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Relationships between High School Chemistry Students' Perceptions of a Constructivist Learning Environment and their STEM Career Expectations

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Considerable attention has been devoted to factors affecting the persistence of women and historically underrepresented ethnic groups in their science education trajectories. The literature has focused more on structural factors that affect longitudinal outcomes rather than classroom experiences. This exploratory survey study described relationships among high school chemistry students' perceptions of a constructivist learning environment (CLE) and STEM career expectations. The sample included 693 students from 7 public high schools within the San Francisco Bay Area. Students' perceptions of a CLE predicted their expectations of entering a science career, but not engineering, computer, health, or mathematics-related careers. When all groups of students perceived the learning environment as more constructivist, they were more likely to expect science careers.

Keywords: *Social constructivism; K-12; Learning environment*

Introduction

The lagging persistence of women and historically underrepresented ethnic groups in their science and engineering educational trajectories has been an ongoing problem. Underrepresented minorities' share of science and engineering bachelor's and master's degrees has increased in the last two decades, but since 2010 when they composed 36% of the population, their attainment of doctorates has flattened at below 10% (National Science Foundation [NSF], 2013). Although women now earn more bachelor's degrees than men in the biological and social sciences, their share of

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physical science and mathematics degrees remains well below those of men (NSF, 2013). Scholars have identified psychological barriers that deter students from continuing to advance in their science educations (e.g. see Blickenstaff, 2005; Ceci & Williams, 2010). These include, but are not limited to, the mismatch between prototypical scientists and students' self-views (Archer et al., 2012; Packard & Nguyen, 2003; Wheeler & Petty, 2001), the threat of confirming negative stereotypes (Cheryan, Plaut, Davies, & Steele, 2009; Spencer, Steele, & Quinn, 1999; Steele, 1997; Steele & Aronson, 1995), and the perception of school science as being boring and irrelevant (e.g. see Osborne, Simon, & Collins, 2003). Alleviating psychological burdens requires understanding sources of the problem.

Society bears a great deal of responsibility for perpetuating the psychological hurdles faced by historically underrepresented students. For example, the media reinforces stereotypes (Ross & Lester, 2011) and the school science curriculum tends to focus on an outdated and decontextualized body of knowledge that students view as disconnected from their lives (Lyons, 2006; Osborne et al., 2003). Societal forces do not affect students deterministically, however. Students' immediate contexts may exacerbate or alleviate psychological burdens. Evidence suggests that classroom environments affect the saliency of stereotype threat (Cheryan et al., 2009) and students' attitudes toward science (Myers & Fouts, 1992; Piburn & Baker, 1993; Woolnough, 1994). However, the influence of classroom factors on students' longitudinal persistence in science education is less clear. Maltese and Tai (2011) found that 9th and 10th grade students who reported there was a strong emphasis on learning facts in mathematics were less likely to earn bachelor's degrees in STEM. Additionally, teacher enthusiasm, placing content in an everyday context, stimulating lessons, and discussion about careers and issues in science all affect students' decisions to continue in science (Woolnough, 1994). While scholars have identified some isolated aspects of curriculum and instruction that influence persistence, they have not explored or developed frameworks that might inform science education more comprehensively. This paper builds on this work by examining how the classroom learning environments relates to career expectations.

Why Career Expectations?

Students who have early career expectations are considerably more likely to advance in science education than those who do not. In a large longitudinal study, Tai et al. (2006) found that eighth graders who expected to enter a science career at the age of 30 were 1.9 times as likely to earn a bachelor's degree in a biological science and 3.4 times as likely to earn a degree in a physical science compared to similar students who did not expect science careers, controlling for achievement scores, student demographics, academic characteristics, and parent background. Similarly, Schoon (2001) found that the greatest predictor of UK students working in the natural sciences at the age of 33 was their educational aspirations at age 16. Thus, early career expectations serve as proxies for longitudinal outcomes.

Studies have found a host of individual and structural characteristics associated with career aspirations; these include, but are not limited to, academic achievement, personality, race/ethnicity, attitude toward science, gender, type of school (boys only, girls only, or mixed), parental occupation, and parental education (Maltese & Tai, 2011; McWhirter, Hackett, & Bandalos, 1998; Paa & McWhirter, 2000; Packard & Nguyen, 2003; Schoon, 2001; Wang & Staver, 2001). One might wonder the extent that classroom experiences influence persistence in comparison to structural and individual factors. In order to advance understanding of the relative impact of structural and environmental characteristics on career expectations, this study explores students' personal (i.e. demographic) and academic characteristics along with classroom factors.

Learning Environment

Research conducted over the past 40 years has found consistent associations between students' perceptions of their learning environments, the social and psychological environment in which learning occurs (Dorman, 2001), and a variety of affective and cognitive outcomes. Studies have found that positive perceptions of the learning environment are associated with favorable attitudes toward learning, beliefs about the nature of science, academic achievement, and academic self-efficacy (Dorman, 2001; Fraser, 1998, 2014; Haertel, Walberg, & Haertel, 1981; Tsai, 2000). However, career expectations, a proxy for longitudinal outcomes, have not been explored in relation to learning environments.

