Examining Factors that Influence High School Physics Students' Choice of Science as a Career

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Abstract

This study on high school physics students examined various factors referenced in the literature that may be related to choices in pursuing science careers. These factors include: students' learning approaches (meaningful versus rote), beliefs about Nature of Science (NOS), self-efficacy toward success in science, scientific reasoning, spatial ability, and science enjoyment. These factors were analyzed according to gender and science career choice. The purposes of this study were to: 1) explore possible differences and interactions between these factors among male and female high school physics students, and 2) determine relationships and possible predictive influences of learning approaches, beliefs about NOS, self-efficacy, scientific reasoning, and spatial ability, on science enjoyment and intentions to pursue science careers. Physics students in three different high schools (N = 138) were administered questionnaires to measure the selected factors. Among the findings were significant differences in learning approaches between males and females, with males using more meaningful learning compared to females; students pursuing science careers showed greater self-efficacy toward success in science; and males had higher spatial ability compared to female physics students. Self-efficacy was a significant predictor among females choosing to pursue science careers, whereas meaningful learning was the most significant predictor among male students.

Keywords: science career choice, scientific reasoning, meaningful learning, spatial ability, self-efficacy, nature of science, science enjoyment, gender differences

Introduction and Literature

The science education community has long struggled with declining scientific literacy and waning interest among students to pursue science-related careers. These issues have been so pervasive in the United States that the National Science Teachers Association (NSTA), American Association for the Advancement of Science (AAAS), American Chemical Society (ACS), and National Committee of Science Education Standards and Assessments (NCSESA) each developed initiatives specifically directed toward promoting scientific literacy among all students and encouraging more students to pursue Science, Technology, Engineering, and Mathematics (STEM) careers. Society is now realizing an immense dependency upon scientific and technological knowledge. However, many of today's students show a reluctance or aversion toward science and mathematics, and thus fail to take additional science and mathematics courses in high school or pursue science career paths. Thus, it is well established that dual problems exist with declining scientific literacy and decreasing interest in science careers among students. The current shortage of students pursuing science-related careers has been a prominent concern in the United States because of our nation's quest for leadership in innovation and economic development.

Several factors have been found relevant to examine in the current study based on findings reported and compiled from previous research as potentially related to students' science career choices [1,2,3,4,5,6]. These variables include *meaningful learning approaches*, *beliefs about Nature of Science (NOS), self-efficacy toward success in science*, *scientific reasoning ability*, and *spatial ability*. Meaningful learning is characterized by learners formulating or constructing interrelationships among information, concepts, and processes of science to achieve sound conceptual understandings. Meaningful learners link new ideas to what is known [7,8]. Unfortunately, many students do not construct interrelationships among information, concepts and processes, and tend to learn science by rote, with facts memorized in isolation with other ideas and concepts [9,10]. Learners' beliefs about nature of science (NOS) have been reported as falling into one of two opposing views, or epistemological beliefs. One view is that science is an authoritative, unchanging, fixed body of knowledge; the opposing view is that science is a tentative, dynamic process [11,12]. Students who hold fixed views of NOS may view science as static body of facts rather than an evidence-based exploratory process. Self-efficacy is the extent to which individuals are confident in their abilities within a specific context or content area [13]. Self-efficacy toward success in science may be related to science achievement and persistence among students [1]. The foundation for scientific reasoning ability is Piaget's intellectual development model [14] in which adolescent through adult learners range in ability from "concrete" to "formal" [15]. Students who are at the concrete stage rely on objects and direct experiences to guide their construction of understanding. Formal reasons do not rely on concrete objects and can learn new concepts in the abstract using logical-mathematical reasoning, mental manipulation, and transformation. Spatial ability is the ability to mentally visualize how objects are arranged in space, the relationships between objects in space, and mental rotation of these objects in space. According to a meta-analysis, spatial ability has a significant, strong influence on learning and achievement in STEM domains [16]. More specifically, spatial ability has been indicated in research to be important factor in learning and achievement in science [17,18,19].

Research has report mixed results on possible differences between male and female students on variables central to this study. Further, it is yet unknown how these variables may be differentially related to science enjoyment and career choices among male and female students in their final years of high school when attitudes toward science have likely been solidified based on past experiences, and career choices are in the process of being made.

