toward a novice-like attitude to statement 3, whereas females shifted to more an expert-like attitude. Akin to females the one significant attitudinal shift regarding real world statements was to statement 4, which resulted in a negative shift (Table 3). Responses to statements 1, 2, 5, and 6 produced expert-like shifts.

Attitudinal shifts regarding self-efficacy statements. Both males and females responded to all self-efficacy statements with novice-like shifts in attitudes, although males shifted more

negatively than females concerning statements 7 and 8 (Figure 2). The one significant shift among both sexes was in female responses to statement 8 (Table 3).

Discussion

The purpose of the study is to understand how students develop science identity within the Patterns Physics and NGSS biology course as impacted through the Physics First sequence in the Beaverton School District. Science identity is one lens of understanding the gender gap in science, in which students develop the psychological tools to persevere in science goals. Evaluating how males and females differ in terms of science identity development through Physics First can provide a better understanding of how to alter curricula to attend to the needs of both sexes. Differences between science identity development through physics (a field typically underrepresented by women), and biology (a field well represented by women), can be indicative of what needs to be addressed within the curricula.

Interest Development in Science

According to the CLASS results, both males and females in the study responded to CLASS statements similarly, as observed in physics (Figures 1) and biology results (Figure 2). However, female responses to physics real world connections statements garnered the most statistical significance compared responses to the remainder of the statements (physics and biology), male and female (Table 2, Table 3). At the start of the physics course, the average female responses to real-world physics connection statements are self-rated as more positive in attitude compared to attitude ratings at the end of the course, resulting in generally negative shifts toward real world connection statements as seen in Figure 1. Comparatively, with the exception of responses to Statement 4, each of the statistically significant attitude shifts among women in physics are negative in attitude shift which differs from the non-statistically significant

and positive in attitude shift responses to real world connection statements among females in biology (Statements 1, 2, 4, and 6; Figure 1 and 2).

The difference between how females make connections in physics compared to connections made in biology has the potential to indicate an area of the physics course that could be adjusted to appeal to the interests of females. Real world connections have the potential to give students a foundation of inspiration in which they realize how science literacy can impact their career choices (Kozoll & Osborne, 2004). By encouraging students to incorporate their real-world interests into the science classroom to make their science education meaningful, it is possible for students to better expand their science identities (Basu et. al, 2009). Furthermore, more experiences relating to physics through additional classes within the discipline has the potential to generate more science and technology interest among women (Gokhale, Rabe-Hemp, Woeste, & Machina, 2015). Particular to the Physics First sequence, it seems possible for students to grow in science identity as they continue through the sequence, given that concepts taught in Patterns Physics can be expanded upon as students continue through Physics First.

Self-Efficacy Development in Science

Self-efficacy has been shown to be one salient factor in determining science career commitment (Chemers, Zurbriggen, Syed, Goza, & Bearman; 2011). In terms of academic achievement in an introductory physics course at a higher education institution, Sawtelle et. al found that self-efficacy built by vicarious learning experiences were more indicative of female success in physics, compared to mastery experiences that were indicative of male academic achievement in physics (2012). However, the contrast may be due to a difference in how males and females rate themselves on self-efficacy surveys. According to Britner & Pajares although

females in their study showed higher levels of achievement in science, they reported the same level of self-efficacy as males, and reported lower levels of mastery experiences (2006).

In evaluating males and female CLASS responses to self-efficacy statements, important to note is that the statements evaluated in the current study reflects mastery experiences sources – ones in which students gain confidence through successful completion of a task (Bandura, 1997). Although males and females did show differences in attitude shifts regarding self-efficacy in problem solving statements, the differences seem minor. The contrast in male and female attitudes regarding self-efficacy in physics reflect past work done on mastery experiences as a source of self-efficacy. Females were more likely to record less positive shifts in self-efficacy attitudes to physics compared to their male peers (Statements 7 and 8, Table 2). However, females did show the same percentage shift in self-efficacy attitude toward Statement 9 as males (Figure 1).

Concerning responses to self-efficacy statements in biology, females responded less negatively in self-efficacy attitude shifts to the biology course compared to males (Statements 7, 8, and 9; Table 3). Potentially, males responded negatively in shifts to biology self-efficacy statements in biology due to the methods in which mastery experiences are developed within biology. In comparison to physics, biology has been known to be less concrete and more descriptive. Consequently, evaluation and demonstration of mastery skills within the biological sciences is different than how students show mastery skills in physics. Males and females may also vary in mastery experiences based on former knowledge of reading and mathematics prior to their physics and biology courses.

Limitations

The limitations to the study include the way in which science identity was evaluated. The dynamics of science identity formation is more than interest in science and self-efficacy in problem solving. Although measurement of these factors was meant to be indicative of science identity growth, more comprehensive understanding of identity growth would require student interviews and observing students in science classrooms. Furthermore, even though instruction was not discussed in this research, instructional practices are important in understanding how students develop science identity. The social component of science identity includes student interactions with their teachers. Support from male peers and teachers are important for the success of women in STEM (Fuselier & Jackson, 2010).

