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***Chapter 3***

# CHANGE IN SELF-EFFICACY IN HIGH SCHOOL SCIENCE CLASSROOMS: AN ANALYSIS BY GENDER

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## ABSTRACT

This chapter compares change in the self-efficacy of male and female high school science students within 11 classrooms (n=2, general science; n=3, biology, chemistry, and physics respectively) during a school year. In some classrooms, there was little change in how difficult both male and female students thought it was for them to learn science. In other classrooms, both male and female students similarly changed their appraisal of how difficult science was for them to learn. In yet others, there were gender differences in this change favoring males (in no case did females increase in self-efficacy while males declined). Changes in students' self-efficacy over the course of a year appear to be related to the ways teachers interact with students. As an example of these different patterns in a single subject area, we then investigate three biology classes, each of which was taught by a different female teacher. In one biology classroom there was little change in the self-efficacy of males or females; in another, both males and females became more confident; and in the third, males became more confident, but females became less confident in their appraisals of their ability to learn science. Using classroom observational and teacher interview data, we examine the teachers' gendered beliefs about science learning and their interactions with male and female students during class. We also analyze student reports of their subjective experience collected using the Experience Sampling Method in these classrooms by gender. Finally, we consider characteristics of students and their families to determine if there are any patterns among student changes in their appraisals of science as difficult to learn. We conclude by discussing how contextual conditions can impact students' beliefs about learning within a subject area.

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The fields of science, technology, engineering, and mathematics (STEM) are widely regarded as critical to the future of our nation for several reasons. First, developing a citizenry that has a basic understanding and appreciation of scientific and mathematical principles is essential for competent daily functioning in an increasingly technological society. Second, building a strong STEM workforce is a necessary step to strengthening America's competitiveness in the global economy (National Academy of Sciences, 2007; U.S. Department of Education, 2006; U.S. Government Accountability Office, 2006). Finally, the U.S. Department of Labor projects that by 2018 nine of the ten fastest-growing occupations for those with at least a bachelor's degree will require significant training in mathematics or science, making the issue of STEM education critical for government, industry leaders, and educators alike (Hill, Corbett, and St. Rose, 2010).

Some of the largest increases are expected to be in the fields of engineering and computing – fields in which women currently hold fewer than 25% of the positions (National Science Board, 2010). In recent decades, longstanding gender gaps in STEM course-taking and grades have closed, with girls earning high school credits in math and science at the same rate as boys, while earning slightly higher grades in these courses (Hyde , Lindberg, Linn, Ellis, and Williams, 2008; U.S. Department of Education, National Center for Education Statistics, 2007). Boys continue to outperform girls, however, on high-stakes tests in mathematics (Corbett, Hill, and St. Rose, 2008); fewer girls than boys take advanced placement exams in STEM related areas; and the girls who do take these exams score lower, on average, than boys (Hill et al., 2010). Beyond high school, gender gaps continue to remain wide, females remain far less likely than males to choose STEM majors, or to enter or persist in STEM fields except biology, where they continue to lag behind males in AP Biology test taking and AP scores during high school and in achieving tenure (see Hill et al., 2010 for a review). Theory and research suggest that self-efficacy for science tasks may be partly responsible for observed gender gaps in science interest, persistence, and retention. A heightened sense of self-efficacy makes individuals more likely to persist when faced with obstacles (Bandura 1986, 1997; Schunk, 1995). When self-efficacy judgments are high, students will engage in tasks that facilitate the development of their skills and capabilities. In contrast, when self-efficacy perceptions are low, students avoid engaging in task situations with such developmental potential, because they are perceived as too risky (Bandura, 1997). By avoiding these situations, students not only deprive themselves of skill development, but also miss out on opportunities to get meaningful corrective feedback from teachers and others that could counter their negative self-efficacy perceptions (Schunk, Pintrich, and Meece, 2008). In this chapter, we report on a study that examined the science self-efficacy beliefs of male and female high school students over the course of an academic year, and explore personal and classroom contextual factors to explain changes in self-efficacy beliefs over time. We focus on the ways that teachers' interactions with students may shape the self-efficacy perceptions of their male and female students.

There is strong evidence that gender differences in representation in STEM fields are linked to gender-related self-efficacy beliefs (Bandura, 1997; Hackett and Betz, 1989; Pajares, 1996a, 1996b). Men report high self-efficacy for a wide variety of careers, whereas women report high efficacy only for "female careers," and report not feeling efficacious for careers in science and other fields traditionally dominated by men (Betz and Hackett, 1981, 1983; Hackett and Betz, 1981). Beginning in middle school and continuing through adulthood, females have been shown to harbor more doubt than males about their abilities in a variety of STEM areas (Meece, 1991; Pajares and Miller, 1994; Wigfield, Eccles, and Pintrich, 1996). In high school science courses where females doubt their science abilities more than males, females back away from academic challenges, becoming less engaged in classroom tasks precisely when they perceive these tasks as being more challenging (Schmidt, Kackar, and Strati, 2010). In contrast, middle- and high school girls have reported higher self-efficacy than boys in other academic domains such as writing (Pajares, Johnson, and Usher, 2007). The systematic disengagement of girls in science further restricts their development of interest and skill in this area. Over time, gender differences in STEM-related self-efficacy are likely to result in gender differences in the academic and extracurricular activities in which students' engage and the investment they are willing to make in such activities. Ultimately, this could result in females being less interested and less qualified for STEM careers.

## SOURCES OF SELF-EFFICACY

According to Bandura (1986, 1997), people develop self-efficacy beliefs by interpreting information from four sources. The first and, according to Bandura, most influential source of information is past performance. Prior success – that is a *mastery experience* – in an activity is thought to build one's self-efficacy beliefs for similar tasks in the future, while repeated failures can lower one's efficacy perceptions. The second source of self-efficacy beliefs is the *vicarious experience* of observing the successes and failures of others who are perceived either as similar (such as classmates or peers, especially those with similar characteristics) or as competent models (such as teachers). The third source of self-efficacy is *verbal persuasion*. Messages of competence or incompetence from teachers, parents, and peers can encourage or undermine individuals' efficacy beliefs. Bandura (1986, 1997) has cautioned that verbal persuasion more often serves to undermine efficacy beliefs than to strengthen them. For example, when women receive overt or covert messages that they do not belong in a male-dominated field like science, this may make them particularly vulnerable to perceiving themselves as less competent (Zeldin and Pajares, 2000). The fourth and final source of self-efficacy is one's *physical and emotional state*. Optimism and positive affect while engaging in a task are believed to enhance one's self-efficacy perceptions while negative affect, stress, and depression are believed to lower them.

