Teaching for Retention in Science, Engineering, and Mathematics: A Guide for Graduate Student Instructors

Adapted from Kendall Brown, Hershock, Finelli, and O'Neal (2009)
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The United States (and the American college-going population) is becoming increasingly diverse, but the diversity of science, engineering, and mathematics (STEM) students and graduates does not reflect the nation's demographics. Further, although the overall number of bachelor's degrees awarded annually in the U.S. has risen by nearly 50% over the last twenty years, (NSF, 2008), the proportion of university students achieving bachelor's degrees in STEM fields has declined by almost 40% (NAS, 2007). Considerable research has demonstrated that instructors can have a significant impact on the retention of a diverse student body (Seymour & Hewitt, 1997). The positive impacts of diversity on student learning and development are also well documented (Gurin, Dey, Hurtado, & Gurin, 2002; Gurin, Nagda, & Lopez, 2004). In this section of the *GSI Guidebook*, we introduce four research-based principles and associated teaching strategies that you can easily incorporate into your classroom teaching practice to supplement departmental and institutional retention efforts. Research suggests that these strategies can enhance the learning and retention of *all* students.

Principle #1: Create a welcoming and supportive learning environment.

Undergraduate students often report that classroom climate (how welcome they feel in class, how well supported they are by instructors, and instructor rapport with students) significantly influences their decisions to stay in or leave STEM disciplines (O'Neal, Wright, Cook, Perorazio, & Purkiss, 2007). In contrast, when students perceive instructors as disengaged, disrespectful, or uncommitted to student learning, it has a negative impact on their interest in taking STEM courses in the future. In your role as a GSI, you can actively create a learning environment that welcomes students from all backgrounds by incorporating the following teaching strategies:

Assign challenging (not trivial) work at a challenging (not overwhelming) pace.

As a GSI, you can help students succeed by setting high standards and providing challenging, yet attainable tasks. Communicate trust in your students' abilities to meet high expectations. Because successful experience is the most important source of fostering self-confidence, it is important to determine students' current level of understanding on a topic and teach concepts just beyond their understanding so they are challenged (rather than frustrated or bored) by new information. This approach helps students remain motivated and thus exert the effort required to succeed academically.

Organize and strategically use teams.
Consider assigning students to diverse work groups that meet regularly to discuss and work through difficult problem sets, assignments, or other issues. Assign and rotate roles within teams, and include ways for students to rate the contributions of all team members.

Advertise available support and resources.
Because many classes will include students representing a range of ability and skill levels, clearly (and repeatedly) communicate the support and resources that are available to assist all students in their learning. Do not assume that students will seek help when they are struggling with a class. Request meetings with students as problems arise.

Actively cultivate instructor-student rapport.
Be on time (or early) to class and make yourself available to students immediately before and after class; engage students about the course or their lives to show your interest in them. Learn and use students' names (as many as feasible). Share your genuine enthusiasm and interest in the subject matter and teaching. Solicit and encourage questions about the course content and its relevance.

Become aware of unconscious biases and subtle messages given to students.
Avoid labeling some students as better than others; they may simply be more confident, not brighter, and be careful not to respond to comments or questions in ways that students might interpret as dismissive or judgmental. Additionally, be aware of gender dynamics and be sensitive to the experiences of visibly underrepresented students in your class. To help create an inclusive classroom, use diverse examples that represent a variety of perspectives and backgrounds and do not bring unwanted attention to students by asking them to speak on behalf of a particular social identity group to which they belong.

Principle #2: Clearly communicate grading policies and provide frequent feedback on student learning.

Students rate their perceived ability to succeed as a primary factor in their decisions to persist in or leave STEM majors, and because course grades are not always indicative of ability to succeed, students' decisions are often ill informed. In a study of U-M undergraduates, O'Neal et al. (2007) found that more than half of the approximately 300 students who reported becoming less interested in STEM received a course grade of 3.0 (out of 4.0) or better (and many of these students reported that course grade was an influence in their decision). Thus, we strongly encourage you to use the following strategies in order to help your students more accurately evaluate their academic performance and capacity for success in STEM:

Reiterate that effort is the most important component of success, and that all students must work hard to succeed.
Encourage your students to view their performance as a measure of their effort, not their innate ability. Help students understand that they are capable and that sustained effort is needed to achieve. Expect that *all* students have strengths and will succeed with effort, and articulate this expectation frequently.

Be transparent about your grading policies.
Clearly explain grading policies—and how students should interpret grades—in your course syllabus, verbally, and when describing course assignments or exam results. Using a grading rubric is an excellent way to communicate course learning goals, your expectations, and criteria for student mastery. Additionally, grading rubrics are a good way to be transparent about how points or grades will be assigned on assignments and tests.