Theoretical Framework

In this study, I utilize Taylor, Fraser, and Fisher's (1997) critical constructivist framework, which conceptualizes of a constructivist learning environment (CLE) as a context that provides opportunities for students to build knowledge collaboratively (Taylor et al., 1997). Additionally, in a CLE, students learn that scientific knowledge results from human inquiry and must be evaluated by shared expectations held by scientific communities (i.e. rather than knowledge existing independent of our minds). Thus, a CLE emphasizes the social construction of knowledge in how students learn and what they learn about science. A CLE also prioritizes opportunities for students to have control over their learning and to see science as relevant to their lives. Thus, a CLE is grounded in the well-established idea that learning is an active and social process in which new learning needs to be integrated and negotiated with pre-existing cognitive schema (Driver & Oldham, 1986; Fraser, 1998; Tobin, 1993). Lastly, a critical constructivist perspective holds the view that students should have opportunities to critically evaluate their education in an effort to develop awareness of a technical controlling ethos that treats knowledge as a product to be delivered (Apple, 1979). These aspects of a CLE are conveyed in the Constructivist Learning Environment Survey (CLES) (Johnson & McClure, 2004; Taylor et al., 1997), and descriptions of the subscales are provided in Table 1.

Scholars have suggested that science classrooms lacking characteristics featured in CLEs may deter students' interest (Osborne et al., 2003), motivation (Bøe, Henriksen,

Table 1. Scale description for each dimension of the CLES

Scale	Scale Description
Personal relevance	Extent to which school science/mathematics is relevant to students' everyday out-of-school experiences.
Uncertainty	Extent to which opportunities are provided for students to experience that scientific/mathematical knowledge is evolving and culturally and socially determined.
Critical voice	Extent to which students feel that it is legitimate and beneficial to question the teachers' pedagogical plans and methods.
Shared control	Extent to which students have opportunities to explain and justify their ideas, to test the viability of their own and other students' ideas.
Student negotiation	Extent to which students share with the teacher control for the design and management of learning activities, assessment criteria, and social norms of the classroom.

(Johnson & McClure, 2004, p. 68; Taylor et al., 1997, p. 296).

Lyons, & Schreiner, 2011), and identity development (Brown, 2004; Carlone, Haun-Frank, & Webb, 2011) in school science, all of which are important to persisting in STEM education trajectories. By extension, constructivist classrooms may bolster students' interest, motivation, and/or identity development in school science, which may affect their career expectations, a proxy for longitudinal outcomes. The goal of this study is to explore whether there are relationships between perceptions of a CLE and STEM career expectations. If there are relationships, further research might explore mechanisms and whether there are causal effects of perceptions of a CLE on STEM career expectations. Consideration of how environments may cue stereotypes and affect career expectations informed my recruitment of study participants. Common images of scientists often involve males in lab coats and instrumentation associated with chemistry (Finson, 2002; Newton & Newton, 1998). These stereotypes affect whether the students see science careers as possible for themselves (Markus & Nurius, 1986). Males may be more likely to see themselves as scientists because of the similarity to stereotypical images of scientists (Lips, 2004). Since the immediate environment cues stereotypes (Cheryan et al., 2009), chemistry students were enrolled as participants.

Research Question

If students perceive chemistry class as more constructivist, are they more likely to expect each STEM career compared to the other careers, and if so, to what extent?

Methods

Teachers and Schools

Public non-charter Bay Area high school chemistry students were recruited to complete a survey (described below), which was the sole instrument used to collect data. Thirteen teachers in a summer professional development that I co-facilitated qualified, and I asked all but four teachers to participate. Those four teachers were beginning at new schools or had expressed a great deal of stress about the imminent school year (e.g. expecting a child), and I was concerned about overburdening them by asking them to participate. Of the remaining nine teachers, all agreed to participate with the exception of one, who felt that she did not have enough time. One teacher's data were omitted because he gave the survey as a homework assignment, rather than issuing the survey in class. An additional teacher participant was a colleague who teaches at a school where I was a faculty member; he was not part of the summer professional development. All of the teachers were from different schools with the exception of two teachers from the same school.

The schools represented a range of enrollment, academic achievement, and student diversity in terms of race/ethnicity and socioeconomic status. Characteristics of the schools were obtained from the most recently available (2010–2011 or 2011–2012 school years) School Accountability Report Cards (SARCs). The similar schools ranking is determined by comparing a school's Academic Performance Index (API) to other schools with similar characteristics (e.g. student demographics, percentage of teachers who are fully credentialed) in California (California Department of Education, 2000). The similar schools rankings for the schools represented the full range (i.e. the lowest and highest similar schools rankings) of academic performance on standardized tests for schools with similar characteristics. As for the racial/ethnic composition of the schools, the fraction of white students at the schools ranged from 1.1% to 58.4% and the fraction of Hispanic/Latino students ranged from 0.4% to 84.6%. Lastly, the proportion of students who were characterized as socioeconomically disadvantaged at the schools ranged from 4.9% to 100%.

The response rate (85%) was calculated as a percentage of enrolled students who took the survey. Only completed surveys were included in the final data set. A total of 791 students completed the survey; 12% of data was omitted due to non-completion, resulting in a final sample of 693 students.