Purpose

The purpose of this exploratory study was to investigate differences and predictive influences of the specified factors on high school male and female students' science enjoyment and choices to pursue science careers. The specific purposes of this research are:

1. To explore possible differences between high school physics students' learning approaches, beliefs about NOS, self-efficacy, scientific reasoning ability, spatial ability, and science enjoyment according to gender, intentions to pursue science careers, and the interaction between these variables.
2. To explore possible relationships and predictive influence of learning approaches, beliefs about NOS, self-efficacy, scientific reasoning, and spatial ability on male and female students' science enjoyment and intentions to pursue science careers.

Method

The student participants were 11th and 12th grade students (17 and 18 years old) enrolled in physics (N = 138) in three different public schools in a large urban area in the south-western United States. All three schools are classified by the state's Education Agency as economically disadvantaged (50 percent or more of students are on free and reduced lunch programs). Four teacher-researchers also participated in the study.

The teacher-researchers administered tests and questionnaires in their classrooms assigning code numbers for each student participant to preserve the identity of students in the data analyses. The code numbers were assigned to also help students feel they could respond to questions with assurance of confidentiality in their responses. The teachers were trained to administer the questionnaires and tests to students in their physics classes adhering to a common protocol and test administration procedure. Tests and questionnaires were administered at the same time during the spring semester of the academic year.

The tests and questionnaires used in this study are briefly described as follows.

Background Questionnaire. This questionnaire obtained information on participant's gender and ethnicity (optional) as well as their age, grade level, number of math and science courses taken, and interest(s) in pursuing science as a career.

The Learning Approach Questionnaire (LAQ). This questionnaire is a Likert-scale instrument that measures the extent to which students learn by memorizing or learning new information on a surface level (rote learning) versus the extent to which students learn by forming connections or interrelationships among concepts learned on a deep-structured level (meaningful learning) [1,2,3].

The Science Knowledge Questionnaire (SKQ). The SKQ is a Likert-scale instrument that measures students' views about the nature of science (NOS). The instrument measures the extent to which students' view science as fixed and authoritatively known, compared to the extent to which students' view science as dynamic and tentatively known (subject to change with new evidence) [2,4,11,12]. This questionnaire also includes questions regarding students' self-efficacy or confidence in their ability to be successful in science [5,13].

Classroom Test of Scientific Reasoning (CTSR). This test measures the scientific reasoning of participants ranging from concrete to formal operational (hypothetical-deductive) [2,15]. For each test item, students respond to a second part by selecting their reasoning for their answers. Both the item and reasoning response must be correct to receive points for the item.

Spatial Ability Test (SAPT). The spatial ability test used in this study was a test published at www.psychometric-success.com. This test determines the extent to which students are able to visualize the orientations of objects in space.

Students' responses to tests and questionnaires were entered onto a spread sheet and analysed using SPSS data analyses software. All appropriate statistical controls and assumptions were utilized in the analysis.

Results

Differences between high school physics students' learning approaches, beliefs about NOS, self-efficacy, scientific reasoning ability, spatial ability, and science enjoyment according to gender, intentions to pursue science careers, and the interaction between these variables.

Descriptive statistics were computed on the factors of this study for all students, and for male and female students. These results are shown in Table 1, and represented graphically in Figures 1 through 6. To determine if observed descriptive data were statistically different and analyze interactions between variables, 2-way analyses of variance (ANOVA) were conducted. The ANOVA procedure determines if the means shown in Table 1 are significantly different for each variable, with significance level set at $p < .05$. Results are reported within the respective figures.

Table 1. Means and SE for All Variables of This Study

Variable	*Meaningful Learning*		*Beliefs in NOS*		*Self-Efficacy*		*Scientific Reasoning*		*Spatial Ability*		*Science Enjoyment*	
Group	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Male	57.96	1.05	43.47	0.99	5.72	0.30	4.39	0.41	35.65	1.06	3.09	0.13
Female	54.69	0.69	43.02	0.65	5.28	0.20	3.42	0.28	32.04	0.71	2.58	0.09
Science Career	58.28	1.11	44.22	1.04	5.92	0.32	4.12	0.43	34.23	1.12	3.31	0.14
No Science Career	54.36	0.59	42.27	0.56	5.08	0.17	3.69	0.24	33.46	0.61	2.36	0.07
Female Yes Science Career	54.68	1.14	44.00	1.07	5.72	0.33	3.35	0.46	32.13	1.19	2.84	1.43
Female No Science Career	54.69	0.77	42.04	0.72	4.84	0.22	3.50	0.31	31.94	0.78	2.31	0.10
Male Yes Science Career	61.89	1.90	44.44	1.79	6.11	0.54	4.89	0.74	36.33	1.89	3.78	0.24
Male No Science Career	54.03	0.90	42.50	0.85	5.33	0.26	3.88	0.38	34.97	0.95	2.40	0.11

