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Inclusivity in Introductory STEM Courses:

A Guide to Improving Student (and Instructor!) Mindsets

STEM

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with
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Foreword

As educators and instructors, we all want to reach our students. As physical science educators, however, we realize there are strong social pressures pushing some students away from our disciplines of physics, astronomy and chemistry. At the Cottrell Scholar Conference in 2019, we heard from a new member of the community, Kerstin Perez, who discussed intervention tactics she developed for her introductory physics class to retain students who have been historically excluded from physics. At her poster, several of us gathered to discuss strategies we had also created. We were excited about the idea of using small strategies to have big impacts on our students, their mindset, and their resilience.

While at the Cottrell Scholar Conference, we hatched an idea for a collaborative proposal on developing and researching interventions. As you can read in the introduction, we wanted to know what actually worked by discussing with social scientists and possibly even studying it. We partnered with FLAMEnet to do this work. Unfortunately, our grand plans were dashed thanks to a worldwide pandemic, the in-person FLAMEnet workshop was canceled, and we resorted to meeting on Zoom, as did everyone else. Under the leadership of professor Tom Solomon, we decided to do a three-part series of virtual workshops on interventions from experts. We were worried that everyone would be "Zoomed out" by spring of 2022, but the turnout was amazing. Well over 100 people were excited to hear from our experts in each session.

The enthusiasm of the speakers and attendees pushed us to keep things going. This booklet is an attempt to capture in writing the excitement from the workshops, put together the interventions discussed (many actually backed up with research and references), and report out some of the interventions we have employed with easy-to-follow methods and example worksheets to make them fit into any class. We are grateful to the amazing community of educators who gathered as part of the workshop series.
We shared your creative and thoughtful contributions as part of Chapters 1-3.
We hope you find something in this book to use in your classroom.
The smallest changes can make a huge difference to your students.

FLAMEnet
https://qubeshub.org/community/groups/flamenet/about

Videos of the Workshops
https://www.eg.bucknell.edu/~tsolomon/cottrell2022.html

Members of our Cottrell Scholar Collaborative include:

- Lou Charkoudian, Haverford College
- Michael Dennin, University of California, Irvine
- David Forbes, University of South Alabama
- Carla Fröhlich, North Carolina State University
- Jen Heemstra, Emory University
- Mike Hildreth, University of Notre Dame
- Kerstin Perez, Massachusetts Institute of Technology, Columbia University
- Shahir Rizk, Indiana University South Bend
- Jennifer Ross, Syracuse University
- Tristan Smith, Swarthmore College
- Tom Solomon, Bucknell University
- Kana Takematsu, Bowdoin College

Introduction

Social-psychological "interventions" are brief exercises that target a student's feelings and beliefs about, for example, their potential to improve their academic performance in the face of initial failure (mindset interventions), their connection between coursework and their personal aspirations (values interventions), or their sense of belonging within an educational community (belonging interventions). Studies over the past two decades have shown that these interventions can have a persistent positive impact on students' self-esteem, identity development, educational achievement, and their likelihood for career success. (See the Bibliography for a series of references for further reading.)

Cottrell Scholars are among the many faculty members who are involved with implementing interventions at their own institutions. This work ranges from ongoing partnerships with educational researchers to deploy belonging interventions in large introductory courses, to individual faculty developing new interventions on their own, to senior administrators overseeing university-wide values intervention trials. The design and implementation of interventions will be most impactful when they are grounded in best-practices from psychology and education research. However, it has historically been challenging to form authentic partnerships with psychology and education researchers, in large part because of lack of awareness on the part of STEM researchers (including ourselves). In partnership with FLAMEnet, we strengthened our connections to psychologists and educational researchers with a shared interest in creating more inclusive STEM learning spaces. With this book, we share some examples of interventions as a practical starting point for instructors.

In Part I of this book you will find usable summaries of each of three mini-workshops on "Inclusivity in Introductory STEM Courses," funded by a Cottrell Scholar Collaborative award from Research Corporation for Science Advancement. The descriptions also include specific approaches that can be implemented in introductory STEM courses. A flier advertising these mini-workshops can be found at the end of this introduction. Recordings of all three of the mini-workshops can be found at the webpage *https://www.eg.bucknell.edu/~tsolomon/cottrell2022.html.*

Or by scanning this QR code

- **Chapter 1** summarizes the first mini-workshop, “Creating Pathways of Kindness and Inclusion in STEM Education,” led by professor Mica Estrada. Estrada presented several different strategies for building a positive culture of inclusivity in academic settings. This included paying specific attention to identity development, first impressions, and a generous application of kindness.
- **Chapter 2** focuses on the second mini-workshop, “Promoting Equity in Science Learning,” led by professor Chandralekha Singh. Singh emphasized the importance of fostering a sense of belonging among underrepresented students, as well as the value of struggling as an integral part of the educational process.
- **Chapter 3** centers on the third mini-workshop, “Whiteness and Structural Racism in Introductory STEM Courses,” led by professor Terrell Morton. Morton challenged us to reflect about ourselves and the role structural racism plays in STEM, explaining how our perceptions, perspectives, and positioning may introduce biases into the classroom that negatively impact our students of color.