Participants

The students represented diverse racial/ethnic, socioeconomic, and linguistic backgrounds. Students in the sample self-identified their race/ethnicity as American Indian or Alaska Native (<1%), Asian American (32%), Black, African American, or Negro (3%), Native Hawaiian and Other Pacific Islander (3%), Spanish/Hispanic or Latino(a) (30%), White (30%), and Other (6%); 13% of participants selected two or more races/ethnicities. Sixty-one percent of students were male, 55% received free or reduced price lunch, and 71 % reported speaking a language other than English at home. A majority (52%) of students were in the 10th grade, and <1%, 32%, and 16% were in 9th, 11th, and 12th grades, respectively. As for the chemistry course type, most (84%) of the students were taking Chemistry. Seven percent were taking Applied Chemistry and 9% were enrolled in Honors Chemistry.

Procedure

The survey was described as a research project being conducted by Stanford researchers.

Students were informed that they would be eligible for a $20 gift card via a lottery, regardless of whether they chose to participate. Teachers were informed in person and/or via email that the survey could only be an assignment if it was ungraded (i.e. students could not be punished for choosing not to participate) or if an alternative assignment was offered with equal value.

Each teacher administered the survey once in November or December of 2013. Students completed the survey individually on a computer or tablet, with the exception of participants at School 4 and School 6, who took the survey in paper form due to limited access to computers. Reponses to the paper survey were input electronically by a research assistant. Students who took the survey online were required to respond to each survey item in order to move on, and they were not able to return to prior items on the survey. The mean length of time for online survey completion was 25 minutes.

Measures

The survey consisted of four components presented in the following order: career expectations, perceptions of self and 'best chemistry students', the CLE, and student characteristics. Due to the scope of this paper, I do not report the data or results for perceptions of self and best chemistry students. The portions of the survey relevant to this study are provided in the Appendix.

Dependent variable: career expectations. The relationship between career expectations and science bachelor's degree attainment found by Tai, Liu, Maltese, and Fan (2006) used data from the 1988 National Education Study, which asked students, 'What kind of work do you expect to be doing when you are 30 years old? (Mark the answer that comes the closest to what you expect to be doing)' (Ingels, Scott, Rock, Pollack, & Rasinski, 1994). The same prompt was used in this study, but the response options were edited to coincide with current careers. Twenty-two occupation groups from the US Bureau of Labor Statistics (2012) were used, accompanied by example careers. The science career expectation response option was 'Life Science, Physical Science, and Social Science (Examples: Biologist, Psychologist, Chemist)'. Additional science, technology, engineering, and math-related outcomes included 'Computers and Mathematics (Examples: Computer Technician, Software Developer, Statistician, Actuary)', 'Architecture and Engineering (Examples: Architect, Drafter, Mechanical Engineer, Chemical Engineer)', and 'Healthcare Support (Examples: Nursing Assistant, Massage Therapist, Dental Assistant)'.

Independent variable: perceptions of a CLE. The CLES (Johnson & McClure, 2004) was adapted for this study. The CLES includes the following subscales: personal relevance, uncertainty, critical voice, shared control, and student negotiation, corresponding to the dimensions of the CLE featured in Table 1. Research using the CLES with American elementary, middle, and high school students has found high internal consistency ($0.93 \leq$ Cronbach's $\alpha \leq 0.94$) (Johnson & McClure, 2004). The CLES sentence stem 'In this class … ' was replaced with 'in chemistry class' to make it clear that the survey was eliciting perceptions of chemistry class. Some prompts were edited slightly or eliminated due to students' sense that the survey was redundant in piloting.

Choices were randomized within each subsection and Johnson and McClure's response scale (almost never, seldom, sometimes, often, or almost always) was used. A higher score on this 31-item 5-point frequency-scale indicates a greater perception of a CLE. More specifically, students scored higher if they reported more frequent behaviors in chemistry, such as 'learn[ing] from other students' and 'get[ing] a better understanding of the world outside of school'. An example item from each of the subscales is provided in Table 2. The sum of each student's responses for the items was calculated, and the value was used as his/her perception of a CLE.

Covariates. As discussed above, studies have found that career expectations differ by gender, socioeconomic background, achievement, and ethnicity (Archer et al., 2010; McWhirter et al., 1998; Paa & McWhirter, 2000; Schoon, 2001). Therefore, the following characteristics were self-identified by students: race/ethnicity, free/reduced price lunch status, grade point average (GPA), home language, and parent/guardian educational attainment.

Data Analyses

Internal consistency and factor analyses. All data were cleaned and entered into Stata/IC 13.1. The perception of a CLE item showed high coherence (Cronbach's $\alpha = 0.90$). A principle components factor (PCF) analysis with varimax rotation extracted five factors with eigenvalues greater than one for the perception of a CLE, consistent with the five theoretical factors of the CLES subscales.

