

## Nonscience Majors Learning Science: A Theoretical Model of Motivation

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**Abstract:** A theoretical model of nonscience majors' motivation to learn science was tested by surveying 369 students in a large-enrollment college science course that satisfies a core curriculum requirement. Based on a social-cognitive framework, motivation to learn science was conceptualized as having both cognitive and affective influences that foster science achievement. Structural equation modeling was used to examine the hypothesized relationships among the variables. The students' motivation, as measured by the Science Motivation Questionnaire (SMQ), had a strong direct influence on their achievement, as measured by their science grade point average. The students' motivation was influenced by their belief in the relevance of science to their careers. This belief was slightly stronger in women than men. Essays by the students and interviews with them provided insight into their motivation. The model suggests that instructors should strategically connect science concepts to the careers of nonscience majors through such means as case studies to increase motivation and achievement.

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More than 50 years ago, Linus Pauling (1951), recipient of a Nobel Prize for chemistry and a Nobel Peace Prize, made a compelling case for nonscience majors learning science in college courses:

It is impossible to deny that science has played a major part in determining the nature of the modern world. The food that we eat, the clothes that we wear, the means of transportation that we use in going from place to place, the medicines that keep us well, the weapons that we use in killing each other have all been changed in recent years through scientific discovery. It may well be contended that the world is now in a dangerous situation because science and its application has developed faster than the understanding of the average citizen. It is evidently of great importance to attempt to improve this situation

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through a program of education of the citizen in science . . . The citizen must have knowledge enough of the world to make the right decisions; and in the modern world this means that the citizen must have a significant understanding of science. (p. 10)

Pauling's argument for nonscience majors learning science in college courses remains just as valid today, perhaps more so. To ensure that nonscience majors learn science, colleges include life science and physical science requirements in their core curricula. These requirements are intended to ensure that colleges, in addition to preparing science majors who will serve as the next generation of scientists, also prepare scientifically literate nonscience majors who can think scientifically in fields such as the social sciences, the arts, consumer science, business, and law (American Association of Colleges and Universities, 2006).

In recognition of the importance of nonscience majors connecting science to their careers, a current mission of the American Association of Colleges and Universities (2006) is "to advance broad-based systemic innovation to connect science education, especially in general education, to large public questions where scientific inquiry and knowledge are essential." The goal is to help nonscience majors become scientifically literate citizens who are able to understand the scientific issues (e.g., global warming, population density, and genetic engineering) that confront them in the rapidly changing world of the 21st century. According to the National Science Education Standards of the National Research Council (1996), scientifically literate citizens should be able to evaluate scientific issues based not only on the available scientific information, but also on the sources of that information and the methods used to generate it. In addition, scientifically literate citizens should be able to use technical terminology, apply scientific concepts, use scientific procedures, evaluate scientific arguments, and draw scientific conclusions (DeBoer, 2000; Reveles, Cordova, & Kelly, 2004).

As instructors of college science courses respond to current reform initiatives to foster students' science literacy, the important role of students' motivation has received increased attention (Dalgety, Coll, & Jones, 2003; Siebert, 2001). At many colleges, the science courses for nonscience majors often have hundreds of students enrolled in each section, making it difficult to address the specific needs of individuals. Anecdotal evidence suggests that many of these students are poorly motivated, do not see the relevance of science to their careers, and find science frustratingly difficult (Arwood, 2004; Druger, 1998). As Duchovic, Maloney, Majumdar, and Manalis (1998) observed, "For the nonscience undergraduate student, satisfying a natural science requirement . . . is often an overwhelmingly threatening prospect. There is an impression that the sciences constitute an intellectual edifice that is impossible to scale" (p. 258).

Poor motivation in nonscience majors likely leads to low achievement. A shared challenge, therefore, for instructors of science at all institutions, particularly those with large enrollment classes, is to motivate nonscience majors to learn science successfully.

### Theoretical Framework

*Motivation* is the internal state that arouses, directs, and sustains students' behavior toward achieving certain goals. In studying the motivation to learn science, researchers attempt to explain why students strive for particular goals, how intensively they strive, how long they strive, and what feelings and emotions characterize them in this process.

According to Brophy (1988), *motivation to learn* is "a student's tendency to find academic activities meaningful and worthwhile and to try to derive the intended academic benefits from them" (pp. 205–206). Within the *social-cognitive* framework of motivation (Bandura, 2001, 2005a, 2005b, 2006), behavior is conceptualized as the product of characteristics of an individual,

such as gender, interacting with characteristics of a specific environment, such as a required science course.

Within the social-cognitive framework, each student is viewed as possessing a self-regulating system that affects beliefs and aids in the development of motivation that enables behavior cognitively and affectively (Schunk & Pajares, 2001). The self-regulatory system affects a student's academic achievement by influencing behaviors such as class attendance, class participation, question asking, advice seeking, studying, and participation in study groups (Pajares, 1996, 2001, 2002; Pajares & Schunk, 2001).

There are at least five key constructs within the self-regulatory system that contribute to a student's overall motivation to learn and, consequently, achievement (Bandura, 2001; Schunk, 2001). First, there is *intrinsic* and *extrinsic* motivation. Motivation to do something for its own sake is mainly intrinsic, whereas motivation to do it as a means to an end is mainly extrinsic (Mazlo et al., 2002). Second, there is *goal orientation*. Students with *learning goals* tend to be intrinsically motivated, seeking understanding and a mastery of science content and skills, whereas students with *performance goals* tend to be extrinsically motivated, seeking to earn the highest grades and impress their instructors (Cavallo, Rozman, Blinkenstaff, & Walker, 2003). Third, there is *self-determination*. When students believe they have some degree of control over their learning, such as selecting some of their lab topics, motivation is increased (Reeve, Hamm, & Nix, 2003). Fourth, there is *self-efficacy*, defined by Bandura (1997) as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p. 3). Students' self-efficacy has been found to predict grades in college science courses (Zusho & Pintrich, 2003). Fifth, there is *assessment anxiety*. A high level of assessment anxiety has been found to hinder students' motivation and achievement (Cassady & Johnson, 2002).