Part II is a collection of contributions from individuals about the interventions they have implemented at their institutions. Specifically:

- **Chapter 4** describes the use of discussion sections to increase the sense of belonging in STEM courses, particularly among women and minority students. The goal is to change the typical lecture into a conversation both in upper-level and introductory courses, so students feel less anxious and become active participants.
- **Chapter 5** is an example of how you can set up a series of mindset interventions at the beginning of your class – starting with your syllabus – to create an environment where you value (with points!) struggling and increase belonging with group work and cohort building.
- **Chapter 6** is a discussion of a set of values and mindset reflections and activities that are being used in the two-semester introductory physics sequence at Bucknell University.
- **Chapter 7** describes a set of interventions designed by FLAMEnet members to help students learn from failure experiences they encounter in STEM lab and lecture courses.
- **Chapter 8** presents a belonging intervention framework that has been developed and tested in introductory physics courses at MIT.

We encourage you to try one or more of these interventions in your own teaching. Not every intervention will work for every instructor or every class, but changes for the better are made one step at a time.

Selected Bibliography

The references below represent a small fraction of the literature on interventions. Each of the articles selected here references many more relevant resources.

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Part 1:
Mini-Workshops

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Workshop 1: Creating Pathways of Kindness and Inclusion in STEM Education

Led by: Professor Mica Estrada, Institute for Health and Aging
University of California, San Francisco

March 21, 2022

Workshop Summary

Estrada talked about how classrooms, training programs and mentorship relationships that provide kindness cues and affirm social inclusion may impact the integration experience for students, faculty, and administrators. She focused on how these shifts impact people historically excluded from academia because of their ethnicity and race and who are underrepresented among Science, Technology, Engineering and Mathematics (STEM) degree earners and career pathways. Her presentation introduced concepts of identity formation and the issues of how an individual is integrated into a scientific community. A key element of this is the process of forming a first impression. This represents an opportunity for a discussion of biases and how they can affect opportunities for inclusivity. Finally, the importance of affirmation through extending kindness was stressed as critically important to fostering inclusion and integration.

Her main themes of how to make a difference can be summarized in the following actions she suggested for those attending the workshop:

- *Awaken* to yours and others' social identities and include everyone equitably.
- *Slow down* and notice how impressions form, impact our thinking, and inform our behaviors towards ourselves and others with different identities.
- *Choose* to use your influence, privileges, and power to grow kindness in your academic world – starting with actions that uphold the dignity of everyone.

Key Takeaways

Inclusivity in academia must focus on the system itself, not the individual who is to be included.

Integration is multi-layered. She introduced the Tripartite Integration Model of Social Influence (TIMSI), which suggests persistent integration is more likely to happen if a person can develop an identity in a relevant context, and then put that identity into practice. For example, in a scientific setting, integration is more likely to occur if a person develops:

- Scientific self-efficacy: “I can do what scientists do”
- Scientific Identity: “I am a scientist”
- Internalization of values: “I agree with the values of the scientific community”

Suggestions for improving inclusivity:

- evaluate who you mean by “we"
  make sure to be inclusive
- incorporate role models and examples into your classes, meetings, etc.
- discard notions of assimilation, but instead focus on widening the dominant culture

First impressions form quickly, persist, are extremely important, and are often incorrect. In a classroom setting, the following points offered to the students can help create a process for forming more constructive first impressions:

1. Slow down your thinking. Take a breath, and don’t rush to form an opinion.
2. Acknowledge we all have biases, formed from life experiences to keep us safe.
3. Be willing to challenge assumptions and look for disconfirmation of your impressions.
4. Be aware that attention to details follows keeping you safe – so remind yourself you are safe in this environment. This will change what you see and remember.
5. Remember not to believe everything your mind says to you. Be open to having impressions of others, be incorrect and be open to challenging other’s first impressions of you.

Incorrect first impressions can lead to impostor feelings if the student immediately decides they do not belong.

Acts of kindness can go a long way to fostering an environment of equity and inclusion. Acts of kindness that come from someone more powerful are more likely to be impactful and remembered, but it’s important to note that altruism alone is not kindness, and neither is simply helping. Acts of kindness are those that affirm dignity. For example, helping someone can make them feel indebted, uncomfortable, or awkward. That would not be an act of kindness. Therefore, it’s not simply what is done, but how it’s done. Here are some ways in which kindness can be expressed that affirm dignity from the receiver's perspective (adapted from the book *Dignity* by Donna Hicks):

- They felt free to express their authentic self without being negatively judged
- Their efforts, thoughtfulness, and talents were positively recognized
- Their feelings, concerns, and experiences were acknowledged as valid
- They felt a sense of inclusion
- Others' actions made them feel safe
- They were treated fairly
- Their choices were respected
- Others made an effort to understand them
- They were given the benefit of the doubt
- They received an apology when their dignity felt violated, whether or not it was intentional.

It is your responsibility to be kind in a way that reflects one or more of these attributes if you want to have maximum positive impact.