Conclusion

The gender gap in science interests have been well documented - specifically with women in physics. From a young age, when children develop the idea that intellectual abilities are gendered, behaviors and interests are influenced to fit the norm (Bian, Leslie & Cimpian, 2017). Therefore, encouraging high school students to perceive science as useful and relevant to their career goals is important. Particularly, when focusing on how students can be inspired by high school science classes to pursue science careers, providing students with more experiences in science is key. Researchers have stated that involving students in activities that are inquiry-based and are authentic are important for the development of mastery experiences (Britner & Pajares, 2006).

Based on the results of the study, support for phenomena-based learning is important to generate interest science, and assist students in science identity development. Curricular adjustments as to appeal to a variety of student interests is necessary. However, these shifts can

be gradual; recognizing how to attract the interest of all students can be difficult. Specific to the Beaverton School District, students completing the 2014-2015 Patterns Physics have had a different experience to students enrolled in Patterns Physics this year. Although these curricular changes have been impactful anecdotally in generating enthusiasm for science learning, more research can be done in evaluating curricula that engages all students.

Regarding the development of science identity, recommendations to improve science identity of underrepresented students include addressing negative stereotypes of scientists. Middle school girls' interests in science and their science identity improved as they interacted with positive STEM role models (Hughes, Nzekwe, & Molyneaux, 2013). Understanding that scientists can be diverse is important for the development of science identity, as well as encouraging students to consciously reflect on how they connect to scientists and to the topic of science.

Future Research

Past research has indicated that underrepresented students do not feel included or a sense of belonging within the STEM field, which makes a difference in STEM interest, and could be a factor in the gender disparity in STEM degrees earned in the U.S. As the science curricula within the Beaverton School District has changed to implement more collaborative work, further research within the district could evaluate students in their attitudes towards group-based projects in facilitating science identity.

Appendix

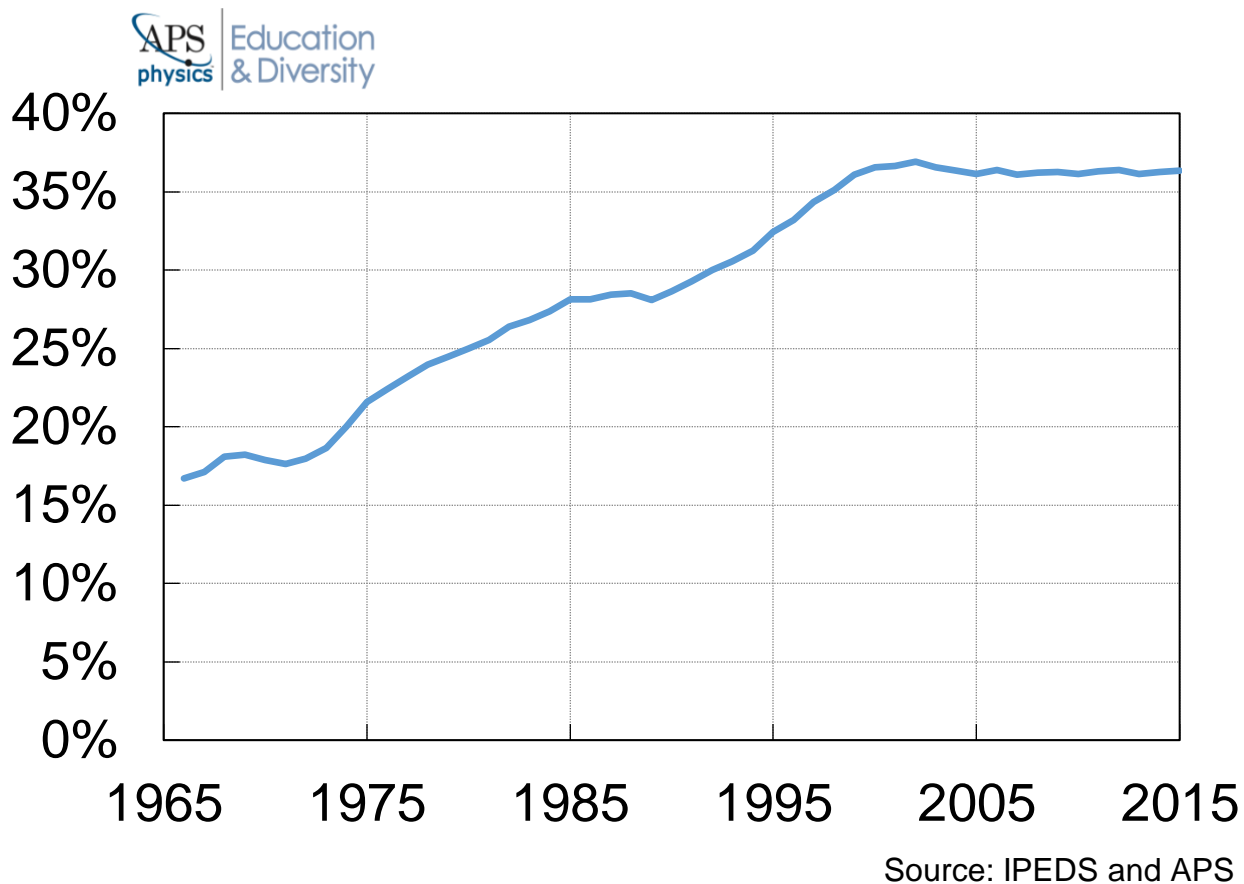


Figure A. Percentage of STEM Bachelor degrees earned by women from 1965 to 2015.

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