New Perspectives in Science Education
International Conference
NEW PERSPECTIVES in SCIENCE EDUCATION
5th Edition

Motivational Decline in Higher Education STEM Courses and its Association with Student Demographics

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Abstract
This study reports declines in pre- to post-semester motivation in college math and science classes as measured by Glynn et al.'s Science Motivation Questionnaire II (SMQII). Researchers collected pre- and post-semester motivation data for 1,157 students across 35 first- and second-year class sections and two semesters. Comparing pre- to post-semester data for students completing both surveys, a statistically significant decline was observed for all motivation factors. Although pre- to post-term motivational declines are not without precedent, we are aware of no other study documenting motivation decline across multiple class sections and STEM disciplines. No differences in overall motivation or motivation decline were detected by race/ethnicity, but differences were evident across genders and years in school. This data can inform strategic reform efforts of STEM programs to improve introductory student experience and retention. Supported by NSF #1347234

1. Introduction
In his Social Cognitive Theory, Albert Bandura [1,2] defines motivation as "an inner drive to action." Glynn et al. [3] developed an instrument to measure this complex construct, the Science Motivation Questionnaire (SMQII). The SMQII assesses five factors of science learning:

- F1 Intrinsic Motivation ("inherent satisfaction in learning science for its own sake")
- F2 Career Motivation ("learning science as a means to [the] tangible end" of career establishment or advancement)
- F3 Self-Determination ("the control students believe they have over their learning of science")
- F4 Self-Efficacy ("students' belief that they can achieve well in science")
- F5 Grade Motivation ("learning science as a means to [the] tangible end" of high grades)

SMQII developers provide evidence for its reliability and validity, and confirmatory factor analysis substantiates the SMQII's five-factor structure of five questionnaire items per factor [3]. The present study focuses on motivational change from the beginning to the end of a course, both with respect to overall motivation, and the five motivational factors of the SMQII.

2. Method
Over the Fall 2014 and Spring 2015 semesters, motivation surveys were administered to 1,157 students across 35 class sections at Otterbein University, a small primarily undergraduate institution in the USA. In contrast to previous studies [4-7], which examined motivation-related factors in individual introductory science courses, the present study targeted all introductory science and mathematics (STEM) classes typically taken by science or math majors at Otterbein University. Students took the survey within the first two weeks of the semester (the "pre-survey") and again within the last week of the semester (the "post-survey"). The voluntary survey was administered with the oversight of Otterbein's Institutional Review Board. Ninety-two percent of students in the targeted classes completed permission forms and surveys.

In our administration of the SMQII, students rate their level of agreement with each of 25 statements on a 5-point Likert scale ranging from Never (coded as 1) to Always (coded as 5). Demographic questions were appended.

All statistical analyses were run in JMP or SPSS software. Although each SMQII item is measured on a 5-point ordinal scale, we follow standard practice in reporting means and standard deviations for theory-supported composite variables of validated and interrelated ordinal-scale items [8]. One mean score for the entire SMQII pre and post was calculated, as well as means for each of the five factors. In pre- to post-semester comparisons, individual students are excluded from analysis when either pre- or post-semester data is unavailable for that student. Nonparametric tests were used as the data is not normally distributed. We ran Kruskal Wallis or Wilcoxon signed rank tests for both the

pre-motivation scores and the difference between pre- and post-scores (Δ_{F1}, Δ_{F2}, etc.) for each of our variables of interest: gender (male or female), race and ethnicity (underrepresented minority [URM] or caucasian/asian), first generation status (yes or no), academic standing in school (self reported freshman, sophomore, junior, or senior), and final course grade.

3. Results

Wilcoxon signed rank tests revealed statistically significant declines across the semester for the overall mean and each individual factor ($p<0.0001$, Table 1, Fig 1). No significant differences were detected for ethnicity or first generation students on any of the factors, but there were differences between genders (Table 2) and for year in school (Table 3). On the pre-survey, males scored higher than females for intrinsic motivation, self determination, and self-efficacy, while females scored higher than males in grade motivation. While there was no initial difference detectable in career motivation between males and females, women declined in this factor at a statistically greater rate than males. There was no difference between men and women in final course grade.
For the pre motivation survey, there was a detectable difference in four factors depending on the students' year in school (Table 3). Freshmen had the highest reported motivation score for intrinsic motivation, career motivation, and self efficacy factors. Seniors had the highest reported self-determination factor.

