Motivation, Achievement, and Advanced Placement Intent of High School Students Learning Science

ROBERT R. BRYAN
Department of Mathematics and Science Education, University of Georgia, Athens, GA 30602, USA

SHAWN M. GLYNN
Department of Educational Psychology and Instructional Technology and Department of Mathematics and Science Education, University of Georgia, Athens, GA 30602, USA

JULIE M. KITTLESON
Department of Mathematics and Science Education, University of Georgia, Athens, GA 30602, USA

Received 25 October 2010; revised 30 January 2011; accepted 11 February 2011

DOI 10.1002/sce.20462
Published online 25 July 2011 in Wiley Online Library (wileyonlinelibrary.com).

ABSTRACT: Within the framework of social cognitive theory, we examined the motivation of students (14–16 years old) to learn science in their introductory science courses. The students responded to a questionnaire about their intrinsic motivation, self-efficacy, and self-determination. The students also wrote essays about their motivation, and individual interviews were conducted with a representative sample of students. We found that the students' intrinsic motivation, self-efficacy, self-determination, and achievement were related. Consistent with social cognitive theory, self-efficacy was the motivation factor most related to achievement. The Advanced Placement Program (AP) aspirants were higher than nonaspirants in intrinsic motivation, self-efficacy, self-determination, and achievement. Patterns in students' essays and interviews identified inspiring teachers, career interests, and collaborative-learning activities as strong motivators. The findings suggest that science teachers should use social modeling and collaborative-learning activities to foster students' motivation, achievement, AP intent, and interest in science careers. © 2011 Wiley Periodicals, Inc. *Sci Ed* **95:**1049–1065, 2011

Correspondence to: Shawn M. Glynn; e-mail: sglynn@uga.edu

INTRODUCTION

Motivation to learn science benefits young students who aspire to be future scientists. But, just as importantly, motivation to learn science benefits *all* students by fostering their *scientific literacy*, which is the capability to understand scientific knowledge, identify important scientific questions, draw evidence-based conclusions, and make decisions about how human activity affects the natural world (Organisation for Economic Cooperation and Development, 2007). The importance of all students becoming scientifically literate is advocated internationally (Feinstein, 2011; Kelly, 2011; Roberts, 2007).

In studying the motivation to learn science, science education researchers attempt to explain why students strive to learn science, what emotions they feel as they strive, how intensively they strive, and how long they strive. To explain students' motivation, it is important to examine what contributes to it. This knowledge can help science teachers sustain and enhance students' motivation.

The purpose of the present study was to examine what motivates girls and boys (14–16 years old) to learn science in their introductory science courses in high school. These courses are critically important because they are gateways to scientific literacy for all students and, for some students, gateways to scientific careers.

Theoretical Framework: Motivation to Learn Science

Social cognitive theory, developed by Bandura (1986, 2001, 2005) and extended by others (e.g., Pajares & Schunk, 2001; Pintrich, 2003), explains human learning and motivation in terms of reciprocal interactions involving personal characteristics (e.g., intrinsic motivation, self-efficacy, and self-determination), environmental contexts (e.g., high school), and behavior (e.g., enrolling in advanced science courses). While there are many theories of learning and motivation that explain certain aspects of behavior (see Schunk, Pintrich, & Meece, 2008), the comprehensiveness of social cognitive theory makes it particularly applicable to the present study. Social cognitive theory was designed to "explain how people acquire competencies, attitudes, values, styles of behavior, and how they motivate and regulate their level of functioning" (Bandura, 2006, p. 54).

Motivation is defined in social cognitive theory as an internal state that arouses, directs, and sustains goal-oriented behavior. Motivated students achieve academically by engaging in behavior such as studying, question asking, advice seeking, and participating in classes, labs, and study groups (Schunk et al., 2008). Consistent with social cognitive theory, we define the *motivation to learn science* as an internal state that arouses, directs, and sustains science-learning behavior. Students who are motivated to learn science and engage in science-learning behavior pursue goals such as good science grades and science-related careers.

Sanfeliz and Stalzer (2003), like many high school science teachers, believe that one of their most important instructional responsibilities is to foster students' motivation to learn. According to Sanfeliz and Stalzer, motivated students enjoy learning science, believe in their ability to learn, and take responsibility for their learning. As this description of motivated students implies, the motivation to learn science is a multicomponent construct, and it is conceptualized as such in social cognitive theory. The components are types and attributes of motivation, which were reviewed by Glynn and Koballa (2006), Koballa and Glynn (2007), Eccles and Wigfield (2002), Pintrich (2003), and Schunk et al. (2008).

Sanfeliz and Stalzer's (2003) description of motivated students suggests that three motivation components—intrinsic motivation, self-efficacy, and self-determination—play important roles in the learning of science. *Intrinsic motivation* is the inherent satisfaction in learning science for its own sake (e.g., Eccles, Simpkins, & Davis-Kean, 2006), s*elf-efficacy* is students' belief that they can achieve well in science (e.g., Baldwin, Ebert-May, & Burns, 1999), and *self-determination* is the control students believe they have over their learning of science (e.g., Black & Deci, 2000). These motivation components can potentially influence the arousal, direction, and sustainment of students' science-learning behavior. These components have been previously studied, but usually alone rather than in relation to each other. A goal of the present study, therefore, was to study these components in relation to each other.

The Present Study

Within the framework of social cognitive theory, we examined what motivates high school students to learn science in their introductory science courses. We administered a questionnaire to the students to assess their intrinsic motivation, self-efficacy, and self-determination. We also asked all students to write essays about their motivation to learn science, and we individually interviewed a representative sample of students. The use of quantitative and qualitative methods provided a better understanding of students' motivation than either method alone (Creswell & Plano Clark, 2007).

In connection with motivation, one of the variables we focused on was gender. Within recent years, women and girls have made strong gains in science achievement, science degrees earned, and science careers (National Science Foundation, 2009). For example, women now earn about 50% of the science undergraduate degrees in the United States. Most of these degrees are in the life sciences, however, and women are still underrepresented in degrees earned in the physical sciences. Women currently account for only 25% of the science and engineering workforce (National Science Foundation, 2009). Thus, despite the strong gains that women and girls have made in science education, they still remain underrepresented in degrees earned in the physical sciences and in science careers in general (Ceci & Williams, 2007; Scantlebury & Baker, 2007).

