

A Classroom Intervention to Reduce the Gender Achievement Gap in College Science Project Overview

The proposed research focuses on the effectiveness and dissemination of a classroom intervention designed to reduce the gender gap in the achievement of women in STEM disciplines. We have conducted an initial test at CU of the effectiveness of a writing exercise that affirms self-worth, finding that it raises the grades and conceptual mastery of women in introductory physics (Miyake et al., 2010). These initial findings are very promising, but we currently lack any funding to explore them further. Funds are requested to extend our findings through studies both at CU and elsewhere. This will allow us to (1) better understand the mechanisms through which women's STEM performance can be improved, focusing specifically on the psychological changes that are produced by self-affirmation which in turn improve performance. Knowing this is important theoretically and can also be used to refine and sharpen our intervention. The proposed research will also (2) test the effectiveness of our intervention in other contexts (e.g., courses with different content, professors with different teaching styles, students of various demographics), (3) provide necessary data for a larger grant focusing on dissemination of the intervention, and (4) bring psychological perspectives more explicitly into CU's work on STEM education.

Background

Women are underrepresented in science, technology, engineering, and mathematics (STEM) disciplines (National Academy of Sciences, 2005; National Science Board, 2003). In 2006, women earned only 28% of Ph.D.s in physical sciences, 25% in mathematics and computer science, and 20% in engineering in the United States (National Science Foundation, 2008). Although women composed 47% of the North American workforce in 2009, the percentage of women in lucrative technical professions, such as "computer and mathematical occupations" and architecture and engineering occupations," reached only 25% and 14%, respectively (United States Bureau of Labor Statistics, 2009). National-level differences at the educational level are reflected at CU, with studies finding lower exam grades and lower scores on standardized tests of conceptual mastery for women as compared to men (Pollock et al., 2007). While gender differences in preparation (e.g., as reflected in SAT or ACT math scores) account for some of the differences in college performance (~60%), not all of the disparity in college STEM classes is accounted for by lower levels of preparation and prior achievement among women.

My colleagues and I have recently examined the contribution of subtle psychological factors to gender disparities in classroom achievement. We have specifically focused on the psychological threat arising from fear of being devalued based on a group identity. Studies have shown that becoming aware that one could be seen in light of a negative stereotype about one's group – creating what is called stereotype threat -- can undermine performance on difficult tests (Spencer et al., 1999). For example, women's performance on difficult math and science tests can suffer if they worry that their poor performance could be seen as confirming the gender stereotype that women are not as good in math and science (Beilock et al., 2007; Cadinu et al., 2005; Logel et al., 2009; Quinn & Spencer, 2001; Schmader & Johns, 2003; Spencer et al., 1999; Steele et al., 2002). These performance impairments are thought to occur because worry and discomfort generated by stereotype threat consumes cognitive resources that are diverted away from the task at hand (e.g., learning new material, taking an exam) (Beilock et al., 2007; Bonnot & Croizet, 2007; Johns et al., 2008, Schmader & Johns, 2003).

We have recently shown that stereotype threat affects women's performance in a CU physics course. Men on average show higher exam scores and better performance on an end-of-semester test of conceptual mastery, and this effect is rooted in beliefs in gender stereotypes (Miyake et al., 2010); the gender gap is increased among women who most strongly endorse the stereotype that men are better at math and physics than women.

Importantly, we also showed that a brief writing exercise could reduce the gender disparity in class performance. Self-affirmation or reflecting on self-defining values, allows people to affirm their core values in a threatening environment, reestablishing a perception of personal integrity and worth,

which in turn can provide them with the internal resources needed for effective coping (Cohen & Garcia, 2008; Sherman & Cohen, 2006; Steele, 1988). Indeed, lab studies show that such affirmations decrease evaluative stress (Creswell et al., 2005) and improve the performance of stereotype threatened individuals (Cohen et al., 2006; Martens et al., 2006).

In our double-blind study, 399 students (283 men and 116 women) in Physics 1110 were randomly assigned to either a values-affirmation or control writing group. Students in the affirmation group selected their *most* important values from a list (such as relationships with friends and family or learning or gaining knowledge) and, in response to structured prompts, wrote about why these values were important to them. Students in the control group selected their *least* important values from the same list and wrote why these values might be important to other people. Thus, both groups wrote about values and their importance, but the exercise was self-relevant only for the affirmation group.