Table 1. Comparison of SMQII Motivation Scores by the Wilcoxon Signed-Rank Test for students who completed both a pre- and a post- survey

Factor	**N**	**$mean_{pre}$±SE**	**$mean_{post}$±SE**	**Δ_{mean} ±SE**	**S**	**r^1**
Overall	764	3.87±0.02	3.67±0.02	-0.20±0.02	70450**	-0.45
F1 Intrinsic Motivation	768	3.46±0.03	3.27±0.03	-0.19±0.02	37344**	-0.65
F2 Career Motivation	768	3.90±0.03	3.60±0.03	-0.30±0.03	48891**	-0.58
F3 Self Determination	768	3.78±0.02	3.67±0.03	-0.11±0.02	23234**	-0.73
F4 Self Efficacy	767	3.80±0.02	3.53±0.03	-0.27±0.02	52761**	-0.56
F5 Grade Motivation	767	4.44±0.02	4.28±0.02	-0.16±0.02	32415**	-0.68

**p < 0.01 [1]r = effect size

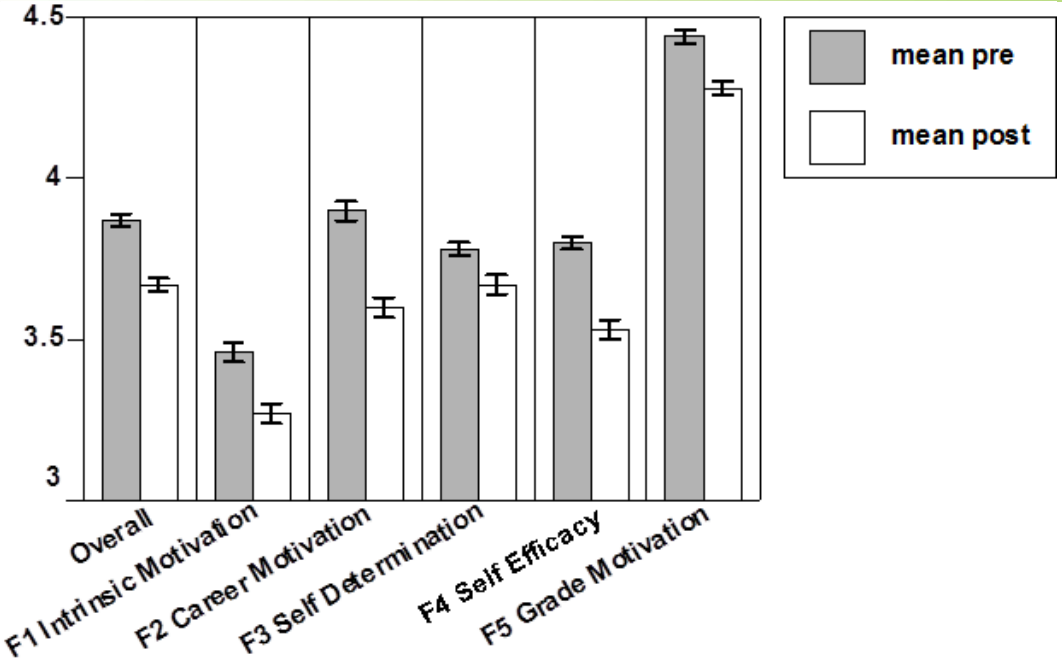

Figure 1. Mean of SMQII Motivation Scores for students who completed both a pre- and a post-survey

Table 2. Comparison of Statistically Significant SMQII Motivation Scores by X^2 Analysis: Gender

Factor or ΔFactor	**N_{male}**	**N_{female}**	**$mean_M$±SE**	**$mean_F$±SE**	**X^2**	**r^1**
$F1_{Pre\ Intrinsic\ Motivation}$	374	658	3.57±0.04	3.45+0.03	6.97*	0.08
$F3_{Pre\ Self\ Determination}$	374	658	3.82±0.03	3.65+0.02	20.34**	0.14
$F4_{Pre\ Self\text{-}Efficacy}$	373	658	4.01±0.03	3.69+0.03	49.05**	0.22
$F5_{Pre\ Grade\ Motivation}$	373	658	4.38±0.03	4.45+0.02	7.69*	0.09
$\Delta_{F2\ Career\ Motivation}$	269	412	-0.22±0.04	-0.35+0.03	7.15*	0.10

