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ABSTRACT

Several researchers have argued that the underrepresentation of women and minorities in professional occupations results from negative beliefs or attitudes, particularly self-efficacy expectations. A Science Self-Efficacy Questionnaire (SSEQ) was designed and later administered to 430 students (all were enrolled in freshman general chemistry and anatomy/physiology courses) to determine if experiencing freshman college science courses had any effect on the student's self efficacy. Results indicated that in general the students at the beginning of the fall semester felt reasonably confident in their abilities to perform science tasks, with females only less confident than males in the area of physical manipulations (i.e. performing laboratory experiments). Three conclusions were drawn regarding students' freshman experience: (1) students gained more confidence in the laboratory; (2) a significant change in their self-efficacy toward chemistry did not exist; and (3) their biology self-efficacy was lowered. The science questionnaire is attached. (Contains seven tables and four graphs.) (ZWH)

GENERAL CHEMISTRY AND SELF-EFFICACY

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Abstract

Several researchers have argued that the chronic underrepresentation of women and minorities in professional occupations results from negative beliefs or attitudes, particularly low self-efficacy expectations. The specific construct of self-efficacy refers to a person's belief that he/she can accomplish a particular behavior. Efficacy expectations influence the choice of performing or avoiding the behaviors, as well as how much effort will be expended.

The Science Self-efficacy Questionnaire (SSEQ) was developed to assess students' self-efficacy in science. To determine if experiencing freshman college science courses had any effect on the students self-efficacy, this questionnaire was administered to 430 students enrolled in the general chemistry and anatomy and physiology courses at Springfield College. In general the students at the begining of the fall semester felt reasonably confident in their abilities to perform science tasks, with females only feeling less confident than males in the area of physical manipulations (i.e. performing laboratory experiments). Their freshman experience gave them more confidence in laboratory, did not significantly change their chemistry self-efficacy, and lowered their biology self-efficacy.

Introduction

College science educators faced with the task of preparing future scientists need to recruit students into their science programs. However, fewer and fewer students are electing science as a course of study or as a profession (Bell, 1989; Ware & Lee, 1988). The National Science Foundation (NSF) has estimated that by the year 2010 the United States could suffer a shortfall of a half a million science and engineering professionals (Rawls, 1991).

The American Chemical Society (ACS) is advocating recruiting minorities and women, two populations long underrepresented in the sciences (Cooper, 1983; Hill, Pettus & Hedin, 1990; Levine, 1985). To enhance this recruitment into the sciences it is essential to know why students, especially women and minorities, tend not to pursue science.

Background

Several researchers (Betz & Hackett, 1981; Lent, Brown & Larkin, 1986; Post, Stewart & Smith, 1991) have investigated the importance of self-efficacy expectations in the explanation of the continued underrepresentation of women and minorities in professional occupations.

The construct of self-efficacy has its roots in social cognitive theory espoused by Albert Bandura (1986). Bandura defines self-efficacy as

> "people's judgements of their capabilities to organize and execute courses of action required to attain designated types of performances. It is concerned not with the skills one has but with judgements of what one can do with whatever skills one possesses." (p.391)

According to Bandura (1986), efficacy expectations about specific behaviors influence the choice of performing or avoiding the behaviors as well as determining how much effort will be expended. Individuals receive efficacy information from four sources: performance accomplishments, vicarious experiences, verbal persuasion, and emotional arousal. The impact of this information depends on the individual's cognitive appraisal.

Betz and Hackett (1981) found that females had greater self-efficacy towards the completion of educational requirements and job duties for traditional female occupations (teacher, secretary, dental hygienist). The results if this study were replicated by Post-Kammer and Smith (1986) who studied math and science career self-efficacy among disadvantaged youth. Post, Stewart and Smith (1991) examined the relationship between self-efficacy and the consideration of math/science careers among Black freshmen. They found that self-efficacy was indeed a factor with Black male freshmen reporting greater self-efficacy than Black females.

Lent, Brown & Larkin (1986) investigated the relationship of self-efficacy to persistence and success in pursuing science and engineering majors among undergraduates. They found self-efficacy contributed significantly to the prediction ᶜ technical grades, persistence and range of career options, even when the variance due to ability, high school achievement and vocational interest had been removed.