A second variable we focused on in connection with motivation was students' intent to enroll in Advanced Placement Program (AP) science courses. This program enables high school students to study science and other subjects at levels that are more rigorous than the standard high school course offerings. The College Board (2009, 2010a), a nonprofit organization, administers this program, and specially trained high school teachers implement it. Students can earn college credit while still in high school if they do well on the AP exams administered nationally. Each college's policy is different, but doing well usually means a score of at least 3 or 4 out of a possible 5. Students who do well on AP exams have better college admission rates, scholarship eligibility, and graduation rates. Although it is possible to take an AP exam without having taken a corresponding AP course, the College Board recommends the AP course. The College Board encourages students who wish to take one or more AP courses to talk to an AP teacher or AP Coordinator at their schools about the courses, the workload, the preparation needed, and the AP exams. In the last 5 years, the number of students taking AP courses has risen by nearly 50% to 1.6 million. This rapid growth is a result of higher academic aspirations by students, with the encouragement of their parents, teachers, and school administrators. Accompanying this growth is the controversial use of AP courses and exams in college admissions, scholarships, and the ranking of "America's Best High Schools" by *Newsweek* (Sadler, 2010).

A third variable we focused on was achievement, an indicator of scientific literacy. It is reasonably and routinely assumed by science educators that high school students' motivation to learn science is related to their achievement; however, this relationship has not been documented often. A recent study that did document this relationship was conducted by Britner (2008): She found that self-efficacy, a component of motivation, was related to high school students' science grades. The present study extended this line of research by examining how intrinsic motivation, self-efficacy, and self-determination are related to achievement.

To summarize, within the framework of social cognitive theory, we addressed the following two research questions about high school students' motivation to learn science in their introductory science courses:

- How are students' intrinsic motivation, self-efficacy, self-determination, and achievement related?
- What similarities and differences exist between male and female AP science aspirants and nonaspirants in intrinsic motivation, self-efficacy, self-determination, and achievement?

METHOD

Participants

The study was conducted in a suburban public high school located in the southeast United States. The total school enrollment was 910 students (449 females and 461 males, ages 14–18 years old); nationally, public high schools average 871 students (U.S. Department of Education, 2010). The participants were 288 first- and second-year students (146 females and 142 males, 14–16 years old). The students' participation was voluntary and consistent with procedures of the school district and university research review boards. The students were given no extra credit or compensation for participating. They were informed "Your participation will help improve science instruction." Informed-consent forms were signed by both the students and their parents.

High school science curricula vary, and the National Science Education Standards (National Research Council, 1996) do not recommend a particular sequence of high school science courses. The high school in this study is typical of those that have introductory biology and physical science courses in the initial 2 years and chemistry, physics, and AP courses (AP Biology, AP Environmental Science, AP Chemistry, and AP Physics) in the latter 2 years. The participants were enrolled in either a first-year (freshman) Introductory Biology course (76 females and 67 males) or a second-year (sophomore) Introductory Physical Science course (70 females and 75 males), both of which are required courses. The multiple sections (ns = 20–25) of the two courses were taught in a coordinated curriculum by five teachers, one of whom is the first author. The teachers (two females and three males) followed state science-curriculum standards that were aligned with the National Science Education Standards, used the same assessment format, and used the same criteria to determine course grades. In all sections of both courses, the course grades were based on a scale from 0 to 100 points, where A = 90–100, B = 80–89, C = 70–79, D = 60–69, and F = below 60.

The participants identified themselves as White (80.2%), Hispanic or Latino (7.3%), African American (6.9%), Asian/Pacific Islander (4.5%), or Multiracial (1.0%). These percentages were similar to those of the high school population. Minority status was not treated as a statistical variable because there were relatively small numbers in these groups and statistical inferences might be misleading. The percentage of students receiving free or reduced-cost lunch through the National School Lunch Program, an indicator of socioeconomic status, was 49.2%; nationally, the percentage of students is 59% (Food Research and Action Center, 2010).

Procedures and Measures

Achievement, as a criterion, was viewed as a correlate of motivation, not an equivalent of it. We note this because some students who are motivated to learn might underachieve for a variety of reasons, such as lacking prerequisite knowledge. A measure of students' science achievement—their final grade in their high school introductory biology or physical science course on a 0–100 point scale—was obtained directly from the course instructors.

At the end of the introductory courses, with knowledge of their grades, the students responded to a confidential, three-part (A, B, and C) online survey administered in the school computer labs. The students' knowledge of their grades enabled them to make informed judgments about their responses. The students were assured that their identities would remain confidential. Under such conditions, self-reported information has been found to be reliable (Cassady, 2001).

In *Part A* of the online survey, we asked students about their academic background and AP intent. Regarding their AP intent, students responded "yes" or "no" to the question: "Do you intend to enroll in one or more third-year (junior) or fourth-year (senior) Advanced Placement science courses?" (A pilot study indicated that a yes/no response format for this item had greater validity than a probability response format because some students chose mid-range probabilities to avoid the question. For this reason, "I don't know" was not a response option either.) The students were informed that their response to this *Part A* item was not an official AP registration, they were free to change their mind up until the official registration date, and that this item was intended to assess their AP intent at this point in time. The registration date for junior-year AP courses was in 1 week for the sophomore students; the date was 1 year away for the freshmen. During their introductory courses, the students had been informed about the AP Program and encouraged to discuss AP registration with their parents, teachers, and academic advisors, as recommended by the College Board (2009).

In *Part B* of the online survey, the students received these instructions: "In order to better understand what you think and how you feel about your high school science courses, please respond to each of the following statements from the perspective of: "When I am in a high school science course..." We then asked the students to respond to items (see Table 1) from the intrinsic motivation, self-efficacy, and self-determination scales of the Science Motivation Questionnaire (Glynn & Koballa, 2006; Glynn, Taasoobshirazi, & Brickman, 2007, 2009). The students responded to each of these 14 randomly ordered items on a Likert-type scale of temporal frequency: never (1), rarely (2), sometimes (3), often (4), or always (5). The possible score range was 5 to 25 on the intrinsic motivation and self-efficacy scales, and 4 to 20 on the self-determination scale.

In *Part C* of the online survey, the students wrote essays. We asked the students to "describe your motivation to learn science and explain it in as much detail as possible because this information will help us to develop more effective science courses." No restriction was placed on the length of the essays.