### A Proposed Model of Motivation to Learn Science

Consistent with a social-cognitive motivational framework (Bandura, 2001, 2006), we propose that characteristics of an individual, such as a student's gender and career interests, interact with characteristics of a specific learning environment, such as a required science course, to influence a student's motivation to learn and, consequently, achievement. Within this framework we pose the question: What motivates a nonscience major to learn science in a large-enrollment science course? The answer is not clear, unfortunately, because previous research has focused on the motivation of science majors; it is they who are "in the pipeline" to the science careers that contribute to our nation's economy. The motivation of nonscience majors merits attention as well, however, because science plays an increasingly important role in careers in traditionally "nonscience" fields (e.g., agriculture) that also contribute to our nation's economy.

The research literature on *science majors* suggests that gender is an important variable in the learning of science in college courses (Green & DeBacker, 2004). For example, Cavallo, Potter, and Rozman (2004) found that, among science majors studying physics, the "male students had significantly higher self-efficacy, performance goals, and physics understanding compared to females, which persisted throughout the course" (p. 288). It has also been found that, among the science majors who "leak from the science pipeline" during the undergraduate years, there is a higher percentage of women than men (Siebert, 2001). It is sometimes assumed that "ability," as measured by the Scholastic Achievement Test (SAT) or a Grade Point Average (GPA), is the cause of this attrition, but many studies have shown that ability is not necessarily the determining factor. "Switchers" from science majors (to nonscience majors) and "nonswitchers" have often been found to be similar in their self-reported GPA and the amount of time they worked in their science courses (Seymour, 1992; Xie & Shauman, 2003). It has been suggested that the

competitive, male-dominated culture of many science programs can inadvertently undermine the motivation of women and impede efforts to retain them (Siebert, 2001).

In comparison with science majors, much less is known about the role that gender plays in the motivation of nonscience majors. Among nonscience majors, women and men may be equally motivated to learn science because all are preparing for careers in fields such as the social sciences, the arts, consumer science, business, and law—fields in which women are relatively well represented (Fadigan & Hammrich, 2004). In fact, the women may be even more motivated than the men, as evidenced by the women's academic behavior. For example, Zusman, Knox, and Liberman (2005) studied 278 undergraduates (science majors and nonmajors) and found that the women were more likely to attend class on time, sit in the front of the class, take notes, study the textbook, and study in an organized way—all behaviors associated with a relatively high motivation to learn.

In connection with gender, another important variable we examined is the belief in the relevancy of learning science to one's career. A central tenet of the social-cognitive framework is that students' beliefs can have a powerful influence on their motivation and achievement (Bryan, 2003; Pintrich, 1990). Students' beliefs about their careers are considered to be particularly influential (Smith, Gould, & Jones, 2004; Solberg, Howard, Blustein, & Close, 2002). Recently, the American Association of Colleges and Universities commissioned a series of student focus groups around the country and found the following:

Professional success was identified by the participants in all eight focus groups as the primary reason for pursuing a college degree, which students recognize as a basic requirement for success in today's competitive job marketplace. They understand, further, that college is important not only for obtaining a first job, but also for career advancement and success down the line. (Humphreys & Davenport, 2005, p. 36)

The few studies conducted on nonscience majors' career beliefs suggest that contemporary women tend to be more career oriented than men (Luzzo, 1995; Morinaga, Frieze, & Ferligoj, 1993; Patton & Creed, 2001). Luzzo (1995, p. 321), studied the "career-mature attitudes" and "career decision-making skills" of 401 women and men and concluded: "Undergraduate women seem to be much more planned in the career decision-making process than undergraduate men." Furthermore, women may be more likely than men to believe that science is relevant to their careers. Seymour and Hewitt (1997) found that women were more likely than men to be influenced by the advice of academic counselors and instructors on topics such as the career value of required science courses.

In the present study, we are proposing a theoretical model that depicts nonscience majors' motivation to learn science as an *intervening* variable (*mediator* variable) between science achievement, as measured by science GPA, and two other variables, gender and belief in the relevancy of science to one's career. The social-cognitive motivational framework and the research we reviewed suggest that these variables are important ones. There are other variables that could be added to the model in an attempt to completely account for students' achievement, but our goal in this study was to begin with a relatively parsimonious model that could later be revised as needed.

The students in the present study had been advised by faculty to enroll in science courses to satisfy core curriculum requirements. Based on Seymour and Hewitt's (1997) research, we anticipated that the women would be more likely than the men to have confidence in their advisement and in the career relevance of these courses. The belief that science has relevance to one's career could influence students' achievement in two ways. The first way is cognitive: the

thoughts associated with the belief could lead to academic behavior (e.g., studying) that directly influences achievement. The second way is both cognitive and affective—in other words, it is motivational. The belief could arouse, direct, and sustain not only thoughts, but also feelings (e.g., anxiety), leading to behavior that influences achievement.

In the present study, we used structural equation modeling (SEM) to test the preceding assumptions about students' gender, career belief, motivation, and science achievement; to understand the patterns of correlations among these individual difference variables; and to explain as much of their variance as possible. We *specified* our theoretical model by proposing the following hypotheses:

- Students' gender affects their motivation and their belief in the relevancy of science to their probable careers.
- Students' belief in the relevancy of science to their careers affects their achievement directly—and indirectly, by affecting their motivation.
- Students' motivation affects their achievement.

Because all of our variables were *observed* rather than *latent*, because there was one measure of each variable, and because we had prior hypotheses about the causal relationships among our variables, we used the SEM technique of *path analysis* to examine the hypothesized relationships among our variables (Kline, 2005). Using path analysis, our specific goals were to estimate the direct and indirect effects in our model, to control for the correlations among the hypothesized causal variables, and to “decompose” the correlations we observed into their component parts (causal and spurious). Although a correlation, in itself, does not imply causation, path analysis makes it possible to cautiously draw causal inferences from patterns of correlations.

