

Improving student outcomes in math through online faculty professional development

Dr. Chris S. Hulleman, University of Virginia

Chris S. Hulleman is a professor of education and public policy at the University of Virginia. He is also the founder and director of the Motivate Lab, which collaborates with educational practitioners to help ameliorate systemic racism and inequality. His team develops and tests changes in educational practice that support the motivation of students from historically marginalized backgrounds in education. He received his BA from Central College (Iowa) in 1993 and his PhD in social and personality psychology from the University of Wisconsin–Madison in 2007. Prior to his career in psychology, he spent six years as a teacher, coach, and social worker. Chris is a second generation educator whose grandparents were tenant farmers in Iowa and Nebraska. He tries to emulate their hard work and persistence in the pursuit of social justice. One of his favorite childhood memories is eating his paternal grandmother’s homemade fruit pies with plenty of ice cream.

Dr. Dustin B. Thoman, San Diego State University

Dr. Dustin Thoman is a Professor in the Department of Psychology and the Center for Research in Mathematics and Science Education at San Diego State University. He also serves as California Research Director for Motivate Lab. His scholarship is grounded in social psychology, diversity science, and a social contextual framework of motivation. He studies how motivation can be supported or disrupted by the social and cultural contexts in which interests are sparked, developed, and ultimately become (or not) lifelong pursuits. He and his team utilize insights from motivation science to identify and remove institutional and social-contextual barriers that impede the development of educational and career interests for students from marginalized and historically underrepresented backgrounds. Improving equity and inclusion is at the heart of his team’s research and translational work to support research on equity and inclusion in STEM education.

**Motivating Learners: Improving Student Outcomes in Math through Online Faculty
Professional Development**

Chris S. Hulleman
University of Virginia

Dustin B. Thoman
San Diego State University

Zach Himmelberger
Motivate Lab

Teresa K. Hulleman
Motivate Lab

Paul Beardlsey
Cal Poly Pomona

Yoi Tibbetts
University of Virginia

Kenneth E. Barron
James Madison University

Introduction

Low student success rates in introductory math courses represent one of the most common and critical barriers to college graduation rates across the United States [1]. The causes of this problem are multifaceted and vary across institutions, but based on a wide range of national reports, math instructors often are not provided the training or resources necessary to best support student learning [2].

Professional development for math instruction is most commonly focused on curriculum and technology tools to support instruction. A critical, yet often overlooked component of instructional practice, however, is supporting student motivation. In higher education, traditional lay models of learning often suggest that the instructor's "job" is to provide content and the students' "job" is to learn that content. Implicit in the job of learning is to be motivated to learn. Decades of research in psychology suggest that this view of motivation is inaccurate. Student motivation is influenced by one's responses to the immediate learning environment; that is, learning contexts can be more or less motivating [3], [4]. Unfortunately, few higher education instructors learn about contemporary theories of motivation, the empirical literature of supporting evidence, or strategies for creating a more motivationally supportive learning environment (i.e., the science and practice of motivation). This is especially important in math where learning mindsets have been found to be important predictors of student success (e.g., [5] – [7]), and early math courses often thwart degree progress for a wide range of students.

The Motivating Learners Course

To address this gap in training, our team of motivation researchers and curriculum designers created the Motivating Learners Course. In this online professional development course, faculty learn how to create college courses that help students develop adaptive beliefs about themselves and the learning context (i.e., learning mindsets). In particular, they learn about three key learning mindsets—Growth Mindset, Purpose & Relevance, and Sense of Belonging (which we refer to as Mindset GPS)—and how learning mindsets are influenced by what we say and do as instructors. Then, faculty are provided opportunities to immediately apply what they are learning to create new materials for their courses that leverage these mindsets to promote equity while being customized to their courses, students, and teaching styles.