Micro-affirmations can go a long way. Acts of kindness shown in subtle ways or using ambiguous cues are likely to help students persist in STEM careers.

Focus on talent development, not talent discovery.

Specific Ideas for Implementation

From the presentation:

For first impressions: In your first class, as an exercise to demonstrate that first impressions need to be more thoughtful, put up a series of true/false questions about yourself and ask the students to decide whether they apply to you or not. Offering some surprising things that students would not expect ("I am an artist" or "I love to ski") and having them choose with no basis of knowing is a good way of examining how first impressions form and how they should be created more carefully.

Acts of kindness:

- Find ways to communicate truth, facts, and knowledge with kindness by respecting the dignity of learners and colleagues
- Remember that when you have higher status and influence, you have more opportunities to bestow kindness in a way that is remembered by others.
- Simple actions, like stopping to talk with someone, giving people the benefit of the doubt, or apologizing when you offend, even if it was accidental, can go a long way.

From the post-presentation discussion:

Techniques for increasing inclusivity and validating identity:

- Gather a few answers from students from homework or exams and anonymously show those excellent answers during lectures. Benefit: Students from various identities can be validated without being put on the spot in front of the whole class, which can be uncomfortable for URM students.
- When reviewing exams, quote answers anonymously and say they were better than ones written by the instructor.
- To encourage input from students who are uncomfortable speaking up in class, include an open-ended question about how the class is going, along with a homework or reading quiz.
- Do Zoom polls before each class, with a meme. Students would have to identify how they felt based on a picture (cartoons, etc). It can be stress-relieving for the students. Silly polls, done well, are another option.
- Offer extra credit for assignments in which students describe how the pandemic or other events have affected them and how they feel this course can help them overcome those challenges. This helps them feel a little more connected in the class and helps the instructor identify needs.
- Create a music playlist. Each student contributes songs they like and they can be played during working time online and at the beginning of class as they are coming in. They love identifying songs they all like (or learning new ones). It helps to build community.
- Use an art assignment as an opportunity for students to be creative and provide them a path to express/inject a bit of themselves into the course.
- Create a homework assignment to meet with the instructor for ten minutes (which could easily translate to Zoom) as a “get to know you” situation to build trust and relationships from the beginning of the course. Students love easy/free points and it often turns into more in-depth conversations.

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To watch a recording of the workshop use this link or scan the QR code below *https://www.eg.bucknell.edu/~tsolomon/cottrell2022.html*

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Workshop 2: Promoting Equity in Science Learning

Led by: Professor Chandralekha Singh, Department of Physics and Astronomy University of Pittsburgh

April 19, 2022

Workshop Summary

STEM education, particularly physics, has traditionally been dominated by white males, and other demographic groups including women and non-white scientists have been marginalized. The culture of physics and other related disciplines has perpetuated lack of diversity in physics, chemistry, and other physical sciences. This non-inclusive culture makes students from marginalized demographic groups feel like they do not belong in the field, a feeling that can have severe destructive effects on a student's engagement with the material, their ability to stay on task, their ability to succeed in the course, and their persistence in STEM.

If you are not sure if your classroom is inviting or welcoming to those historically excluded from your field, put yourself in the shoes of your students and consider these questions:

- How does this classroom look to a student sitting at a desk in the third row?
- Does what the instructor is saying increase or decrease students' anxiety about being in the class?
- How might some students feel about their potential in the course? Can a student's gender or race affect how they feel?
- Does the instructor empower their students to embrace their struggle and use them as a learning opportunity in a low-anxiety learning environment?

Key Takeaways

Singh emphasized several concepts in her mini-workshop.

- Praise students for their efforts rather than for intelligence. Data show that praising student intelligence (e.g., communicating to the class that a student performed well on an exam due to their intelligence) makes low-performing students feel unintelligent and takes away their desire to work on challenging problems. Instructors should emphasize, celebrate, and normalize struggling as a fundamental aspect of the educational process. In particular, students should be encouraged to embrace their struggle and recognize that struggling is normal when learning new materials and that it is temporary because students would learn the materials if they work hard, work smart, and take advantage of the resources including getting help from instructors and peers. Instructors should also help students recognize that struggling is an integral part of the learning process and that they should be proud of struggling (and they should be proud of attempting challenging problems) since that means that they are on their way to learning something new.
- There are significant biases that are prevalent in introductory courses based on gender, race, and culture. In particular, it can be very destructive if a student feels that they do not "belong" in a course; e.g., if they feel that they are not as "smart" or capable as others in the course. Self-efficacy, the "belief in one's ability to succeed in a particular task, course or subject area" (Bandura 1974) has been shown to negatively affect students from marginalized demographic groups (e.g., in one study, women who obtained A grades in introductory physics had self-efficacy comparable to men who obtained C grades in the same course).

Specific Approaches That Can Be Used in Introductory Courses

Don'ts:

- Don't tell students that 25% of the class will fail or this is a weedout course.
- Don't announce to the class that if students do not have a strong prior preparation for the class, they may fail if they do not work harder than others.
- Don't emphasize negative performance.
- Don't say "this problem is trivial."
- Don't trivialize the students' struggles.
- Don't give insincere praise.
- Don't praise student intelligence.
- Don't give neutral praise.