The Science Self-efficacy Questionnaire was developed to assess high school students' self-efficacy in science. To estimate the reliability and the dimensionality of this instrument, a pilot test was conducted among 826 high school students in New England in June 1992. The data were subjected to an exploratory principal factor analysis with both oblique and orthogonal rotations. Four factors were extracted, explaining 89% of the item covariance; the oblique rotation gave the most satisfactory interpretation. Cronbach's alpha estimates for the four scale scores were satisfactory: Biology Self-efficacy (8 items), 0.87; Physics Self-efficacy (5 items), 0.93; Chemistry Self-efficacy (7 items), 0.85; and Laboratory Self-efficacy (6 items), 0.90 (Smist, 1992).

Methods

Subjects

During the second week September, 1992, the Science Self-efficacy Questionnaire and a biographical data sheet were administered to 430 college students enrolled in either anatomy and physiology or general chemistry at Springfield College in Springfield, Massachusetts. Both of these courses are designated as freshman level courses. Table 1 shows the demographics of the total sample. Although the age range of the students was 17 to 48 years, the 17-19 year old population comprised 78.9% of the sample. The majority of the students were white (88.3%) freshmen (62.9%). The male/female breakdown was approximately equal with slightly more females (53.3%).

The focus of this paper is only on those students enrolled in the general chemistry course. Table 2 shows the demographics of this subpopulation of 140 students. The mean age was 18.2; the majority were white (82.4%) freshmen (67.7%). Due to the preponderance of women in the physical therapy major, there were slightly more females (58.3%) than males (41.7%) in this course. This group of students had a good amount of experience with science courses in high school. The entire population had taken biology; 94% had taken chemistry; 75% physics.

In the last week of April, 1993, the Science Self-efficacy Questionnaire was readministered to the students enrolled in the second semester of the same courses.

Table 1

Total Sample Description N=430

AGE:		
	RANGE	17 - 48
	MEAN	19
	MODE	18
	17	11.0% (47)
	18	46.1% (197)
	19	21.8% (93)
	20	8.4% (36)
SEMESTER:		
	First semester freshman	62.9% (259)
	First semester sophomore	18.2% (75)
GENDER:		
	Males	46.7% (201)
	Females	53.3% (229)
ETHNICITY:		
	Asian	3.0% (13)
	Black	4.4% (19)
	Hispanic	3.0% (13)
	White	88.3% (378)
SELF-EFFICACY MEAN SCORES:		
Biology Self-efficacy (BSSE)		3.59
Chemistry Self-efficacy (CSSE)		3.07
Lab Self-efficacy (LSSE)		3.66
Physics Self-efficacy (PSSE)		2.98

Table 2

Initial Sample Description n=140

AGE:		
	RANGE	17 - 23
	MEAN	18.2
	17	14.0% (18)
	18	55.0% (71)
	19	15.5% (20)
	20	10.1% (13)
SEMESTER:		
	First semester freshman	67.7% (86)
	First semester sophomore	15.0% (19)
GENDER:		
	Males	41.7% (55)
	Females	58.3% (77)
ETHNICITY:		
	Asian	9.2% (12)
	Black	1.5% (2)
	Hispanic	4.6% (6)
	White	82.4% (108)
MAJOR		
	Biology	7.1% (10)
	Sports Biology	20.0% (28)
	Physical Therapy	31.0% (44)
	Rehabilitation	8.6% (12)
SCIENCE EXPERIENCE:		
	High School Biology	100% (132)
	High School Chemistry	94% (124)
	High School Physics	75% (99)
	College Science Courses	24% (32)

Analyses

The data were initially screened for mulitvariate outliers, 14 were found and removed from the sample; 37 cases had missing data and were also dropped from the subsequent analyses. To empirically determine the construct validity of the instrument, the remaining 379 cases were subjected to an exploratory common factor analysis with an oblique rotation. Four factors explaining 88% of the covariance were extracted. Table 3 is a list of the items and their factor loadings; table 4 the factor intercorrelatons.

The internal consistency reliability estimates for each factor were quite satisfactory: Biology Self-efficacy (6 items) 0.89; Chemistry Self-efficacy (6 items) 0.90; Physics Self-efficacy (5 items) 0.92; Lab self-efficacy (8 items) 0.81.