Semistructured individual interviews of a representative sample ($n = 28$) of the participants were conducted. There were 14 interviewees randomly selected from the girls and 14 randomly selected from the boys. All agreed to be interviewed before or during school. Following the procedures described by Patton (2002), the interviews were conducted by the first author using an *interview guide* of core questions that were asked during 15- to 20-minute interviews in a classroom. The interview guide included the following orientation and four questions:

> To better understand what you think and how you feel about the high school science courses you've taken, I'd like to ask you some questions. The information you provide will help

TABLE 1
Questionnaire Items About Intrinsic Motivation, Self-Efficacy, and Self-Determination

Intrinsic Motivation
I find learning the science interesting
I enjoy learning the science
I like science that challenges me
Understanding the science gives me a sense of accomplishment
The science I learn is more important to me than the grade I receive
Self-Efficacy
I believe I can master the knowledge and skills in the science course
I believe I can earn a grade of "A" in the science course
I am confident I will do well on the science tests
I expect to do as well as or better than other students in the science course
I am confident I will do well on the science labs and projects
Self-Determination
I use strategies that ensure I learn the science well
I put enough effort into learning the science
I prepare well for the science tests and labs
If I am having trouble learning the science, I try to figure out why
Response Scale: O Never O Rarely O Sometimes O Usually O Always

Note: The items were from the Science Motivation Questionnaire (Glynn & Koballa, 2006; Glynn, Taasoobshirazi, & Brickman, 2009).

> instructors to develop more effective science courses. Question 1: Could you describe your motivation to learn science: In other words, how motivated are you and why? Question 2: What aspects of your science courses motivate you to learn? Question 3: What aspects of your science courses discourage you from learning? Question 4: What isn't being done enough in your science courses, which could be done more, to increase your motivation to learn?

The interview guide ensured that the same basic line of inquiry was pursued with each interviewee, yet the guide also allowed for follow-up questions to further explore or probe a response in greater depth. The guide provided a framework within which the interviewer asked relevant questions and encouraged each interviewee to respond and elaborate. The interviews were recorded and transcribed.

The students' essay and interview statements were coded, categorized, labeled, and annotated by the first and second authors (interrater reliability was $r = .89$). The interview guide provided a framework for content analysis by *analytic induction*, which Patton (2002, p. 454) defines as "examining the data in terms of theory-derived sensitizing concepts.... After or alongside this deductive phase of analysis, the researcher strives to look at the data afresh for undiscovered patterns and emergent understandings (inductive analysis)." As Patton explains, analytic induction differs from a grounded-theory content analysis, which is typically inductive in the early stages. Following Patton's guidelines, we first used the four questions in our interview guide as "sensitizing concepts" to deductively identify patterns of statements; we then looked inductively for additional patterns.

RESULTS

With the *Statistical Program for the Social Sciences*, version 17.0 (SPSS, Inc., 2008), we computed descriptive statistics for questionnaire items, achievement scores, and AP intent and found that the students in the first-year biology and second-year physical science courses did not differ significantly, so we combined the data from the courses; however, in one analysis, a difference in AP intent approached statistical significance at the 0.05 level, and that is reported below.

First, the reliabilities (internal consistencies) of the questionnaire scales and their correlations with each other and achievement were determined. Second, with the Analysis of Moment Structures (AMOS) program, version 7.0 (Arbuckle, 2006), a structural equation model (SEM) was tested to determine if the items were good indicators of their corresponding motivation components. AMOS was also used to examine relationships between the students' motivation components and their achievement. Third, male and female AP aspirants and nonaspirants were compared in terms of their motivation and achievement. Finally, the students' essays and interview data were analyzed and interpreted using procedures described by Patton (2002).

Scale Reliabilities and Correlations

The Cronbach's alphas (internal consistencies) of the motivation-component scales were: intrinsic motivation (.85), self-efficacy (.83), and self-determination (.75). According to DeVellis (2003), a coefficient above .80 is "very good," .70 to .80 is "respectable," .60 to .69 is "undesirable to minimally acceptable," and below .60 is "unacceptable."

The Pearson product-moment correlations among the scales were .68 for intrinsic motivation and self-efficacy, .54 for intrinsic motivation and self-determination, and .55 for self-efficacy and self-determination, all ps $< .001$. The correlations of intrinsic motivation, self-efficacy, and self-determination with achievement were .37, .56, and .31, respectively, all ps $< .001$.

Structural Equation Modeling

Our structural equation model incorporated two submodels: a measurement model and a structural model. The measurement model provided information about construct validity by examining the links between observed variables (i.e., the questionnaire responses) and the latent constructs (i.e., the motivation components). In the first step of our two-step model-building approach, following procedures specified by Byrne (2001), we performed a confirmatory factor analysis to test the measurement model in Figure 1. The order of the items in the figure corresponds to the order of the items in Table 1.

In the second step, we built a structural model on the measurement model that examined relationships between the students' motivation components and achievement. We used a two-step approach because "once it is known that the measurement model is operating adequately, one can then have more confidence in findings related to the assessment of a hypothesized structural model" (Byrne, 2001, p. 147). On the basis of social cognitive theory, we hypothesized that (1) each item is a good measure of its corresponding motivation component, (2) the components are mutually supporting and, therefore, positively related, and (3) the components are positively related to students' achievement.

We assessed the goodness of fit of the measurement model with well-established indices and criteria (Byrne, 2001; Kline, 2005). Because any given index evaluates only particular aspects of model fit, we used multiple indices. Our first index was a normed χ^2. The χ^2 statistic assesses a model's "badness of fit" or the extent that a proposed model varies from the data. Nonsignificant p-values are ideal, but unrealistic because the statistic is very dependent on sample size: Larger samples yield larger χ^2. Consequently, to reduce the effect of sample size on the χ^2 statistic, it is recommended that the obtained χ^2 be divided