Differences in students' meaningful learning approaches according to gender and intentions to pursue science careers. As shown in Table 1 there are observed numerical differences in means in meaningful learning approaches according to gender and science career choice. The 2-way ANOVA results inset in Figure 1 indicated these differences were significant in main effect means, and in the interaction between gender and science career choice. Accordingly, male students use significantly more meaningful learning approaches compared to female students. Students pursuing science careers use significantly more meaningful learning approaches. The source of the significant interaction is that males pursuing science careers use significantly more meaningful learning approaches than males not pursuing science careers and compared to females who are pursuing science careers. Female students tend to use more rote strategies, regardless of whether or not they are pursuing science careers.

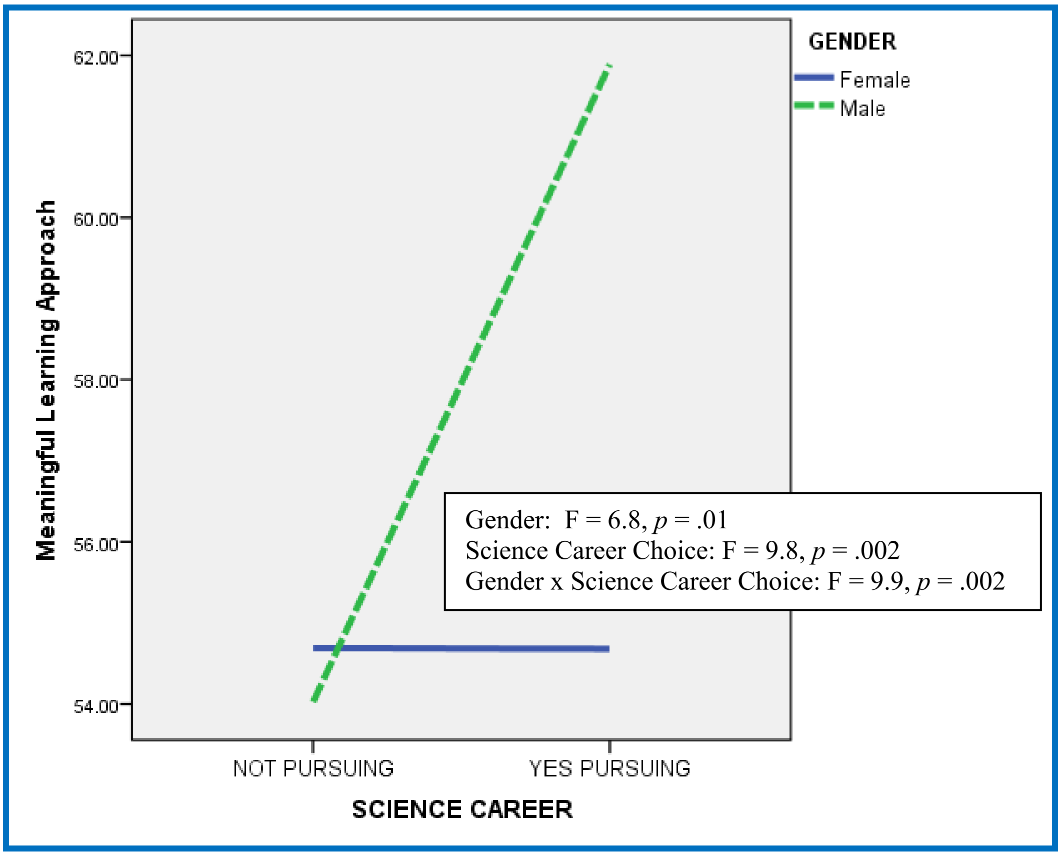

Figure 1. Meaningful Learning and Science Career Choice According to Gender

Differences in students' beliefs about NOS according to gender and intentions to pursue science careers. As shown in Table 1 and represented in Figure 2, the means for both males and females pursuing science careers were descriptively higher in the direction of more tentative views of NOS. However, the 2-way ANOVA results inset in Figure 2 indicated no statistical differences between males and females and between students pursuing/not pursuing science careers according to their beliefs in NOS.