Hotelling's T^2 test was used to examine gender differences among the general chemistry students. Because there are four dependent variables (the four self-efficacy factors) which are somewhat correlated (factor intercorrelations ranged from 0.32 to 0.54), using separate t tests for each dependent variable would inflate Type I error (Tabachnick & Fidell, 1989).

Multivariate regressions were done on the data from the first administration to see if self-efficacy was a predictor of the final grade in the first semester general chemistry course.

A Matched t test was done to examine how self-efficacy changed over the course of the freshman year. There was attrition between the fall and spring semesters in the general chemistry course and attendance was poor for the second administration of the questionnaires. Therefore only a sub-sample of 67 students had complete data for both administrations. Table 5 shows the demographics of this sub-sample. The feature that makes

Table 3

Science self-efficacy factors (n=379)[a]

Item #	Item	Loading
Biology Self-efficacy (α = 0.89)		
4	Doing well on a **biology** exam	.865
14	Getting good grades in **biology**	.822
15	Answering questions in **biology** class	.786
2	Understanding concepts in a **biology** textbook	.766
12	Taking essay tests in **biology**	.723
19	Asking questions in **biology** class	.565
Chemistry Self-efficacy (α = 0.90)		
22	Getting good grades in **chemistry**	.875
5	Doing **chemistry** homework problems well	.837
18	Understanding concepts in a **chemistry** textbook	.765
3	Using **chemical** formulas and equations	.716
23	Understanding abstract **chemical** concepts	.665
16	Asking questions in **chemistry** class	.479
Physics Self-efficacy (α = 0.92)		
25	Getting good grades in **physics**	.891
21	Understanding concepts in a **physics** textbook	.865
11	Doing **physics** homework problems well	.827
6	Doing **physics** lab experiments well	.826
24	Asking questions in **physics** class	.486
Laboratory Self-efficacy (α = 0.81)		
26	**Performing lab experiments** with simple machines	.745
13	**Performing lab experiments** using electricity	.693
10	**Handling** laboratory **chemicals**	.648
8	**Lighting** a laboratory (Bunsen) **burner**	.590
27	**Doing** science **activities** for fun	.513
7	**Using a microscope**	.492
9	Winning a science fair award for a **biology project**	.312
1	**Using a computer** in science class	.309

Note. Principle Factor Analysis, oblique rotation.
BMDP program 4M.

[a]complete cases only were used

Table 4

Science Self-efficacy Factor Intercorrelation Matrix (n=379)[a]

	BSSE	CSSE	PSSE	LSSE
BSSE	1.000			
CSSE	.499	1.000		
PSSE	.322	.543	1.000	
LSSE	.495	.407	.384	1.000

Note. Principle Factor Analysis, oblique rotation.
BMDP program 4M.

[a]multivariate outliers and cases with missing data removed

Table 5

Final Sample Description n=67

AGE:		
	RANGE	17 - 23
	MEAN	18.2
	17	18.2% (12)
	18	63.6% (42)
SEMESTER:		
	First semester freshman	83.3% (55)
	First semester sophomore	7.6% (5)
GENDER:		
	Males	30% (20)
	Females	70% (47)
ETHNICITY:		
	Asian	6.0% (4)
	Black	0.0%
	Hispanic	1.5% (1)
	White	92.5% (62)
MAJOR		
	Biology	7.4% (5)
	Sports Biology	25.4% (17)
	Physical Therapy	49.3% (33)
	Rehabilitation	4.5% (3)
SCIENCE EXPERIENCE:		
	High School Biology	100% (67)
	High School Chemistry	99% (66)
	High School Physics	79% (53)

this sample different from the whole pcpulation is the gender breakdown. This sub-sample had 70% females.

Results and Discussion

The gender comparison results are shown on table 6 and figure 1. Although the female means were lower on all four self-efficacy factors, the difference was only statistically significant on the lab factor. Looking at effect sizes as a measure of practical significance, the lab mean difference has an effect size of 0.52, which Cohen (1988) would classify as "medium." These results are consistent with studies done with high school students (Smist & Owen, 1993; Smist, 1992).