Focus on Equity

Much of the research on learning mindsets interventions, including much of the content covered in the Motivating Learners Course, focuses on strategies that are designed and have been shown to reduce equity gaps (e.g., [8] – [11]). Indeed, the Motivating Learners Course course begins with framing students' learning mindsets as adaptive responses to educational environments. That is, when students adopt a maladaptive mindset belief in a particular class, rather than

“blaming the student” the Motivating Learners Course suggests that we must attend to the cues or signals in the learning environment through the student’s perspective to understand what shapes the student’s beliefs. By adopting a student-centric perspective, the Motivating Learners Course helps guide participants to think about how students’ backgrounds might shape their learned and current experiences in learning environments. The goal of improving equity is at the heart of the Motivating Learners Course approach, and this goal directs our focus on foundational math courses with historical equity gaps in this study.

Study Overview

We recruited 25 math instructors within a single department who taught foundational level math courses with historical equity gaps, as identified by the department, to participate in a version of the Motivating Learners Course that was tailored for math courses. We reasoned that if we can equip math instructors with the knowledge and tools for how to create course materials that support students to develop adaptive beliefs about learning and school, we will observe improved student outcomes in these math classes. Specifically, our study aimed to address two **research questions**:

1. Do students taking classes from instructors who participated in the Motivating Learners Course perform better than those taking classes from instructors who did not participate in the Motivating Learners Course?
2. Does the Motivating Learners Course help reduce equity gaps in student outcomes across math classes?

Methods

Participants

We offered the Motivating Learners Course to a cohort of math faculty from a single department at a large Hispanic Serving (HSI) state university in California during the 2022-2023 academic year. Information about the Motivating Learners Course was distributed widely across the department and instructors volunteered to participate. For more information on the course, see the Appendix.

We evaluated the effectiveness of the course using institutional data from 60 math instructors, including 25 who participated in the course and a group of 35 comparison instructors teaching matched courses in the same department who did not participate in the Motivating Learners Course. Math courses taught by faculty in our sample included College Algebra, Precalculus, Calculus 1, Calculus 2, and Statistics with Applications.

Student Record Data

We obtained student record data ($n = 3,118$) from 1,124 undergraduates enrolled in courses taught by a math instructor who participated in the Motivating Learners Course and 1,994 students enrolled in a course from a comparison instructor. We also obtained data from an additional 90 students who were enrolled in more than one math course, though we did not use their data to avoid violating independence assumptions. For each student, we collected course grade, withdrawal status, cumulative GPA prior to the current semester, underrepresented minority status (i.e., Black, Hispanic, Native Hawaiian, and Filipino; URM), and Pell grant recipient status. Some students ($n = 296$) did not receive a course grade because they withdrew or were otherwise dropped from the course.

Results

Baseline Student Comparisons

We conducted t -tests to assess potential baseline differences between students who had faculty participate in the Motivating Learners Course and students whose faculty did not participate in the Motivating Learners Course. As presented in Figure 1, the results indicated that instructors who participated in the course had a higher percentage of students with a historically marginalized racial or ethnic identity than instructors in the comparison group (60.8% v. 52.7%;, $\chi^2(1) = 18.81, p < 0.001, h = 0.16$). Instructors who participated in the course also had a higher percentage of Pell grant recipients than instructors in the comparison group (45.0% v. 41.9%), though this difference was not statistically significant, $\chi^2(1) = 2.77, p = 0.096, h = 0.06$. Finally, students with an instructor who participated in the course had a lower GPA entering the course ($M = 2.92, SD = 0.74$) than students with an instructor who did not participate in the course ($M = 3.06, SD = 0.65$), $t(3116), p < 0.001, d = 0.19$. In summary, instructors who participated in the course were more likely to have students with a historically marginalized racial or ethnic identity, Pell grant recipient, and lower cumulative GPA compared to their colleagues who did not participate in the course.