Summary of analyses. All analyses were exploratory in the sense that hypothesized relationships in the data are explored for the purpose of informing more rigorous studies (Schochet, 2008). I used multinomial logistic regression to model how categorical

Table 2. Example Items for each dimension of the CLES

Scale	Example item • Prompt: In chemistry class …
Personal relevance	I learn interesting things about the world outside of school.
Uncertainty	I learn that science cannot always provide answers to problems.
Critical voice	I feel safe questioning what or how I'm being taught.
Shared control	I help plan what I am going to learn.
Student negotiation	I talk with other students about how to solve science problems.

(Johnson & McClure, 2004).

outcomes (expecting each of the four STEM careers) were predicted by the continuous variable (perception of CLE) in comparison to the other careers. If there were statistically significant differences between the relationship between students' perception of a CLE and their expectation of a particular STEM career compared to at least half of the other careers, I proceeded to add student gender, race/ethnicity, and GPA as covariates to the model to see whether the main effect remained robust. The coefficients that result from logistic regression analysis are in units of log odds. An odds ratio (OR) can be calculated by taking the mathematical constant *e* to the power of the logistic regression coefficient. This ratio is the probability of an event happening divided by the probability of it not happening (Sainani, 2011). Risk ratios (RR) are simply the probability of an event happening compared to another. A risk ratio of 1.78 of outcome A compared to outcome B means a 78% greater likelihood of obtaining outcome A than outcome B. Since they are easier to interpret than ORs, I calculated RR for statistically significant relationships, following the method of Sainani (2011, p. 265):

$$\mathrm{RR} = \frac{\mathrm{OR}}{(1 - p_{\mathrm{ref}}) + (p_{\mathrm{ref}} * \mathrm{OR})}.$$

The quantity $(1 - p_{\mathrm{exp}})$ is the probability (risk) of the outcome of interest NOT occurring (i.e. the probability of not expecting a particular STEM career) and $(1 - p_{\mathrm{ref}})$ is the probability of the reference outcome of interest NOT occurring (i.e. the probability of not expecting a different career). Multinomial logistic regression rests on different assumptions than ordinary least squares regression (i.e. linearity, normality, and continuity). Specifically, the former assumes independence of irrelevant alternatives (IIA), which is the assumption that adding or removing an outcome category does not affect the likelihood of choosing one career over another (McFadden, 1987). To test whether the model met the IIA assumption, I used Long and Freese's (2014) Hausman and seemingly unrelated estimation (sue) Hausman tests in STATA 13.

Logistic regression model evaluation. The ratio chi-square values indicate whether the model as a whole fits significantly better than a model with no predictors. In logistic regression, pseudo *R*-squared values have a different meaning than *R*-squared values in linear regression (i.e. they are not the proportion of the variance in the outcome variable explained by the model). Although pseudo *R*-squared values cannot be interpreted independently or compared across data sets, they can be used to compare models for the same data set. Higher pseudo *R*-squared values indicate which model better predicts the outcome.

Results

The fraction of students expecting each of the science careers is provided in Table 3 to provide context for the results. The proportions of students expecting STEM careers—life, physical, and social science, architecture and engineering, computers

Table 3. Proportion of students expecting each career

Career	Percentage of students who expected career (%)
Management	4.3
Business and financial operations	6.4
Computers and mathematics	8.8
Architecture and engineering	9.1
Life, physical, and social science	12.8
Community and social service	3.6
Building and grounds cleaning and maintenance	0.1
Legal	5.8
Education	5.9
Arts, design, entertainment, sports, and media	13.3
Healthcare support	17.3
Protective services	3.2
Food preparation and serving	1.6
Personal care and service	2
Sales	0.4
Office and administrative support	0.4
Farming, fishing, and forestry	0.3
Construction and extraction	0.7
Installation, maintenance, and repair	1
Production	0
Transportation and material moving	0
Military	2.9

and mathematics, and healthcare support—were 12.8%, 9.1%, 8.8%, and 17.3%, respectively.

I performed multinomial logistic regression to determine whether students were more or less likely to expect each STEM career compared to the other careers if they perceived chemistry class as more constructivist. Table 4 presents the results of these analyses with no covariates. Production and transportation and material moving careers were omitted from the table since no students expected to be working in those occupations. Negative coefficients indicate that the comparison career is less likely than the STEM career when students perceive the learning environment as more constructivist. Thus, a one-unit increase in students' perception of a CLE is associated with a 0.043 decrease in the log odds of expecting a management career compared to a physical, life, and social science career ($p < .05$). When students perceived chemistry class as more constructivist, they were more likely to expect physical, life, and social science careers than ten other careers: management, business and financial operations, computers and mathematics, architecture and engineering, community and social service, education, arts, design, entertainment, sports and media, healthcare support, protective services, and food preparation and serving. As Table 4 shows, students were no more or less likely to expect architecture and engineering, computers and mathematics, and health career support than any other careers (with the exception of physical, life, and social science) if they perceived chemistry class as more constructivist.