Research investigating the relative influence of these four sources of self-efficacy has largely confirmed that four distinct sources of influence do exist (Lent, Lopez, Brown, and Gore, 1996), and that all are related to self-efficacy in STEM academic areas like mathematics (Lopez and Lent, 1992; Lent, Lopez, and Bieschke, 1991). Britner and Pajares (2006) studied influences on middle school students' self-efficacy beliefs in science and found that mastery experiences, but not the other sources, predicted science self-efficacy. Thus, one goal of the study presented in this chapter is to use multiple methodologies to explore the influences of mastery experiences, vicarious experience, persuasion, and affective sources on students' science self-efficacy during high school.

Given similar tasks, male and female students may respond differently to influences on self-efficacy (Schunk et al., 2008). For example, male students have reported more mathematics-related performance accomplishments than females, while female students have reported more vicarious learning and persuasive experiences than did males in mathematics

(Lent, Lopez, et al., 1996), life sciences, and physical sciences (Britner, 2008). Additionally, female students tended to cite physiological reactions (like anxiety) in their science self-efficacy perceptions (Britner, 2008) and both anxiety and teaching quality considerations more often than did males in their accounting of their own science and mathematics self-efficacy perceptions (Britner, 2008; Lent, Brown, Gover, and Nijjer, 1996). In a qualitative study of women who selected and excelled in STEM careers, Zeldin and Pajares (2000) found that verbal persuasions and vicarious experiences in particular were critical sources of self-efficacy beliefs among women in male-dominated fields. These particular gender patterns may be specific to STEM fields: Contrary to what has been found in STEM fields, in a study of writing self-efficacy, Pajares et al. (2007) reported that prior performance accounted for the greatest amount of variation in writing self-efficacy for both females and males, and that females reported greater salience of prior performance than did males.

Stevens, Olivarez, Lan, and Tallent-Runnels (2004) suggested that, in addition to gender, other personal characteristics like race/ethnicity may be related to self-efficacy beliefs within certain academic domains. They found that prior mastery experiences were more salient for Hispanic students than Caucasian students in the development of mathematics self-efficacy. Thus, relationships between gender and ethnicity and self-efficacy-judgments were examined in this chapter.

Beyond personal characteristics, environmental factors, like family and classroom contexts, also have been identified as critical environments for influencing self-efficacy (Zeldin and Pajares, 2000). A student may experience high self-efficacy for science tasks in one classroom context, but may experience low self-efficacy for these same tasks in a different classroom context. Teachers play an important role in creating classroom contexts that can shape students' self-efficacy judgments in multiple ways. Teachers build classroom structures and supports to facilitate students' mastery experiences. They provide vicarious experiences for their students, serving as models for different academic tasks and facilitating student collaboration. They are also the principal source of verbal persuasion in the classroom, sending explicit and implicit messages about competence. Finally, through the classroom environment they create, teachers can influence students' positive affect and anxiety during learning tasks. Through the quality of their daily interactions with students over the course of an academic year, science teachers have the potential to facilitate dramatic shifts in students' self-efficacy perceptions.

In their study of women who excelled in STEM fields, Zeldin and Pajares (2000) found that women in their study were especially responsive (more so than social cognitive theory might suggest) to the vicarious experiences and verbal persuasions provided by their teachers. All women in their study described teachers (both male and female) who they believed were instrumental in the development of their competence and confidence – many of these were middle- and high school teachers. The women spoke of the importance of feeling supported emotionally and academically by their teachers, and of how their teachers were enthusiastic and committed to the success of their female students. Of course, these successful women described obstacles as well that were eventually overcome, and on several occasions, particular teachers were cited as obstacles. In younger populations as well, females have been shown to be more responsive to teacher behaviors and characteristics in STEM areas than were males. For example, Lloyd, Walsh, and Yailagh (2005) found that elementary and middle school girls were more likely to attribute mathematics failure to a lack of teachers' help than were boys.

Self-efficacy theorists have argued for the value of adding a more qualitative approach to the study of self-efficacy to complement the considerable insights that have been gained using primarily quantitative methods (Pajares, 1996b, 1997; Schunk, 1991). Qualitative research focusing on the life stories of successful women in STEM careers (e.g., Zeldin and Pajares, 2000) and those who have left the STEM pipeline (e.g., Stage and Maple, 1996) have greatly enhanced our understanding of how self-efficacy beliefs operate. This chapter uses both quantitative and qualitative approaches to understand high school science teachers as potential influences on the self-efficacy beliefs of their male and female students.

## CHANGES IN SELF-EFFICACY OVER TIME

Given that teachers have the potential to profoundly influence students' self-efficacy perceptions, we were interested in understanding how students' self-efficacy beliefs may change over the course of an academic year in a given classroom, and just how these changes may be linked to the characteristics, behaviors, and attitudes of the teacher.

Studies indicate that one's academic self-efficacy judgments do change over time, with some researchers suggesting developmental trends such that academic self-efficacy generally increases over time as students have more exposure to academic material (Shell, Colvin, and Bruning, 1995; Zimmerman and Martinez-Pons, 1990). Self-efficacy has also proven responsive to various instructional practices, particularly those that inform students about their capabilities and progress in learning (Schunk, 1995; Zimmerman, Bandura, and Martinez-Pons, 1992).

Positive trends in self-efficacy can be thwarted, however, by a number of school- and classroom-related factors such as increased competition, norm-referenced grading, reduced teacher attention, negative teacher messages, and other school stressors (Schunk and Pajares, 2001).

