Gender, Motivation, and Pedagogy in the STEM Classroom: A Quantitative Characterization

Prof. Jonathan D. Stolk, Franklin W. Olin College of Engineering

Jon Stolk strives to design and facilitate extraordinary learning experiences. He creates project-based and interdisciplinary courses and programs that invite students to take control of their learning, grapple with complex systems, engage with each other and the world in new ways, and emerge as confident, agile, self-directed learners. Stolk’s research aims to understand how students experience different classroom settings, particularly with regard to how individuals express situational motivations and develop their own beliefs about learning. Stolk endeavors to translate research-to-practice, and to assist other instructors in creating innovative student experiences and driving educational change. A core aspect of his professional work involves creating simple design tools and conceptual frameworks that enable faculty to understand their classrooms in new ways, and to gain confidence in trying new approaches and deploying course prototypes. Stolk consults with a wide range of academic institutions on the design of unconventional curricula, and he offers hands-on workshops to faculty around the world.

Dr. Yevgeniya V. Zastavker, Franklin W. Olin College of Engineering

Yevgeniya V. Zastavker, Ph.D., serves as a Director of the Research Institute for Experiential Learning Science (RIELS) at Northeastern University and an Adjunct Associate Professor of Physics at Franklin W. Olin College of Engineering. She earned her B.S. degree in Physics from Yale University in 1995 and her Ph. D. degree in Biological Physics from MIT in 2001. Dr. Zastavker’s research interests lie in the field of STEM education with specific emphasis on innovative pedagogical and curricular practices at the intersection with the issues of gender and diversity. Dr. Zastavker is currently working with Dr. Stolk on an NSF-supported project to understand students’ motivational attitudes in a variety of educational environments with the goal of improving learning opportunities for students and equipping faculty with the knowledge and skills necessary to create such opportunities. One of the founding faculty at Olin College, Dr. Zastavker has been engaged in development and implementation of project-based experiences in fields ranging from science to engineering and design to social sciences (e.g., Critical Reflective Writing; Teaching and Learning in Undergraduate Science and Engineering, etc.) All of these activities share a common goal of creating curricular and pedagogical structures as well as academic cultures that facilitate students’ interests, motivation, and desire to persist in engineering. Through this work, outreach, and involvement in the community, Dr. Zastavker continues to focus on the issues of women and minorities in science/engineering.

Dr. Michael D. Gross, Wake Forest University

Dr. Michael Gross is a Founding Faculty and Associate Professor of Engineering at Wake Forest University and is part of the team that is planning, developing, and delivering the brand new Engineering program. The Engineering department is viewed as an opportunity to break down silos across campus and creatively think about reimagining the undergraduate engineering educational experience, integration and collaboration across departments and programs, and how to achieve the motto of Wake Forest University: Pro Humanitate (“For Humanity”). Michael received his B.S. in Chemical Engineering at Bucknell University, and his Masters and PhD in Chemical & Biomolecular Engineering at the University of Pennsylvania. Before coming to Wake Forest, Michael was an Associate Professor of Chemical Engineering at Bucknell University. He has broad research interests in materials and composite processing and design, primarily for solid oxide fuel cells, but also for batteries, solar absorbers, and gas adsorption. However, he also has a passion for designing educational experiences that support student intrinsic motivation. Using the Situational Motivation Scale (SIMS), Basic Needs Satisfaction (BNS) survey, and cluster analysis, Gross helps faculty understand the types of motivations their students are experiencing and practical, effective strategies for making positive shifts in student motivation.
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Abstract

This research paper examines students’ situational, or activity-level, motivations in STEM classrooms, with a focus on gendered patterns of motivation in different pedagogical environments. The dataset includes over 5000 unique responses to the Situational Motivation Scale (SIMS), an instrument that measures four types of motivation (intrinsic, identified regulation, external regulation, and amotivation) based on Self-Determination Theory (SDT). The SIMS was administered weekly to undergraduate students enrolled in a diverse range of undergraduate STEM courses across multiple institutions. Variable-based quantitative analysis reveals significant differences in motivations across traditional, mixed, and non-traditional course pedagogies. Students report the most internalized or autonomous motivations in non-traditional settings such as discussion- or project-based courses, and the most externalized or controlled motivations in traditional courses. Quantitative analysis also reveals significant gendered patterns in students’ situational motivational responses. For the motivation subscale measures and self-determination index (SDI), the strongest gender-based differences appear in traditionally taught courses, with women reporting lower autonomous motivations and higher controlled motivations compared to men. The motivations of men and women are both more similar, and more positive overall, in STEM courses that employ non-traditional and mixed pedagogies.