Table 4. Multinomial logistic regression results of students' perceptions of a CLE and their expectations of STEM careers compared to other careers ($N = 693$)

Comparison career	Life, physical, and social science log odds (s.e.)	Architecture and engineering log odds (s.e.)	Computers and mathematics log odds (s.e.)	Healthcare support log odds (s.e.)
Management	−0.043* (0.017)	−0.008 (0.017)	−0.002 (0.018)	−0.020 (0.016)
Business and financial operations	−0.036* (0.015)	−0.002 (0.016)	−0.004 (0.016)	−0.014 (0.014)
Computers and mathematics	−0.041** (0.013)	−0.006 (0.014)		−0.018 (0.012)
Architecture and engineering	−0.034* (0.013)		0.006 (0.014)	−0.012 (0.012)
Life, physical, and social science		0.034* (0.013)	0.041** (0.013)	0.022 (0.011)
Community and social service	−0.044* (0.018)	−0.010 (0.019)	−0.003 (0.019)	−0.022 (0.017)
Building and grounds cleaning and maintenance	−0.106 (0.076)	−0.071 (0.077)	−0.065 (0.076)	−0.083 (0.076)
Legal	−0.030* (0.015)	0.004 (0.016)	0.011 (0.016)	−0.008 (0.014)
Education	−0.041** (0.015)	−0.007 (0.016)	−0.001 (0.016)	−0.019 (0.014)
Arts, design, entertainment, sports, and media	−0.053*** (0.012)	−0.019 (0.013)	−0.012 (0.013)	−0.031 (0.011)
Healthcare support	−0.022* (0.011)	−0.012 (0.012)	0.018 (0.012)	
Protective services	−0.053** (0.019)	−0.019 (−.019)	−0.012 (0.020)	−0.031 (0.018)
Food preparation and serving	−0.080** (0.025)	−0.047 (0.025)	−0.040 (0.025)	−0.059 (0.024)
Personal care and service	−0.039 (0.023)	−0.005 (0.023)	0.002 (0.023)	−0.017 (0.022)
Sales	−0.040 (0.046)	−0.006 (0.047)	0.0004 (0.047)	−0.018 (0.046)
Office and administrative support	−0.071 (0.046)	−0.036 (0.046)	−0.030 (0.046)	−0.048 (0.045)
Farming, fishing, and forestry	−0.077 (0.055)	−0.042 (0.055)	−0.036 (0.055)	−0.054 (0.055)
Construction and extraction	−0.016 (0.037)	0.018 (0.037)	0.024 (0.037)	0.006 (0.036)
Installation, maintenance, and repair	0.002 (0.032)	0.037 (0.032)	0.043 (0.032)	0.025 (0.031)
Military	−0.034 (0.020)	−0.001 (0.020)	0.006 (0.020)	−0.013 (0.019)

Model evaluation	χ^2	p	*Pseudo-R^2*	χ^2	p	*Pseudo-R^2*	$\chi2$	p	*Pseudo-R^2*	χ^2	p	*Pseudo-R^2*
	34.13	*.018*	*0.010*	34.13	*.018*	*0.010*	*34.13*	*.018*	*0.010*	*34.13*	*.018*	*0.0010*

*$p < .05$ (two-tailed).

**$p < .01$.

***$p < .001$.

Covariates for student gender, race/ethnicity, and GPA were added to the baseline model predicting students' expectations of working in a life, physical, and social science career, which resulted in Model 2 (Table 5). Parental education and free/reduced price lunch status were not included in the model because Pearson chi-squared tests of differences revealed no differences among groups and students' expectations of STEM careers. Model 2 was better than Model 1 based on the pseudo-R^2 value. When student gender, race/ethnicity, and GPA were included as covariates, all of the differences in the likelihoods of students expecting a physical, life, and social science career compared to other careers remained statistically significant at the .05 level or greater, with the exception of legal and healthcare support careers, which fell to non-significance. The coefficient attenuated for all of the comparison careers with the exception of architecture and engineering and mathematics and computer careers, for which the coefficient increased in magnitude. The attenuation was always less than two-thirds of a standard error.

For careers with statistically significant differences compared to physical, life, and social science careers, I calculated RR. A one standard deviation increase in students' perception of a CLE is associated with a 77% greater likelihood of expecting a career in physical, life, and social science compared to a management career and 169% more likely compared to a food service career, keeping gender, GPA, and race/ethnicity constant. In other words, students are more than 1.7 times as likely to expect a career in physical, life, and social science compared to a management career and 2.69 times more likely compared to a food service career for each standard deviation increase in perception of CLE, controlling for personal characteristics. As for the IIA assumption, for all models in Tables 4 and 5, Long and Freese's (2014) Hausman tests found that the assumption was not met, but sue Hausman tests indicated that the assumption was met. Lastly, all models were significantly better than predicting the outcomes by chance ($p < .001$).

Discussion

In their discussion of classroom factors affecting persistence in science education trajectories, Maltese and Tai (2011) write,

> The type of experiences students have in their STEM classes may play a large role in who decides to remain and who leaves STEM (Cleaves, 2005; Munro & Elsom, 2000; Oakes, 1990; Ware, Steckler, & Leserman, 1985); however, these studies shed little light on what classroom experiences impact student persistence. (p. 882)

The results of this investigation build on the literature by revealing a previously unexplored association between perceptions of a CLE and science career expectations. When students perceive the learning environment as more constructivist, they are more likely to expect physical, life, and social science careers.