These types of statements reflect a fixed mindset on the part of the instructor. They convey to the students that they cannot excel in the course if they came with less prior preparation (which is often due to different prior opportunities and privileges). This is the antithesis of teaching! What is important is not the instructor's intentions when communicating with students but the impact they are having on them.

Dos:

- Do tell students that they can be successful if they work hard and apply themselves and that, as an instructor, you are there to support them.
- Do remind students that you have confidence that they can learn this material.
- Do give honest feedback about the importance of failures and struggle in learning, and remind them that they can do it.
- Do normalize struggling! It is a part of good learning practices.
- Do praise hard work and deliberate practice. Emphasize affirmations.
- Do tell them to be proud of struggling while learning since it would lead to students engaging with the materials in a deliberate manner and eventually figuring things out.

The following are suggestions of specific approaches made by participants in the workshop, either in the "chat," during the breakout sessions, or as part of the post-workshop survey.

- Do use encouraging language with the students, e.g., "You are making good progress. I'm confident that you will do well." Validate and affirm, and recognize the students for things that they are doing well.
- Do give examples of successful scientists, mathematicians, and engineers from a variety of backgrounds and identities.
- Do remind students that making mistakes is part of the learning process.
- Do emphasize that all successful scientists/mathematicians/engineers have struggled in the past (and continue to struggle). Tell students about your own experiences and cases in which you struggled and even failed but viewed it as a part of the learning process.
- Do reward students for pointing out your mistakes in class.
- Do praise students when they say "I don't understand." That shows that they are trying.
- Do give students an opportunity to reflect on their struggles with open-ended questions each week about the course material and how the course is going for them. These questions can also address students' emotional states. Comment about the responses to these questions in class, pointing out (anonymously) to the class, for example, that struggling is a common experience.
- Do have students who have previously succeeded in the course write "lessons learned" statements or record videos of their experiences in the course. Give current students the opportunity to view these and see how students who are like them succeeded.
- Do reward effort in the grading scheme for the course and reduce anxiety around high-stakes assessment. This can be done either minimally by increasing the percentage of course points that are based on effort vs. timed

exams, or perhaps by restructuring the grading system entirely based on standards-based approaches.
- Do tell students that homework is like sports practice, a chance to develop and practice skills ... and an exam is like a sports game.
- Do stay after class to talk with engaged students who want to chat.
- Do train TAs for a course to be aware of all of the issues discussed here.
- Do have a conversation at the start of each semester and ask students, "Why don't students realize EVERYONE is struggling and that struggling is a good thing?"
- Do establish norms of behavior that would hopefully result in functional and positive student group spaces.
- Do use belonging interventions in upper-level classes as well as in introductory courses.

In general, do have a growth mindset about your students' ability to learn and grow. The entire point of a class is for your students to change – to go from not knowing to knowing. You are their coach. Coaches do not do the work for them. Coaches give guidance and appropriate support to allow people to learn how to do things for themselves.

Other Notes From the Mini-Workshop

Singh discussed using a coaching analogy to think about how to prepare students for their learning struggles. The analogy extended to thinking of offense and defense – like in a sports game. Most of us focus on the "offense," which is the learning goals we envision for the class.

Offense:

- Efficient problem solving
- Effective problem solving
- Transfer of learning
- Robust understanding

But it is essential to build the defensive skills in your students, too. If it is all offense, you are missing opportunities to help build your students mentally for these challenges in your class. It is like cross training – working out your abs when you actually have a weak back – both sides are necessary for productive training. This is particularly important for students from marginalized demographic groups.

Defense:

- Develop a sense of belonging in students
- Help students identify with the material in the class and see themselves as someone who can excel in the class
- Engender a growth mindset in class and in your students

- Induce self-efficacy in students so they take their learning in their own hands
- Engender interest in the subject
- Set achievement and learning goals
- Embrace the struggle of learning and teach that the brain is a muscle that is malleable and is shaped by hard work and deliberate practice

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More references can be found at *https://www.uky.edu/~eushe2/Bandura/BanduraReferences.html*

To watch a recording of the workshop use this link or scan the QR code below *https://www.eg.bucknell.edu/~tsolomon/cottrell2022*.

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Workshop 3: Whiteness and Structural Racism in Introductory STEM Courses

Led by: Professor Terrell Morton, College of Education and Human Development University of Missouri

May 11, 2022

Workshop Summary

During the workshop series, we were challenged to think more deeply about the *student experience* and how we have the ability as teachers to greatly impact students' sense of belonging in STEM. In this final workshop, Morton challenged us to reflect more deeply about *ourselves* and how *our* perceptions, perspectives, and positioning may introduce biases into the classroom that negatively impact the student experience. Workshop participants were introduced to the idea of "whiteness" and structural racism within STEM. By "seeing" these structures, we can better understand how these structures have affected all of our experiences in STEM and how they have negatively influenced black and brown students in our introductory courses. We can then begin to address how we as teachers and scientists must work collectively to improve our classrooms and institutions so that we can support students of all identities in STEM.