Introduction and Research Background

Learner motivation, the psychological intention and energetic drive to do something [1], is a critically important aspect of the learning process. While learner motivations are complex and multifaceted, a simplified model positions motivational processes between personal and contextual factors as antecedents, and learning engagement, behaviors, and outcomes as consequences (Figure 1). Research shows that positive forms of motivation, such as value- or interest-based drive, are linked to deeper learning approaches, better performance, and outcomes such as critical thinking, pro-social behavior, and self-regulation [2]-[5]. By contrast, less positive motivations, such as rewards-based drive, relate to surface-level learning, poorer performance and persistence, and negative emotions [3], [6]. These relationships are not simply correlational: path models illustrate causal links between different types of motivations and specific learning outcomes [7]-[10]. Furthermore, research shows that instructors have agency in shaping motivations through course design decisions: factors such as autonomy support and goal framing can have an important effect on student motivations [6], [11], [12]. Conceptualizing student motivation as a dynamic variable in our larger system enables educators to move beyond the inaccurate and unconstructive portrayals of motivation as a fixed, all-or-nothing construct (e.g., she’s motivated but he isn’t, or students at my school are unmotivated, or all my students care about are grades), and toward a model that empowers instructors to understand motivations more deeply and intervene more intentionally through curriculum design. In this study, we use quantitative methods to characterize the connections between pedagogical practices in undergraduate STEM courses and students’ situational motivations, with a particular focus on the ways women and men express different motivations in different pedagogical environments.
Self-Determination Theory for Motivation

One theoretical model for motivation that has gained traction in education over the past few decades, and that has helped educators understand the forms and processes of motivation, is Self-Determination Theory (SDT) [3], [13], [14]. A central concept of SDT is that there are different types of motivation that may be described along a continuum that ranges from internal (autonomous) to external (controlled) motivations [13]. At one extreme is intrinsic motivation, a state described by interest, enjoyment, inherent satisfaction, and personally valuable goals. At the other extreme of the continuum is amotivation, a condition that occurs when learners find no value in the learning activity and expect no desirable outcomes. Between the two extremes lies extrinsic motivation, a state in which initiative and regulation of action may be prompted by a range of inputs, from external rewards and punishments (external regulation) to an identification of value in the learning activity (identified regulation). The SDT-defined types of motivation considered in this study are summarized in Table 1. Research shows that not all types of motivation are equally effective for learning: in general, autonomous motivations (identified regulation and intrinsic motivation) bear positive relationships to desirable learning outcomes and healthier engagement with learning, while controlled motivations (external regulation and amotivation) do not [7], [15]-[17], [20].

![Figure 1. Simplified model for motivation in learning. Adapted from social-cognitive theoretical frameworks and motivation theoretical frameworks, e.g., [7], [18]-[21].](image)

<table>
<thead>
<tr>
<th>Motivation Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrinsic Motivation</td>
<td>Deeply internalized engagement based on interest, enjoyment, satisfaction, or passion in an activity</td>
</tr>
<tr>
<td>Identified Regulation</td>
<td>Internal drive that is congruent with an internal sense of self, and based on perceived value, importance, or usefulness of a task</td>
</tr>
<tr>
<td>External Regulation</td>
<td>Engagement based on a sense of compliance, external pressure, punishment avoidance, or contingent reward</td>
</tr>
<tr>
<td>Amotivation</td>
<td>Impersonal or non-intentional action described by perceived lack of control and a disconnection between actions and outcomes</td>
</tr>
</tbody>
</table>
As a needs-based motivation theory, SDT argues that individuals will adopt internalized forms of motivation when three basic needs are satisfied: competence, the development of a sense of mastery or self-efficacy; relatedness, a sense of positive and supportive connections to others; and autonomy, a sense of choice and control [14]. Addressing these needs in the classroom enables students to more easily internalize learning goals and shift their motivations from extrinsic to intrinsic [3]. When students internalize learning, they see the value in these goals and gradually accept them as their own. Over time, the learning goals become part of their own identity, and thus much easier to maintain and endorse [13].

Individuals’ motivational responses in real-world situations, however, do not typically appear as either internalized/autonomous or externalized/controlled. That is, the different types of motivation do not exist in isolation; rather, individuals can simultaneously express multiple forms of motivation in a given activity [22]-[25]. For example, a student may feel external pressure to perform well on a learning task (external regulation), but simultaneously find a sense of personal value or importance in the activity (identified regulation). In this case, the student would express a combination of controlled motivations and autonomous motivations. Examining the ‘quality’ of learner motivations with a multidimensional characterization can provide additional diagnostic information as well as practical insights to guide motivation interventions through course design.