It is notable that there were no differences in male and female students' expectations of physical, life, and social science careers. The response option may be able to account for this null finding. Consistent with the results of this study, Maltese and Tai (2011) did not find differences in students' expectations of entering science, technology,

Table 5. Multinomial logistic regression results of students' perceptions of a CLE and their expectations of life, physical, and social science careers compared to other careers controlling for student characteristics ($N = 693$)

	Model 1	Model 2	
Covariates (gender, race/ethnicity, GPA)		Included	
Comparison career	Log odds (s.e.)	Log odds (s.e.)	Increase in likelihood of expecting physical, life and social science careers relative to comparison career for each standard deviation increase in perception of CLE
Management	−0.043* (0.017)	−0.042* (0.018)	77%
Business and financial operations	−0.036* (0.015)	−0.034* (0.015)	88%
Computers and mathematics	−0.041** (0.013)	−0.043** (0.014)	107%
Architecture and engineering	−0.034* (0.013)	−0.038** (0.014)	92%
Community and social service	−0.044* (0.018)	−0.040* (0.019)	88%
Building and grounds cleaning and maintenance	−0.106 (0.076)	−0.128 (0.085)	
Legal	−0.030* (0.015)	−0.029 (0.0160)	
Education	−0.041** (0.015)	−0.035* (0.016)	78%
Arts, design, entertainment, sports, and media	−0.053*** (0.012)	−0.048*** (0.013)	132%
Healthcare support	−0.022* (0.011)	−0.017 (0.012)	
Protective services	−0.053** (0.019)	−0.042* (0.020)	93%
Food preparation and serving	−0.080** (0.025)	−0.065* (0.027)	169%
Personal care and service	−0.039 (0.023)	−0.031 (0.024)	
sales	−0.040 (0.046)	−0.006 (0.050)	
Office and administrative support	−0.071 (0.046)	−0.064 (0.050)	
Farming, fishing, and forestry	−0.077 (0.055)	−0.077 (0.058)	
Construction and extraction	−0.016 (0.037)	−0.004 (0.039)	
Installation, maintenance, and repair	0.002 (0.032)	0.022 (0.034)	
Military	−0.034 (0.020)	−0.022 (0.021)	

(*Continued*)

Table 5. Continued

	Model 1			Model 2		
Covariates (gender, race/ethnicity, GPA)					Included	
Model evaluation	*Likelihood ratio χ^2 (df = 19)*	*p*	*Pseudo-R^2*	*Likelihood ratio χ^2 (df = 143)*	*p*	*Pseudo-R^2*
	34.13	*.018*	*0.010*	*428.03*	*.000*	*0.122*

$^{*}p < .05$ (two-tailed).

$^{**}p < .01$.

$^{***}p < .001$.

engineering, and mathematics careers by gender, ethnic, or parental education. There may not have been group differences in this study and that of Maltese and Tai because the response options were broad in the sense that they included science careers in which there are still considerable underrepresentation of women, Latinos, and African Americans (i.e. physical science, engineering) and areas in which the underrepresentation is less extreme (i.e. life science and social science).

Possible selves theory provides a possible explanation for the lack of gender differences in science career expectations and the presence of gender differences in health, engineering, and mathematics-related career expectations. Possible selves theory suggests that actual representation in careers affects students' career expectations since they signal the characteristics of individuals who are in the careers, thereby affecting what people view as possible for themselves. Individuals from historically underrepresented groups would be more likely to expect science careers if response options included careers in which their groups are better represented. Consistent with this idea, male students were more likely to expect careers in which males are overrepresented (e.g. computers, mathematics, engineering, and architecture) and female students were more likely to expect careers in which women are overrepresented (e.g. healthcare). A limitation of this interpretation is that it hinges on students having some awareness of the representation in science careers, which may not be the case. Possible selves are not limited to being cued by representation in careers, however. For example, the underrepresentation of women and ethnic minorities is signaled in television (Dudo et al., 2011), films (Steinke, 2005), and other socialization experiences (Markus & Nurius, 1986). Thus, the consistency of expectations of science careers and actual representation in those careers might be viewed as an indication of pervading societal messages about what is possible for students.

The results also raise the question of why perceptions of a CLE are salient for science career expectations, but not for engineering, computer, mathematics, and health-related career expectations. Recent research suggests that students make clear distinctions between science and other STEM careers. Sha, Schunn, and Bathgate (2015) found that students' choice of 'engineer or doctor careers are not a part of children's preference toward science' (p. 703). It may be the case that engineering, computer, mathematics, and health-related careers are less readily associated with students' perceptions of science class. These careers involve applications of science outside of the standard curriculum, so students may view them as peripheral to science class. In contrast, perceptions of a CLE are tied to students' experiences in science class, which may be more associated with 'standard' science careers reflected in school science. Additional research that explores the depiction of STEM careers in curriculum and textbooks (an unexplored area) would provide further insight into this interpretation.

Limitations

All relationships revealed in the study are correlational rather than causal. There may have been variables associated with perceptions of a CLE, prototype match, and science career expectations that were not revealed by the data. Moreover, data were not collected for the period students were taking chemistry, so clustering errors by classroom, which would have accounted for endogenous factors in the learning environment, was not possible. Additionally, data were collected once, so the results are a 'snapshot' of relationships at a particular time. Experimental and quasi-experimental studies, which collect data over the course of a school year, would be beneficial in studying causal hypotheses.