Key Takeaways

During the workshop, Morton posed a series of questions and ideas to lead us through our self-reflection:

Who am I and who do you see?
Given an image and asked to describe what we see, we often provide not only a physical description of the image but also our embodied feelings of what we think is transpiring in the image. How do our perceptions, perspectives, and positioning affect how we view and understand our students' experiences in STEM? Our positioning arises from our identities (based on gender, race,

sexual orientation, socioeconomic status, etc.) and the privileges that arise from our identities; this subsequently affects our exposure and awareness to issues in the classroom (and society in general) and the commitment and actions that we choose to take.

When we say we understand the challenges that our BIPOC students encounter in their learning spaces, how do we rationalize these challenges?
Many of us acknowledge the challenges that black and brown students encounter in their learning spaces; the problems range from representation, heightened social-emotional fear and anxiety arising from isolation and imposterism to constrained resources and networks. We often frame solutions to these problems as addressing the deficits rather than strengths of our students.

Why do we need critical race theory in this discussion?
Our black and brown students are disproportionately underrepresented in STEM. We often examine the deficits of the students as causing the underrepresentation. As a thought exercise, suppose we were to find one dead fish in a pond. We would certainly ask what was wrong with the fish and how we could have addressed the fish's health. If we were, however, to find a thousand dead fish in a pond, we would ask what was wrong with the ecosystem or environment (Hayes-Green, 2018). Should we not investigate how systematic racism is affecting our black and brown students in STEM?

What are examples of whiteness or structural biases in STEM?
What is whiteness in the classroom? Consider that learning spaces were initially designed for white, cisgender, heterosexual, European males. Whiteness in STEM arises from the ideologies, methodologies, and practices that stress values that do not reflect the values of students and scientists beyond these identities nor provide avenues for persons beyond this narrow selection to contribute to the shaping of new values in STEM. For example, in evaluations, we often value individual effort and promote competition, undervaluing collaborative efforts and problem-solving. We often resort to "mirror-tocracy," where we look for others and students who mirror our approaches and our familiar notions of science.

What can we do?
We can name "science" as a Western, Eurocentric science and acknowledge that there are other ways of knowing and doing science (Cobern & Aikenhead, 1997). We can diversify our curriculum and content, catering to the lived experiences and realities of our students (Moll, Amanti, Neff, and González 1992; Yosso 2005). We can expand possibilities for assessing and valuing knowledge. For example, we can create assessments that encourage group work and collaboration. In problems, we can use scenarios that better

connect to our students and their communities. Finally we can account for intersecting identities in the classroom (Patterson 2019; Tanner 2013). For example, during group work, we often focus on diversifying the groups to promote inclusion but spend less time on the assigned roles such that within the groups, biases remain.

To frame our classroom activities, Morton shared some frameworks he uses to design activities in his classroom, including Afrofuturism (Womack 2013), Community Cultural Wealth (Yosso 2005), Black Feminism (Collins 2000), and Abolitionist Teaching (Love 2019). He also provided information on different forms of pedagogy, including culturally relevant pedagogy (Ladson-Billings 1995), culturally responsive pedagogy (Gaye 2018), funds of knowledge (Moll, Amanti, Neff, and González 1992), warm demander pedagogy (Ware 2006; Kleinfield 1974), and teaching to transgress (Hooks 1994). Charts explaining the different frameworks and pedagogy approaches have been provided in the appendix.

In summary, we need to continually practice self-reflection and check our biases and assumptions as we enter STEM spaces. Beyond course content, classroom management, and pedagogy, departments should revisit their course sequencing and program content. This will be hard work, and we and our students must practice self-care as we remain committed and take action to make STEM a more inclusive space.

Survey Questions During the Zoom Breakout Sessions

1. *At the beginning:* What student behaviors and responses do you see within your introductory STEM courses? Why do you think students are demonstrating these behaviors?

2. *During the middle:* “Seeing” the Roots: Given the ideas presented, revisit your thoughts about the “observed behaviors.” Discuss in small groups how the noted student behaviors previously shared among this group can be connected to specific components or events of a STEM classroom, and how those specific components or events of the STEM classroom either perpetuate or challenge the culture of whiteness and structural racism.

3. *At the end:* Take about 1-2 minutes to write down how you will begin (expand, enhance) efforts to mitigate whiteness and structural racism as they manifest within your courses AND across your department. *For structural change, there has to be collective, structural action.* Revisiting your small groups, share those commitments with one another and offer suggestions, support, or resources for the others after they articulate their commitments.