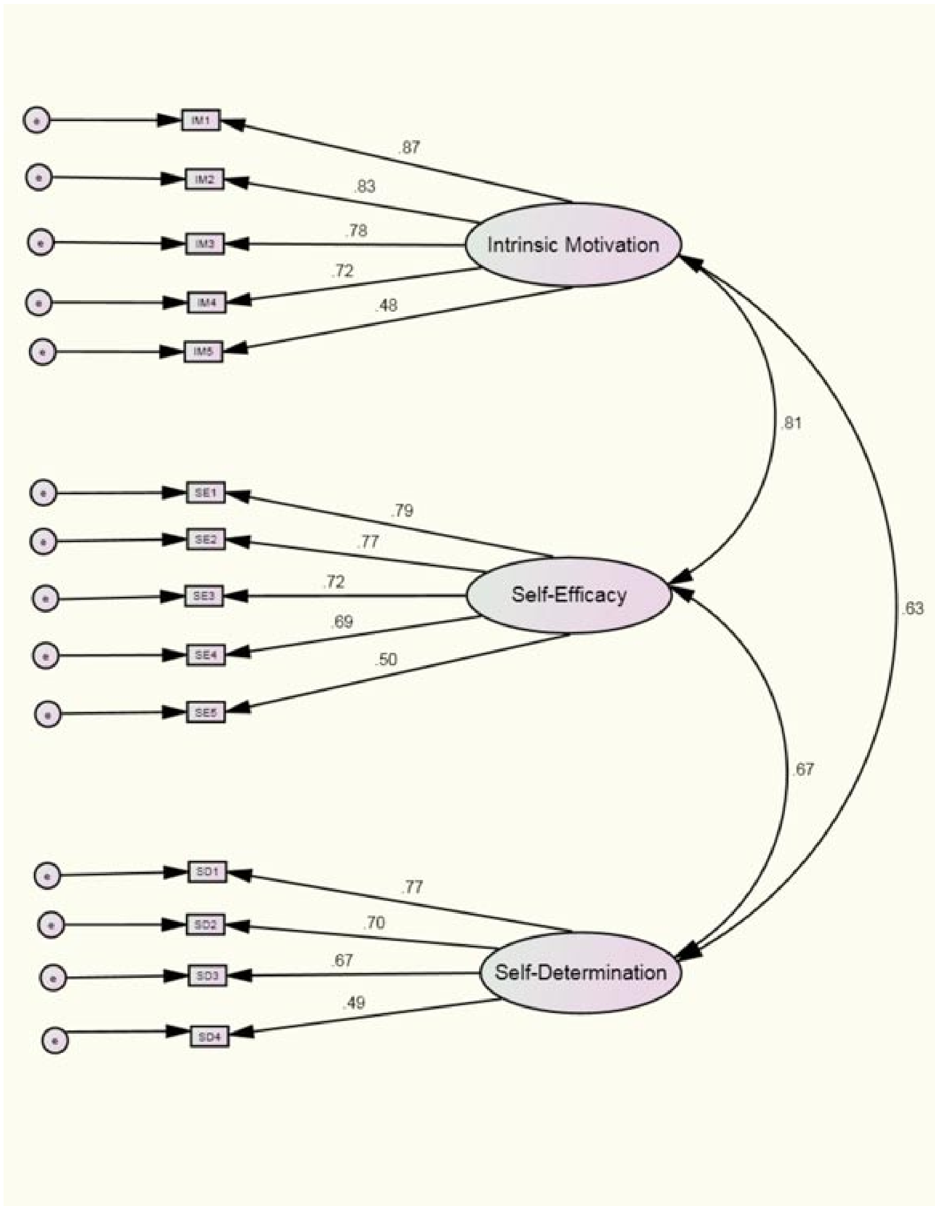

Figure 1. Confirmatory factor analysis model, with standardized loadings of items (e.g., IM1) on the motivation components, and the relationships among the components. The $n = 288$.

by the degrees of freedom (χ^2/df), producing a normed χ^2, with a value in a recommended range of 1.0 to 3.0.

Our second index was a standardized root mean square residual (SRMR), which represents the average value, ranging from 0 to 1, across all standardized residuals. This value will be .05 or less in a well-fitting model. Our third index was a goodness-of-fit (GFI) index, which estimates the proportion of variability in the sample covariance matrix explained by the model. The GFI ranges from 0 to 1, with a value of .90 or higher indicating a good model fit. Our fourth index, the Bentler comparative fit (CFI) index, compares our model with the standard "null" (independence) model that assumes zero population covariances among the observed variables. The CFI ranges from 0 to 1, with a value of .90 or higher indicating a good fit. Our fifth index, the Steiger-Lind root-mean-square error of approximation (RMSEA), assesses a lack of fit of the population data to the estimated model; a value of less than .10 indicates a good model fit.

The analysis of the questionnaire data yielded fit indices of $\chi^2/df = 2.63$, SRMR = .05, GFI = .91, CFI = .93, RMSEA = .08, indicating that the measurement model fits the data well, providing evidence of construct validity. The unstandardized estimates of parameters—the item regression weights, covariances of factors, and variances of factors and errors—were all reasonable and statistically significant; all standard errors were appropriate in size. The standardized factor loadings and relationships among the factors provided by AMOS are in Figure 1. The factor loadings (validity coefficients) indicate how well a given item measures its corresponding factor. The loadings ranged from high to moderate—the lowest was .48, exceeding the factor-loading criterion of .35. The relationships shown among the three motivation components in Figure 1 (all ps < .001) were disattenuated (i.e., adjusted for measurement error) and thus may be viewed as representing the true associations between components (in comparison with the zero-order correlations reported in the previous section). In the second step of the model-building approach, we determined that the relationships of intrinsic motivation, self-efficacy, and self-determination with achievement were .40, .62, and .38, respectively (all ps < .001).

Gender and AP Intent

An independent samples χ^2 test revealed no statistically significant difference between the expected and observed frequencies (see Table 2) of male and female AP aspirants and nonaspirants: 34.51% of the males were AP aspirants, and 35.62% of the females were AP aspirants.