**Motivation and Pedagogy**

Self-determination theory translates well to practice, as its proposed relationships among basic needs satisfaction, motivations, and learning outcomes are readily applied and tested in academic environments. Based on SDT, we expect to observe autonomous motivations and desirable learning outcomes in settings that promote a sense of success and progress (competence), build positive interpersonal connections (relatedness), and support choice and control (autonomy). Conversely, settings that thwart learners’ basic needs should lead to controlled motivations and less desirable outcomes. Research across a range of settings clearly demonstrates the importance of autonomy support to motivation (e.g., [6], [12], [26], [27]). In addition, intrinsic goal framing, supportive communication styles, efficacy-building experiences, peer support, and emotional sensitivity lead to internalized forms of motivation and positive engagement [11], [28]-[30]. On the contrary, controlling teacher behaviors have been shown to lead to negative motivation types and restricted engagement [31], [32]. Using structural modeling, Fortier et al. (1995) demonstrate the positive influence of perceived competence and self-determination on autonomous motivations and academic performance [7]. Greene et al. (2004) illustrate linkages between autonomy support and self-efficacy, mastery goals, strategy use, and achievement [33]. Walker et al.’s path model shows that self-efficacy and intrinsic motivation can predict meaningful cognitive engagement, while extrinsic motivations predict shallow cognitive engagement [8].

Although empirical research that directly links different pedagogical approaches with motivation types is limited, active and student-centered pedagogies appear to be well aligned with the principles of self-determination and intrinsic motivation [34]. For example, Stefanou et al. (2013) reported high levels of perceived autonomy support among students in problem- and project-based courses [35]. Stolk and Harari (2014) illustrated connections among positive motivations and high-level cognitions in project-based courses [36]; and Nie and Lau (2010)
found higher student self-efficacy and perceived value in courses with constructivist instruction compared to didactic instruction [37]. Generally, more highly self-regulated learning (SRL) settings are shown to support more positive motivations [2], [4], [38]. In their study of undergraduate students’ motivations, however, Wijnia et al (2011) reported no differences between lecture and problem-based settings – a finding that highlighted the importance of implementing an autonomy- and competence-supportive rather than controlling environment, regardless of the pedagogy [39].

Regardless of pedagogy, motivational responses that instructors observe in the classroom are not static or fixed traits tied to individuals. Rather, situational motivations are temporally dynamic responses that are influenced by personal and contextual variables, and shaped by students’ appraisals and interpretations of the learning experience [3], [21] [27], [32], [40], [41]. Individuals are not limited to either autonomous or controlled motivations; they may move toward more or less internalized forms of drive during the learning process [23], [42]. In addition, educators are not bound to either autonomy supportive or controlling behaviors; they may adapt instructional styles to be more or less oriented toward self-determination [43].

**Gender and Motivation**

Given the extent to which women are underrepresented in engineering and other technical fields, one might guess that the educational community would have a well-developed understanding of women and men’s motivations in STEM fields. Unfortunately, this is generally not the case. Empirical research on gender and motivation has developed unevenly across different motivational themes or constructs. While work on gendered self-efficacy/perceived confidence and interest/values in STEM has progressed over the past two decades, studies of students’ motivational orientations (intrinsic versus extrinsic) in STEM are quite limited.

Perceived confidence and self-efficacy strongly influence academic motivations [44] and serve as mediators of learning engagement and persistence [8]. As such, STEM educators are concerned with how learners cultivate a strong sense of efficacy and expectations of success. Indeed, measurement of self-efficacy and perceived competence represents an area of notable progress in STEM education research. Gendered patterns in learners’ perceived competence and self-efficacy within gender-role stereotyped domains such as mathematics and engineering are widely reported [45], [46]; but examination of the literature reveals mixed empirical findings across educational levels, domains, and contexts. Some studies report mixed results or no significant gender differences in self-efficacy in technical domains (e.g., [2], [47]-[53]). The majority of investigations, however, show that girls or women express lower self-efficacy or perceived confidence in their technical abilities compared to boys or men, regardless of demonstrated ability or success in their programs (e.g., [54]-[67]).

