Pedagogical Environments in Chemistry: Effects on Women's Self-Efficacy Beliefs

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ABSTRACT

The underrepresentation of women in STEM fields has been an area of national focus for several decades. Research has focused on many areas, educational levels, and theoretical constructs in an effort to understand the continued shortage of girls and women in STEM. Self-efficacy beliefs have been strongly correlated to choice of academic major, persistence, and career interests. This qualitative study investigated the experiences and self-efficacy beliefs of women in chemistry, with a focus on understanding the role of pedagogical environments in the development of self-efficacy beliefs. Through a series of interviews, participants discussed their entry into a chemistry academic program, their progress, and their future goals. Emergent findings included the role of large classrooms, instructor approachability, exams with low class averages, and peer comparisons in shaping the participants' self-efficacy beliefs. Particularly early in their academic programs, comparisons with peers were a primary source of information about their abilities. In typical chemistry programs at large universities, this is problematic because women are likely to underestimate their abilities and have inaccurate perceptions, leading to low self-efficacy beliefs. To improve self-efficacy beliefs, it is important to address these common pedagogical practices and provide more accurate and meaningful ways for students to evaluate their abilities.

Keywords: STEM, Conference Proceedings, Women and Girls in STEM, Student Support

INTRODUCTION

Considerable attention has been paid to the recruitment and retention of women in STEM fields, including chemistry, due to a continuing underrepresentation in degree attainment (National Science Foundation, 2011). Research efforts have focused on multiple educational levels and numerous theoretical constructs in an attempt to understand the interest and persistence of girls and women in STEM in an effort to improve the recruitment and retention of girls and women in STEM. One construct of interest has been self-efficacy beliefs (Bandura, 1977; 1993; 1997; Bandura & Schunk, 1981), which describes an individual's perceived confidence about his or her ability to accomplish a specific task. It has been posited that negative or low self-efficacy beliefs among women pertaining to science and chemistry have contributed to the continued underrepresentation of women in STEM (Chemers *et al*., 2001; Hackett, 1985; Lent *et al*., 1991; Multon *et al*., 1991; Nauta *et al*., 1998).

Within self-efficacy theory, there are four constructs that contribute to the development of self-efficacy beliefs in individuals. These are (1) mastery experiences, (2) vicarious experiences, (3) verbal and social persuasion, and (4) physiological and affective states. Previous work has indicated that mastery experiences tend to have the strongest effect on self-efficacy beliefs, as they encompass successfully completed tasks. As one would expect, confidence in an individual's ability increases as related tasks are accomplished. In new and unknown situations, however, social comparisons tend to play a stronger role (Ames, 1992; Grunert & Bodner, 2011; Meece, 1991; Schunk, 1991). These new situations, such as starting college or a graduate program, cause self-efficacy beliefs to re-set, as individuals are uncertain of their abilities in a new setting. Individuals compare themselves to peers to gauge their abilities until they acquire sufficient mastery experiences to better inform their self-efficacy beliefs. These peer comparisons fall under the verbal and social persuasion construct of self-efficacy theory. Research has also shown that women tend to underestimate, while men tend to overestimate, their abilities compared to their peers (Workman & Bodner, 1996).

RESEARCH QUESTIONS

This qualitative study explored the following research questions to identify how the pedagogical environment in chemistry affects women's self-efficacy beliefs in chemistry.

- How do the self-efficacy beliefs of women in chemistry develop?
- What experiences positively or negatively affect the self-efficacy beliefs of women in chemistry?

METHODOLOGY

This qualitative study investigated the self-efficacy beliefs of women chemistry students near completion of their undergraduate degree and women graduate students in chemistry who had passed their PhD qualifying exam. Participant pseudonyms are used throughout this paper to protect the participants' identities. Shannon, Erica, and Anne were undergraduate chemistry majors and Jenna, Trista, and Melanie were doctoral chemistry students at a large Midwestern University. All data collection was conducted in accordance with IRB regulations at the participating institution.

Self-efficacy theory (Bandura, 1977; 1993; 1997; Bandura and Schunk, 1981) and feminist standpoint theory (Brooks, 2007; Harding, 2007) guided the design, data collection, and data analysis of this study. Interviews were designed to explore the four constructs contributing to the development of self-efficacy beliefs, as well as the experiences participants' identified as significant in their chemistry programs. Feminist standpoint theory was used in this study to provide a comprehensive understanding of the experiences of women, particularly in a male-dominated field. Feminist standpoint studies focus on the knowledge that can be gained from the perspectives of an underrepresented group, in this case, women in chemistry. This study also provided a voice for the women participating in it, allowing their experiences and knowledge to be used to understand the pedagogical environment, challenge conventional practices, and inform change.

Three unique hour-long interviews were conducted with six participants over the course of one semester, using semi-structured interview protocols. These interviews were collaborative and participatory, allowing participants to express themselves with minimal direction from the researcher. Additional data collection included demographic data and completion of a chemistry self-efficacy beliefs survey prior to starting the first interview. Both of these surveys were used as discussion points during the interview, but were not analyzed individually. All interviews were conducted by the first author and were audio-recorded and later transcribed verbatim. Participants reviewed their own transcripts prior to the start of data analysis and were allowed to make changes or omissions, although none did.