This 15-min writing exercise was administered in the first recitation of the semester (week 1) and in an online homework assignment (week 4) shortly before the first midterm exam (week 5). Each student was assigned to the same condition at both administrations. The course instructor and teaching assistants were unaware of students' condition assignments, and the teaching assistants and students were unaware of the purpose of the writing exercises. Exam performance, course grade, and performance on a standardized test of conceptual mastery were all improved for women in the affirmation relative to control group, and this effect was particularly strong for women who most strongly endorsed gender stereotypes about science ability.

The results from this initial examination were very promising. They generated numerous requests from instructors outside of CU interested in implementing the intervention in their own classes, as well as our own interest in further understanding the proximal mechanisms by which the intervention acts. The proposed research is designed to capitalize on our initial success. We specifically intend to extend our initial findings into other classroom contexts to test their generalizability, and explore *why* they occur (i.e., mechanisms by which) affirmation improves performance.

Methodology

We will follow a two-pronged approach by working collaboratively with instructors at other universities to implement the intervention in other contexts and by implementing the intervention again at CU, this time with additional measures designed to assess the underlying cause of self-affirmation's positive effect on women's course performance.

Implementation at different sites. We were contacted by numerous faculty outside CU following publication of our initial study who were interested in the affirmation. Because we feel it is important to test the intervention's effectiveness in different contexts, we have chosen to pair with faculty who (1) have previously done research on STEM education, (2) are interested in empirically assessing the impact of the intervention, (3) have documented gender differences in the classes they teach, and (4) teach in educational settings different from CU. In this initial test of generalizability, we will work with Vince Colletta (Loyola Marymount University) and Eric Brewe (Florida International University), which will provide a test of our intervention at a much smaller liberal arts school and a large school with a more ethnically diverse population. Our initial implementation at CU involved balancing important theoretical aspects of self-affirmation and how it works with the pragmatics of the class. We are working with Colletta and Brewe to advise them on the optimal application of the invention in their particular classes. While some of the specifics may differ from our initial study (e.g., writing exercise done in lecture rather than recitation), the general form will be the same (see Miyake et al., 2010). Students in introductory physics classes will be randomly assigned to complete either the affirming or control version of the writing exercise twice: once as early in the semester as possible and again shortly before an important evaluation such as a midterm. All instructors and TAs will be blind to condition assignment. The writing assignment will be framed as a critical writing assignment, and no other mention of the relevance of the writing to the course will be made. At a different point in the term, students will be asked to indicate their agreement with the cultural stereotype that men are

better than women and math and science. If the course structure allows, instructors will also collect measures of additional factors that may reveal the proximal effects of the intervention (see below).

Assessment of outcomes. At the end of the semester, we will obtain full course grades (e.g., midterms, homework assignments, attendance, final course grades). We will also obtain as much demographic and background information as possible to determine whether intervention effectiveness is affected by variables such as class gender composition, students' majors, past math and science background, or pedagogical aspects (e.g., emphasis on peer instructor). Because we will use the same design as our past research, analyses will follow Miyake et al. (2010). We expect affirmation to selectively improve performance for women, especially on assignments with the greatest evaluative significance (exams). Consistent with our prior work, this effect should also be moderated by stereotype endorsements, with the greater benefits seen for women who most strongly endorse the stereotype.

Replication and extension at CU. We will deliver the intervention in the same course at CU (Physics 1110) that we had focused on in our prior work in order to replicate our past findings. In the proposed work, however, we hope to include additional questionnaires throughout the semester that will test the proximal effects of the affirmation (see below). We know from prior research on self-affirmation that it facilitates coping with adversity by bolstering the sense of self. In addition to this, we expect that there are numerous other specific effects self-affirmation might have – particularly among individuals facing stereotype threat in an actual classroom setting. Knowing exactly what changes underlie the improved performance among affirmed women will not only contribute theoretically to the self-affirmation literature, but will also help us refine the current intervention for future classroom studies.