Researchers have also explored how women and men in STEM develop different interests and values, constructs that are related to academic motivations and self-efficacy in important ways. As with self-efficacy, the findings on gendered interests and values in STEM are mixed. Weisgram and Bigler (2006) showed that girls report less interest in science and more strongly endorse altruistic values and egalitarian interests compared to boys [65]; and Diekman and Steinberg (2013) found that women more strongly endorse communal goals than men [68]. In
some studies, interest in STEM topics was reportedly higher among boys and men compared to girls or women [46], [69], [70]. Other studies show no gendered differences in STEM domain interests or values, even when significant gender differences in self-efficacy exist [58], [60], [66], [67], [71], [72].

Gender-related differences in self-efficacy and interests are proposed to arise, at least in part, from gender-role stereotypes and gendered socialization processes in traditionally male dominated domains such as mathematics and engineering [73]-[76]. Development of gender identity can lead to gender-typed interests and perceptions of competence beginning at an early age [67], and these orientations may be actively reinforced or reduced by activities, interactions, cues, norms, and opportunities in an environment or situation such as a classroom [77]. Instructional conditions can have direct influence on competence and interest, which can impact both near-term situational and long-term sustained motivations [33], [73], [78]-[80].

Studies that describe the autonomous versus controlled motivations of women and men are scarce, particularly at the college level and within STEM fields. Moreover, the findings on gender and motivational orientations are mixed. Outside of STEM, several studies showed that women reported higher autonomous motivations and lower levels of controlled motivations [22], [81], [82] compared to men. Other studies, however, reported no gender differences in situational- or contextual-level motivations [32], [83], [84], or less positive motivations among women [85]. Within STEM, Lavigne and Vallerand (2010) reported no gender differences in the situational- or contextual-level motivations of high school students in science [40]. In a study of first-year engineering students, Heylen et al. (2012) show more women than men in “good” and “high quality” motivational orientations [59].

Our knowledge of the connections among motivation, gender, and pedagogy is severely underdeveloped. Most of the work linking motivation and gender lies outside of STEM, and most studies that examine gendered expression of intrinsic versus extrinsic motivations are conducted at the contextual level (e.g., why students attend school). While contextual motivations provide insights into why students enroll and persist in college programs, they do not provide the fine-grained insights necessary for course-level design decisions. Finally, since few studies have directly linked women and men’s situational motivations to pedagogy, we have little information on how instructors may more effectively create experiences that engage all students. This study begins to address these research gaps, by quantitatively characterizing college students’ controlled versus autonomous situational motivations in STEM courses, and exploring connections among gender, pedagogy, and motivation in STEM environments.

Methodology

Part of a larger mixed-methods study aimed at understanding student motivations in the classroom, this paper presents quantitative characterizations of situational motivations in undergraduate STEM courses, with a focus on gendered patterns of motivation in diverse pedagogical environments.

Participants in the study are undergraduate students enrolled in 40 introductory-level STEM courses across 11 institutions. Survey respondents included 394 men (46.6%), 447 women (52.8%), and 5 students (0.5%) of unspecified or non-binary gender. The institutions included
three large public research universities, a large public undergraduate university, a medium-sized private research university, a medium-sized private master’s university, two private liberal arts undergraduate schools, and a private undergraduate specialty school.

Our dataset includes over 5000 unique responses to the Situational Motivation Scale (SIMS), a self-report instrument based on Self-Determination Theory (SDT) that measures four types of motivation along the self-determination continuum: amotivation, external regulation, identified regulation, and intrinsic motivation. Guay et al.’s (2003) analysis shows that the SIMS instrument has good internal consistency and construct validity based on current theory [86]. The SIMS was administered weekly in each course via a web-based survey. Men provided a total of 2290 responses (42.5%), and women provided 3086 responses (57.3%). A total of 9 survey responses from students of unspecified or non-binary gender were not included in the present analysis. The dataset comprises 2009 (37.3%) responses from first-year students, 2041 (37.9%) responses from sophomores, 968 (18.0%) responses from juniors, and 369 (6.8%) from seniors. This breakdown of survey responses by year reflects the introductory-level course focus of this study, and the response frequencies closely match the overall participant distribution.

Based on weekly activity reports from students, the pedagogy of each course was classified as traditional (e.g., lecture-lab), non-traditional (e.g., project-based), or mixed (e.g., lectures with projects). For example, courses described by student as primarily lectures and problems sets were classified as “traditional;” courses described as combination of lectures and projects or discussions were classified as “mixed;” and courses described as primarily project-based or group discussion-based were classified as “non-traditional.” The motivation dataset is weighted toward traditional pedagogies, with 3988 survey responses (74%) from traditionally taught courses, 784 responses (15%) from courses with mixed pedagogies, and 578 responses (11%) from non-traditional courses.