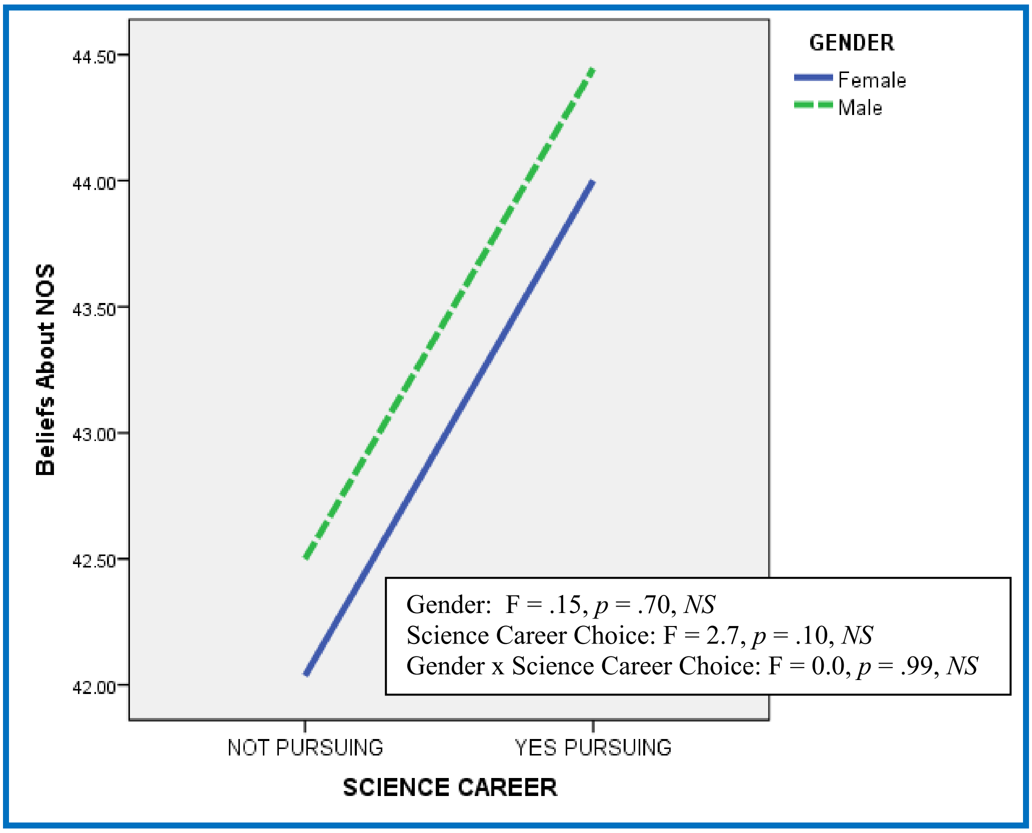

Figure 2. Beliefs about NOS and Science Career Choice According to Gender

Differences in students' self-efficacy according to gender and intentions to pursue science careers. As shown in Table 1 and Figure 3, there were descriptive level differences in self-efficacy means between students pursuing science careers compared to those not pursuing science careers. The 2-way ANOVA results inset in Figure 3 indicated these observed mean differences were significant, with students pursuing science careers having higher self-efficacy in their ability to be successful in science compared to students not pursuing science careers.