Specific Ideas That Can Be Implemented in the Course

From the Presentation

The "Dos and Don'ts" from Morton

- Do focus on students' strengths. ("Strength-based approaches").
- Do use affirming language such as "You are bold and brilliant …."
- Do consider the backstory of the students. Humanize them.
- Do put structures that support underrepresented and disabled students front and center (e.g., ramps in front of buildings instead of around back).
- Do consider alternate ways of assessing knowledge and achievement.
- Do use a wide range of culturally relevant examples. E.g., examples with building bridges are culturally relevant only for students who experience bridges in their daily lives or discussion of sickle-cell anemia for African Americans.
- Do recognize and STATE the different ways in which people might approach science, mathematics and engineering from a cultural perspective, and discuss these fields that affect society.
- Do build in opportunities for self-care into the curriculum.
- Do consider how groups are assigned in courses, and rotate the power dimensions, e.g., so that it isn't always women as secretaries/reporters, or white as people who know/black as people who copy and paste. Rotate power within groups. And rotate who is in the groups.
- Don't focus on traditional measures of and structures such as GPA that can act as "gatekeepers." Recognize that what is traditionally used to measure "merit" has inherent biases.
- Don't focus on student weaknesses ("deficit-based approaches").
- Don't try to make all students "like us." Instead, celebrate differences. Don't "fix the student."

From the Participants

In the post-workshop surveys, many participants expressed their appreciation to Morton for introducing them to the idea of "whiteness" in STEM and challenging them to reflect on what they take for granted and assume in the classroom.

Participants shared that they would try the following in the classroom:

- Use group exams to turn an exam more into a formative assessment rather than summative and reflect that in the "real world" high stakes endeavors benefit from working together.
- Be more cognizant of different learning styles and burdens by providing class materials in a variety of formats.
- Talk with your mentor to assess your sphere of influence to see where you can make structural change.

- Open your classes with some time spent on the ethics and human history of how knowledge is "made," articulated, and transferred (having open discussion about the whiteness and Eurocentric impact on what we see in textbooks, for example).
- Use examples/events from the community to embed into problems.
- Search for more scientists who are not in the typical textbook who have contributed importantly to principles in STEM. Then share them with your students.
- In mathematics, really enforcing the notion that what we traditionally teach in terms of proof, etc., is ONE way of knowing and doing and not THE way.
- Have students provide their personal perspectives on what they believe a good learning environment looks like BEFORE the class begins, and share those perspectives on the first day.
- Read recommended articles about group work and participation to make teamwork more effective and a more positive experience for all students.
- Make explicit a justice-oriented approach in your teaching philosophy in your syllabus.
- Integrate self-care into assignments.
- Make note of the fact that the historical material we cover has a focus on rich white men because only rich white men had the time and resources to make discoveries in science/mathematics/engineering.
- Ask students for their input in how they best demonstrate their learning.
- Consider how attendance policies might affect different students differently (e.g., if a student has to work or take care of family members).
- Develop more curriculum around "how knowledge gets made and communicated" and talk about the history of colonial exploration and the importance for recognizing local knowledge and expertise.
- Group similar cultural identities and backgrounds together for certain assignments and then mix the groups to let the students also see the diverse perspectives, motivations, and experiences of their peers.
- Reinforce the notion that what we traditionally teach about a topic or method in mathematics and science is ONE way of knowing and doing and not THE way.
- Consider how student disengagement is not necessarily lack of interest but may reflect the physical and emotional exhaustion that students may be experiencing outside the classroom.

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To watch a recording of the workshop use this link or scan the QR code below
https://www.eg.bucknell.edu/~tsolomon/cottrell2022.html

Appendix

Framework	General Premise	Application to Practice
Afrofuturism Ytasha Womack 2013	Understanding the multiple truths of the past to ensure a promising, Afrocentric future. Unapologetic centering of and focus on Black culture, Black creativity, Black capabilities, and Black possibilities. Engaging science/speculative fiction, creativity, STEM innovation, and futuristic possibilities.	Situate anchor phenomenon within a futuristic setting that intentionally addresses a Black community-specific need. Pose all perspectives and plans from a strengths-based (i.e., targeting environmental/structural interventions).
Community Cultural Wealth Tara Yosso 2005	Identifies six forms of capital racialized groups possess that aid in their social mobility. Aspirational, Social, Familial, Linguistic, Resistance, and Navigational Capital.	Centering and building content, pedagogy, assessments, and ethos around students' cultural identity and strengths.
Black Feminism Patricia Hill Collins 2000	Attends to the experience, understanding, knowledge, and perspective of Black women given their unique social positioning. Challenges notions of "truth" and "reality" based on one's standpoint or position within society.	Centering content, pedagogy, assessments, and ethos around the perspectives of Black women and other women of color.
Abolitionist Teaching Bettina Love 2019	Teaching from a place of resistance, agitation, purpose, love, and mattering. Teaching as a catalyst for freedom, dreams, cultural expression, and visionary thinking.	Engaging content from the perspective of advancing liberation. Humanizing the learning experience (e.g., Vanessa Louis and Natalie King, 2022).