Effects of Participating in the Motivating Learners Course

Results indicate that, overall, students taught by instructors who participated in the course earned significantly higher grades ($M = 2.33, SD = 1.29, n = 990$) than those whose instructors did not ($M = 2.19, SD = 1.32, n = 1832$), $t(2820) = 2.87, p = 0.004, d = 0.11$. Further, students with instructors who participated in the course had higher pass rates (68.9%) than those whose instructors did not (64.9%), $\chi^2(1) = 4.93, p = 0.026, h = 0.09$. See upper graph of Figure 2.

This pattern of findings remained even after controlling for students' cumulative GPA prior to beginning the target math class, as well as URM status and Pell grant recipient status (see Figure 2). More specifically, in separate models, we regressed grades and pass/DFW on an indicator variable for course participation, cumulative GPA, URM status, Pell grant recipient status. The effect of participating in the course was significant in both models. In follow-up analyses, we allowed course participation, URM status, and Pell grant recipient status to interact. Though the effect of course participation remained significant, none of the interactions were significant. This indicates that, contrary to hypothesis 2, there was no evidence that participating in the Motivating Learners Course reduced classroom equity gaps.

Propensity Score Matching

There were baseline differences between faculty who participated in the course and comparison faculty in the proportion of URM students and students' cumulative GPA prior to beginning the semester, as well as a non-significant trend for the proportion of Pell grant recipients. To account for these baseline differences, we estimated an average treatment effect (ATE) for course grade and pass rate using propensity score matching. All propensity score matching analyses were conducted using the MatchIt package [12] in R. Propensity scores were estimated using a logistic regression based on URM status, Pell grant recipient status, and cumulative GPA. One-to-one nearest neighbors was then used to match students, though URM status and Pell grant recipient status were matched exactly. Our final matched sample included 990 students in each of the groups (course participants and comparison faculty). The groups were well-balanced, with all standardized mean differences below .03 after matching. Cluster-robust variance was used to estimate the standard errors in subsequent regression analyses.

To estimate the ATE of grades, we regressed grade on an indicator variable for course participation in a simple linear regression. Our results indicate that participating in the course had a significant effect on grades, $ATE = 0.22$, $CI_{95\%} = [0.12, 0.32]$. Similarly, to estimate the ATE of pass rates, we regressed pass/DFW on an indicator variable for course participation in a generalized linear regression using a logit link. As presented in the bottom graph of Figure 2, our results indicated that course participation also had a significant effect on pass rates, odds ratio = 1.42. Alternatively, we can say that the probability a student passes the course, given their instructor participated in the course, is 76.4%, compared to a probability of 69.5% for students who did not have an instructor who participated in the course ($h = 0.16$).

Discussion

These findings demonstrate that a brief, intensive, online professional development course focused on equipping mathematics faculty with knowledge and tools to support student motivation can have downstream effects on student learning outcomes. Professional

development for math instruction is most commonly focused on curriculum and technology tools to support instruction. This study demonstrates that attention to instructors' knowledge and practices with respect to supporting student motivation can also be important for improving student outcomes overall and for reducing equity gaps.

These findings illustrate the potential benefits of the Motivating Learners Course, but of course we do not assume that this is the only course that could produce such effects. Although few professional development courses focus on teaching lessons from motivation science and student-centered instruction, these aims could, in theory, be achieved through other courses.

Future Directions

Future research is needed to examine changes to instructor's knowledge, attitudes, and instructional practices as a result of taking the course, and how these changes impact student learning outcomes. The theory and logic model guiding this work suggest that the Motivating Learners Course will improve student outcomes by influencing instructor knowledge, attitudes, and behaviors. In this study, we were only able to measure student outcomes, without direct measures of instructor knowledge, attitudes, and behaviors. This future work is important for establishing the process through which improvement occurs. Such an understanding can guide both the refinement of the Motivating Learners Course and future efforts to improve mathematics instruction.