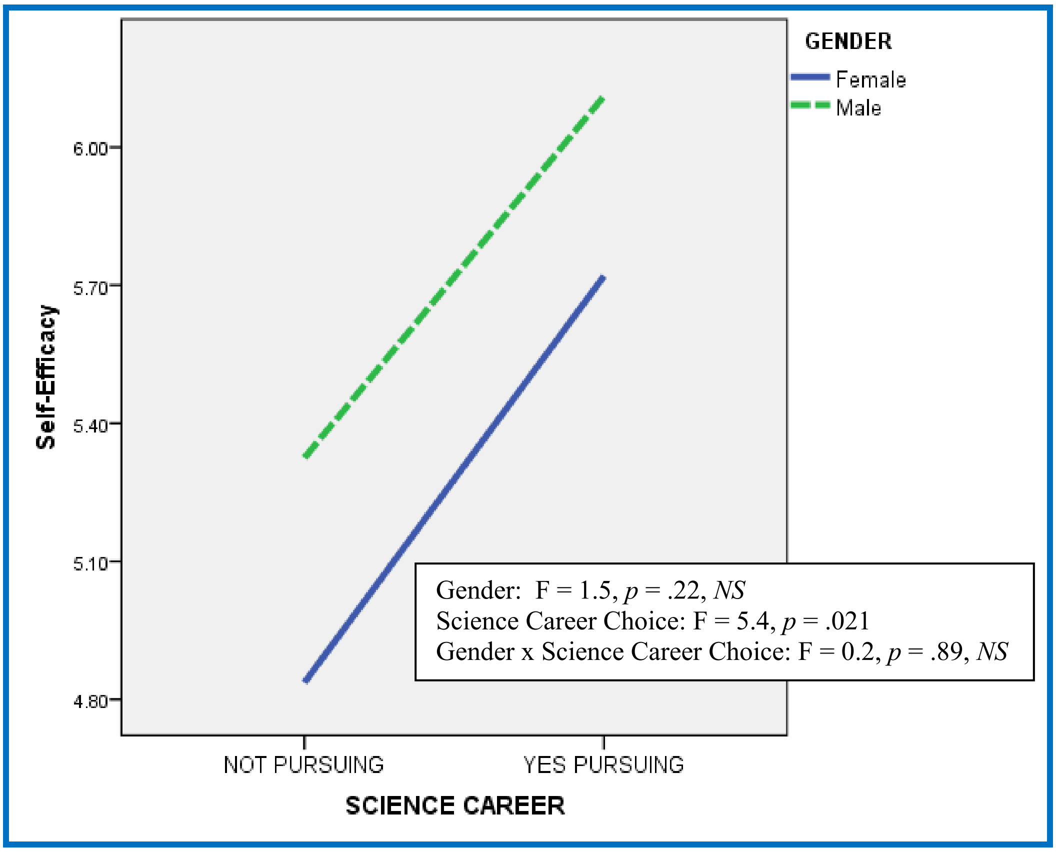

Figure 3. Self-Efficacy and Science Career Choice According to Gender

Differences in students' scientific reasoning ability according to gender and intentions to pursue science careers. As shown in Table 1 and Figure 4, scientific reasoning ability was descriptively higher for males compared to females. The 2-way ANOVA results inset in Figure 4 indicated the main effect of gender on scientific reasoning was not significantly different, though it approached significance (p = .056) and may be worthy of future investigation. There were no differences in scientific reasoning ability between students pursuing/not pursuing science careers.

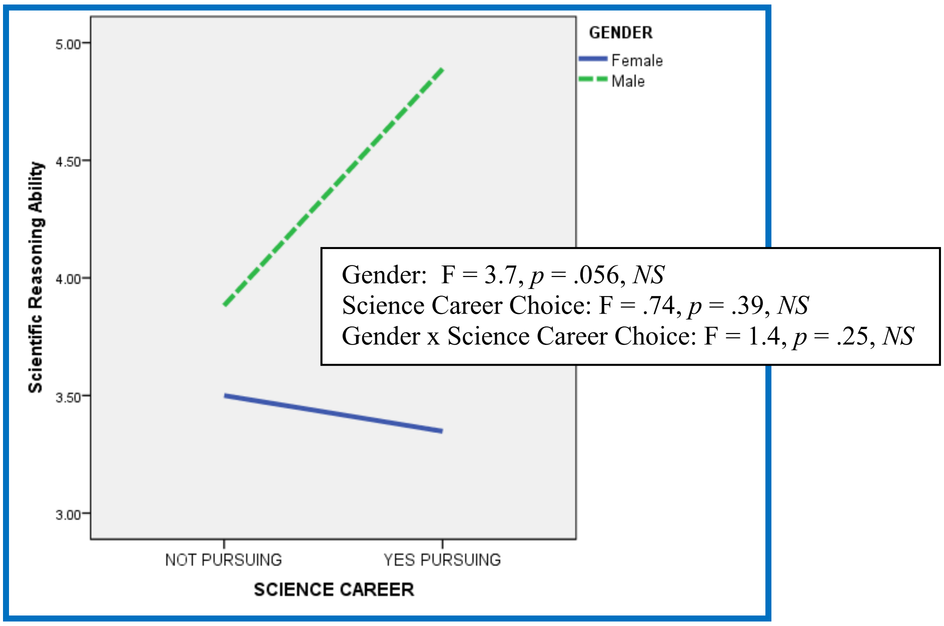

Figure 4. Scientific Reasoning Ability and Science Career Choice According to Gender

Differences in students' spatial ability according to gender and intentions to pursue science careers. As shown in Table 1 and Figure 5 there was a descriptive difference between males and females on spatial ability. This observed descriptive difference was found to be significant, as indicated in the 2-way ANOVA results inset in Figure 5. Males have significantly higher spatial ability than females in this study. There was no statistical difference in spatial ability according to choice to pursue or not pursue as science career, and no interaction between gender and science career choice.