Another χ^2 test, $\chi^2(1) = 3.76$, $p = .05$, approached statistical significance between the expected and observed frequencies of first-year biology and second-year physical science AP aspirants and nonaspirants: 40.56% of the first-year biology students were

TABLE 2
Motivation and Achievement Scores of Male and Female AP Aspirants and Nonaspirants

		AP Aspirants			Nonaspirants		
		Male ($n = 49$)	Female ($n = 52$)	Total ($n = 101$)	Male ($n = 93$)	Female ($n = 94$)	Total ($n = 187$)
Intrinsic	*M*	18.90	17.63	18.25	15.25	13.93	14.58
Motivation	*SD*	3.15	4.18	3.75	4.09	3.79	3.98
Self-Efficacy	*M*	19.61	19.56	19.58	16.68	15.65	16.16
	SD	3.33	3.38	3.34	3.90	3.59	3.77
Self-Determination	*M*	14.45	14.56	14.51	12.52	13.09	12.80
	SD	3.15	2.67	2.90	2.88	2.86	2.88
Achievement	*M*	86.71	85.15	85.91	76.48	77.77	77.13
	SD	8.43	9.79	9.14	10.85	10.20	10.52

Note: Intrinsic motivation and self-efficacy scores could range from 5 to 25, self-determination scores from 4 to 20, and achievement scores from 0 to 100.

AP aspirants and 29.66% of the second-year physical science students were AP aspirants. This is noteworthy because the former were registering in 1 year, whereas the latter were registering in 1 week.

In the following sections, means were compared using independent samples t-tests. When the comparisons were statistically significant ($p < .05$), Cohen's d effect size (Cohen, 1992) was computed, interpreting effects as negligible (0 to .19), small (.20 to .49), medium (.50 to.79), or large (.80 and above). Effect sizes are helpful for making practical decisions.

Motivation components. As can be seen in Table 2, the AP aspirants scored higher than the nonaspirants on intrinsic motivation, $t(286) = 7.60$, $p < .001$, Cohen's $d = 0.95$; self-efficacy $t(286) = 7.64$, $p < .001$, Cohen's $d = 0.96$; and self-determination, $t(286) = 4.78$, $p < .001$, Cohen's $d = 0.59$. Males and females scored similarly, with one exception: Among nonaspirants, males scored higher than females in intrinsic motivation, $t(185) = 2.30$, $p < .05$, Cohen's $d = 0.33$. The size of this effect was small.

Achievement. As can be seen in Table 2, the AP aspirants had higher achievement ($M = 85.91$; $SD = 9.14$) than the nonaspirants ($M = 77.13$; $SD = 10.52$), $t(286) = 7.07$, $p < .001$, Cohen's $d = 0.89$. The AP aspirant males and females did not differ significantly in their achievement, nor did the nonaspirant males and females.

Essays and Interviews

We asked all 288 students to write essays and subsequently interviewed 28 of them—14 randomly selected females and 14 randomly selected males—to provide insight into their motivation to learn science. Examples of students' explanations of their motivation are in Table 3. The relatively high, moderate, and low motivation categories were based on the students' questionnaire responses. There were no statements about AP science courses in the low motivation category.

Following Patton's (2002) recommendations, we used the questions in our interview guide as "sensitizing concepts" to deductively identify patterns of statements in the interviews and essays; we then looked inductively for additional patterns. "How motivated are you and why?" was associated with statements about the relationship of science to one's future education and career possibilities. Students' use of words like "interest," "confident," and "challenge" suggested that intrinsic motivation, self-efficacy, and self-determination, respectively, contributed to the strength of this relationship. "What aspects of your science courses motivate you to learn?" was associated with statements that hands-on activities, good grades, and good teachers were motivating. Good teachers were described as knowledgeable, inspiring, enthusiastic, and caring. "What aspects of your science courses discourage you from learning?" was associated with statements that "boring" instruction, complicated content and tests, and too many facts discouraged learning. "What isn't being done enough in your science courses, which could be done more, to increase your motivation to learn?" was associated with statements that more socially interactive projects, collaborative-learning labs, field trips, and demonstrations would be motivating. In addition to the patterns of statements directly related to the questions, there was a pattern inductively identified: Students interested in AP science courses stated they valued science highly, welcomed an intellectual challenge, and wanted an advantage getting into a good college.

DISCUSSION

Within the framework of social cognitive theory, we examined high school students' motivation to learn science in their introductory science courses. The students responded to a questionnaire about their intrinsic motivation, self-efficacy, and self-determination.

TABLE 3
Example Quotes from Students' Explanations of Their Motivation to Learn Science and AP Intent

High Motivation to Learn Science

Science didn't start off as a subject that I was very strong at. Still, I made straight A's in my middle-school classes .... I started enjoying the facts and figures in science. Entering high school enlightened me that knowledge was very important .... and having a great teacher. I believe that I have tried my hardest this year, striving to get good grades, along with learning interesting facts. Although I am young, I have learned that to be successful, you have to try your hardest in your classes, science included.

I'm very motivated because I have the goals I set for myself that include a lot of science. I want to go to school to be a vet. I really like biology and other sciences. I guess when it's just lecture, it doesn't catch my attention. I do more in lab settings rather than at my desk. It's easier to learn when I do hands-on stuff. I'm motivated when the class is fun. I don't dread it. When it's lecture I learn a lot, but it's harder to learn and harder to pay attention. [To motivate students] show how you would use science ... and what you have to do to get to your goals. That would help ... me know what I need, and I want to learn it. You could talk about different careers and how science is used for those.

I will sign up for AP science classes because I feel like I can do it and I need the challenge. I have always liked learning science. I love it. I want to be an elementary school teacher and I will need to know science for when I teach the students.

AP science courses ... I enjoy challenging myself and I know that they would be a challenge and I've decided to go for it. In the other [regular] science courses, I'd be more advanced and wouldn't even need to study. I want to learn something, not just memorize things.

I am very motivated to learn science and take harder science classes because it will help me get into college. I will sign up for two AP science classes. My mom wants me to. She said others [regular science courses] are a waste of time. Science and math are my favorite subjects.

Moderate Motivation to Learn Science

I have always loved science, and it's my favorite subject. It comes natural to me, and I like labs. When you like something, you try harder at it. I'm a physical person and [I like] doing things, so I like labs and it helps me understand better.... Because I want to be an athletic trainer ... anatomy and chemistry are important. I don't think there is any part of science that discourages me. I love science. I'm highly motivated and I try hard in science.... I don't know, it [motivation] just depends on the person. I like doing more physical things, but some people like math and problem-solving more.

I'm motivated to learn science because it will help me in my future career as a doctor. If I learn as much as I can now, there will be less to do later ... if that makes any sense. Also, I love science because you learn why things happen, and why they happen the way they do.

AP science ... I just really want to push myself because I know I can go above my standards, and it looks better on college application. So I pick a higher class, so I can see how much better I can get.