## CHAPTER GOALS

The purpose of this chapter is to examine the science self-efficacy beliefs of male and female high school students, with a particular focus on the classroom influences on self-efficacy over the course of an academic year. To do this we will:

1) Compare males' and females' science self-efficacy at the beginning of the academic year;
2) Describe the ways that males' and females' science self-efficacy changes in a classroom over the course of an academic year;
3) Examine the social and personal sources of students' changes in science self-efficacy, using Bandura's (1986, 1997) theoretical framework;
4) Provide an in-depth examination of 3 science classrooms in which male and female students demonstrated differing self-efficacy trajectories over the course of an academic year; and

5) Present illustrative cases of two female students from these classrooms: one whose science self-efficacy increased over the course of a year and one whose science self-efficacy decreased.

# METHOD

## Context

Data for this chapter was drawn from a larger project conducted in regular track science classrooms in a large public high school ($9^{th}$ - $12^{th}$ grades; enrollment = 3,323) serving students from a diverse community. Overall, 33% of the student body came from low-income families. The school graduation rate was 86%. The school's science department had 28 faculty members (16 female, 12 male) offering a total of 23 different courses in AP, Honors, Regular, Applied, and Vocational tracks. In contrast to the diversity of the student body, all of the science faculty members were White.

## Participants

Our quantitative analysis focuses on the full sample of 228 students from 11 regular-track science classes. The sample consisted of students from 2 general science, 3 biology, 3 chemistry, and 3 physics classrooms. The overall student participation rate across all classrooms was 91%, with half of the classrooms studied having complete (100%) participation.

The study was designed to oversample freshman because almost all freshman took science and the ninth grade year sets the stage for the rest of high school and beyond: 43 % were $9^{th}$ graders, 21% were $10^{th}$ graders, 34 % were $11^{th}$ graders, and 2% were $12^{th}$ graders. Participants were: 53% male and 47% female; 42% White, 37% Latino, 12% African American, 2% Asian, 1% Native American, and 6% multi-racial; 43% received free or reduced lunch.

A more in-depth qualitative analysis focused on the three biology teachers and their classrooms. All three teachers were White women. The demographic characteristics of this subsample mirrored the full sample, and there were no differences between the three classrooms in terms of students' gender, ethnicity, level of parental education, free lunch status, future academic aspirations, cumulative GPA, general attitude towards science, or grades.

## Data Collection Procedures

Within each of the classrooms, data were collected over two time periods (waves) during the 2008-2009 academic year – once in fall and once in spring. Methods of data collection included traditional surveys, experience sampling techniques, videotaping, classroom observation, and teacher interviews. Data from different sections of the same course were collected simultaneously so that the data from each section would represent the same point in the science curriculum, thus enabling analysis of the effects of particular content units while controlling for the effects of the instructor. Each teacher was interviewed about one of the observed instructional units and about personal beliefs about gender, science, and students' science abilities.

*Experience Sampling Method*. During each wave of data collection, students' subjective experience in each science classroom was measured repeatedly over a period of five consecutive school days using a variant of the Experience Sampling Method (ESM; Csikszentmihalyi and Larson, 1987; Hektner, Schmidt and Csikszentmihallyi, 2007). Participants wore a vibrating pager which was used to signal them unobtrusively using a remote transmitter at two randomly selected time points during each day's science class. To minimize the disruption to class flow and maximize the variety of classroom activities recorded, the pool of participants in each classroom was divided in half, with each half following a different signal schedule. In response to each signal, students completed an Experience Sampling Form (ESF) in which they briefly recorded their activities and thoughts at the time of the signal, as well as various dimensions of their subjective experience. The ESF took approximately one to two minutes to complete.

Using Likert scales, students reported on multiple dimensions of their subjective experience using the ESF. By the study's completion, each participant had reported on multiple aspects of subjective experience on as many as 20 separate occasions with each descriptive array linked to a specific course, content unit, and classroom activity. An average of 9.2 responses per participant (92% signal response rate) were collected in fall and an average of 9.1 responses per participant (91% signal response rate) were collected in spring. Participant non-response to the ESM was nearly entirely attributable to school absence. The ESM provided quantitative data from which we were able to draw conclusions about students' general affective experiences, and qualitative data charting the momentary experience of particular students over time.

*Video Data.* During the five days of ESM signaling in both fall and spring, a videographer was positioned in each classroom to unobtrusively record classroom activities. The focus of the video was on the teacher's activities. The video data were coded in several ways described in the measures section.

*Interviews*. We interviewed all teachers about the classroom time we observed, and asked them to share their views about gender, science, and students' abilities. In this chapter we focus on interviews conducted with the 3 biology teachers. All interviews were conducted during the second half of the fall semester, after our fall data collection was complete.

## Measures

*Science Self-Efficacy*. Four items from the fall student survey comprised a self-efficacy measure. On a seven point scale from 1 = not at all true to 7 = very true, students rated their: (a) confidence in their ability to learn course material, (b) capability of learning course materials, (c) ability to achieve goals in the course, and (d) ability to meet the challenge of performing well in the course. Cronbach's alpha of .93 indicated excellent internal consistency. A related item appeared on both the fall and spring surveys asking students to rate to what extent "Science is a difficult subject for me to learn" on a 4-point scale from 1=

strongly disagree to 4 = strongly agree. The self-efficacy scale was significantly correlated with difficulty learning science (r=.39***). To examine change in self-efficacy, the difficulty learning science rating is used as a proxy for self-efficacy. High science difficulty indicates low science self-efficacy.

In order to examine changes in self-efficacy, we subtracted student's ratings of their perception that science was difficult for them to learn in fall semester from their spring perceptions of difficulty ratings. The resulting change variable ranges from -3 to +3 and is constructed such that positive change values indicate an increase in self-efficacy and negative change values indicate a decrease in self-efficacy.

*Background characteristics.* Students reported their racial and ethnic background on the fall survey. Students also reported their gender on that survey. We investigated whether change in self-efficacy differed by these background characteristics.