Conclusion

Faculty often think of motivation as the students' responsibility. Motivation science, however, provides substantial evidence that messages and cues within the learning environment influence student motivation. This study demonstrates that student outcomes in math can be improved by teaching faculty about this science of motivation and how to support student motivation through messages and instructional practices. Supporting such evidence-based professional development can be an effective strategy for improving student outcomes overall and equity gaps in math.

Appendix - Motivating Learners Course Description

The Motivating Learners Course

Brought to you by Motivate Lab



Course Description

In this online professional development course, you will learn how to create college courses that help students develop adaptive mindset beliefs about learning.

In particular, you will learn about 3 key learning mindsets — Growth Mindset, Purpose & Relevance, and Sense of Belonging (which we refer to as Mindset GPS) — and how they are influenced by what we say and do as instructors.

Then you will be provided opportunities to immediately apply what you are learning to create new materials for your courses that leverage these mindsets to promote equity while being customized to your courses, students, and teaching styles.

Expected time commitment: 8 - 10 hours.

Learning Outcomes

- **Understanding the principles** for supporting student motivation through 3 learning mindsets — Growth Mindset, Purpose & Relevance, and Sense of Belonging.
- **Identify** supportive and unsupportive learning mindset messages.
- **Identify and adopt** learning mindset supportive messages and instructional practices.
- **Identify inequities** for key student groups and adopt learning mindset interventions to counteract them.

Course Overview

Section 0. Onboarding

Before you begin, we want you to feel comfortable moving around this course and the platform we've housed it in. We'll introduce you to the **technology** that you'll use throughout the course, what you'll **learn and create** during the course, and how you can **connect and learn from others** while taking the course. We'll also introduce you to a statement about equity and how what you're learning can promote more equitable outcomes with your students.

Section 1. Introduction to Learning Mindsets

Next, we'll introduce **Mindset GPS** and the **key concepts** that we'll continue building on through the entirety of the course. We'll also introduce you to a student, Reggie, and how he initially experienced these key concepts at the start of college.



Section 2. Talking the Talk, Walking the Walk



Talk the Talk. The language that you use to frame your course, activities, and assignments can profoundly impact your students in lasting and measurable ways. We'll take time to explore the principles behind messaging that motivates students.

Walk the Walk. But sending Learning Mindset supportive messages isn't the only way we can support students' Learning Mindsets. Students also need their instructors to provide opportunities to experience productive Learning Mindsets and have our messaging reinforced through our learning mindset supportive instructional practices.



Section 3. Creating Materials for Your Instruction

Finally, we'll introduce example "talk the talk" and "walk the walk" projects to help you begin creating materials that you can immediately use in your course(s).

Section 4. Course Wrap Up

We'll close with a final reflection activity and course reaction survey, and we'll share a list of **research references** and **additional resources** to learn more about the content of the course.