Feminist standpoint theory, narrative analysis (Polkinghorne, 1988), and the constant-comparative method (Miles & Huberman, 1994) guided data analysis. The interview transcripts were coded and organized into themes for each participant. Three other researchers assisted with coding and the establishment of inter-rater agreement. Narratives were constructed for each participant from the interview data, and then were compared on a cross-case basis to identify common themes.

RESULTS

Several typical large university practices were highlighted as being problematic for women in this study. Large class sizes and a "weed-out" mentality were challenging for these women because they felt isolated, unable to approach their professors for help, and as if they were meant to fail. Additionally, being in new situations, such as the start of a college or graduate school career, led these women to compare themselves to their peers in an effort to evaluate their abilities. In all the situations they cited, they felt that their classmates and peers were smarter or more qualified than they were. In general, these experiences were barriers they had to overcome to persist in their programs, rather than serving as positive and supportive experiences.

Large Class Sizes and Professor Approachability

Shannon, an undergraduate student in this study, discussed how difficult it was for her to ask for help in her organic chemistry class. This university experience was vastly different from her experiences in high school, where she felt comfortable asking her teacher questions.

> I was able to approach my high school teacher about anything because she was very approachable and she would go out of her way and be like, "hey, do you need extra help?" like you know if you did bad on an exam, whereas like in organic, it was like whatever, you know, we don't care about you, you're just another student, you're one in 350 students, not a big deal to us.

She ended up failing her organic chemistry course during the semester she referred to here, and retook it with a different professor the following year. Although the class was still large, she explained that she felt more comfortable approaching her second professor for help. This large-class experience is very common at big universities during the first and second years, where there are hundreds to thousands of students enrolled. Anne, another participant, discussed having to ask "stupid questions" and feeling like she could not approach her instructors. For both Anne and Shannon, their instructors' did not foster an environment that encouraged students to seek help and ask questions.

Comparisons with Peers

The women in this study relied heavily on peer comparisons to help inform their self-efficacy beliefs and gauge their abilities in their courses and programs, especially early in their programs.

When just starting an academic program, these women lacked mastery experiences in their new environment and did not know if they were adequately prepared or making reasonable progress in their coursework. In the absence of mastery experiences, peer comparisons became the primary source of information about their abilities.

The undergraduate students in this study, Erica, Anne, and Shannon, talked at length about the role exams played in their evaluation of their abilities. As Shannon mentioned earlier, she felt that she couldn't get help from her professor after having a bad exam. Erica repeatedly discussed one of the common practices in chemistry courses: exceptionally difficult exams with very low class averages. This practice is problematic for students who do not understand or recognize that the whole class is getting low grades. Erica explains the role of low exam scores on her self-efficacy, saying,

> …I mean definitely like grades on chemistry exams were definitely really negative for me because I mean, I was used to you know 90's and if you didn't get a 90 it was obviously not successful and I'm getting exams back you know, my first semester in organic and 46's, 48's, and like, oh, I got a 65 this time, I did pretty good. But you kind of have to get like figure out that that's what everyone's getting, and once you figure out that you know, it wasn't you that got the 48 when everybody else averaged a 90, you know that average was a 48 and you got a 48, so it'll be okay.

As she alludes to at the end of the quotes, she eventually adjusted to receiving low grades and understanding that everyone was receiving those grades. Instead of assuming that other students were getting excellent grades, she learned to compare her score to the class average, rather than grades she had gotten in high school, or even in other college courses. Both Anne and Shannon discussed a similar shift in their thinking and evaluation of themselves after exams. This change in thinking helped these women persist in their majors, as they had all discussed thinking about switching majors after having such discouraging experiences. Erica explained,

> Originally, yeah [getting bad grades on an exam] definitely did [make me doubt my abilities], I was like I suck at this and I'll go do something else, clearly this isn't working out, but now it's just kind of like, okay, I had a bad exam or you know, I didn't study hard enough, I didn't study the right stuff.

For two women in the study, they felt particularly challenged because they were newcomers to the chemistry program. Anne was a non-traditional student, who came back to college after working for a few years. This led to her feeling behind and at a disadvantage because she lacked familiarity that she felt all the other students had. She explained,

> …it's kind of undermining because when you're, I'm in courses with some sophomores and there are things they're better at or just little things like in lab it's not so much that I don't know this or that, but it's harder for me 'cause I don't know where things are and it, and that doesn't help. Like silly things, like I don't know where things are located to things take me longer because I don't actually know were to find them and I always have to ask stupid questions…

Erica started college with a different major, through a different college on campus. She described her previous major as being very easy, leading to some concern about her actual ability to succeed in a more difficult program like chemistry. Her concern was compounded by the fact that her first course as a chemistry major was organic chemistry, a notoriously difficult course. Erica said,

> …because I changed my major to chemistry so I was really nervous about it at the beginning, 'cause, I didn't know, is it going to be so hard? Like, you know am I ever going to actually graduate and like I was used to getting A's all the time so I was really concerned. I was like I'm going to get C's in everything and I really, and the first class that I took like when I switched to chemistry was, I switched as a sophomore so I took organic first, and I just struggled so much, I mean finally eventually I ended up getting a B but like I didn't have any idea what was going on and it was really hard for me to understand that no one had any idea what was going on; I mean I wasn't any worse off than the kid sitting next to me.