*Potential sources of self-efficacy.* Two variables were used as indicators of students' science mastery experiences: students' first quarter science grades and their report of in-the-moment success during science classes. Two variables were used as indicators of persuasion. The first was the fall survey item student rating of "my teacher conveyed confidence in my ability to do well in the course" on a seven-point scale from *not at all* true to *very true*. The second was the student report of *parent involvement at school* (Cronbach's alpha = .77) comprised of four items reporting on whether during that school year their parent: talked to their science teacher at school, knew their science teacher, attended any school events, or ever came to school to watch them perform. Bandura (Bandura, Barbaranelli, Caprara, and Pastorelli, 1996) identified parental expectations and involvement as a source of persuasion, which others have shown, operate through parent involvement (Hoover-Dempsey, Bassler and Brissie, 1987). In-the-moment stress ratings from the ESM reports during science class gauged students' emotional state in science. We did not have a quantitative measure of vicarious experience that could be used in the statistical analyses, so we were unable to test this potentially important source.

*Interactions with students*. The video data were also coded with a focus on what the teachers were saying. Each teacher utterance was coded on five different dimensions. A single utterance had a consistency in the person being addressed or the function of the statement (defined below). As such, utterances could be very short (e.g. "everyone take out your homework") or much longer (e.g. "everyone take out your book, turn to page 27, read the section on ionic bonding, and then answer questions 4 and 5 at the end of the chapter. If you do not finish this work in class, please finish it as homework."). The end of one utterance and the beginning of the next utterance was defined in terms of a shift in the person(s) being addressed or in the function or purpose of the statement. For example, "everyone take out your books" (utterance ends/new utterance), "Julian, did you bring your book today?" or "look at the graph on p. 352" (utterance ends/new utterance) "what happens when the catalyst is added to the reactant?" The 50 minute class sessions reported in this chapter typically contained 250 – 400 teacher utterances accounting for an average of 24 minutes of class time.

Teachers' utterances were coded using NVivo8 (2008) software using a coding scheme derived from the authors' previous research. The dimensions analyzed in this chapter include: 1) who initiated the utterance (teacher or student); 2) the function or purpose of the utterance, coded as focusing either on content (presents or requests declaratory knowledge about science) or elaboration (an explanation such as how or why)[1]; 3) whether or not the utterance was a question; and 4) whether the utterance fostered student thinking (i.e. the statement included students intellectually as opposed to simply requiring them to be recorders of information).

# RESULTS

## Gender Differences in Science Self-Efficacy

The first question investigated is whether there were gender differences in fall when the school year was beginning. Science self-efficacy differed by gender ($t = 2.53$, $p < .01$), with males (M=5.22, SD=1.36) scoring higher than females (M= 4.76, SD=1.40). Our proxy for science self-efficacy -- difficulty learning science – differed significantly by gender as well, with males reporting less perceived difficulty than females in both fall [$M_{male}$=2.3 (.94), $M_{female}$=2.6 (.97); $t = -2.94$, $p<.001$] and spring [$M_{male}$=2.2 (.90), $M_{female}$=2.8 (.91); $t = -4.25$, $p < .001$].

## Change in Science Self-Efficacy during a School Year

*Change in self-efficacy by gender*. We were interested to know whether self-efficacy beliefs were consistent over the course of an academic year for male and female students. Looking across students in the sample, 45.1 % remained stable, representing equal proportions of the males and females in the sample (45.9% of males, and 44.2 % of females remained stable). An increase in self-efficacy was observed for 27.5 % of the entire sample, with males being more likely to increase than females (31.2 % of males increased, while 23.2 % of females did). Declines in self-efficacy were observed for 27.5 % of the full sample; females were more likely than males to exhibit a decline (22.9 % of males decreased, while 32.6% of females did).

*Change in self-efficacy by classroom*. We examined gendered patterns of change within 11 classrooms. There were only 2 in which the average science self-efficacy ratings of both males and females remained relatively constant from the beginning to the end of theyear. Average self-efficacy ratings among females declined in 5 classrooms. The male students in these same classrooms exhibited different patterns, with an average self-efficacy decrease observed for males in only one classroom. In one of these classrooms males on average exhibited no change in self-efficacy perceptions, and in the remaining 3 males reported average increases in science self-efficacy while females reported declining levels. In more than half of the classrooms observed, males' science self-efficacy ratings increased. There was not a single classroom in which males reported average declines in self-efficacy and females reported average increases in self-efficacy.

[1] Additional functions that are coded but not used for analysis in this chapter are functions of moving the lesson along, managing the classroom, or irrelevant statements.

## Sources of Self-Efficacy and Self-Efficacy Change

We investigated whether personal characteristics (gender and ethnicity) and other hypothesized sources of self-efficacy (indicators of mastery, persuasion, and affect) tended to characterize the students who changed, controlling for initial rating of science self-efficacy. Table 1 shows the results of Ordinary Least Squares (OLS) regression models predicting fall science self-efficacy and change in self-efficacy from fall to spring. Student gender was associated with initial science self-efficacy and changes, in that girls had lower self-efficacy to begin with and were less likely than boys to improve in self-efficacy about science learning. Race/ethnicity was not related to change in self-efficacy and was only marginally predictive of fall science self-efficacy. In terms of mastery experiences, first quarter science grades were not related to initial science self-efficacy or change, but students' feeling of success during class was related to both initial science self-efficacy and improvements in self-efficacy over the year.

For the sample overall, neither indicator of persuasion was related to change in self-efficacy, but teacher confidence positively predicted fall self-efficacy. In terms of affective influences, feeling stressed during class was not significantly associated with initial self-efficacy but was associated with declines in self-efficacy over time.

**Table 1. Ordinary Least Squares Regression Predicting Change in Self-efficacy**

| | Fall Science Efficacy | Change in Science Efficacy |
|---|---|---|
| Fall Science is Difficult Rating | -.23*** | .65*** |
| Personal characteristic (Student gender) | .12* | .15** |
| Personal characteristic (White) | .12^ | -.01 |
| Mastery experience (1st Quarter Grades) | .03 | .03 |
| Mastery experience (In the moment success) | .23*** | .18** |
| Persuasion (Teacher confidence) | .35*** | .01 |
| Persuasion (Parent Involvement in School) | .06 | .09 |
| Affect (In the moment stress) | -.02 | -.13* |
| $R^2$ | .46*** | .41*** |
| Adj $R^2$ | .44*** | .39*** |

Note. Gender 1= male, 0 =female; White 1=white, 0=minority. ^ p<.06, *p<.05, ** p < .01, ***p <.001.