Pedagogy and Key Authors	Components	Requirements
Culturally Relevant Pedagogy Gloria Ladson Billings	Academic Achievement. Cultural Competence. Sociopolitical Consciousness.	Anthropological view of learning. Desire to give back. Strengths-based approach of students.
Culturally Responsive Pedagogy Geneva Gaye	Cultivating Cultural Integrity. Cultivating Individual Abilities. Cultivating Academic Success.	Culturally responsive climate. Strong student-teacher relationships. Care. Creative approaches.
Funds of Knowledge Luis C Moll Cathy Amanti Deborah Neff Norma González	Building on students' cultural wealth (Yosso, 2005) and their social-cultural epistemologies.	Bridge-builder (Cultural Ambassador). Soliciting students' cultural wealth. Respecting and valuing other perspectives. Flexibility and adaptability.
Warm Demander Pedagogy Franita Ware Judith Kleinfield	Belief that Everyone is Capable. High Expectations for Success.	Concerted effort to meet students where they are and properly scaffold them. A goal orientation that doesn't change.
Teaching to Transgress Bell Hooks	Teaching as a Performative Act. Education as a Practice of Freedom. Belief that anyone can learn. Teaching as intellectual and spiritual growth.	Meeting students where they are and cultivating them. Challenging existing boundaries in and through education, fighting for a "free-er" world.

Part 2: Narratives from the Classroom

4

From Lectures to Conversations: Increasing the Sense of Belonging in STEM Courses Through Active Learning Interventions

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While the courses I teach vary drastically in class size, depth of information, level of difficulty and students' background and interest in the subject, I constantly try to maintain a single theme, namely making the courses less of a lecture and more of a conversation. This is designed to increase student participation in ways that engage the students into the material, lower their anxiety about the subject matter, and enhance their sense of belonging in the classroom and within a strong community of scientists. This is especially important in my institution where ~60% of STEM students are women, ~28% are underrepresented minorities, and ~40% are first-generation college students (source: *https://www.iusb.edu/fast-facts/index.html*). The vast majority of our STEM students have never met a scientist, and most come in with a sense of being out of place for various reasons relating to their particular backgrounds.

Creating Conversations in Senior Level Courses

In senior courses, such as biochemistry I, II and biochemistry lab, it is relatively easier to generate conversations compared to larger introductory courses. This is due to the small class sizes (10-30 students) and the level of interest of the students in the subject matter. In both biochemistry lecture courses I teach, I dedicate several of the discussion sections to open conversations about topics that relate to science policy in an effort to better prepare the students for their careers in graduate/professional schools or in industrial settings. Another purpose for these discussions is to allow the students to form well-composed arguments and to train them to be open-minded to opposing views. In many ways, this is a strategy to immerse the students in thinking about areas relating to their future careers, providing them a sense of belonging to the pursuit of success in STEM careers.

While many of the general education courses help pave the way for this type of training, my goal is to focus on specific issues that relate to aspiring scientists. We first read articles on topics such as drug development and the patent process (what happens when there is a patent dispute) (Ledford 2017), why drugs are so expensive (Vincent Rajkumar 2020), and how the rise of misinformation is creating hurdles to public health (Ball and Maxmen 2020). We also examine examples of high-profile retractions of scientific literature, exploring instances of the mistreatment of graduate students in academia (Check Hayden 2008). Then we spend the time in the discussion sections to ask questions like: what is the role of science in the political process, what is the responsibility of a scientist toward the society, and how do we engage non-scientists in an open discussion on controversial topics, such as climate change, vaccination and evolution. These topics are selected specifically to relate to material discussed in the class and topics the students are expected to encounter throughout their careers. What I found is that these topics can make students who are not confident about the scientific material more vocal in discussions that go beyond the classroom. Not only does it provide a sense of a long-term view of their career and allow them to imagine themselves as successful scientists, it also increases their interest in the "academic" aspect of the class and motivates them to work harder on the coursework.

When the pandemic began, all students were affected in different ways, and I actively modified the discussions to reflect the ongoing pandemic and the political divide on vaccination. I introduced the students to articles about the spread of misinformation and the research conducted to monitor and combat false information on social media platforms (Ball and Maxmen 2020). Many were able to relate to the skepticism surrounding vaccines that was reflected in discussions with their own families and friends. Many of the students who were often quiet began to actively participate in the discussions and share their own experiences. Several of them relayed to me that these types of discussions helped them feel more in touch with the material taught in the lectures, which could have otherwise seemed theoretical, impractical, or even irrelevant.

I also strove to provide the students with reading materials that personified and represented the struggle of the specific groups in the classroom. For example, we discussed research about how the pandemic has disproportionately affected the careers of women and minorities in the sciences and erased so much of the progress in equity that had been gained in the past three decades (Woolston 2020). We also explored issues specific to the prevalence of the lack of trust in scientists among minorities. We learned about the history of the mistreatment of ethnic groups by the medical and research systems in America with examples including the Tuskegee syphilis experiments (Gamble 1997). Many of these discussions relating directly to the struggle of underrepresented minorities in STEM were not only beneficial to the sense of belonging within those groups, but it was also important for white students to become aware of the past, present, and future of inequality in science, research, and healthcare.