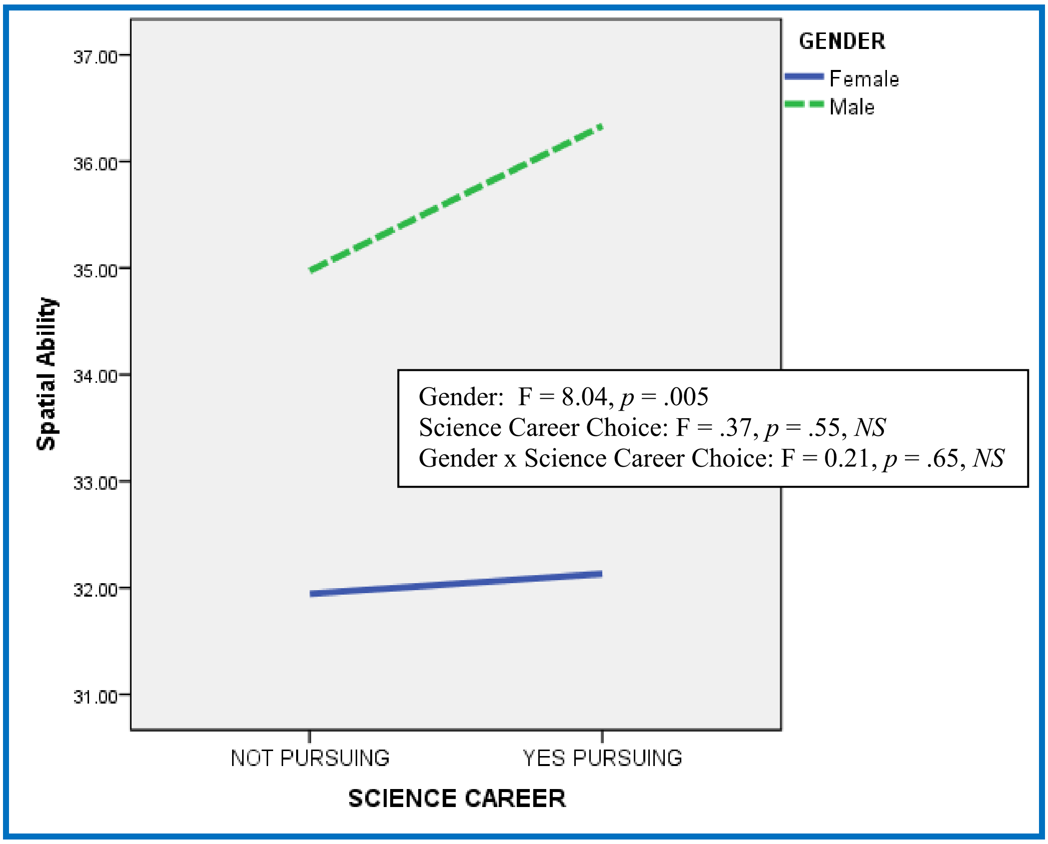

Figure 5. Spatial Ability and Science Career Choice According to Gender

Differences in students' science enjoyment according to gender and intentions to pursue science careers. As shown in Table 1 and Figure 6, there were descriptive differences in means between males and females and students pursuing/not pursing science careers. According to 2-way ANOVA table inset in Figure 6, there were significant differences between males and females in science enjoyment with males showing greater science enjoyment as the main effect. There were also significant differences, as would be expected, between students pursuing science careers and those not pursing science careers, with those pursuing careers having higher science enjoyment. A significant interaction was also indicated, with the males pursing science careers showing significantly greater science enjoyment compared to their female counterparts pursuing science careers.