Figure 1 depicts our theoretical model, with each of the hypothesized *paths* among the variables. In this model, the career variable and the motivation variable are intervening (mediating) variables. An intervening variable serves a dual role because it “conducts” some of the causal effects of a prior variable onto a subsequent variable. For example, the career variable is hypothesized to conduct some of the causal effect of the gender variable onto the motivation variable. Similarly, the motivation variable is hypothesized to conduct some of the causal effect of the career variable onto the science GPA variable.

To satisfy the conditions of path analysis for the inference of causality, our hypothesized relationships involved time precedence and a logical direction of causality, consistent with the research reviewed. Also, our relationships were hypothesized to remain intact when external variables were held constant. Finally, our model was *recursive*: the sources of unexplained variance (*disturbances*) were assumed to be uncorrelated and the causal effects to be unidirectional.

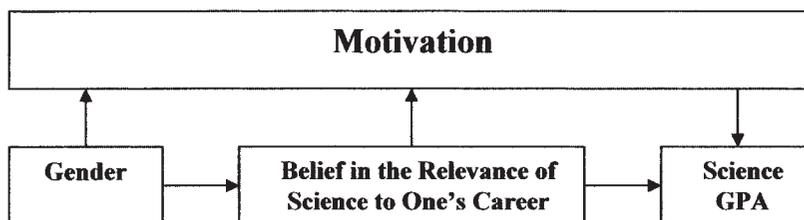


Figure 1. Theoretical model of nonscience majors' motivation to learn science.

## Method

### *Participants*

At a public university with 25,204 undergraduate students in the southern United States, we studied 369 undergraduate students (282 women and 87 men) enrolled in two sections of *Basic Concepts in Biology*, a 15-week semester course for nonscience majors, with three 1-hour lectures and a 2-hour lab each week. The greater number of women than men in this sample is representative of the unequal gender distribution in this course. Two factors are responsible for this distribution. First, the university, like many large public universities, has more women (58%) than men (42%) undergraduates. Second, among the nonscience majors, the women outnumber the men. (The university does not report data categorizing women and men by majors, but men are considered to be underrepresented in large-enrollment nonscience majors in the humanities, the arts, education, and consumer science.)

Some of the participating students were from underrepresented groups, including Asian/Pacific Islander (5.8%), African American (5.5%), Multiracial (2.4%), Hispanic or Latino (2.0%), and Native American (0.2%). These percentages were similar to those of the university population. Minority status was not treated as a statistical variable because there were relatively small numbers in each underrepresented group and statistical inferences might be misleading.

A majority of the students in both sections of the course participated: 66% and 69%, respectively. The students' participation was voluntary, following the guidelines for research with human participants specified by the university's institutional review board, with informed consent forms signed by the students. The students volunteered "to help us better understand the goals of nonscience majors" and to earn a small amount of extra credit. The students participated during the 13th and 14th weeks of the 15-week fall semester. Those who did not participate explained later that they "forgot," "lost the instructions," or "didn't have time." The same professor, a woman with a PhD in genetics and 10 years teaching experience, taught both sections using the same syllabus.

### *Procedures and Measures*

We used a confidential on-line questionnaire to gather information from the students. In *Part A* of the questionnaire, we explained to the students that "Your responses will help science-education researchers to better understand and improve science instruction." We then asked the students to report their gender, the relevance of science to their probable careers, and their science GPA. To promote candid responses to the questionnaire, the students were assured their identities would remain confidential. Under such conditions, self-reported GPA has been found to be reliable (Cassady, 2001).

We asked the students, "What is the relevancy of science to your probable career," to which they responded on a Likert-type scale where 5 = *very high relevancy*, 4 = *high*, 3 = *medium*, 2 = *low*, and 1 = *very low relevancy*. All students received three variations of this question, and they responded similarly to all variations.

We also asked students to report their science GPA, which was the average grade they had received in the college science courses ( $M = 4.85$  courses;  $SD = 2.52$ ) they had already taken, such as chemistry, geology, geography, astronomy, or physics. The students' science GPA ( $M = 3.07$ ;  $SD = 0.75$ ) was on a scale where 4.0 = A, 3.0 = B, 2.0 = C, 1.0 = D, and 0 = F.

In *Part B* of the on-line questionnaire, we asked the students to respond to the 30 items of the *Science Motivation Questionnaire* (SMQ; Glynn & Koballa, 2006). The items were presented

without the SMQ title and with the instructions: “In order to better understand what you think and feel about your college science courses, please respond to each of the following statements from the perspective of: When I am in a college science course . . .”

The SMQ items (see Table 1) were developed based on the motivation concepts described earlier in this article and on previous interviews conducted with students learning science in college courses. The SMQ items ask students to report on *intrinsically motivated science learning*

Table 1  
*Science Motivation Questionnaire (SMQ)*

In order to better understand what you think and feel about your college science courses, please respond to each of the following statements from the perspective of: “**When I am in a college science course . . .**”

01.	I enjoy learning the science. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
02.	The science I learn relates to my personal goals. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
03.	I like to do better than the other students on the science tests. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
04.	I am nervous about how I will do on the science tests. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
05.	If I am having trouble learning the science, I try to figure out why. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
06.	I become anxious when it is time to take a science test. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
07.	Earning a good science grade is important to me. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
08.	I put enough effort into learning the science. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
09.	I use strategies that ensure I learn the science well. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
10.	I think about how learning the science can help me get a good job. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
11.	I think about how the science I learn will be helpful to me. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
12.	I expect to do as well as or better than other students in the science course. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
13.	I worry about failing the science tests. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
14.	I am concerned that the other students are better in science. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
15.	I think about how my science grade will affect my overall grade point average. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
16.	The science I learn is more important to me than the grade I receive. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
17.	I think about how learning the science can help my career. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
18.	I hate taking the science tests. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
19.	I think about how I will use the science I learn. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
20.	It is my fault, if I do not understand the science. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always
21.	I am confident I will do well on the science labs and projects. <input type="radio"/> Never <input type="radio"/> Rarely <input type="radio"/> Sometimes <input type="radio"/> Usually <input type="radio"/> Always