Long and Freese's (2014) Hausman tests found that the models did not meet the IIA assumption, but sue Hausman tests found that they did. In addition to the statistical tests, consideration of the process of choosing a career expectation reveals that the IIA assumption may not have been met. If a student participant weighed his/her expectation of working in a physical, life, and social science career compared to a management career, it is plausible that the relative likelihood of the student expecting these careers changes upon omission or deletion of other response options. Thus, it is plausible but not conclusive that the IIA assumption was not met.

Omitted variable bias may have also affected the models. Parental occupation was not included as a covariate because I neglected to include response options for unemployed and stay-at-home parents. Teachers reported that students whose parents fell into this category chose other career options on the survey, thereby jeopardizing the validity of the parental occupation data. Students whose parents are in STEM careers are more likely to gain exposure to science outside of school and imagine themselves in science careers (Archer et al., 2010; Aschbacher, Li, & Roth, 2010; Sonnert, 2009). However, it is not clear that these students would view the learning environment any differently than other students, and Pearson chi-squared tests did not reveal differences in the STEM career expectations of students with different free/reduced price lunch status and with different levels of parental education, so there may have been little if any bias due to the omission of parental occupation as a covariate.

An additional source of error may have been social desirability bias, especially with respect to students' perceptions of a CLE. Students may have viewed a CLE more positively and therefore provided more socially desirable responses, a bias that may have been exacerbated by the administration of the survey by the teacher. Moreover, non-random sampling limits the generalizability of the study. The participants were all chemistry students in the Bay Area and further studies can determine if the relationships are found for students in other science classes and in other locations. The teachers whose students participated in the study were all professional acquaintances, and sample bias may have affected the results. One teacher was a former colleague and the others were participants in a two-week summer professional development that I co-facilitated. Those who participated in the professional development spent a substantial portion of their summer voluntarily improving their practice without being compensated for their time, and these teachers may not be representative of teachers within the region or outside the region. The professional development modeled and encouraged constructivist teaching in the sense that teachers had control over their learning and they developed their understanding of the phenomena socially. It is plausible that attendees were more likely to foster CLEs than other teachers, but we cannot be sure. I am also not able to confirm that students' perceptions of the learning environment reflect the actual learning environment. Researchers have demonstrated discrepancies between students' perceived norms and those enacted within the classroom (Levenson, Tirosh, & Tsamir, 2009; Taylor et al., 1997). Therefore, I do not claim that students' perceptions are accurate measurements of the classroom environment. Since I was interested in the relationship between perceptions of the learning environment and career expectations, students' subjective interpretations of their classroom environments were prioritized.

Conclusion

This paper began by raising the question of what classroom factors affect the persistence of historically underrepresented groups in science education. Perceptions of a CLE are associated with students' expectations of expecting science careers, but the relationship did not differ by gender or race/ethnicity. In other words, perception of a CLE appears to benefit students of all backgrounds equally in terms of their expectations of entering physical, life, and social science careers. The lack of group differences does not diminish the finding. If all study participants were to earn doctorates in a science, the proportion of degree earners from historically underrepresented groups would be considerably greater than their current share. Moreover, science education as it stands privileges overrepresented students, and there is value in identifying a factor that provides equal benefits to all students rather than disadvantaging some students. Imagine a finding of equal benefits in the context of athletics, and assume that practice benefits all players equally. If we were coaching a basketball team, we would not dismiss practice. Players who were coached in the past would benefit from practice, as would those who had less access to such opportunities. Although practice may not decrease the gap between players, the disadvantaged athletes may now have a greater opportunity to play due to their increased skills and identities as basketball players. If a goal of science education is for all students to see science careers as possible for them, then the CLE may help to achieve this outcome.

The CLE does not appear to be capable of ameliorating the persistence of historically underrepresented groups in other STEM careers. Predictable gender differences were found in participants' expectations of engineering, computer, and mathematics-related careers, raising the question of whether classroom factors are salient in comparison to structural characteristics. Hazari, Sonnert, Sadler, and Shanahan (2010) offered insight into this issue, finding that discussion about the underrepresentation of women in science benefitted females' physics identities and physics career aspirations more than that of males. We know more about aspects of the learning environment that deter underrepresented groups (e.g. stereotype threat and irrelevance) than we know about curriculum and instruction that improve persistence, so it is important to continue this line of research.

In order to reap the possible benefits of constructivist classrooms, research suggests there is a great deal of work to be done.

Globally, science education predominantly consists of lectures on science content with little interaction between students (Lyons, 2006). This default model of science instruction contrasts with a CLE, which prioritizes the social construction of knowledge. Additionally, the results of this study suggest the importance of student-centered classroom discourse, but the participation structure in classrooms predominantly takes the form of initiation–response–evaluation (Cazden, 2001; Lyle, 2008; Nystrand, Gamoran, & Carbonaro, 1997). Moreover, one characteristic of a CLE is teaching science as evolving and culturally situated, but teachers' understanding of epistemic and sociological features of scientific knowledge is limited (Gallagher, 2006; Lederman, 1992, 2006; Tsai, 2007). As for relevance, many students perceive science as high-tech and connected to their lives, but school science as disconnected from society (e.g. see Ebenezer & Zoller, 1993; Osborne et al., 2003).