I will take AP science classes because I get to learn more and I'm challenged, otherwise it's boring. The people you associate with are in AP.

When I am learning something new and interesting that I can apply, I am encouraged. I will take AP science classes because I want a challenge and you have to apply yourself more and go more depth in learning in AP classes. Science is related to my career, I guess ... I want to pursue computer/engineering/electronics, so science would apply to that.

(Continued)

TABLE 3
Continued

Low Motivation to Learn Science
I am motivated to learn science when we are learning in a fun way. I don't like doing book work, it just makes me really unmotivated to learn. I hate having homework too. Homework also makes me unmotivated. When we get to pick our groups, that motivates me. When teachers pick our partners or groups, and I don't know anyone in the group, I feel intimidated, and I don't work. I just sit there. When you teach us in a fun way, that really motivates me. But if it's just book work, I don't like it, so I really don't care or try.
I passed biology with a 70 something. . . . When we do projects, I like that better because there are more people in a group to help. You can use the book with projects, and it's easier than the tests. When we do tests, I'm not good at taking tests, so I don't like that part. I feel like I forgot everything when I'm taking a test because we can't use the book, even though I felt like I knew before I came in. When I'm taking a test I don't understand it, but when I'm not taking the test, I understand it. I get frustrated when taking tests. We don't have enough time on all the chapters and move too fast to learn. If I had more time, I wouldn't feel as anxious when testing.
I didn't do very well in my science class this year, probably because I didn't try hard enough. I don't really like science. It's boring. Why would you want to learn it anyway? It can be cool when they do labs and stuff, but I don't really care to learn anything about science. More labs and less worksheets and tests and quizzes would make me more motivated to learn science. My middle school science classes . . . [my teachers] shouldn't have rushed through it [science] so fast, because we had science and social studies together.
Some of the science is interesting because it's hands-on, and I do better with hands-on. I do better with someone helping me . . . explaining how to work formulas and do labs before I have to do it . . . then I could complete the worksheet after the activity or lab. Energy lessons aren't that interesting, and we're given worksheets and that's more discouraging. I don't like the energy stuff, and I don't like learning about plants . . . . More hands-on learning would increase motivation [and] like the teacher helping you complete the work by working an example or activity first and then having the class complete it.

We found that these motivation components were related to each other and achievement and that self-efficacy was the component most related to achievement, consistent with its emphasis in social cognitive theory:

> Efficacy beliefs play a central role in the self-regulation of motivation through goal challenges and outcome expectations. It is partly on the basis of efficacy beliefs that people choose what challenges to undertake, how much effort to expend in the endeavor, how long to persevere in the face of obstacles and failures, and whether failures are motivating or demoralizing. (Bandura, 2001, p. 10)

In addition to being consistent with social cognitive theory, our finding regarding the strong relationship of self-efficacy to achievement is consistent with the educational histories of noted scientists such as Dorothy Crowfoot Hodgkin. In the British secondary school she attended, girls were not permitted to study chemistry, but she persevered and was admitted to the boys' chemistry classes. Several years later, she majored in chemistry at Oxford where "the biggest problem—and one she minded a great deal—was that the chemistry club uniting Oxford's chemists did not permit women to belong or attend meetings" (McGrayne, 2001, p. 235). Like many other noted scientists, Hodgkin's self-efficacy enabled her to persevere in the face of difficulties—she received the Nobel Prize in chemistry in 1964 for determining the structure of vitamin B-12.

Gender, AP Intent, and Achievement

In connection with the students' motivation, the variables we focused on were gender, AP intent, and achievement. The girls and boys were similar in their AP intent: About one-third of the girls and one-third of the boys were AP aspirants. The girls and boys were also similar in their self-efficacy, self-determination, and achievement. Among the students who were not intending to take AP courses, the girls had lower intrinsic motivation than the boys, but this difference was small. Gender-related differences of this kind are believed to be due to socialization by parents, teachers, peers, media, and role modeling rather than to "innate or natural differences" between girls and boys (Xie & Shauman, 2003, p. 215).

In terms of the motivation components, the AP aspirants scored higher than the nonaspirants on intrinsic motivation, self-efficacy, and self-determination. These findings indicate that the AP aspirants' motivation to learn science was broadly based in that all three components contributed to it. On a less positive note, although about 41% of students in their first year planned to register for AP courses, only about 30% of the students in their second year planned to do so. It may be that the first-year students were relatively liberal in their self-assessment of their AP potential because they had a year to register, whereas the second-year students were conservative because they were registering in 1 week.

Implications for Science Teaching

Motivation and achievement both play a role in a student's decision to register for AP science courses. Proficient science teachers are aware of this and take these variables into account when encouraging a student to register for AP courses. This encouragement is important because some students may not be aware they have AP potential. It is also important for science teachers to recognize when students are not yet ready for AP courses. Some students who might do well in a regular science course might do poorly in an AP science course if they lack the motivation and prior achievement needed to learn at the AP level. In fact, the percentages of students nationally earning a failing score of 1 or 2 on AP exams has been increasing in recent years, raising concerns that students are being encouraged to participate in the AP Program without adequate preparation (Sadler, 2010).

The College Board developed a Web-based tool called AP Potential that allows schools to identify students who are likely to score a 3 or better on a given AP exam. This tool is based on research that shows correlations between scores on the AP exams and the Preliminary SAT/National Merit Scholarship Qualifying Test (PSAT/NMSQT). AP Potential is designed to help schools increase access to AP and "ensure that no student who has the chance of succeeding in AP is overlooked." A limitation of AP Potential is that it does not take into account a student's motivation, but the College Board (2010b) emphasizes the importance of doing so:

> AP Potential should never be used to discourage a motivated student from registering for an AP course, since the AP Potential results only account for some of the factors that contribute to the students' exam results, and do not take into account the power of an individual student's motivation. (p. 1)

In introductory science courses, it can be challenging for teachers, particularly new ones, with a full load of courses to estimate and monitor each student's motivation. To facilitate this, we recommend that teachers use motivation questions like ours to assess students' motivation at the beginning, midpoint, and end of courses. During advisement, the teachers should discuss students' responses and emphasize the importance of motivation. Students who are metacognitively aware of their motivation are better equipped to self-regulate their science-learning behavior (Bandura, 2001; Schunk et al., 2008). Students' motivation responses—along with classroom observations, career interests, grades, standardized test scores, and the AP Potential Web-based tool—should be taken into account by teachers when speaking with students (and their parents or guardians) about AP science courses. Students' motivation responses can also be used to improve instruction when integrated into comprehensive science-assessment programs (e.g., Liu, 2009).