(Continued)

Table 1  
(Continued)

In order to better understand what you think and feel about your college science courses, please respond to each of the following statements from the perspective of: “**When I am in a college science course . . .**”

22.	I find learning the science interesting.	<input type="radio"/> Never	<input type="radio"/> Rarely	<input type="radio"/> Sometimes	<input type="radio"/> Usually	<input type="radio"/> Always
23.	The science I learn is relevant to my life.	<input type="radio"/> Never	<input type="radio"/> Rarely	<input type="radio"/> Sometimes	<input type="radio"/> Usually	<input type="radio"/> Always
24.	I believe I can master the knowledge and skills in the science course.	<input type="radio"/> Never	<input type="radio"/> Rarely	<input type="radio"/> Sometimes	<input type="radio"/> Usually	<input type="radio"/> Always
25.	The science I learn has practical value for me.	<input type="radio"/> Never	<input type="radio"/> Rarely	<input type="radio"/> Sometimes	<input type="radio"/> Usually	<input type="radio"/> Always
26.	I prepare well for the science tests and labs.	<input type="radio"/> Never	<input type="radio"/> Rarely	<input type="radio"/> Sometimes	<input type="radio"/> Usually	<input type="radio"/> Always
27.	I like science that challenges me.	<input type="radio"/> Never	<input type="radio"/> Rarely	<input type="radio"/> Sometimes	<input type="radio"/> Usually	<input type="radio"/> Always
28.	I am confident I will do well on the science tests.	<input type="radio"/> Never	<input type="radio"/> Rarely	<input type="radio"/> Sometimes	<input type="radio"/> Usually	<input type="radio"/> Always
29.	I believe I can earn a grade of “A” in the science course.	<input type="radio"/> Never	<input type="radio"/> Rarely	<input type="radio"/> Sometimes	<input type="radio"/> Usually	<input type="radio"/> Always
30.	Understanding the science gives me a sense of accomplishment.	<input type="radio"/> Never	<input type="radio"/> Rarely	<input type="radio"/> Sometimes	<input type="radio"/> Usually	<input type="radio"/> Always

Note. From Glynn & Koballa (2006). Science educators who wish to use the *Science Motivation Questionnaire* © 2005 by Shawn M. Glynn & Thomas R. Koballa, Jr., for research and teaching have permission to do so if they acknowledge the authors, the source, and comply with the *fair use* of this copyrighted and registered work. This permission extends to SMQ versions such as the *Biology Motivation Questionnaire* (BMQ), *Chemistry Motivation Questionnaire* (CMQ), and *Physics Motivation Questionnaire* (PMQ) in which the words *biology*, *chemistry*, and *physics* are respectively substituted for the word *science*.

(items 1, 16, 22, 27, and 30), *extrinsically motivated science learning* (items 3, 7, 10, 15, and 17), *relevance of learning science to personal goals* (items 2, 11, 19, 23, and 25), *responsibility (self-determination) for learning science* (items 5, 8, 9, 20, and 26), *confidence (self-efficacy) in learning science* (items 12, 21, 24, 28, and 29), and *anxiety about science assessment* (items 4, 6, 13, 14, and 18). Students respond to each of the 30 randomly ordered items on a 5-point Likert-type scale ranging from 1 (*never*) to 5 (*always*). The *anxiety about science assessment* items are reverse scored when added to the total, so a higher score on this component means less anxiety.

The SMQ maximum total score is 150 and the minimum is 30. For present purposes, a score in the range of 30–59 is relatively low, 60–89 is moderate, 90–119 is high, and 120–150 is very high. Previous findings (Glynn & Koballa, 2006) indicate that the SMQ is reliable in terms of its internal consistency, as measured by coefficient alpha ( $\alpha = .93$ ), and valid in terms of positive correlations with college students’ science grades, decision to major in science, interest in science careers, and number of science courses taken. For present purposes, to examine a theoretical model of motivation to learn science, the total score on the SMQ served as a comprehensive measure of the students’ motivation. The six five-item scales that make up the SMQ are discussed in another context (Glynn & Koballa, 2006).

After the students responded to the SMQ items, we asked them to write essays 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. Also, standardized open-ended individual interviews (Patton, 2002; Silverman, 2000), using an interview guide form of basic questions (e.g., How useful is the science you learn in terms of your career?), were conducted with a sample of 38 students to gain additional

insight into the role that gender, belief in the relevance of science to one's career, and motivation play in science achievement. The students were randomly selected, with the following limitations: the students were selected from those who found it convenient to be interviewed before or after class, and who were willing to be interviewed. The only students who declined to be interviewed were two who said it was inconvenient for them.

The quantitative data were analyzed by means of SEM. SEM refers to a family of related statistical techniques, not to a single one. Path analysis and confirmatory factor analysis are examples of SEM techniques; exploratory factor analysis, on the other hand, is not an example of the SEM family, in part because it does not require a priori hypotheses to conduct it. SEM is a priori, requires relatively large ( $N > 100$ ) samples, and is used to determine the magnitude of influence of one or several hypothesized causes on one or several hypothesized effects. SEM typically involves building or "specifying" a model, often depicted in a drawing, about how the variables in a set influence each other. SEM is most frequently used in nonexperimental (correlational) research in which neither the independent nor the dependent variables are manipulated, but SEM is also useful in experimental and quasi-experimental research. In the past, there were only a few software programs for conducting SEM, and these were awkward to use because they involved computer-code instructions; however, now there are a variety of user-friendly programs (e.g., see Kline, 2005, for a discussion of LISREL, EQS, CALIS, AMOS, and Mplus). SEM is being used increasingly in science education research because much of this research involves the representation and measurement of hypothetical constructs (e.g., Willson, Ackerman, & Malave, 2000).