In this paper, we report descriptive statistics for the motivation subscale responses (e.g., intrinsic motivation, external regulation) of all learners, and statistically compare the motivation responses across different pedagogies and self-reported gender identities. Following the procedure commonly used in self-determination research [87], we also calculated the self-determination index (SDI) for situational motivations as: SDI = 2×(intrinsic motivation) + 1×(identified regulation) – 1×(external regulation) – 2×(amotivation). The SDI, applied in a range of motivation investigations [81], [87]-[89], weights subscale constructs according to their position on the self-determination continuum to give a single number that represents students’ overall levels of autonomous versus controlled types of motivation in the course activities. The range of possible SDI scores is –18 to +18, with higher scores indicating greater self-determination toward the learning activities. Statistical significance of between-groups differences was determined by independent samples t-tests or one-way ANOVA, and effect sizes were calculated using Cohen’s d [90]. Finally, we compared women and men’s simultaneous expression of different types of motivation in different pedagogical environments to some of the motivational profiles previously described in the literature (e.g., [22], [25]). This method of examining the response ‘shape’ provides a more nuanced perspective on motivation by revealing how learners simultaneously express a combination of different motivation types.
Results and Discussion

Subscale mean values for the full dataset, as well as mean responses by gender, are shown in Table 2 and Figure 2. On average, students in this study show low amotivation, high external regulation and identified regulation, and moderate intrinsic motivation in STEM classroom situations. The mean self-determination index value is positive, yet fairly close to the midpoint of the SDI scale. This indicates that, on average, STEM students engage in learning activities because of external controls or constraints, as well as an internal sense of utility or importance. The moderate intrinsic motivation level indicates that, on average, undergraduates in this study do not experience a strong sense of enjoyment and interest in their learning activities. The low amotivation value indicates that students effectively perceive connections between their actions and outcomes, and identify a motive or motives for engagement in the course activities [3]. Ratelle et al. (2007) referred to this type of motivation as “moderate autonomous-controlled (AU-C),” a response common among high school students but not college students, and associated with desirable high school outcomes such as “high persistence and achievement, low absenteeism, and high cognitive and affective functioning” [22]. In an analysis of first-year undergraduates’ motivation profiles during a semester, Gillet et al. (2017) found a “strongly motivated” profile similar to the mean response observed here to be quite common among undergraduates [25].

The mean motivational response profiles for women and men in the study are similar (Table 2). Although quantitative analyses show statistical differences by gender in every subscale measure and the SDI, with women reporting higher external regulation and lower amotivation, identified regulation, and intrinsic motivation compared to men, the effect sizes are small, at best.

![Figure 2](image-url). Situational motivation subscale responses (left) and self-determination index (right) for the full dataset, showing differences in mean responses by gender. Error bars show 95% confidence intervals.
Table 2. Descriptive statistics for SIMS motivation subscales and the calculated self-determination index (SDI), showing responses of all students and comparison by gender. Between groups p-values are from independent samples t-tests, and effect sizes are Cohen’s d values.

<table>
<thead>
<tr>
<th>Motivation Subscale</th>
<th>All Responses (N=5324)</th>
<th>Men (N=2256)</th>
<th>Women (N=3068)</th>
<th>Effect size</th>
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<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Intrinsic Motivation</td>
<td>3.77</td>
<td>1.48</td>
<td>4.10</td>
<td>1.44</td>
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<tr>
<td>Identified Regulation</td>
<td>4.80</td>
<td>1.27</td>
<td>4.87</td>
<td>1.29</td>
</tr>
<tr>
<td>External Regulation</td>
<td>4.34</td>
<td>1.55</td>
<td>4.23</td>
<td>1.54</td>
</tr>
<tr>
<td>Amotivation</td>
<td>2.25</td>
<td>1.26</td>
<td>2.38</td>
<td>1.37</td>
</tr>
<tr>
<td>Self-Determination Index</td>
<td>3.70</td>
<td>6.14</td>
<td>4.08</td>
<td>6.15</td>
</tr>
</tbody>
</table>

More striking distinctions appear when learner motivations are examined as a function of course pedagogy (Figure 3 and Table 3). The traditional, non-traditional, and mixed pedagogies all show significant differences in external regulation, intrinsic motivation, and SDI, with students in non-traditional settings reporting higher intrinsic motivation and lower external regulation compared to students in traditional and mixed pedagogies. Motivations in mixed pedagogy courses lie between those of traditional and non-traditional courses. Amotivation levels are lowest in non-traditional courses, and statistically equivalent in the traditional and mixed.