Collect and use formative course-level data about students' comprehension.
In order to gauge students' understanding of course material, periodically ask your students to write anonymously for a minute about what concept is most confusing to them, then analyze student responses and allocate future class time to address the most common student concerns or misconceptions. Or, ask your students to make concept maps that diagram the connections between major course concepts and other material, and then use the results to guide class conversation.

Teach students to rely less on performance comparisons and more on content mastery.
Help your students recognize when they have achieved mastery by using explicit criteria for assigning grades. Also, provide your students with clear, informative, and frequent feedback. Avoid using norm-referenced grading (a.k.a. "grading on a curve") because it increases student stress and anxiety, and makes it difficult for students to gauge their true performance (i.e., an individual's grade is dependent on the performance of other students).

Principle #3: Encourage students to engage in the scientific method.

Engaging undergraduates in the process of inquiry is a key component of fostering their interest in and excitement about science and engineering. Inquiry-based learning incorporates open-ended, exploratory activities that ask students to investigate problems or phenomena and allow them to construct their own understanding of concepts. Below, we suggest several strategies that GSIs can use to infuse inquiry-based learning experiences into their courses.

Ask students to generate hypotheses and ways to test them.
When explaining research findings, don't begin by showing the results or conclusions. Instead, introduce the problem, observations, or data that generate the underlying scientific question, and ask students to generate and critique hypotheses to explain the phenomenon. Encourage students to identify data that would support alternate hypotheses or to brainstorm experiments that could generate the data to test these hypotheses.

Invite students to practice interpreting data and drawing their own conclusions.
Display graphs or tables of data from research literature or popular media, and model your thought process and way of making sense of the data. Provide students with additional examples and ask them to practice interpreting the data to test hypotheses or research questions. Before explaining what you or other expert researchers concluded from the data, ask students to assess critically the implications of the data for research or practical application.

Ask students to make predictions by applying course concepts to unfamiliar situations.
Before doing classroom demonstrations or simulations, invite your students to make predictions (and explain them) rather than telling them what should happen. After the demonstration, ask students to describe what they observed before telling them what happened and why.

Principle #4: Bring real-world relevance into the classroom and highlight careers in STEM.

For many students, interest in STEM may be influenced by how readily they make connections between course content and its relevance or usefulness in the "real world." For example, research conducted by CRLT (Hershock & O'Neal, 2008) revealed that students who learned about career opportunities related to course content were significantly more likely to report interest in majoring in STEM. That research also showed that engaging students in discussions about real-world applications of course concepts or modeling STEM careers in the classroom was associated with increased student interest in pursuing STEM majors. GSIs wishing to encourage student interest and persistence by bringing the real world into the classroom might consider the following strategies:

Highlight connections between STEM learning and real-world applications.
Intentionally situate classroom activities or assignments in the context of current events, real-world technologies, and applications of STEM concepts and skills in order to help students understand, evaluate, or solve real-world problems (e.g., how polynomial functions can be used to estimate how quickly a disease could be eradicated). To harness students' enthusiasm for learning about current scientific, technical, and social problems, devote class time and student preparation to learning about the background and

relevance of the real-world issue, controversy, or problem. Also, use real-world examples to illustrate abstract concepts, or help your students derive abstract concepts from sets of real-world examples.

Introduce students to career opportunities related to STEM learning.
Highlight career options related to course content. Advertise and discuss the professional development value of opportunities for summer employment, internships, and undergraduate research in STEM disciplines. Explain how STEM professionals employ course concepts and skill-based learning in their work. Highlight and discuss your research (and that of others), its application and relationship to course content at a level that is accessible and understandable to your students. Convey your excitement about your own research when relevant, and share how you became interested in your field of study.

While not an exhaustive list of approaches, the concrete teaching strategies described here should assist GSIs in enhancing the learning of all students while also assisting departmental and institutional efforts to attract and retain students in STEM disciplines. For additional information, see CRLT Occasional Paper No. 25 (Kendall Brown, Hershock, Finelli, & O'Neal, 2009) or contact the Center for Research on Learning and Teaching.

References

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Other CRLT *Occasional Papers* on inclusive teaching:

- *Teaching for Retention In Science, Engineering, and Math Disciplines: A Guide for Faculty* (Kendall Brown, Hershock, Finelli, & O'Neal, 2009)
- *Making Accommodations for Students with Disabilities: A Guide for Faculty and Graduate Students* (Bierwert, 2002)
- *The Effect of Student Diversity on Student Learning at the University of Michigan: Faculty and GSI Perspectives* (1999)
- *Knowing Your Students Better: A Key to Involving First-Year Students* (Fenty, 1997)
- *Undergraduate Women in Science and Engineering: Providing Academic Support* (Montgomery & Barrett, 1997)
- *Development and Assessment of Intercultural Engagement* (Kusano, Conger, & Wright, 2016

These are available online at http://www.crlt.umich.edu/resources/occasional