A core SEM technique, path analysis, was applied to the present data. Path analysis involves the estimation of hypothesized causal relations among observed variables. The path analytic technique involves building a model aimed at explaining why variables 1, 2, 3, and so forth, are correlated. This explanation should take into account effects that are causal (e.g., variable 1 causes variable 2) and noncausal or spurious (e.g., variable 2 and variable 3 are related, but only because they are both caused by variable 1). Thus, the main goal of a path analysis, such as the one conducted in this study, is to build a model that explains the causal and noncausal components of observed correlations in a set of variables.

## Results

With the *Statistical Program for the Social Sciences*, version 13.0 (SPSS, Inc., 2004), we computed descriptive statistics, mean comparisons, and correlations among the variables in the proposed theoretical model of motivation. We then used SEM to test and refine our model of motivation. Specifically, we used LISREL Version 8.52 (Jöreskog & Sörbom, 2002), with a covariance matrix generated by PRELIS Version 2.52 (Jöreskog & Sörbom, 1996). Preliminary analyses indicated that the students in the two course sections did not differ significantly in number, gender, career belief, motivation, or science GPA, so these sections were combined ( $N = 369$ ) for subsequent analyses. There were no missing data values.

### *Descriptive Statistics, Mean Comparisons, and Correlations*

The belief that science was relevant to one's career was stronger in the women ( $M = 2.56$ ,  $SD = 1.21$ ) than the men ( $M = 2.20$ ,  $SD = 1.07$ ),  $t(367) = 2.52$ ,  $p < .05$ , as indicated by an independent samples  $t$ -test. Neither the women nor the men, however, believed that science had "high" relevance to their careers—both groups had mean ratings between "low" and "medium" relevance. Career relevance was a dominant theme in both the students' written explanations (Table 2) and their interview responses.

Table 2

*Samples of nonscience majors' explanations of their motivation to learn science**Very High Motivation to Learn Science (SMQ scores of 120 or above)*

I am a journalism major. I am interested in science, and I believe that it affects my life because I have been raised in it—my mother is a retired biology, anatomy, and physiology teacher of 30+ years.

My major is exercise and sports studies. With this major, I look to be an athletic trainer in the future.

Therefore, because science is a huge part of my major and career, it is a very important and interesting area for me.

I am a business major, and I'm not sure how much science will play a role in my career. I know that it will play a role in my everyday life though. My mom is a science teacher, and she has sparked an interest in science in me.

Being a physical therapy major, science is very important to my career. Thus, I feel it is important for me to learn and understand science. I have always enjoyed science.

My major is dietetics, and learning science is definitely going to help in that field. Science is very applicable in what I'm doing. It's also very interesting.

Since my major is early childhood education, and I plan on teaching 2nd grade, science will be one of the many subjects that I teach. Therefore, it will be a big part of my future career.

*High Motivation to Learn Science (SMQ scores of 90–119)*

Learning science is important in my field of psychology. For example, I need to understand basic science to understand chemical imbalances in people. I also need to learn good basic biology to help me with life.

Since I am a business major, science has less of an effect on my future career. I have learned about diet and genetics though, which are topics of high interest to me because they are relevant to my life.

My major does not require that much science, but it does require a little, so it is still important. Also, science in general is important, not just for my major or career, but for my life and body. I must understand science to better my life and career. It is everywhere and always present, so we must understand it.

I am a mathematics and math education major, and there is some math involved in some sciences. The parts of science classes I like are the parts that help me better understand the world around me.

I like science, but I tend to get B's in most science classes. I am a History/French major, and I plan to go to law school. I think the logical aspect of the sciences, as well as understanding cause-and-effect, will help me in my law career.

I am an international affairs major, so science is not really relevant to my major; however, I am interested in science in general because science explains everything that we are. Sometimes it's hard for me to grasp science material, but I work hard at it.

*Moderate Motivation to Learn Science (SMQ scores of 60–89)*

I am a Romance Languages major, so science does not really mean a whole lot to me as far as a career. I do, however, thoroughly enjoy learning about nature and especially the human body. Biology is very important to me because it helps me look at my health in a different light. I don't plan on focusing on science, but I recognize the importance of it.

While I like science, I do not see it as important to my major. However, I want to be a lawyer, and I do believe that learning about DNA could be very helpful. Maybe the things I learn about biology are probably not useful for my major or career, but are useful for understanding life.

I don't believe science (biology, chemistry, etc.) will help me understand business finance. However, although science may not help me in my career, I do think and realize that having a basic understanding of it is important to living a successful life.

I, personally, do not have a high interest in science. I want to be a speech pathologist and there is some science involved in that, so I know that I have to learn some science. My career goals definitely influence my science interest and performance in science. I know that I do need to learn it.

My major is art/interior design, so I do not have to have an extensive knowledge of science for my job. I am interested and motivated to learn science, however, even though it doesn't relate to my major. I sometimes enjoy learning science, but I still get anxious before tests.

Much of the time, I enjoy learning science. I just don't see the relevance of it in relation to my future career as a publicist.

*Low Motivation to Learn Science (SMQ scores of 30–59)*

As a history major, I plan to one day go on archeological digs. That being said, I do not expect to use much science in my career.

(Continued)

Table 2  
(Continued)

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I am an exercise and sports studies major. I have been told that once you are in the field, you never use science. I think that is unfair that I am required to take science, since I am struggling with the science courses.

I study political science and international affairs, and feel I do not need to know biology and other sciences in such great detail. The science of the body that I could learn in a basic health class is, in my opinion, sufficient for my field of study.

I'm planning on becoming an early education teacher, where high-level science will not likely be relevant. Also, I lack motivation because I'm forced to take science; it is not a choice.

For me, taking science classes is only a matter of fulfilling core requirements, and thus, my focus is the grade. I believe this is largely based on my major and career plans—journalism. I don't see science as any part of my future, and so, it's difficult for me to be very interested.