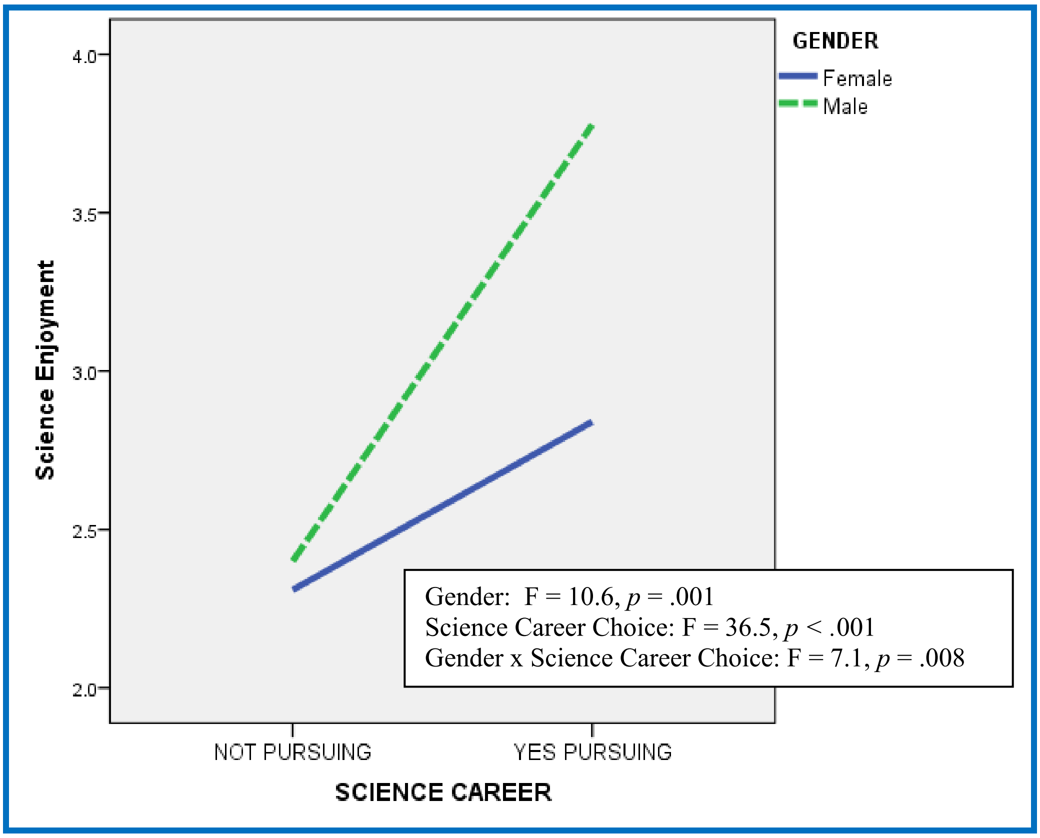

Figure 6. Science Enjoyment and Science Career Choice According to Gender

Relationships and predictive influence of learning approaches, beliefs about NOS, self-efficacy, scientific reasoning, and spatial ability on male and female students' science enjoyment and their intentions to pursue science careers.

Results of Stepwise Multiple Regression analyses revealed that meaningful learning, self-efficacy, and more tentative beliefs in NOS best predicted science enjoyment among males, ($p < .05$) explaining 52% of the variance in science enjoyment scores. Scientific reasoning ability and self-efficacy predicted science enjoyment among females in this study ($p < .05$), explaining 41% of the variance in science enjoyment scores. Meaningful learning best predicted choice of science as a career among the males (R-square = .23, $p < .01$), whereas self-efficacy best predicted science as a career choice among the females (R-square = .08, $p < .05$). Enjoyment of science and scientific reasoning ability significantly predicted science as a career choice for all students (R-square = .28, $p < .05$).

Discussion

The primary findings of this study are summarized as follows:

- Males use more meaningful learning/females more rote memorization; males who learn meaningfully more likely to pursue science careers.
- Students pursuing science careers have greater science self-efficacy.
- Males have higher spatial ability compared to females.
- Males pursuing science careers have greater enjoyment of science compared to females pursuing science careers.
- Self-efficacy a common predictor of science enjoyment:
    - Meaningful learning and beliefs of NOS also predictors among males; reasoning ability was also a predictor among females.
    - Meaningful learning predicts science career choice among males; self-efficacy among females.

- Science enjoyment and scientific reasoning ability predicts science career choices for all students in this study.

The information attained through this research informs teachers and science education researchers of learner characteristics and educational factors that may be important to students' decisions to pursue STEM careers. These findings may help educators better understand and therefore foster the skills and/or learner characteristics that promote their students' science career decisions. With knowledge obtained through this research, educators will be better prepared to impact students in ways that increase interest and reverse the downward trend in the numbers of science professionals currently endured.

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