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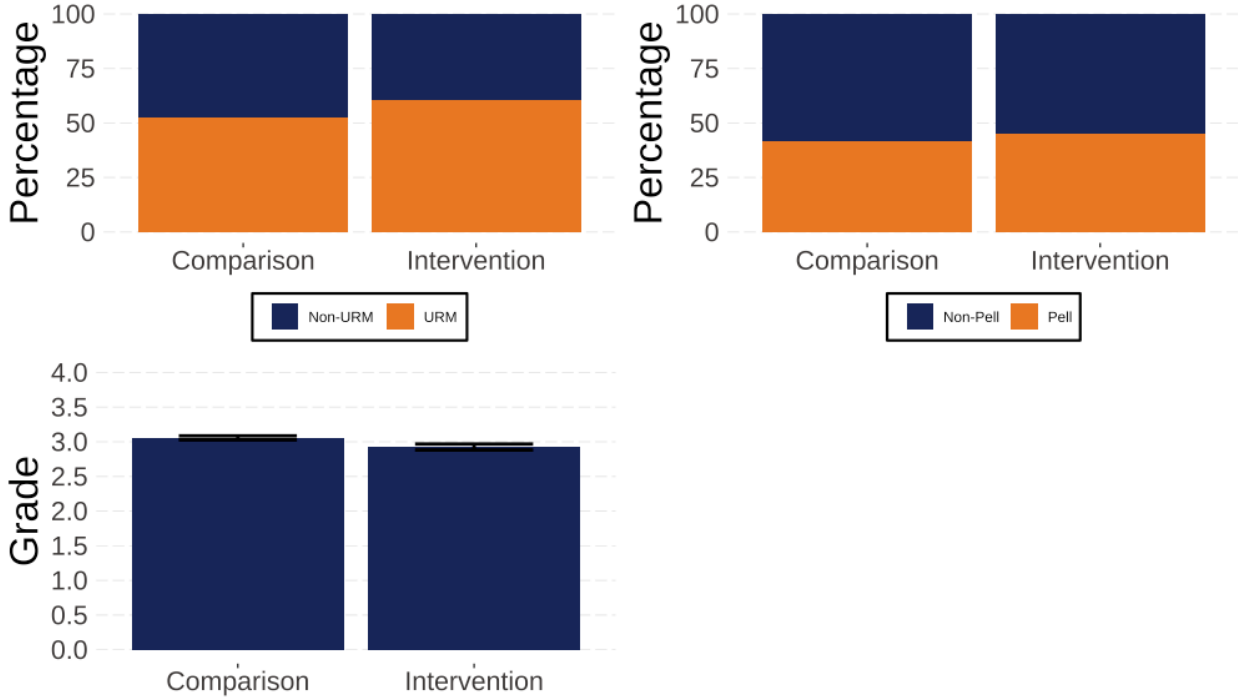
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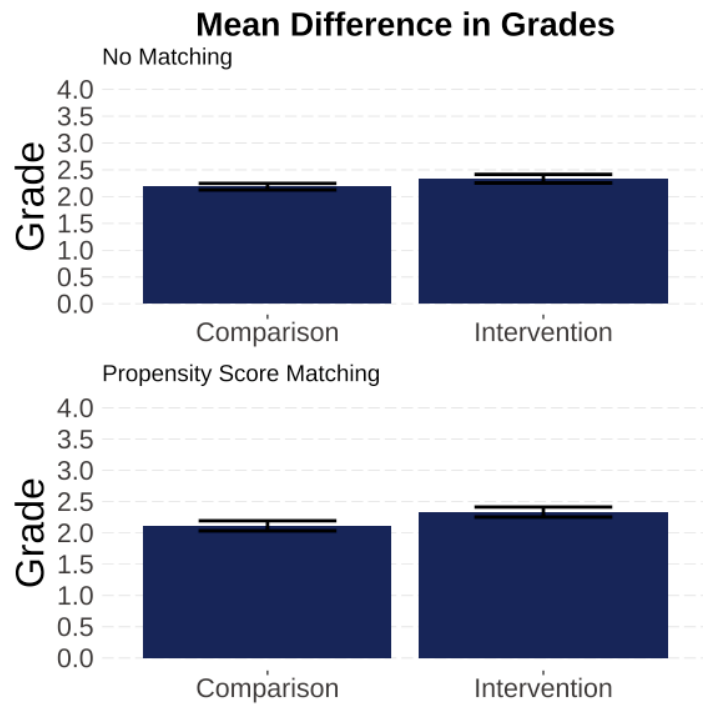
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Figure 1. Baseline differences in student demographics between math faculty who participated in the Motivating Learners Course (intervention) and a comparison group of math faculty who did not participate in the course (comparison).



Note: Comparison = a matched comparison group of faculty who did not participate in the Motivating Learners Course. Intervention = faculty who participated in the Motivating Learners Course.

Figure 2. Main effect of participating in the Motivating Learners Course on student course grades in mathematics.



Note: Comparison = a matched comparison group of faculty who did not participate in the Motivating Learners Course. Intervention = faculty who participated in the Motivating Learners Course.