Science has never been a strong subject for me, which is why I have decided to pursue a business degree. My field of interest is definitely not science. This explains why I do not put as much effort into my science core courses as I do my business-oriented ones.

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There was no significant difference in the motivation ratings of the women ( $M = 96.68$ ,  $SD = 14.47$ ) and men ( $M = 96.10$ ,  $SD = 16.01$ ),  $t(367) = 0.32$ ,  $p > .05$ . Both the women and the men had mean motivation ratings that were relatively “high” (90–119) on the SMQ. The students' written explanations and interview responses indicated that many students were motivated to learn science, not because they found it relevant to their careers, but because they found it relevant to their health, life, and understanding of the world.

There was no significant difference between the science GPA of the women ( $M = 3.10$ ,  $SD = 0.72$ ) and the men ( $M = 2.97$ ,  $SD = 0.84$ ),  $t(367) = 1.42$ ,  $p > .05$ . Both the women and the men had a mean science GPA equivalent to a “B” (3.0).

As can be seen in Table 3, there was no significant Pearson product-moment correlation between gender and motivation; however, there was a significant, but low, correlation between gender and career, indicating that the women considered science to be more relevant to their careers than the men. There was also a significant, and more substantial, correlation between career and motivation, indicating that the belief that science was relevant to one's career was related to higher motivation. Likewise, a significant correlation between career and science GPA indicated that the belief that science was relevant to one's career was related to a higher science GPA. Finally, a significant correlation, and the highest one in the set at  $r = .56$ , between motivation

Table 3  
Correlation matrix, standard deviations, skewness, and kurtosis for the model variables

Variable	Gender	Career	Motivation	Science GPA
Gender	—			
Career	.13*	—		
Motivation	.02	.51**	—	
Science GPA	.07	.18**	.56**	—
<i>M</i>	—	2.48	96.55	3.07
<i>SD</i>	—	1.19	14.83	.75
Skewness	—	.49	−.64	−.73
Kurtosis	—	−.68	.56	1.12

\* $p < .05$ ;

\*\* $p < .01$ .

and science GPA, indicated that higher motivation was related to a higher science GPA. This latter correlation, in conjunction with the one between career and motivation, provides additional evidence of the validity of the SMQ as a measure of motivation. To provide evidence of the reliability of the SMQ, in terms of the internal consistency of its 30 items, a Cronbach coefficient alpha was computed, and it was found to be relatively high ( $\alpha = .93$ ).

### *Model Testing*

Before empirically testing the model, the data were examined for normality and homoscedasticity. Based on the data plots (histograms of the variables), examination of skewness and kurtosis statistics (see Table 3), and Mardia's coefficient = .99, the data met the assumptions of both univariate and multivariate normality. Based on a DeCarlo macro test, no outliers were found, also suggesting normality of the data.

We used LISREL Version 8.52 (Jöreskog & Sörbom, 2002), with a covariance matrix generated by PRELIS Version 2.52 (Jöreskog & Sörbom, 1996), to test the model by means of the maximum likelihood method of estimation. This method was used because the data were normally distributed. To evaluate the goodness of fit of the model, we considered a number of different indices (explained in the following paragraphs), as recommended by Kline (2005), because any given single index evaluates only particular aspects of model fit. The fit indices indicated that the overall fit of the theoretical model was acceptable: the model chi-square statistic was  $\chi^2(1) = 3.68$ ,  $p = .06$ ; the Steiger-Lind root-mean-square error of approximation was .08; the standardized root-mean-square residual was .03; the Bentler comparative fit index value was .99; and the incremental fit index was .99.

*Trimmed Model.* Because the correlation between gender and motivation was almost zero ( $r = .02$ ), and because the model may *misspecified* if an unimportant path is included (Kline, 2005; Pedhazur, 1997), the Gender-Motivation path was deleted, and we tested the more parsimonious, trimmed model depicted in Figure 2. We found the overall fit of this trimmed model to be good, as indicated by the fit indices used previously. First, we used the model chi-square statistic, an absolute fit index that addresses the degree to which the variances and covariances implied by the theoretical model match the observed variances and covariances. As used in SEM, it is a statistical test of "badness of fit," with significant values suggesting that the model does not reproduce the underlying covariance matrix (Hoyle & Panter, 1995). This logic is the reverse of what is typically the case in statistical testing, in which the goal is to reject the null hypothesis. Although frequently used in SEM, this statistic has two shortcomings. One is that it does not have a clear upper boundary because it is not "normed" so that values fall between 0 and 1. Another shortcoming is that the statistic is very dependent on sample size: larger samples yield larger chi-squares. Our failure to reject the null hypothesis indicated that our model fit well,  $\chi^2(2) = 4.93$ ,  $p = .09$ . To reduce the dependency of our obtained chi-square statistic on our sample size, we divided the statistic by the degrees of freedom, producing a normed chi-square of 2.47, a value that falls within the recommended fit range of 2.0–3.0 (Bollen, 1989; Kline, 2005).

We used the Steiger-Lind root-mean-square error of approximation (RMSEA) because it is an index that includes adjustments for model complexity so that evaluation of fit is not overly influenced by the number of parameters in the model (Steiger, 1995). The RMSEA assesses a lack of fit of the population data to the estimated model. Browne and Cudeck (1993) suggest that a RMSEA value of .08 or less indicates a good model fit. Our obtained value was .06.

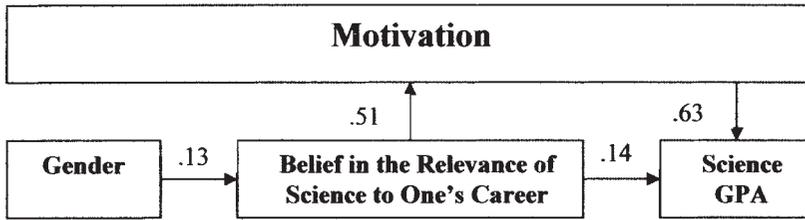


Figure 2. Trimmed model of nonscience majors’ motivation to learn science, with standardized path coefficients.