## How Teachers Might Be Influencing Changes in Science Self-Efficacy

Given that there appeared to be gender-related patterns of change in self-efficacy within particular classrooms, we were interested in understanding something about the environmental features of classrooms in which males' and females' self-efficacy increased, decreased, or did not change. To begin this exploration we focused on 3 classrooms from the same subject area that had different patterns of change among male and female students. We chose the three biology teachers because they represented 3 different gender patterns within the same subject area and because each of the teachers was female so the potential impact of a female role model was held constant. The classrooms in which the biology classes were held were nearly identical: students sat in pairs at lab tables that were also used as desks. All three classes followed a standardized curriculum: thus we observed the "same" lessons in each of the classrooms during our observation periods. Teacher 1 was 33 years old and had been teaching science for 5 years. She has bachelor's degrees in both anthropology and biology, a master's degree in education and was pursuing a doctoral degree in education at the time of the study. Teacher 2 was 52 years old and had taught science for 19 years. She has a bachelor's degree in biology with a chemistry minor, and was pursuing a master of arts in teaching degree with a specialization in engineering. Teacher 2 also holds National Board Certification in Science. Teacher 3 was 24 years old and had been teaching for 2 years. She holds a bachelor's degree in biology with an emphasis on secondary education and a minor in chemistry, and was enrolled in the same master's program as Teacher 2 at the time of the study.

In Teacher 1's classroom, both male and female students exhibited little change in self-efficacy from the beginning to the end of the year. In Teacher 2's classroom, average science self-efficacy increased among both male and female students. In Teacher 3's classroom, female students' self-efficacy decreased while male student's self-efficacy increased.

Our examination of these three classrooms began with the dozens of hours of classroom video data we gathered during the weeks students were completing the ESM. We examined the amount of time each teacher spent using various instructional practices like lecture, labs, and seatwork, and found that these three teachers looked remarkably similar to one another in this regard. This similarity in classroom activity is not terribly surprising given the standardized curriculum and the fact that the teachers planned lessons together. Labs were the most common activity in all three classrooms: each teacher spent approximately one third of all the classroom time observed doing labs. Seatwork was the second most common instructional practice, comprising close to 20% of all classroom time for each teacher. Each of the three teachers spent close to 15% of all classroom time lecturing. The remainder of classroom time was spent doing a variety of less common activities like watching videos, having class discussions or student presentations, taking care of non-instructional 'housekeeping' tasks, and being completely off-task, having discussions about homecoming dances or sporting events.

Since the instructional practices teachers chose to use in their classrooms were similar, we next focused on teachers' verbal interactions with their students. As explained in the method section, we coded every verbal interaction for each teacher. The three teachers were different with respect to their overall level of talk with students. Teachers 1 and 3 spent approximately equal amounts of class time talking: In a typical 50-minute class period each of these teachers spent about 25 minutes talking (either to the entire class, to groups of students, or to individual students). Teacher 2 spent more time talking in her class than the other two teachers, talking for just over 30 minutes per class period, on average. As can be seen in Table 2, the teachers also differed markedly in the frequency with which they used certain types of verbal interactions with students. Teacher 1 (whose students' self-efficacy did not change) asked fewer questions than did the other two teachers. Teacher 2 (whose male and female students' self-efficacy increased) asked the most questions of any teacher, and more of her verbal interactions fostered students' thinking. Teacher 3 (whose male students increased and female students declined in self-efficacy) spent more time managing her class than the other two teachers, and had more irrelevant talk. It is also notable that Teacher 3 had more student-initiated utterances than the other two teachers. This is mostly because students were asking questions of the teacher about what to do next, etc., and indicates that they did not have as strong a sense of what the teacher expected of them as students in other classrooms.

**Table 2. Teachers' verbal interactions with students**

| | Question | Student Initiated | Content Knowledge | Elaboration | Fostering Thinking |
|---|---|---|---|---|---|
| T1 (no change in self-efficacy) *Frequency* | 365 | 420 | 560 | 95 | 60 |
| *Duration(sec.)* | 1457 | 2450 | 4064 | 942 | 349 |
| T2 (M and F increase in self-efficacy) *Frequency* | 835 | 381 | 543 | 100 | 108 |
| *Duration(sec.)* | 3304 | 1543 | 3161 | 990 | 578 |
| T3 (M increase, F decrease in self-efficacy) *Frequency* | 555 | 943 | 448 | 106 | 46 |
| *Duration(sec.)* | 2292 | 4076 | 3667 | 1992 | 237 |

Teachers' interaction patterns with students are consistent with change in students' self-efficacy in their classrooms. The bids Teacher 2 made to engage her students and to promote their thinking can be seen as a form of persuasion for them to participate in learning. Teacher 3's diminished focus on content and learning and increased focus on classroom management were likely to create negative affect and fewer mastery experiences.

We next examined the types of verbal interactions each teacher had with their male and female students (see Table 3). Teacher 2 (whose male and female students' self-efficacy increased) addressed her male and female students with identical frequency. When we totaled the amount of time this teacher spent addressing males and females, the difference between the two was only 50 seconds. This pattern poses a sharp contrast to that of Teacher 3, whose male students increased and female students declined in self-efficacy. The time Teacher 3 spent talking to her male students was 2.5 times greater than the time she spent talking to her female students (about 4 min/day for females compared to nearly 10 min/day for males). Teacher 1, on the other hand (whose students' self-efficacy did not change) addressed her female students slightly more often than her male students, but this only amounted to an average differences of about 1 minute per day, so it is questionable whether this represents a meaningful difference in the teacher's attention.

When we focus on the types of interactions each teacher had with male and female students, we note further differences. All teachers addressed boys more often than girls with regard to discipline or classroom management. If we focus on teacher statements that are focused on academics, some patterns emerge. Teacher 1 (whose male and female students' self-efficacy did not change) engaged more with girls than boys on content and questioning, but made more frequent comments to boys that were likely to foster thinking. Keep in mind however, that statements that fostered thinking were very rare among both boys and girls in this teacher's class. Teacher 1 made elaborative statements with equal frequency to boys and girls.