The graduate students in this study also compared themselves to their peers, and often found themselves lacking. Trista discusses how she felt starting her graduate program in chemistry, where she felt underprepared, leading her to doubt herself. She said,

> I think there was more doubt in grad school. Yeah, 'cause…umm, I assumed that most of the people that came to graduate school knew that they wanted to go to graduate school, they prepared for it, and I was not prepared for it at all. So… I felt I wasn't prepared for it. I wasn't really prepared for it. But then I realized that my classmates weren't really either.

As the undergraduate students discussed, Trista eventually realized that she was not that different from her peers. This helped her feel more confident in her abilities, although it was a challenge to her self-efficacy beliefs early in her program. Jenna, on the other hand, never felt that she was at the same place as her peers. She compared herself to other students in her research group, who were also more advanced in their programs, and found herself lacking. She said,

> I don't feel like I'm ever going to be as good as either one of them…and I have expressed that concern to my boss, but he's like, "oh, don't talk like that," and you know, "you're just as smart as they are," and everything, but…I just feel like I'm a couple of steps behind.

In this case, Jenna's peer comparisons are internal and difficult to correct. Even support from her advisor cannot alleviate her feelings of inadequacy. Unlike the other participants', Jenna does not learn that her peer comparisons are unfounded or misinformed, leading to her continued self-doubt.

Discussion

The experiences discussed by the women in this study point to unnecessary, but very common, features of the pedagogical environment in chemistry that are detrimental to students' progress. These features include large class sizes, lack of professor approachability, and difficult exams with low class averages. Large class sizes lead to feelings of isolation from the professor, and from other classmates, as Shannon and Erica discussed. Anne also discussed not asking questions for fear of looking dumb, pointing to an instructor who did not foster an environment where she could feel comfortable asking questions. Difficult exams with low class averages are problematic because they do not provide accurate information to students about their abilities. One of the keys to forming positive self-efficacy beliefs is having meaningful mastery experiences. When exams are so difficult that class averages are below 50 percent, they do not allow students to evaluate their progress or capabilities. It also places an additional learning burden on students, as they must now learn to interpret their test scores in light of a different set of expectations. As graduate students, Trista and Jenna also struggled with feeling underprepared or inadequate due to peer comparisons. One challenge in graduate school is a lack of quality feedback, especially once coursework is completed and students are working on their research. While working on research, feedback comes from the advisor, and peer comparisons continue to be relied upon with regards to productivity, usually in terms of presentations and publications. As with the undergraduate environment, graduate chemistry programs continue to lack accurate and meaningful ways for students to judge their abilities and form their self-efficacy beliefs.

These practices have significant implications for recruitment and retention of women in chemistry, as the women interviewed in this study were able to persist in the face of substantial challenges to their self-efficacy beliefs. National studies on recruitment and retention of women in chemistry and other STEM fields show that many women do not persist in their degree programs, suggesting that the barriers generated by the pedagogical environment in chemistry may contribute to women's decisions to leave chemistry programs or other STEM fields where chemistry is required coursework.

It is imperative to recognize that students are using peer comparisons to form their self-efficacy beliefs and judge their likelihood of success in the program, yet the pedagogical environment is giving them inaccurate or unreliable information about their abilities. It is crucial to have appropriate, meaningful mastery experiences, and reliable, accurate feedback, either directly from the professor or through well-designed assignments and exams. It is also helpful to incorporate group work or peer interaction into the class, so that students feel less isolated, have a better sense of how others are doing in the class, and are less likely to feel the need to compete with other students.

IMPLICATIONS

One of the emergent findings was the role of the competitive, "weed-out" environment on the participants' self-efficacy beliefs. The first two years of coursework in chemistry tend to have negative reputations amongst students, who cite instructors' attempts to fail as many students as possible as one of the most problematic aspects of those courses. As noted previously, new situations are particularly vulnerable times for many individuals, as they believe they lack adequate information about their abilities and likelihood of success in new pursuits. The result is a population of students unsure of themselves who look to peers and early mastery experiences to help them judge their intelligence.

The participants in this study had negative self-efficacy beliefs and serious doubts about their choice of academic program as a result of their experiences early in their programs. For these women, getting low exam grades, even when class averages were low, led them to believe everyone else was smarter than they were. When other students answered problems seemingly without difficulty or gave the impression that they knew all the course material, doubts again crept in. The pedagogical environment negatively contributed to their self-efficacy beliefs by providing skewed information, limiting quality mastery experiences, and demonstrating a lack of instructor feedback. These results allow for the identification of problematic aspects of the pedagogical environment in chemistry departments, but also point to possible reform efforts that would better support entering students, particularly women. Adopting more supportive, positive classroom environments and practices could lead to improved experiences and more positive self-efficacy beliefs for students in chemistry, which might thereby increase retention in chemistry programs.

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