The standardized root-mean-square residual (SRMR) is an index based on the residuals between the observed and estimated covariance matrices (Hu & Bentler, 1998, 1999). The advantage of the SRMR is that it is sensitive to model misspecification. A value below .08 suggests a good model fit (Hu & Bentler, 1999). Our obtained value was .02.

Using the Bentler comparative fit index (CFI) (Bentler, 1990; Hu & Bentler, 1999), we compared our model with a model in which all variables were assumed to be uncorrelated. The latter is the standard “null” model (independence model) that assumes zero population covariances among the observed variables. The CFI ranges from 0 to 1, with larger values indicating a better fit in relation to the null model. An obtained value of .95 is generally considered to be a good fit, and our obtained value was .99.

Finally, we used the incremental fit index (IFI) (Widaman & Thompson, 2003) to compare our model to a baseline model in which the covariances among all the variables were assumed to be zero. Like the CFI, this index ranges from 0 to 1, with larger values indicating a better fit. Our obtained value was .99, indicating a good fit.

*Decomposition of Effects.* We used path analysis to estimate the direct and indirect effects in our model, control for the correlations among the hypothesized causal variables, and “decompose” the observed correlations into their component causal parts. The standardized path values and their associated *t*-values for our model are reported in Table 4. The direct and indirect path values were all statistically significant,  $p < .05$ , based on a cutoff value of  $t = 1.96$

Table 4  
Decomposition of effects in the estimated model

Predictor	Criterion	Effect			
		Direct		Indirect	
		PC	<i>t</i>	PC	<i>t</i>
Gender	Career	.13	2.52		
	Motivation			.07	2.46
	Science GPA			.02	2.05
Career	Motivation	.51	11.30		
	Science GPA	.14	2.73	.32	8.40
Motivation	Science GPA	.63	12.56		

Note. PC refers to standardized path coefficient. All *t* values were significant,  $p < .05$ ; tests were two tailed. In terms of the relative size and meaningful influence of the path coefficients: those below .10 were considered negligible, those between .10 and .15 were small, those between .15 and .25 were moderate, and those above .25 were large (Keith, 1993).

for a two-tailed test. The criterion  $R^2$  (proportion of variance explained) by career was .02, by motivation was .26, and by science GPA was .32.

Figure 2 depicts the variable paths and the standardized path values. In interpreting the relative size and meaningful influence of the standardized path values, which can range from 0 to 1, we adopted criteria similar to those of Keith (1993): path values in the .10 to .15 range were considered relatively small, but still meaningful in their influence; path values in the .15 to .25 range were moderate in size and in their influence; and path values above .25 were large in size and influence.

The Gender-Career direct path value (.13) was small, indicating that gender had a small direct influence on the belief in the relevance of science to one's career. The Career-Motivation direct path value (.51) was large, indicating that the belief in the relevance of science to one's career had a large direct influence on motivation to learn science. The Career-Science GPA direct path value (.14) was small, indicating that the belief in the relevance of science to one's career had a small direct influence on science GPA. The Motivation-Science GPA direct path value (.63), which was the largest of any of the effects, indicated that motivation to learn science had a large direct influence on science GPA.

The Gender-Career-Motivation indirect path value (.07) and the Gender-Career-Science GPA indirect path value (.02) were negligible in their influences; however, the Career-Motivation-Science GPA path value (.32) was relatively large in its influence, indicating that the belief in the relevance of science to one's career affects motivation to learn science which, in turn, affects science GPA.

Taken together, the preceding findings were generally consistent with the hypotheses of the present study and provide support for the theoretical model of motivation proposed. First, the findings indicated that students' gender had a small direct influence on their belief in the relevance of science to their probable careers. Second, the students' belief in the relevance of science to their careers had a small influence on their science GPA directly—but a large influence indirectly, by affecting the students' motivation to learn science. Finally, the students' motivation to learn science had a large direct influence on their science GPA.

## Discussion

We examined a theoretical model of nonscience majors' motivation to learn science. The model was based on a social-cognitive framework of motivation and tested by means of path analysis, a core SEM technique (Kline, 2005). The findings were generally consistent with the proposed model. The path analysis provided quantifiable evidence that the students' motivation to learn science, as measured by the SMQ, had a very strong influence on their science achievement, as measured by science GPA. The students' motivation was influenced by their belief in the relevance of science to their careers. This belief tended to be stronger in women than men.

The gender of the nonscience majors did not influence their motivation to learn science. This is important because, in many studies of science majors (e.g., Cavallo et al., 2004), men have been found to have higher motivation than women. We interpret this finding as having a positive implication: in science courses for nonscience majors there is a relatively "level playing field" that supports the women's motivation as well as the men's. We believe our finding generalizes across science courses for nonscience majors because the students in the present study were asked about their science courses in general, not just about their current course. In science courses for nonscience majors, the women are not as likely to be marginalized, as they sometimes are in courses for science majors, by a predominantly male culture that can inadvertently undermine some women's motivation, by mechanisms such as too few women instructors serving as role

models (Siebert, 2001). In science courses for nonscience majors, the women are more likely to be regarded as “players” by all concerned—advisors, instructors, the men in the courses, and most importantly, the women themselves. This is most likely to occur when the course instructors include women and the women’s enrollment equals or exceeds that of the men (Ginorio, 1995).

Although gender did not influence motivation, it did have a small influence on another variable, the belief in the relevance of science to one’s career. We found that the women were more likely to hold this belief than the men. This finding is consistent with the view that college women have greater confidence in the “wisdom” behind their advisement (Seymour & Hewitt, 1997), particularly advisement about the value of their core curriculum science courses.

Although the women believed that science was more relevant to their careers than the men, neither group believed that science was highly relevant to their careers. These nonscience majors did not make strong connections, the kind of connections advocated by American Association of Colleges and Universities (2006) and the National Research Council (1996), between what they were learning in their science courses and what they would be doing professionally for the rest of their lives.