A hierarchial multiple regression was done to see the predicative effect of self-efficacy on the first semester final grade. The biographical variables of gender, race and age, entered as a group, were extremely weak predictors (adjusted $R^2 = 0.008$) explaining less than 1% of the variance. The effect of having taken chemistry in high school also did not have much of a predictive effect (adjusted $R^2 = 0.009$). The mean chemistry self-efficacy score proved to be a somewhat better predictor, explaining 16% of the variance (adjusted $R^2 = .159$). In terms of effect sizes for multiple regression, $R^2 = .13$ is classified as "medium" (Cohen, 1988).

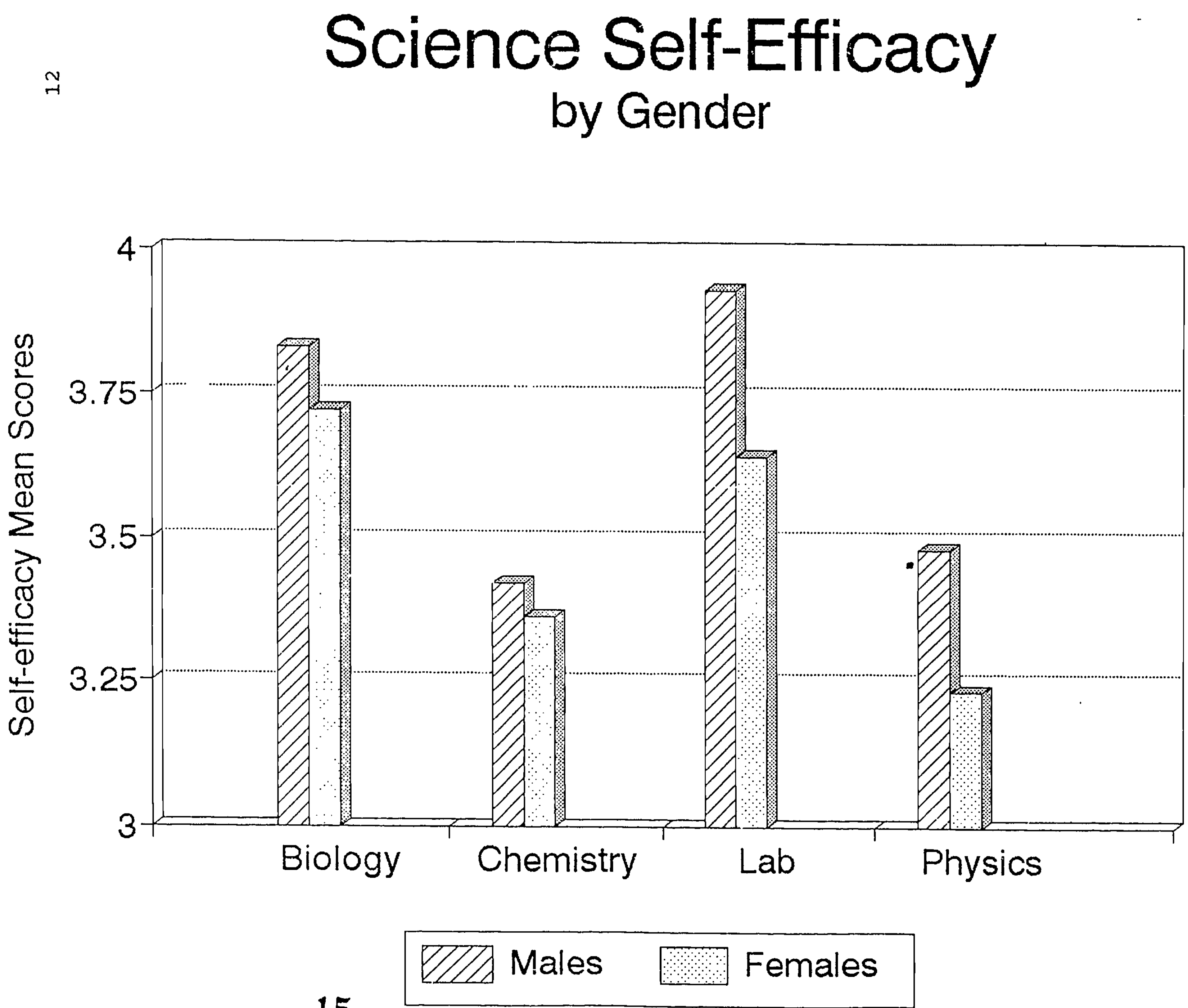
The results of the Matched t test are shown in table 7 and figures 2 - 4. The increase in lab self-efficacy was statistically significant (matched $t = 2.51$, $p < 0.01$) with a small (0.32 effect size. The apparent lowering of chemistry (matched $t = 1.80$, $p < .08$) and physics (matched $t = 1.27$, $p < 0.21$) self-efficacy were not statistically significant. However, the decrease in biology self-efficacy (matched $t = 3.51$, $p < 0.0008$) was