The motivational response profile for non-traditional courses has a distinct appearance, compared to the profiles for mixed and traditional courses (Figure 3). The non-traditional response is characteristic of motivation profiles described in prior studies as “autonomous” [25], “truly autonomous” [22], “good quality motivation” [16], or “self-determined” [24], [91].

Figure 3. Situational motivation subscale responses (left) and self-determination index (right) for the full dataset, showing differences among traditional, mixed, and non-traditional pedagogies. Error bars show 95% confidence intervals.
response type, although less commonly reported among undergraduates [25], is associated with the most optimal learning outcomes [16], [22], [91].

Table 3. Descriptive statistics and pedagogy-based comparisons of SIMS subscale measures for traditional (T), mixed (M), and non-traditional (NT) pedagogies. Between groups p-values from one-way ANOVA, and effect sizes are Cohen’s d. Small(*), medium(**), and large(***)) effect sizes are indicated. ns = not significant.

<table>
<thead>
<tr>
<th>Motivation Subscale</th>
<th>Trad. (T) N=3972</th>
<th>Mixed (M) N=784</th>
<th>Non-Trad. (NT) N=568</th>
<th>Between-Groups Analysis</th>
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<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
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<tr>
<td>Intrinsic Motivation</td>
<td>3.58</td>
<td>1.45</td>
<td>3.90</td>
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<tr>
<td>Identified Regulation</td>
<td>4.83</td>
<td>1.29</td>
<td>4.55</td>
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</tr>
<tr>
<td>External Regulation</td>
<td>4.52</td>
<td>1.51</td>
<td>4.15</td>
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<tr>
<td>Amotivation</td>
<td>2.30</td>
<td>1.30</td>
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<td>SDI</td>
<td>2.88</td>
<td>5.79</td>
<td>3.70</td>
<td>6.14</td>
</tr>
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</table>

Gender, Pedagogy, and Motivation

Strong gendered patterns in student motivation are apparent when women and men’s situational motivations are compared across different pedagogies (Figure 4 and Table 4). Overall, the largest gender-based differences across pedagogies occur in the intrinsic motivation and external regulation subscales, suggesting that the gender-pedagogy interactions most strongly influence these forms of motivation. Identified regulation is generally high for all students in all pedagogies, indicating that undergraduates find autonomous drive through value, usefulness, or importance of their classroom activities, regardless of the learning approach. Men report slightly

Figure 4. Situational motivation subscale responses for men (left) and women (right), for traditional, mixed, and non-traditional pedagogies. Error bars show 95% confidence intervals. Note the large differences in women students’ motivations in traditional and non-traditional pedagogical environments.
higher identified regulation than women in traditional and non-traditional courses, but the effect sizes are small. Amotivation values are low for both women and men in all settings, particularly in non-traditional courses. Women report significantly lower amotivation than men across all pedagogies, but the gender difference is strongest in courses with mixed approaches. For the motivation subscale measures, the strongest gender-based differences appear in traditionally taught courses. In traditional settings (Table 4a), e.g., lecture-based courses, women report significantly lower intrinsic motivation and higher external regulation compared to men, indicating that, on average, women experience more pressure and less interest and enjoyment in traditional STEM courses. The gendered intrinsic motivation findings for traditional courses are particularly concerning, given the medium effect size ($d=0.54$). Since intrinsic motivation is strongly influenced by basic needs satisfaction (competence, relatedness, and autonomy), this result suggests that women do not find as much support in their environment as men, and they might not develop a strong sense of self-determination and internalization of the learning.

Table 4. Descriptive statistics and gender-based comparisons of SIMS subscale measures for women and men in courses with (a) traditional pedagogy, (b) mixed pedagogy, and (c) non-traditional pedagogy. Between groups $p$-values are from independent samples t-tests, and effect sizes are Cohen’s $d$. Small (*) and medium (**) effect sizes are indicated. ns = not significant.