**Table 3. Teachers' Verbal Interactions with Students by Gender**

| | Content | | Elaboration | | Thinking Yes | | Question Yes | |
|---|---|---|---|---|---|---|---|---|
| | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* |
| T21 Average N males = 13, N females = 11 | | | | | | | | |
| Frequency | 40 | 66 | 5 | 4 | 5 | 2 | 51 | 76 |
| Duration (seconds) | 273 | 515 | 29 | 28 | 38 | 12 | 159 | 233 |
| T22 Average N males = 12, N females = 13 | | | | | | | | |
| Frequency | 101 | 95 | 12 | 8 | 18 | 18 | 219 | 207 |
| Duration (seconds) | 467 | 550 | 84 | 65 | 85 | 96 | 729 | 689 |
| T23 Average N males = 13, N females = 10 | | | | | | | | |
| Frequency | 99 | 57 | 19 | 3 | 9 | 7 | 181 | 88 |
| Duration (seconds) | 548 | 400 | 142 | 8 | 31 | 45 | 553 | 430 |

Relative to Teacher 1, Teacher 2 evidenced much more talk addressed to individual male and female students in all categories, both in terms of the number of utterances and the duration of these comments. Furthermore, Teacher 2 addressed her male and female students approximately equally with regard to presenting content, elaborating, fostering thinking, and questioning. She also had notably more focus on content and fostering thinking (to both males and females) than the other two teachers. Teacher 3 spent substantially more time addressing the boys in each of the function categories we examined, except for fostering thinking, which was too infrequent to use for drawing meaningful conclusions.

## How Teachers Talk about Their Male and Female Students

*Student participation*. Teachers had different perceptions of student class participation as it related to gender. Teachers 1 and 2 believed participation was more equal by gender than Teacher 3 did. Teacher 1 said, "Those that actually do raise their hands and answer, it's usually equal. They're usually the same ones over and over, but at least it's fifty-fifty in gender." Teacher 2 said:

> In one class, I think the boys are much more vocal, but in another, girls are more vocal. So, if you're taking a tally (in the class you are studying) my guess is the boys might come out higher, but if you call them by name they participate and if you're doing an activity … the girls, they're gonna get up and do it just like the boys, they might just not be quite as vocal.

Teacher 3 saw distinct gender differences:

> … in my classes, usually the guys are more comfortable being outspoken, they're more uh confident… Males, definitely participate more… I don't have to keep the girls on task, I have to tell the guys to get back on task, get back on task.

*Relationships with female and male students*. Teachers discussed their relationships with male and female students. Teacher 1 noted,

> years past, by the end of the year, I just feel like I have, for whatever reason, a better connection with the girls as I do with the boys. For all I know, it's just because that the girls seem to be able to relate to me more.

Teacher 2 defined her relationship and role as follows:

> I don't think there's that much difference. There is a difference between me relating to a kid who doesn't bring his stuff to class and a kid who's trying … I don't care what color you are don't care what gender you are, bring your book to class and do your work … I told them from day one, 'if I'm getting on to you about something it's because what you're doing is gonna affect your grade. Like this one kid *Felix*. He wasn't doing his work but he was drawing all over the tabletop which should get a referral and I called 'im up yesterday. I said, 'What's going on?,' you know, 'Why?' I said 'Look at the grade, you know, maybe I'm annoying sometimes but we need to try to work toward progress here.' If it's a girl doing the same thing I would have done the same thing, they're gonna hear from me about it… We need to try to find out what the problem is so we can work on it…

Teacher 3's relationship with her male and female students is revealed in the following interchange:

> Interviewer: Okay, now is there any girl in the class that you think might possibly go on in science? R: [Sighing] I'm sure there is, I'm just drawing a blank. I: And how about the highest achieving girl? R: See the girls are not as outspoken and so without seeing their names or their faces, it's hard to pick them out. Yeah, I'm drawing a blank, I'm sorry.
>
> I don't know, in talking to other female teachers, I feel like I relate to the guys better than some of them do so I, I don't know if I'm just more tolerant of them, I grew up with three brothers so, that probably has something to do with that but you know, guys don't faze me and I have no problem relating to them and if they can relate to me, if the kids can relate to the teacher that certainly helps with their understanding, by far.

*Teacher's reflections on gender, science, and their own background.* Teacher 1 reminisced about her own science teachers before relating her concerns about her own teaching:

> my science teachers in high school tended to focus more on the boys… sometimes I'm concerned that because I am a female, I explain it in a more creative female way, and I sometimes wonder if the girls seem to get it more than the boys because I'm explaining it. I don't know a lot about like video games and sports and uh cars, I do a lot of talking about my family.

Teacher 2 explained gender differences in the physical science as due to

> people don't explain physical concepts to (*girls*), but I have just as many girls who, for example, wanna be a vet , as guys, a lot of girls are interested in the medical field and so they're interested in science. I got a lot of guys that aren't interested in science at all. So it goes both ways.

Teacher 3 was critical of both her male and female high school science teachers:

> My biology teacher was a female, she wasn't bad, she just wasn't awesome, uhm, and we just basically did worksheets, and if I asked anything about science that wasn't directly in the book, she didn't know the answer to it, uhm, and so she didn't have a broad understanding of science. My chemistry teacher, so uhm, he's like, 'so I don't really like chemistry' - that was a great start to the school year. Well I got an A because I was a girl all the girls got As, uhms….I think because he was biased.

*Summary of interviews*. Although she said both participate equally, Teacher 1 felt more affinity with female students and gravitated towards them in interactions. She thought that the examples she used in class might be more engaging for females. In several statements, including the one on participation (who raises hand and thus is called on), she seemed to accept the status quo, never suggesting that she might encourage or intervene to initiate greater participation or improvement so it is not surprising that, overall, students' self-efficacy did not change much in her class. On the other hand, on average, both male and female students improved in Teacher 2's class. She related to both male and female students and stood out in her belief that she should, can, and does intervene with students proactively to prevent failure. She saw her role as that of a problem solver, and she was aware that boys in her fifth hour class, which we observed, might participate a bit more but noted that if she calls on girls then they will participate, which was borne out in her behavior. She had also mentioned several girls as talented and attributed any gender differences to environment, culture, and experience. Teacher 3 related better to boys and saw them as more confident than girls; the idea that she might have any role in promoting a relationship or increasing the confidence of girls was not apparent. She acknowledged doing more to keep males on track and perceived girls as compliant. Distressingly, she could not remember one girl's name. The overall decline in girls' and slight increase in boys' self-efficacy in her classroom is consistent with her interaction patterns and beliefs.