Proximal effects of the intervention will be assessed via questions posed in class and answered via clickers. Because the questions will be presented as “of interest to the professor” and students regularly answer clicker questions already, students should not find their presentation unusual.

1. **Changes in subjective stress:** Anxiety and worry have been directly implicated in stereotype threat's negative effects (e.g., Marx & Stapel, 2006; Steele, 1997; Schamder & Johns, 2003). If affirmation improves coping, the benefits of affirmation may arise from decreased stress during evaluative challenges. If so, affirmed women may report less stress before exams, which we will assess with questions such as “I am confident in my ability to do well on the upcoming exam” and “I am worried about the upcoming exam.”
2. **Changes in identification with physics:** Disidentification, or a reconceptualization of one's self-definition to de-emphasize the importance of a domain, has been noted as a potential consequence of stereotype threat (e.g., Steele, 1997). Bolstering the self via affirmation may oppose this, leading to higher identification with physics among women in the affirmation than control condition, which we will test with questions like “Doing well in physics is important to me” and “Physics is an important part of who I am.”
3. **Increased willingness to seek help:** Stereotype threat may cause women to worry that any difficulty they have with the course will be interpreted as confirmation of the gender stereotype. This may discourage them from consulting with instructors and TAs outside of class, or from asking questions in class. Affirmation may ameliorate this, so students will be asked how comfortable they feel approaching the instructors or TAs (e.g., “If I had a question, I would go to my TA's office hours”) as well as how often they have actually sought help (“How many times have you gone to your professor's office hours this semester?”). If possible, we will also have the instructor and/or TAs make note of who attends office hours, then later code for student gender and affirmation condition.
4. **Compatibility of physics with communal goals:** One reason women tend to avoid physics and other STEM domains is because they view the disciplines as incongruent with communal goals (e.g., working to help others; Diekmann et al., 2010). These goals are often very important to women when they select a career path. Undergoing self-affirmation in a physics setting may allow

women to make the link between their “gendered” values (e.g., communal goals) and physics, allowing them to feel more comfortable in physics and perform better later on. To test this, we would include questions such as “I believe that physics can be used to solve real-world problems” and “The knowledge that I gain in my physics class can be used to help people.” We could also ask even more explicit questions such as “I think it will be easy to balance family life with a career in physics.”

Assessment of outcomes. Analyses of the effect of the affirmation on exam scores, course grades, and the test of conceptual mastery will follow Miyake et al. (2010). The measures of stress, physics identification, willingness to seek help, and compatibility with communal goals will be analyzed with similar models, testing for the effects of gender, affirmation condition, and level of stereotype endorsement. We expect women in the affirmation condition to show improved performance, less stress, and/or increased identification, comfort in seeking assistance, and perceived compatibility with communal goals. These effects may interact with stereotype endorsement, such that they are larger for women who most strongly endorse the stereotype. We will also specifically test whether changes in stress, identification, willingness to seek help, and perceived compatibility with communal goals underlie the changes in performance among affirmed women using tests of mediation (Mackinnon et al., 2002) (e.g., whether a decrease in stress accounts for the effect of affirmation on women’s improved performance).

Impact of Proposed Project

My own background is in experimental social psychology, with a particular focus on aspects of stereotyping and prejudice. This work on stereotype threat represents an important focus on translating my basic, lab-based research into field contexts. This research perfectly exemplifies the goals of translational research by using basic research on stereotype threat and affirmation to improve outcomes in authentic classrooms.

Funding for the proposed research will provide a critical step in our progression. Our long-range goal is to develop an easy-to-administer, robustly effective intervention. Getting to this point will require us to demonstrate that the intervention can be readily administered outside of CU. We also need to know which aspects of our current protocol are critical for its success, and how best to instruct others to administer it. We plan to apply for NSF and/or Spencer Foundation funding to support the scaling up of our efforts, with the goal of developing a manual for administration as well as a web page to disseminate the materials and administer the affirmation. (Although our initial focus here is on physics, future work will extend to other STEM disciplines.) The proposed research is a critical component of this plan, as it will provide information on the replicability and generalizability of our approach. It will also provide information about the mechanisms through which affirmation operates, which could allow us to refine the intervention to sharply focus on the most critical aspects.