In their essays and interviews, the students in the present study stated that they were motivated, in part, by the relevance of science to their education and career interests. This implies that science teachers should make a special effort to connect science concepts to students' current and future lives by explaining the importance of scientific literacy, describing the many career opportunities in science, and inviting scientists from the community to participate regularly in school science activities (Aschbacher, Lee, & Roth, 2010).

The students also stated they were motivated by hands-on activities, good grades, and teachers who were knowledgeable, inspiring, enthusiastic, and caring. The students were discouraged by information overload, and they were particularly critical of teachers who relied excessively on PowerPoint presentations. Understandably, given that they were 14–16 years old, the students wanted more autonomy, inquiry, and social interaction in their science classes (see Blumenfeld, Kempler, & Krajcik, 2006). Specifically, they wanted more labs, field trips, and collaborative projects. The students with high motivation eagerly anticipated AP science courses because, they believed, these courses have challenging science content and teachers who are particularly gifted. References to such teachers are frequent in the educational histories of noted scientists. For example, Steven Chu provided this description of one of his teachers:

> In my senior year [of high school], I took advanced placement physics.... Instead of a long list of formulas to memorize, we were presented with a few basic ideas.... My physics teacher, Thomas Miner, was particularly gifted.... In addition to an incredibly clear and precise introduction to the subject, Mr. Miner also encouraged ambitious laboratory projects.... At Garden City High, I constructed a physical pendulum and used it to make a "precision" measurement of gravity.... Ironically, twenty-five years later, I was to develop a refined version of this measurement using laser cooled atoms in an atomic fountain interferometer. (Chu, 1997)

For the development of methods to cool and trap atoms with laser light, Chu received the Nobel Prize in physics in 1997. He is currently the U.S. Secretary of Energy.

Future Research Directions

One direction for future research is to examine ways to increase all students' motivation to learn science and interest in AP courses and science-related careers. One way, consistent with social cognitive theory and its emphasis on role models, is to recruit women and men who are in science-related careers in the community to participate in school science activities and serve as science role models. These women and men should share their educational histories—particularly high school histories—career responsibilities, and professional and personal challenges, focusing on science experiences that will increase students' intrinsic motivation, self-efficacy, and self-determination. The sharing of experiences and feelings about those experiences will foster the social-modeling process and the students' identities as science learners (Halpern et al., 2007; Pugh, Linnenbrink-Garcia, Koskey, Stewart, & Manzey, 2010).

Another direction for future research is to conduct longitudinal studies of high school students' motivation to learn science. The present study found that fewer second-year students than first-year students planned to register for AP science courses. The first 2 years of high school may be a critical period when students turn toward or away from a science career path (Potvin, Hazari, Tai, & Sadler, 2009). For those students who turn toward a science career path, their last 2 years of high school may be a critical period for motivation to learn particular areas of science. During this period girls may turn toward or away from a physical science career path. Longitudinal studies are needed that examine how students' motivation to learn science changes over the course of 4 years in high school in response to science instruction, and how these changes influence variables such as students' achievement, AP course enrollments, AP course grades, AP exam scores, career interests, and college plans.

CONCLUSION

It is essential that students' motivation to learn science be assessed and fostered in introductory high school science courses. The motivation to learn science can lead students to scientific literacy—to understand scientific knowledge, identify important scientific questions, draw evidence-based conclusions, and make decisions about how human activity affects the natural world. The motivation to learn science can also lead students to AP science courses, college science majors, scientific careers and, perhaps, to remarkable scientific discoveries, such as those of Nobel laureates Dorothy Crowfoot Hodgkin and Steven Chu.

REFERENCES

Arbuckle, J. L. (2006). Amos 7.0 User's Guide. Chicago: SPSS.

Aschbacher, P. R., Lee, E., & Roth, E. J. (2010). Is science me? High school students'identities, participation and aspirations in science, engineering, and medicine. Journal of Research in Science Teaching, 47, 564–582.

Baldwin, J., Ebert-May, D., & Burns, D. (1999). The development of a college biology self-efficacy instrument for non-majors. Science Education, 83, 397–408.

Bandura, A. (1986). Social foundations of thought and action: A social cognitive theory. Englewood Cliffs, NJ: Prentice-Hall.

Bandura, A. (2001). Social cognitive theory: An agentive perspective. Annual Review of Psychology, 52, 1–26.

Bandura, A. (2005). The primacy of self-regulation in health promotion. Applied Psychology: An International Review, 54, 245–254.

Bandura, A. (2006). Going global with social cognitive theory: From prospect to paydirt. In S. I. Donaldson, D. E. Berger, & K. Pezdek (Eds.), The rise of applied psychology: New frontiers and rewarding careers (pp. 53–70). Mahwah, NJ: Erlbaum.

Black, A. E., & Deci, E. L. (2000). The effects of instructors' autonomy support and students' autonomous motivation on learning organic chemistry: A self-determination theory perspective. Science Education, 84, 740–756.

Blumenfeld, P. C., Kempler, T. M., & Krajcik, J. S. (2006). Motivation and cognitive engagement in learning environments. In R. K. Sawyer (Ed.), The Cambridge handbook of the learning sciences. New York: Cambridge University Press.

Britner, S.L. (2008). Motivation in high school science students: A comparison of gender differences in life, physical, and earth science classes. Journal of Research in Science Teaching, 45, 955–970.

Byrne, B. M. (2001). Structural equation modeling with AMOS: Basic concepts, applications, and programming. Hillsdale, NJ: Erlbaum.

Cassady, J. C. (2001). Self-reported GPA and SAT: A methodological note. Practical Assessment, Research & Evaluation, 7. Retrieved January 9, 2011, from http://PAREonline.net/getvn.asp?v=7&n=12.

Ceci, S. J., & Williams, W. M. (2007). Why aren't more women in science? Washington, DC: American Psychological Association.

Chu, S. (1997). Steven Chu—Autobiography. Retrieved January 9, 2011, from http://nobelprize.org/nobel_prizes/physics/laureates/1997/chu-autobio.html.