## Summary of Observed Teacher Patterns

Up to this point, we have presented data from several sources to characterize the instructional practices, interaction patterns, and stated beliefs of 3 high school biology teachers whose students evidenced different gender-related patterns of self-efficacy change over the course of an academic year. Together, these various sources of data suggest fairly different profiles of each teacher that seem to map onto the observed gender patterns among their students in understandable ways.

Teacher 2, whose male and female students generally increased in self-efficacy over the course of the year, spent more time talking to her students than the other two teachers, made more frequent use of questioning in her classroom, and more often spoke to students in ways that fostered thinking, as compared to asking students to simply recall previously provided facts. In contrast to the other teachers, Teacher 2 addressed her male and female students equally throughout the semester, directing with equal frequency statements related to content, elaboration, fostering thinking, and questioning. Our observations of her interactions with her students were consistent with her own statements about the male and female students in her class. She perceived approximately equal participation among the male and female students in her class, and noted that her interactions were guided by students' preparedness and participation in class, regardless of factors like gender or race/ethnicity.

In contrast, Teacher 3, whose male students increased and female students declined in self-efficacy, spent more class time than the other teachers on classroom management and talk that was irrelevant to science. She spent less time on science content than the other two and rarely made comments that fostered student thinking. A substantial portion of Teacher 3's verbal interactions with students was student-initiated which, on the surface might appear positive. However, closer examination of the classroom video data indicates that this can be explained as student confusion about material that was provided, rather than student ownership of their learning. Teacher 3 addressed her male students far more often than her female students, and this bias toward males cut across many types of verbal interaction including conveying content, elaboration, and questioning. Her interviews similarly reflected this bias in that she shared her belief that the males in her class were more outspoken, participated more, and required more of her attention. She admitted feeling more at ease with her male students and colleagues than her other female peers, and when pressed, was unable to recall the name of a single female student in the class we observed.

Our examination of Teacher 1 produced a profile that seemed to fall somewhere between the extreme parity of teacher 2 and the apparent bias of Teacher 3. In Teacher 1's class, the self-efficacy beliefs of both male and female students remained relatively stable across the year. Teacher 1 spent less time talking than the two other teachers, and this difference was mostly accounted for by the fact that she didn't engage in student questioning to the degree that the other teachers did, preferring instead to convey content through lecture and seatwork. In her interviews Teacher 1 expressed particular affinity toward the girls in her class, and this affinity was apparent in her verbal interactions with students, as she was the only teacher who evidenced a pattern of addressing her female students more often than her male students. These gender-related patterns were not, however, as persistent or as dramatic as those observed for Teacher 3.

While the patterns we highlight above are suggestive that teachers' interactions with students in the classroom are shaping the trajectories of students' self-efficacy over the course of an academic year, our data do not allow us to draw such causal conclusions. The nature of classrooms is so complex that changes in self-efficacy may have been due to other factors we were unable to observe or measure.

As a final inquiry and validity check into the ways that teachers' interactions and beliefs may influence students' self-efficacy beliefs, we present two examples of students' reports of their own experiences in science classrooms. We use data collected using the Experience Sampling Method to document the fluctuations in students' momentary ratings of self-efficacy as they relate to different classroom activities.

## Profiles of a Self-Efficacy 'Improver' and a Self-Efficacy 'Decliner'

The ESM provides unique insight into the thoughts of students during their science learning activities. We use the ESM to chart the activities and thoughts of two female students: one whose self-efficacy improved and one whose self-efficacy declined over the course of the year.

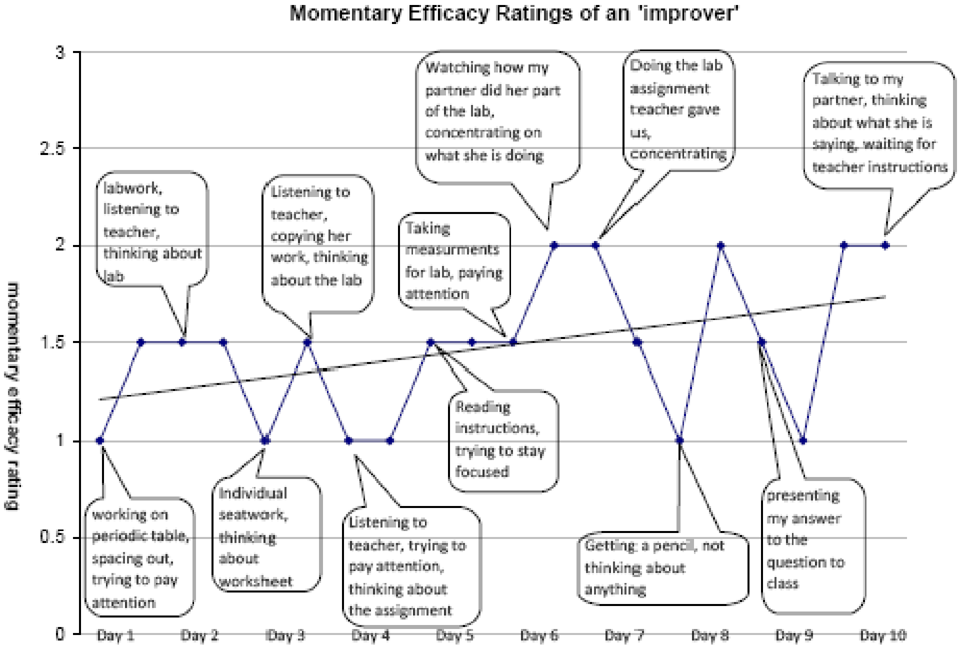


Figure 1. Momentary science efficacy ratings of an "improver".