Table 6

Comparison of self-efficacy scores with respect to gender (n=128)

Self-Efficacy	Male Mean	Female Mean	Mean Difference	Effect Size
Biology	3.83	3.72	.11	
Chemistry	3.42	3.36	.06	
Lab	3.93	3.64	.28**	.52*
Physics	3.48	3.23	.25	

**significant at $p < 0.005$
*medium effect size



Science Self-Efficacy
by Gender
Self-efficacy Mean Scores
4
3.75
3.5
3.25
3
Biology
Chemistry
Lab
Physics
Males
Females

Figure 1

Table 7

Change in Self-efficacy scores (n=62)

Self-Efficacy	First Admin.	Second Admin.	Mean Difference	Effect Size
Biology	3.94	3.68	-0.26**	.45[a]
Chemistry	3.59	3.42	-0.17	
Lab	3.73	3.89	+0.16*	.32[b]
Physics	3.42	3.27	-0.15	

**significant at $p < 0.005$ *significant at $p < 0.05$
[a]medium effect size
[b]small effect size

Changes in Self-efficacy

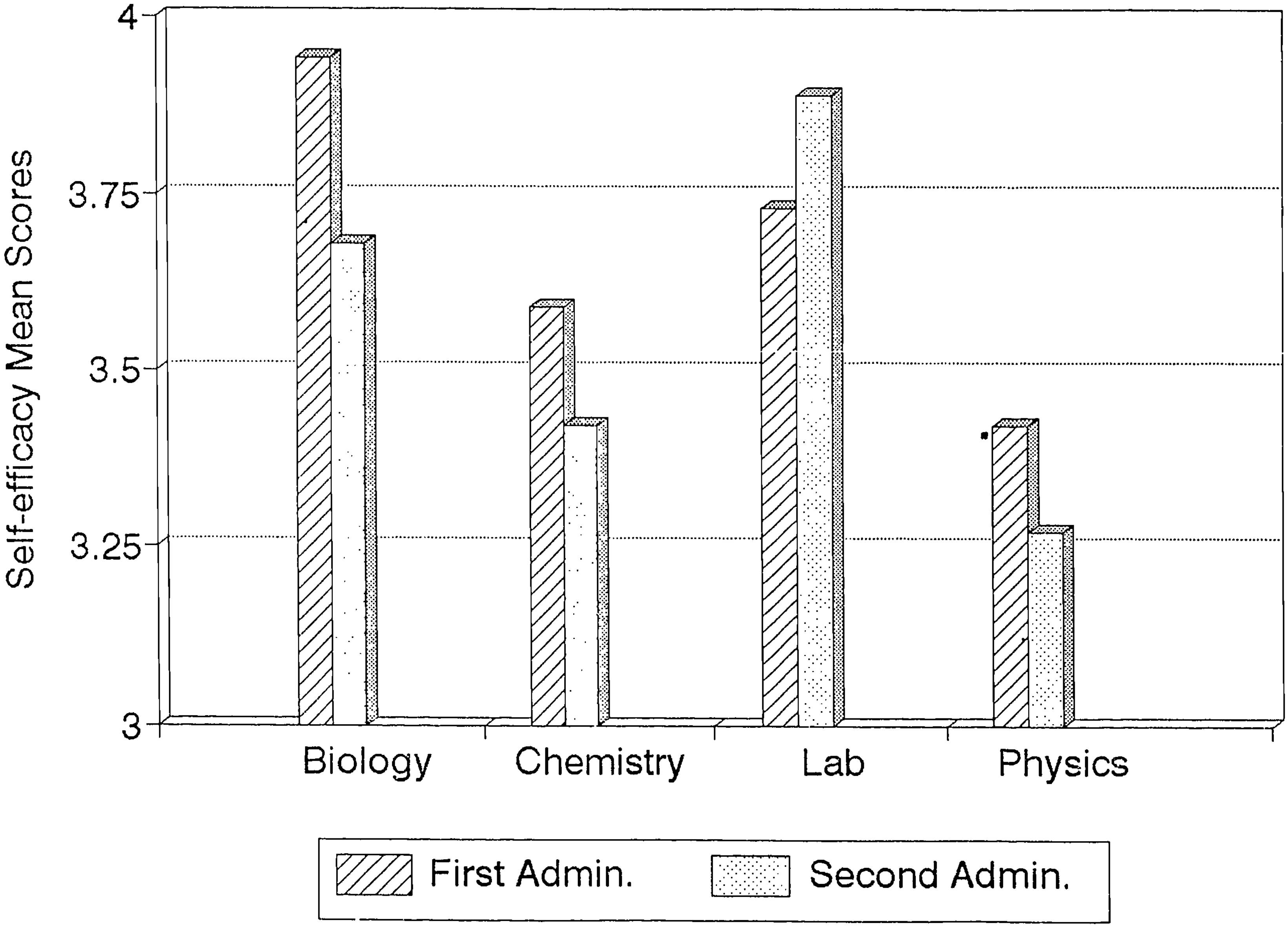


Figure 2

Changes in Self-efficacy
Chemistry & Lab

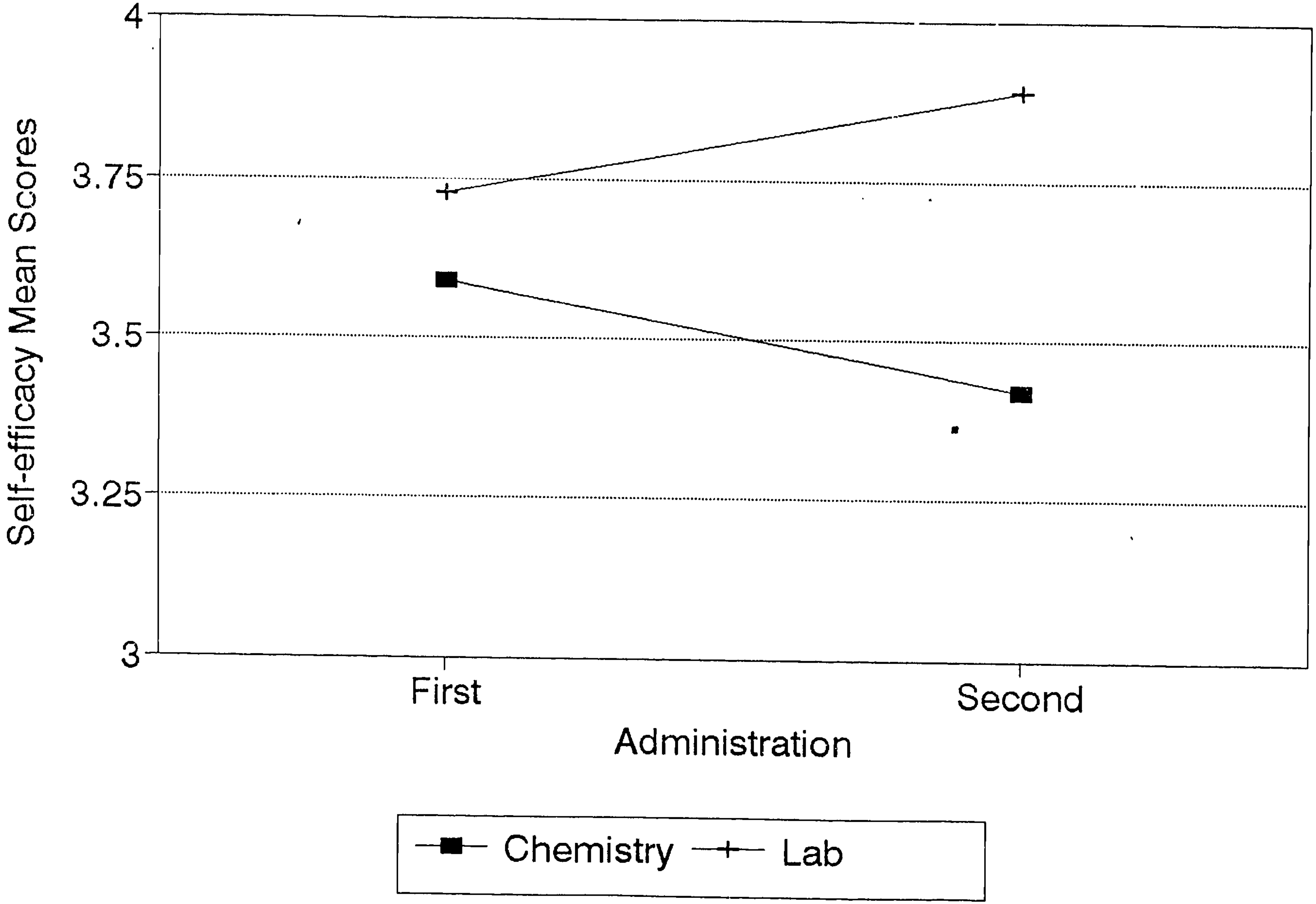


Figure 3

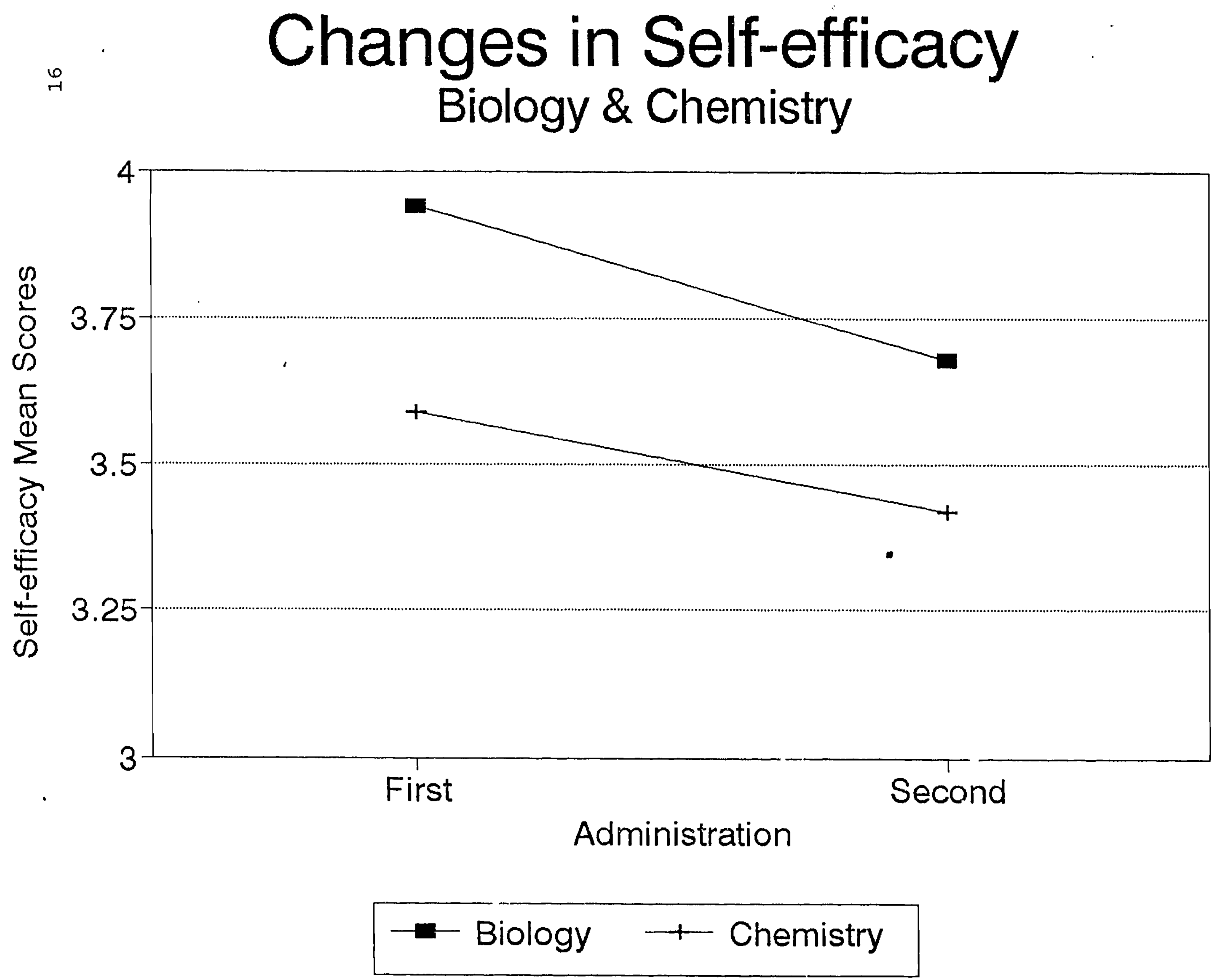

Changes in Self-efficacy
Biology & Chemistry
Self-efficacy Mean Scores
4
3.75
3.5
3.25
3
First
Second
Administration
Biology
Chemistry