Cohen, J. (1992). A power primer. Psychological Bulletin, 112, 155–159.

College Board. (2009). 2009–10 Bulletin for AP students and parents. New York. Retrieved January 9, 2011, from http://professionals.collegeboard.com/profdownload/ap-student-parent-bulletin-2009-10.pdf.

College Board. (2010a). The sixth annual AP report to the Nation. Retrieved January 9, 2011, from http://www.collegeboard.com/html/aprtn/pdf/ ap_report_ to_the_nation.pdf.

College Board (2010b). AP Potential. Retrieved January 9, 2011, from https://appotential.collegeboard.com/app/loginGetAction.do.

Creswell, J. W., & Plano Clark, V. L. (2007). Designing and conducting mixed methods research.Thousand Oaks, CA: Sage.

DeVellis, R. F. (2003). Scale development: Theory and applications (2nd ed.). Thousand. Oaks, CA: Sage.

Eccles, J. S., Simpkins, S. D., & Davis-Kean, P. E. (2006). Math and science motivation: A longitudinal examination of the links between choices and beliefs. Developmental Psychology, 42, 70 – 83.

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. Annual Review of Psychology, 53, 109 – 132.

Feinstein, N. (2011). Salvaging science literacy. Science Education, 95, 168 – 185.

Food Research and Action Center (2010). Child nutrition fact sheet: National School Lunch Program. Retrieved January 9, 2011, from http://www.frac.org/pdf/cnnslp.PDF.

Glynn, S. M., & Koballa, T. R., Jr. (2006). Motivation to learn college science. In J. J. Mintzes & W. H. Leonard (Eds.), Handbook of college science teaching (pp. 25 – 32). Arlington, VA: National Science Teachers Association Press.

Glynn, S. M., Taasoobshirazi, G., & Brickman, P. (2007). Nonscience majors learning science: A theoretical model of motivation. Journal of Research in Science Teaching, 44, 1088 – 1107.

Glynn, S. M., Taasoobshirazi, G., & Brickman, P. (2009). Science motivation questionnaire: Construct validation with nonscience majors. Journal of Research in Science Teaching, 46, 127 – 146.

Halpern, D. F., Aronson, J., Reimer, N., Simpkins, S., Star, J. R., & Wentzel, K. (2007). Encouraging girls in math and science [IES Practice Guide]. Washington, DC: Institute of Education Sciences, U.S. Department of Education.

Kelly, G. J. (2011). Scientific literacy, discourse, and epistemic practices. In C. Linder, L. Östman, D. A. Roberts, P. Wickman, G. Erikson, & A. McKinnon (Eds.), Exploring the landscape of scientific literacy (pp. 61 – 73). New York: Routledge.

Kline, R. B. (2005). Principles and practice of structural equation modeling. New York: Guilford Press.

Koballa, T. R., Jr., & Glynn, S. M. (2007). Attitudinal and motivational constructs in science education. In S. K. Abell & N. Lederman (Eds.), Handbook for Research in Science Education (pp. 75 – 102). Mahwah, NJ: Erlbaum.

Liu, X. (2009). Essentials of science classroom assessment. Thousand Oaks, CA: Sage Publications.

McGrayne, S.B. (2001). Nobel Prize women in science: Their lives, struggles, and momentous discoveries (2nd ed.). Washington, DC: Joseph Henry Press.

National Research Council (1996). National science education standards. Washington DC: National Academy Press.

National Science Foundation. (2009).Women, minorities, and persons with disabilities in science and engineering. Division of Science Resources Statistics Report, NSF 09-305. Retrieved January 9, 2011, from http://www.nsf.gov/statistics/wmpd/pdf/nsf09305.pdf.

Organisation for Economic Cooperation and Development. (2007). Assessing scientific, reading and mathematical literacy: A framework for PISA 2006. Retrieved January 9, 2011, from http://www.oecd.org/dataoecd/63/35/37464175.pdf.

Pajares, F., & Schunk, D.H. (2001). Self-beliefs and school success: Self-efficacy, self-concept, and school achievement. In R. Riding & S. Rayner (Eds.), Self-perception (pp. 239 – 266). London: Ablex Publishing.

Patton, M. Q. (2002). Qualitative research and evaluation methods (3rd ed.). Thousand Oaks, CA: Sage.

Pintrich, P. R. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. Journal of Educational Psychology, 95, 667 – 686.

Potvin, G., Hazari, Z., Tai, R. H. & Sadler, P. M. (2009). Unraveling bias from student evaluations of their high school science teachers. Science Education, 93, 827 – 845.

Pugh, K. J., Linnenbrink-Garcia, L., Koskey, K. L. K., Stewart, V. C., & Manzey, C. (2010). Motivation, learning, and transformative experience: A study of deep engagement in science. Science Education, 94, 1 – 28.

Roberts, D. (2007). Scientific literacy/science literacy. In S. K. Abell & N. G. Lederman (Eds.), International handbook of research on science education (pp. 729 – 780). Mahwah, NJ: Erlbaum.

Sadler, P. (2010). Advanced Placement in a changing educational landscape. In P. Sadler, R. Tai, K. Klopfenstein, and G. Sonnert (Eds.), Promise and impact of the Advanced Placement Program (pp. 3 – 16). Cambridge, MA: Harvard Education Press.

Sanfeliz, M., & Stalzer, M. (2003). Science motivation in the multicultural classroom. The Science Teacher, 70(3), 64 – 66.

Scantlebury, K., & Baker, D. (2007). Gender issues in science education research: Remembering where the difference lies. In S. Abell & N. Lederman (Eds.), Handbook of research on science education (pp. 257–286). Mahwah, NJ: Erlbaum.

Schunk, D. H., Pintrich, P. R., & Meece, J. L. (2008). Motivation in education. (3rd ed.). Upper Saddle River, NJ: Pearson.

SPSS, Inc. (2008). SPSS Base 17.0 User's guide. Chicago, IL: SPSS, Inc.

U.S. Department of Education (2010). Institute of Educational Sciences, National Center for Education Statistics: Numbers and types of public elementary and secondary schools from the common core of data: School year 2008–09. Retrieved January 9, 2011, from http://nces.ed.gov/pubs2010/2010345.pdf.

Xie, Y., & Shauman, K. A. (2003). Women in science: Career processes and outcomes. Cambridge, MA: Harvard University Press.