* p<0.05, **p < 0.01 [1]r = effect size

Table 3: Comparison of Statistically Significant SMQII Motivation Scores by X^2 Analysis: Year in School

Factor or ΔFactor	**$mean_{Yr1}$±SE**	**$mean_{Yr2}$±SE**	**$mean_{Yr3}$±SE**	**$mean_{Yr4}$±SE**	**X^2**	**r^1**
$Overall_{Pre}$	3.95±0.03	3.87±0.03	3.70±0.04	3.75±0.05	30.44**	0.17
$F1_{Pre\ Intrinsic\ Motivation}$	3.60±0.04	3.44±0.04	3.33±0.06	3.40±0.08	17.34*	0.13
$F2_{Pre\ Career\ Motivation}$	4.17±0.04	3.92±0.05	3.52±0.08	3.61±0.09	79.46**	0.28
$F3_{Pre\ Self\ Determination}$	3.70±0.03	3.81±0.03	3.79±0.05	3.87±0.06	8.67*	0.09
$F4_{Pre\ Self\text{-}Efficacy}$	3.91±0.03	3.80±0.03	3.66±0.05	3.64±0.08	23.42**	0.15

* p<0.05, **p < 0.01 [1]r = effect size

4. Discussion

4.1 Gender Differences

Men pre-surveyed higher than women in intrinsic motivation toward science, which may, in turn, impact women's lower rates of majoring in and graduating in STEM fields [9, 10]. A variety of circumstances may contribute to this male/female STEM imbalance [11], but there is evidence that interest in science is a key factor [12]. Although a pre- to post-semester decline in intrinsic motivation was observed for men as well as women, the possibility that STEM coursework contributes to this decline, and possibly to lower STEM persistence among women, is worrying. Equally worrying, and possibly related, is that women and men begin the semester with indistinguishable career motivation levels, yet women experience a greater pre- to post-semester decline in career motivation. To the extent that STEM courses contribute to this decline, adjustments in course design are warranted. Paradoxically, women exhibited higher grade motivation than men in the pre-survey, yet exhibited lower self-determination (Table 2). However, we observed no difference in course grades by gender, indicating that women are putting roughly the same effort into STEM courses as men. Yet in light of women's higher grade motivation, they are more likely to perceive this effort level to be inadequate. This may build on high-school trends, where boys outperform girls on standardized exams, but girls earn more science and math credits than boys and earn higher grades in these courses [9]. Girls' underperformance on standardized exams may result from stereotype threat [13], but higher self-discipline appears to contribute to girls' stronger achievement [14]. To the extent that this self-discipline habit continues in college, women may feel that STEM courses require more effort than they are able to commit, which may also contribute to the strongest gender pre-survey difference observed in the factor of self-efficacy (Table 2).

4.2 Motivational Decline

We observed pre- to post-semester declines in overall motivation and each of five motivational factors across seven disciplines in four academic departments. Whereas some previous studies have measured course-specific declines in individual constructs [4, 6, 7], this is the first study to measure a comprehensive, multi-factor pre- to post-semester motivational decline.

A possible explanation for this pre- to post-semester decline is simple fatigue: With final exams looming and projects, papers, and final lab reports due, perhaps anyone would feel less scientific curiosity, confidence that they have worked hard enough, or confidence that they can earn a good grade. Yet if fatigue were the only factor, we would expect a pre-survey rebound in motivation at the beginning of the following semester. Comparison of pre-survey motivation by year in school (Table 3) does not support this hypothesis. Overall motivation is lower for second-year students than first-year students, and overall motivation is lower for third-year students than second-year students, then rebounds slightly for fourth-year students. The same pattern holds for intrinsic motivation and career motivation. Self-efficacy declines all four years. Only self-determination increases steadily from year to year. Taken together, these results indicate a lasting effect; motivation levels do not rebound from their pre- to post-semester decline. Perhaps this decline reflects a gradual loss of naiveté about what STEM achievement and careers entail, but if this were the case we would expect a rebound after the first year. Instead such systemic motivational decline points to structural issues in the STEM experience at this university--in course structure, professor-student or student-student interactions, or other elements that could perhaps be addressed.

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