Although these nonscience majors did not believe that science was highly relevant to their careers, many were highly motivated to learn science, but this was often for reasons that had nothing to do with career relevancy. For example, many students were motivated by health reasons. These students explained that understanding basic concepts in biology is relevant to the health issues that confront them and their friends at this point in their lives—issues such as diet, eating disorders, conception, abortion, and sexually transmitted diseases.

The students with low motivation to learn science explained that there was little need to understand basic concepts in biology, or in other areas of science in which they had taken courses, such as chemistry. According to these students, basic concepts in biology and chemistry are irrelevant for majors such as business. In our opinion, however, these students were not considering the possibility that they might some day work for corporations such as Johnson & Johnson<sup>®</sup> or The Dow Chemical Company<sup>®</sup>, and that an understanding of biology and chemistry concepts *could* play a significant role in their business careers.

Career concerns dominated the thinking of many of these nonscience majors, and these concerns were evident in their essays and interview responses. Our findings suggest that instructors should do more to connect concepts in life science and physical science to the varied careers that nonscience majors have in mind. Expecting that most of the students will make such connections on their own, especially specific connections, is probably unrealistic. Our model indicated that making specific connections is important for developing motivation and increasing achievement.

The curriculum of the biology course for nonscience majors in this study was standard in that it included lectures, demonstrations, labs, and a widely used textbook (Krogh, 2005) that covered concepts such as cellular respiration, photosynthesis, immune-system function, and plant reproduction. Like most contemporary biology courses for nonscience majors, the curriculum stressed the relevance of biology to everyday life. For example, the students learned how meiosis has helped shape the living world by making it more diverse, and students even learned about topics such as the physiology of acne, the dangers of suntans and loud music, and the reasons for menstruation. The curriculum also included case studies (Herreid, 2005) that encouraged students to connect biological concepts with real-world issues and to think critically about these issues. In one of the case studies, for example, the students learned that the cell cycle is critically involved in the initiation of cancer; the students were then asked to hypothesize about what environmental factors lead to cancer. In another case study, the students learned how to evaluate food labels; the

students were then asked to distinguish ingredients containing carbohydrates from those containing proteins and lipids.

Standard case studies such as these, although relatively effective in fostering critical thinking, had a limitation: they rarely connected the concepts in the course to the students' future careers in areas such as the social sciences, the arts, consumer science, business, and law. This was a significant limitation because the present findings showed that the students' belief in the relevance of science to their careers influenced their motivation to learn science which, in turn, influenced their achievement. These findings suggest that instructors should make a special effort to connect biology concepts to students' future careers. Case studies that incorporate career information are ideal tools for strategically fostering these connections. For example, pre-law students could be provided with a case study in which a lawyer must prove that the acid rain (acid deposition) from the coal- and oil-burning power plants in a region interfered with the metabolic processes of the local wildlife, such as the fish in the region's lakes. In analyzing this case study and thinking critically about the issues involved, the students would come to understand that the lawyer's knowledge of the metabolic processes of the wildlife played a crucial role in winning the lawsuit. As a result, the students would connect the case study to their own future careers, increasing their motivation to learn science.

The social-cognitive framework and the research we reviewed suggested that the variables we examined were important ones, but other variables merit attention as well. Our goal was to formulate a parsimonious model, but also one that could be expanded to describe the variation in students' motivation, by examining additional variables, such as membership in underrepresented groups. Membership in underrepresented groups was not treated as a statistical variable in the present study because the number in each group was small, each constituting less than 6% of the sample, and inferences might be misleading. But, such membership merits attention in future research, because some of the participants from underrepresented groups explained that it can be difficult for them to make learning partners and join study groups. This problem is intensified in a lecture-based science course that allows for little interpersonal interaction. Purposeful sampling strategies (Patton, 2002) applied to "information-rich cases" could yield more specific insights and in-depth generalizations regarding underrepresented groups.

Our model of nonscience majors' motivation to learn science should be expanded by incorporating multiple measures of science achievement. The inclusion of only one measure, science GPA, in the model was a limitation of this study, and it would be desirable in future research to include additional, more specific measures such as course examinations, projects, and labs. Another direction for future research is to conduct longitudinal, multisemester studies to examine the cumulative influence of variables such as science course grades on students' motivation. Over extended periods of time, higher grades will likely lead to higher motivation and lower grades to lower motivation. This kind of pattern of cumulative advantage and disadvantage over an extended period of time, with the academically "rich" getting richer and the "poor" getting poorer, has been referred to as the Matthew Effect in science (Merton, 1968). The Matthew Effect, first used to describe differences in the reputations of scientists, subsequently has been used to describe patterns of cumulative growth and decline in students' science achievement (Walberg, 1991).

Still another direction for future research is to compare nonscience majors with science majors in terms of their motivation to learn science. It is reasonable to assume that the motivation to learn science would be higher among science majors than nonscience majors; however, the motivation of some science majors could be relatively superficial. For example, some premed majors' motivation to learn science could be focused solely on gaining the knowledge that they think is necessary to get into and succeed in medical school. Such motivation is too limited and

extrinsic in nature, when considered in light of the goals of the American Association of Colleges and Universities (2006) and the National Research Council (1996) for scientifically literate citizens.

In conclusion, we return to the challenge that Pauling (1951) posed to science educators: “The citizen must have knowledge enough of the world to make the right decisions; and in the modern world this means that the citizen must have a significant understanding of science” (p. 10). The present findings suggest that progress in meeting Pauling’s challenge can be made by developing and refining theoretical models of how college students’ characteristics interact with science instruction to influence the students’ motivation and achievement. Furthermore, to meet Pauling’s challenge, the present findings suggest that science educators should endeavor to arouse, direct, and sustain their students’ motivation to learn by making explicit connections between the students’ future professional lives and the science they are learning.

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