Figure 4

statistically significant with a medium effect size (0.45).

Conclusions

The students who came to Springfield College in the 1992-1993 academic year, felt reasonably confident in their ability to perform science related tasks. Females only felt less confident than males in the area of physical manipulations (i.e. performing experiments). Their freshman chemistry experience gave them more confidence in the laboratory but did not increase their self-efficacy in chemistry.

Physics self-efficacy was not expected to change, since these students were not being exposed to physics. Perhaps the non significant decrease was due to time. At the first administration of the questionnaire, many of the students had just completed physics as high school seniors. By the second administration, they were at least a year away from their previous physics experience.

The decrease in biology self-efficacy was surprising. The vast majority of the students in the general chemistry course were simultaneously enrolled in an introductory biology course. This decrease seems to imply that after taking a college biology course, students had less self-efficacy in biology than when they entered college.

The fact that chemistry self-efficacy was a fair predicator of achievement (i.e. final grade in the course) suggests that increasing a student's chemistry self-efficacy could lead to an increase in his/her achievement.

Future work

The work described herein has opened up many areas of future research. First the Science Self-efficacy Questionnaire has proven to be a valid and reliable instrument with high school students. It appears from this work that the factor patterns vary only slightly with college students. Another college sample needs to be examined to confirm the college factor pattern and to determine if the pattern is invariant with respect to gender.

To determine if manipulation of self-efficacy could indeed cause an increase in achievement, a controlled experiment needs to be done. Taking a random sample of students and working on building their self-efficacy and then comparing their achievement with a "control" group.

Because many of the students from this cohort will spend all their college years at Springfield, it would be interesting to monitor their self-efficacy each year. At the very least I would like to have them take the questionnaire when they complete organic chemistry and the following year when they complete physics.

To study the biology anomaly, I hope to focus on the introductory biology course this year.

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Appendix A

SCIENCE QUESTIONNAIRE

Please try to answer all the items below. However, you are not required to complete this questionnaire, and you may omit any items that you do not want to answer.

How much confidence do you have about doing each of the behaviors listed below? **If you have not had physics, <u>predict</u> your confidence level.** Circle the letters that best represent your beliefs.

A B C D E
quite a lot <------------------------> very little
CONFIDENCE

A B C D E 1. Using a computer in science classes.
A B C D E 2. Understanding concepts in a biology textbook.
A B C D E 3. Using chemical formulas and equations.
A B C D E 4. Doing well on a biology exam.
A B C D E 5. Doing chemistry homework problems well.
A B C D E 6. Doing physics lab experiments well.
A B C D E 7. Using a microscope.
A B C D E 8. Lighting a laboratory (Bunsen) burner.
A B C D E 9. Winning a science fair award for a biology project.
A B C D E 10. Handling laboratory chemicals.
A B C D E 11. Doing physics homework problems well.
A B C D E 12. Taking essay tests in biology.
A B C D E 13. Performing lab experiments using electricity.
A B C D E 14. Getting good grades in biology.
A B C D E 15. Answering questions in biology class.
A B C D E 16. Asking questions in chemistry class.
A B C D E 17. Memorizing factual information.
A B C D E 18. Understanding concepts in a chemistry textbook.
A B C D E 19. Asking questions in biology class.
A B C D E 20. Learning about famous scientists.
A B C D E 21. Understanding concepts in a physics textbook.
A B C D E 22. Getting good grades in chemistry.
A B C D E 23. Understanding abstract chemical concepts.
A B C D E 24. Asking questions in physics class.
A B C D E 25. Getting good grades in physics.
A B C D E 26. Performing lab experiments with simple machines.
B C D E 27. Doing science activities for fun.