<table>
<thead>
<tr>
<th>a. TRADITIONAL PEDAGOGY</th>
<th>Men (N=1606)</th>
<th>Women (N=2366)</th>
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<td>$SD$</td>
<td>$M$</td>
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<td>1.42</td>
<td>3.27</td>
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<td>Identified Regulation</td>
<td>4.95</td>
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<td>4.76</td>
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<td>External Regulation</td>
<td>4.34</td>
<td>1.52</td>
<td>4.64</td>
</tr>
<tr>
<td>Amotivation</td>
<td>2.46</td>
<td>1.42</td>
<td>2.19</td>
</tr>
<tr>
<td>SDI</td>
<td>3.76</td>
<td>5.97</td>
<td>2.28</td>
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<table>
<thead>
<tr>
<th>b. MIXED PEDAGOGY</th>
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<th>Women (N=314)</th>
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<td>$M$</td>
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<th>c. NON-TRADITIONAL PEDAGOGY</th>
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</thead>
<tbody>
<tr>
<td><strong>Motivation Subscale</strong></td>
<td>$M$</td>
<td>$SD$</td>
<td>$M$</td>
</tr>
<tr>
<td>Intrinsic Motivation</td>
<td>4.86</td>
<td>1.29</td>
<td>4.94</td>
</tr>
<tr>
<td>Identified Regulation</td>
<td>5.00</td>
<td>1.16</td>
<td>4.80</td>
</tr>
<tr>
<td>External Regulation</td>
<td>3.67</td>
<td>1.32</td>
<td>3.05</td>
</tr>
<tr>
<td>Amotivation</td>
<td>1.67</td>
<td>0.86</td>
<td>1.54</td>
</tr>
<tr>
<td>SDI</td>
<td>7.70</td>
<td>5.26</td>
<td>8.55</td>
</tr>
</tbody>
</table>
Women and men’s motivations are most similar in courses with mixed pedagogies. Here, the only significant gender difference occurs in amotivation, with women reporting sufficiently lower amotivation than men to give significantly different values for the calculated SDI (Table 4b). Interestingly, women report a higher SDI in mixed pedagogies compared to traditional pedagogies, while men’s SDI values are statistically equivalent in traditional and mixed courses.

Non-traditional courses prompt the most positive motivational responses from both women and men (Table 4c). In non-traditional courses, the intrinsic motivation of men and women is statistically equivalent, and substantially higher than in the mixed and traditional courses. Non-traditional courses provide for the lowest reported external regulation values for both women and men, and represent the only pedagogical environment where external regulation dips below the mid-point of the 7-point Likert scale of the SIMS instrument. Women express much lower external regulation than men in courses with non-traditional pedagogies, indicating that these environments provide women with a reduced sense of extrinsic pressure or obligation to engage in the learning activities. Amotivation values are also at their lowest, and SDI values are at their highest, in the non-traditional courses.

Table 5. Descriptive statistics and pedagogy-based comparison of SIMS subscale measures for (a) men and (b) women in traditional and non-traditional courses. Between groups p-values are from independent samples t-tests, and effect sizes are Cohen’s d. Small(*), medium(**), and large(***), effect sizes are indicated. ns = not significant.

<table>
<thead>
<tr>
<th>Motivation Subscale</th>
<th>MEN (N=1606)</th>
<th>Traditional</th>
<th>Non-Traditional</th>
<th>p</th>
<th>d</th>
<th>WOMEN (N=2365)</th>
<th>Traditional</th>
<th>Non-Traditional</th>
<th>p</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrinsic Motivation</td>
<td>4.03</td>
<td>1.42</td>
<td>4.86</td>
<td>1.29</td>
<td>.000</td>
<td>0.59**</td>
<td>3.27</td>
<td>1.39</td>
<td>.000</td>
<td>1.21***</td>
</tr>
<tr>
<td>Identified Regulation</td>
<td>4.95</td>
<td>1.28</td>
<td>5.00</td>
<td>1.16</td>
<td>ns</td>
<td>0.04</td>
<td>4.76</td>
<td>1.29</td>
<td>.000</td>
<td>0.03</td>
</tr>
<tr>
<td>External Regulation</td>
<td>4.34</td>
<td>1.52</td>
<td>3.67</td>
<td>1.32</td>
<td>.000</td>
<td>0.45*</td>
<td>4.64</td>
<td>1.49</td>
<td>.000</td>
<td>1.09***</td>
</tr>
<tr>
<td>Amotivation</td>
<td>2.46</td>
<td>1.42</td>
<td>1.67</td>
<td>0.89</td>
<td>.000</td>
<td>0.58**</td>
<td>2.19</td>
<td>1.19</td>
<td>.000</td>
<td>0.58**</td>
</tr>
<tr>
<td>SDI</td>
<td>3.76</td>
<td>5.97</td>
<td>7.70</td>
<td>5.26</td>
<td>.000</td>
<td>0.67**</td>
<td>2.28</td>
<td>5.58</td>
<td>.000</td>
<td>1.15***</td>
</tr>
</tbody>
</table>

Different pedagogical approaches prompt markedly different motivation response profiles for all students. The motivations of women and men are both more similar and more positive overall in courses that employ non-traditional versus traditional approaches. Traditional courses support “moderately autonomous-controlled” [22] or “high self-determined/high controlled” [83] forms of motivation. Non-traditional courses, on the other hand, spark “truly autonomous” [22] or “high self-determined/low controlled” [83] motivational responses. These findings are consistent with prior work that illustrates the motivational benefits of active learning environments (e.g., [35], [37], [92]-[94]) and they suggest that pedagogies such as project-, problem- and discussion-
based learning could provide pathways for self-determined engagement of all students, where traditional pedagogies may not.