*Juana, a self-efficacy improver.* Juana is a 9th grade student in Teacher 2's biology class. She is Hispanic, and at the time of the study was not certain how far in school she would get or what type of career she would have when she grew up. Her favorite subject when we began the study was foreign language, and her previous grades in science had been Bs and Cs. Her science self-efficacy score, as measured on our global survey, improved 2 full points from the beginning of the year to the end.

Figure 1 depicts all of Juana's ESM ratings of momentary self-efficacy (measured as the mean of momentary success and skill), and her corresponding responses to open-ended questions about her activities and thoughts at the time of each signal. Juana's first ESM report could be characterized as representing relatively low self-efficacy.

Juana reports at this signal, as she does during nearly all signals where her self-efficacy is low, that she is struggling to pay attention and stay focused. Those moments where Juana reports higher self-efficacy suggest a greater level of focus and attention to classroom activities. Many of her highest self-efficacy points make clear reference to the vicarious experience of observing her teacher and peers (e.g. "listening to the teacher, copying her work, thinking about the lab;" "watching how my partner did her part of the lab, concentrating on what she is doing;" "talking to my partner, thinking about what she is saying, waiting for teacher instructions"). Zeldin and Pajares (2000) have argued that these types of vicarious experiences are particularly important for fostering the self-efficacy of females in STEM domains. Many of these momentary high points in science self-efficacy occurred during lab work, suggesting that for Juana, the labs this teacher provided presented an opportunity for her to observe others modeling skills and strategies. As these observational opportunities accumulated over the course of the year, her average momentary ratings of science self-efficacy increased slightly, as suggested by the trend line in Figure 1. This pattern of improvement in science self-efficacy was seen even more dramatically in her end-of-year global science self-efficacy ratings.

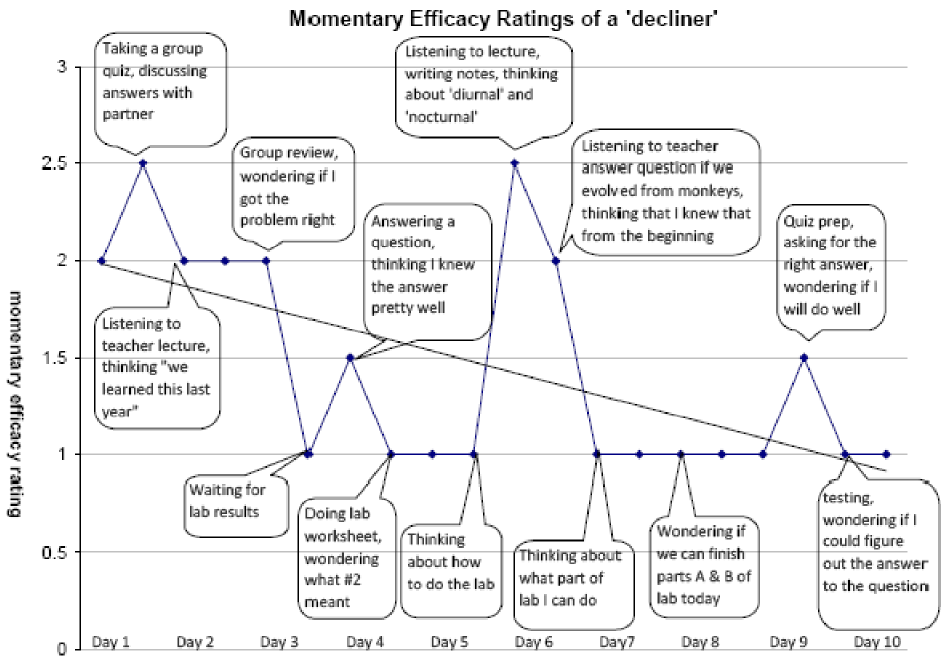


Figure 2. Momentary science efficacy ratings of a "decliner".

*Christina, a self-efficacy decliner.* Christina is a 9th grade student in Teacher 3's biology class. She is Hispanic, and at the time of the study had planned to study medicine in college and become a doctor. Her favorite subject was math and her previous grades in science had been As and Bs. Her science self-efficacy score, as measured on our global survey, declined 2 full points from the beginning of the year to the end. At the beginning of the study, Christina's science self-efficacy starts off high, and she reports feeling quite efficacious as she is discussing her answers to a group quiz with her partner. After this initial high start, her science self-efficacy ratings drop fairly consistently. Interestingly, the spikes of higher self-efficacy correspond to moments where the class is covering content that Christina knows already, rather than a situation where she is learning something new by observing others' successes, as was the case with Juana. Instead Christina's high self-efficacy points seem to draw more heavily on her prior mastery experiences.

Examples of Christina's activities and thoughts during her self-efficacy high points include "listening to teacher lecture, thinking 'we learned this last year;'" and "Listening to teacher answer question if we evolved from monkeys, thinking that I knew that from the beginning." The fact that these prior mastery experiences were not adequate to sustain a high level of science self-efficacy is consistent with Lent, Lopez and colleagues' (1996) argument that mastery experiences are not especially influential among females in STEM areas. In contrast to Juana, nearly all of Christina's lowest science self-efficacy scores occur during lab. Her comments suggest that in this particular classroom (or at least in her perception of it) labs are a source of confusion rather than clarity, serving to thwart, rather than enhance, her self-efficacy. ESM reports suggesting this include: "doing lab worksheet, wondering what #2 meant;" or "thinking about what part of lab I can do;" or "wondering if we can finish parts A and B of lab today." In contrast to Juana, whose classroom experiences (lab in particular) appeared to provide her with valuable sources of science self-efficacy, Christina's classroom experiences appeared to undermine her self-efficacy in a domain that had been very important to her as suggested by her educational and occupational aspirations.

## CONCLUSION

Our findings align change in high school students' science self-efficacy over a school year with teacher beliefs and verbal interaction patterns with students. The ESM allowed us to see that these changes appear to be mediated through students' subjective experiences of feeling successful and stressed during class. The fact that female students had lower self-efficacy entering their science classes and subsequently declined more than males across the school year points to the critical need to intervene in this process – it is currently females' motivation to do science, not their performance and ability, that appears to be driving their choice of science majors and careers. Our chapter shows that some teachers can and do positively impact their students' science self-efficacy. Such teachers should be identified and used as role models for others.

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