This project also has implications on STEM education within my department and the CU community. There are many faculty within Psychology and Neuroscience whose research has implications for STEM education, but we have hitherto not coalesced around this focus. The current project has fostered collaboration between social (Geoff Cohen and myself) and cognitive psychologists (Akira Miyake) to examine how social processes related to stereotyping affect learning and memory. Through talks and presentations within the department, we have increased the awareness and interest of our colleagues in this topic. We have also successfully recruited a very promising post-doctoral fellow to join a related project. Her background is in experimental social psychology, so this project will provide her with more explicit training in STEM education and in applied research more generally.

This project also facilitates collaboration beyond the department with physicists Noah Finkelstein and Steve Pollock. They began advising us on a grant focused on lab-based studies of the basic mechanisms of stereotype threat. Our prior classroom intervention study grew out of our mutual interests in understanding and reducing gender disparities. The current classroom work represents an important extension of this work that we hope will strengthen and extend our collaboration. Our work is, to our knowledge, quite unique for combining the perspectives of

psychology into discipline-specific science education research. Psychological perspectives have also to this point been largely missing from CU's STEM education work. Please note that while we have other funding to conduct research on stereotype threat, the proposed project focuses on a qualitatively different issue, that of classroom interventions. Our current grant instead focuses on lab studies and has a more basic focus on the impact of stereotype threat on working memory. While this work has informed our classroom work, the development of a ready-to-disseminate intervention is not the focus of our current funding, and that current funding is not appropriate to support the proposed research.

The publication of our first classroom study generated tremendous interest from other science educators (and from parents and secondary school educators). We hope that refining our intervention will contribute to CU's reputations for conducting translational research that simultaneously elucidates the mechanisms underlying learning while also focusing on pedagogical interventions that improve classroom outcomes.

Timeline

Summer/early fall 2011: Consult with Colletta and Brewe on integration of intervention in their courses, train their personnel on administration and coding of data. Administer intervention at CU.

Late fall 2010/winter 2012: Collect outcome data from LMU, FIU, and CU. Perform analyses. Prepare NSF and/or Spencer Foundation grants based on results to extend tests of classroom interventions and develop methods for wide-spread dissemination.

Budget

1. \$200 for classroom observers: Our administration at CU involves unobtrusive observation of the intervention's administration in recitations by trained observers who record notes on the fidelity of the administration. All recitations occur on a single day, with 3 sections running concurrently. This money will be used to pay 2 observers.
2. \$300 for programming on-line administration: The second writing exercise at CU is completed on-line. We had previously delivered it via CULearn, but this is not optimal for several reasons: (1) the formatting options on CULearn are not well-suited for a data collection context, (2) it is CU-specific, so we would be unable to use it at LMU and FIU, and (3) it is being phased out, so we need to explore a replacement. Funds will be used to pay a graduate student to re-program the writing exercise on Qualtrics.com. This is a secure on-line survey company used extensively in the department. It has much better formatting and flexibility for our uses. Moreover, we can have students at other university access it, so data collection can be centralized on a single system.
3. \$1500 for post-doc: The bulk of the budget will be used to fund a post-doctoral researcher (~15% time) who will supervise both the CU and non-CU components of the research. This post-doc, Jane Stout (vita attached), has extensive experience studying psychological factors affecting gender disparities in STEM. She will devote the majority of her time to another project. On this project, she will serve as one of the observers for the CU administration, assemble and distribute all materials, conduct all training at CU and elsewhere, supervise other research assistants, assemble and analyze all data, and assist in the preparation of manuscripts and grant proposals. She will also attend the DBER seminar series. Given the range of tasks and sophistication of the analyses, we found it necessary in our initial work to have a senior trainee oversee our prior intervention work. The ability to support a post-doc is, therefore, crucial for the success of the project. It will also provide the trainee with important training in field research.

Consultations with Colletta and Brewe occur over email or Skype, so no funds are needed to support that. Costs for copying materials for Physics 1110 are covered by my department, and the costs at LMU and FIU will be covered by the instructors there.

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