The gender-based analysis also suggests that traditional STEM courses may serve to disadvantage women more than men from a motivational perspective (Table 4), and that pedagogy has a stronger impact on the motivational response profiles of women compared to men (Table 5). For women, the difference between traditional and non-traditional pedagogies is stark, with effect sizes for intrinsic motivation and external regulation reaching the “very large” threshold [95]. According to SDT, learners adopt positive types of motivation in situations that provide a sense of progress and mastery (competence), supportive connections to others (relatedness), and choice and control (autonomy). SDT research further suggests that learners will not experience intrinsic motivations without feeling a strong sense of autonomy support [1], [16]. Given women’s responses to the different pedagogical environments, we may safely assume that the non-traditional courses more effectively meet women’s basic needs than do traditional STEM course. In many ways, this finding is not surprising.

The research describes how specific classroom factors can contribute to women’s expression of different motivations in traditional and non-traditional settings. Generally, instructors can actively catalyze and facilitate intrinsic motivations by creating classroom conditions of optimal challenge, positive feedback, and freedom to explore; or actively undermine intrinsic motivation through performance-contingent rewards, condescending feedback, isolation, and rigid and controlling structures [1], [53], [96]. Active learning environments are often intentionally designed to support student self-direction, enable hands-on demonstration of mastery, encourage interpersonal collaboration, and trigger a sense of societal value – goals that can serve as precursors to positive motivations (e.g., [35], [93], [97], [98]), especially among women students [99]. On the contrary, in traditional learning environments of male-normed STEM fields, researchers call attention to the ways weed-out competition, controlling structures and assessments, stereotype threat, and impersonal or condescending faculty may create conditions that undermine women’s sense of self-efficacy, interpersonal support, and autonomy [31], [61], [100], [101]. Given the systemic gender biases that exist in traditional technical education, it is not surprising that the motivational benefits of alternative pedagogies are amplified for women.

Implications for Practice

These findings have important implications for practitioners concerned with providing inclusive and student-centered learning experiences. The concept of motivational co-expression illustrated with the motivational response profiles emphasizes a need for instructors to move past the simple “intrinsic” or “extrinsic” labels, and toward an appraisal that recognizes how students adopt complex forms of drive in response to classroom activities. The gender-based analysis raises questions about how instructors may use course design to effectively promote the positive motivational engagement of all students, through their pedagogical choices. In the same way we may not wish to see women and men leave STEM courses with significantly different skills or understandings, we might not want women and men to engage technical learning with dramatically different motivations, or exit STEM courses with vastly different levels of learning internalization. Given that the motivations of women and men are both more similar, and more positive overall, in STEM courses that employ non-traditional and mixed pedagogies, a systemic
shift to active, student-centered learning may be key to a more inclusive and engaging STEM learning environment. Instructors would play a critical role in this shift: research shows that instructor beliefs about motivation contribute to their course approaches, goal framings, interactive style, and, ultimately, their students’ motivations [43], [102], [103].

**Limitations**

This analysis has some notable limitations. First, this paper presents a *characterization* of motivation with *interpretations* based on motivation theory and empirical research; we do not provide *explanations* based on analysis of direct measures in the form of qualitative student response data. Second, this analysis presents an aggregate of situational motivations based on gender and pedagogical groupings. The results presented here do not illustrate temporal changes in students’ situational motivations over time in different activities, or differences that may exist between institutions, disciplinary domains, or years of study. It is important to recognize that the aggregated motivational responses do not reflect the lived experiences of individual students in specific settings, nor do they provide commentary or evaluation on specific instructors, courses, or institutions. Finally, this paper treats gender as a binary variable, per the socio-culturally constructed, traditional classifications. Although students were provided with an opportunity to identify as non-binary or non-specified gender, the group sizes for these classifications were too small to include in the analyses. The authors recognize that treating gender as a binary variable potentially presents an unintended consequence of further marginalizing minority student populations through lack of inclusion in the reporting. Future analyses will include more person-centered narratives of situational motivation that include analyses of quantitative and qualitative data from a diverse population of students.

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