Despite the challenges, the current wave of curriculum reform outlined in the Next Generation Science Standards (NGSS) (Achieve, 2013) may nudge teachers to facilitate more constructivist classrooms. Topics such as climate change and the science underlying technology provide opportunities for teachers to support students in finding relevance in their learning. Moreover, the NGSS performance expectations require students to integrate scientific practices, core disciplinary ideas, and cross-cutting concepts. The performance expectations will inform assessments, which are likely to affect instruction (Au, 2007). In order for students to successfully demonstrate competence in scientific practices, they will need to engage in them. Scientific practices such as modeling and argumentation require epistemic knowledge such as the provisional nature of scientific knowledge (Osborne, 2010; Schwarz et al., 2009). Moreover, to authentically engage in scientific practices, students must interact with each other and have some control over their learning. Although it remains to be seen how the NGSS will affect classrooms, the considerable overlap between features of a CLE and the vision of the Standards provides glimmers of hope for more equitable science education (Table 3).

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Appendix

Survey

The complete survey, which includes questions peripheral to this study, can be found at http://tinyurl.com/chemistryperceptionsstudy. The headings—Learning about the world, Learning about science, Learning to speak out, Learning to learn, and Learning to communicate—correspond to the dimensions of the constructivist learning environment—Personal relevance, Uncertainty, Critical voice, Shared control, and Student negotiation, respectively.

Chemistry class

This section contains statements about learning in chemistry class. You will be asked how often each behavior or characteristic takes place. There are no 'right' or 'wrong' answers. Your belief is what is wanted.

Learning about the world

In chemistry class...

	Almost never (1)	Seldom (2)	Sometimes (3)	Often (4)	Almost Always (5)
I learn interesting things about the world outside of school.	❍	❍	❍	❍	❍
My learning starts with problems about the world outside of school.	❍	❍	❍	❍	❍
I learn how science can be part of my out-of-school life.	❍	❍	❍	❍	❍
I get a better understanding of the world outside of school.	❍	❍	❍	❍	❍

Learning about science

In chemistry class...

	Almost never (1)	Seldom (2)	Sometimes (3)	Often (4)	Almost Always (5)
I learn that science cannot always provide answers to problems.	❍	❍	❍	❍	❍
I learn that scientific explanations have changed over time.	❍	❍	❍	❍	❍
I learn that science is influenced by people's cultural values and opinions.	❍	❍	❍	❍	❍
I learn that science is a way to raise questions and seek answers.	❍	❍	❍	❍	❍

Learning to speak out

In chemistry class...

	Almost never (1)	Seldom (2)	Sometimes (3)	Often (4)	Almost Always (5)
I feel safe questioning what or how I'm being taught.	❍	❍	❍	❍	❍
I feel I learn better when I am allowed to question what or how I'm being taught.	❍	❍	❍	❍	❍
It's OK for me to ask for clarification about activities that are confusing.	❍	❍	❍	❍	❍
It's acceptable for me to express concern about anything that gets in the way of my learning.	❍	❍	❍	❍	❍

Learning to learn

In chemistry class...

	Almost never (1)	Seldom (2)	Sometimes (3)	Often (4)	Almost Always (5)
I help plan what I am going to learn.	❍	❍	❍	❍	❍
I help to decide how well I am learning.	❍	❍	❍	❍	❍
I help to decide which activities work best for me.	❍	❍	❍	❍	❍
I let the teacher know if I need more/less time to complete an activity.	❍	❍	❍	❍	❍

Learning to communicate

In chemistry class...

	Almost never (1)	Seldom (2)	Sometimes (3)	Often (4)	Almost Always (5)
I talk with other students about how to solve science problems.	❍	❍	❍	❍	❍
I explain my science ideas to other students.	❍	❍	❍	❍	❍
I ask other students to explain their science ideas.	❍	❍	❍	❍	❍
I am asked by others to explain my science ideas.	❍	❍	❍	❍	❍

Personal Background

We'll finish by asking you a few more questions about yourself.

What is your sex?

- ❍ Male
- ❍ Female

What is your race/ethnicity? Mark all that apply.

- ❑ American Indian or Alaska Native
- ❑ Asian American
- ❑ Black, African America, or Negro
- ❑ Native Hawaiian and Other Pacific Islander
- ❑ Spanish/Hispanic or Latino(a)
- ❑ White
- ❑ Other (please specify): ____________________

Indicate whether you receive free or reduced price lunch.

- ❍ Free
- ❍ Reduced
- ❍ I do not receive free or reduced price lunch.

What is your grade point average (GPA)?

- ❍ 0-1.00
- ❍ 1.01-1.50
- ❍ 1.51-2.00
- ❍ 2.01-2.50
- ❍ 2.51-3.00
- ❍ 3.01-3.50
- ❍ 3.51-4.00
- ❍ 4.01+