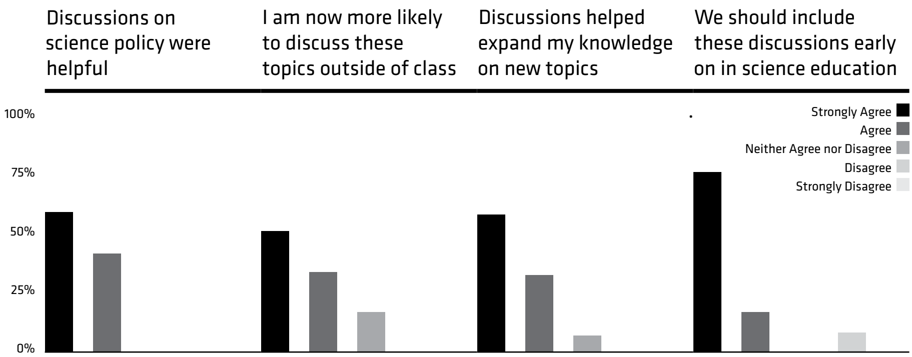
To make the students even more involved in the discussion around the topic of misinformation and inequity in science, I devised an exercise where the students engaged directly with someone in their community with whom they disagree. The assignment was optional (extra credit) and was designed to help students practice being active participants in the community. In a sense, the students were asked to continue the mindset of a conversation beyond the classroom. The following are the rules of engagement:

1. Find a friend, relative, or acquaintance that you know you disagree with on a controversial topic, like climate change, evolution, politics, vaccines, mask-wearing or whether the earth is flat or round, etc.
2. Try to engage with them in person (safely) or virtually through Zoom, video call, or social media but NOT on the topic on which you disagree.
3. Find something you both agree on, maybe a hobby, an interest in the arts, pets, or a common world view.
4. Spend some time listening to them, ask questions, learn more about them and their views.
5. Write a summary of your experience (1-3 pages) and submit it by midnight Sunday, October 25, 2020, for 10 points of extra credit.
6. Throughout the exercise: ***avoid being combative, avoid trying to convince the other person(s) of your point of view. If the subject you disagree on comes up, keep asking questions, let them try to convince you that their position is correct, don't be condescending, and above all be kind.***

The student responses were diverse, and many found the assignment to be challenging, especially when it came to avoiding a controversial topic. Most of the students were frustrated by their inability to communicate with loved ones about their differences, but all the students agreed that the assignment helped them come out of their shell, to feel more part of the community, and to work hard to bridge the misinformation gaps that the pandemic has exacerbated. They also felt like a cohesive group whose mission was no longer simply surviving a class or getting a good grade, but to work for a higher goal outside the walls of the classroom and its traditional expectations. Many felt compelled to be advocates for science in their community.

Another approach I used to enhance the sense of belonging in upper-level biochemistry courses is to invite guest lecturers to talk about their experience as they pursued careers in STEM. I focus on inviting former students who act as near-peers, providing hope and embodying a role model for the students to aspire to. These near-peers offer representation, share an experience of having gone through the same institution, and provide a "light at the end of the tunnel."

As an assessment tool, I have embedded specific questions within the course evaluations to gauge the students' reaction to the discussions and guest lectures. An overwhelming majority of the students found the experience beneficial and relevant to a future as a scientist.



In addition, the students were asked to comment anonymously on the approach. The following are some examples of their comments:

- "The discussion portion of this class was very engaging and informative to biochemistry subjects that will affect our future careers. I really enjoyed having class discussion about things like pharmaceutical companies and how the pandemic affects science."
- "These discussions helped to provide a more thorough comprehension of the course material, but also facilitated the process of understanding how these concepts translate to real world scenarios."
- "I really enjoyed having guest speakers come in and talk about how their studies are and what they are involved in."
- "The discussions were relevant and interesting as heck."

Creating Conversations in Introductory Courses

Creating conversations is much more difficult to institute in a first-year chemistry course such as C102 (chemistry for pre-health sciences), mostly due to the large size, upwards of 120 students. Additionally, a lot of the students in those classes have little interest in chemistry, and to many, this course represents an obstacle that they have to overcome to achieve their goal of joining a graduate program in nursing, dental hygiene, or physical therapy. In my institution, the students in these courses are predominantly women (up to 95%), and mostly underrepresented minorities. Furthermore, many are freshmen, and the majority are anxious about this course. As a result, some aspire to do the minimum amount of work that will get them past this perceived obstacle. The bottom line is that the vast majority of the students lack a sense of belonging, many of whom live with a fear of STEM subjects and many have had "bad" experiences in high school which reinforced the idea that they just don't belong. The challenge here becomes twofold: lowering the anxiety level and increasing the excitement level about the subject matter, both with the aim of enhancing belonging. This also makes it even more important to keep the class as a conversation to avoid a setting where I am simply "lecturing at them."

Since the fall of 2015, I have had the chance to teach this class several times. Over that period, I learned that engaging the students early on with class participation is the key to getting the students interested in doing the work. The class is formatted in such a way where the lecture and discussion sections are combined as one continuous session. Typically, I begin by providing a few slides with information, followed immediately by a set of questions that gradually increase in difficulty. This strategy of alternating lecture material and practice questions makes the course engaging and allows the student to see how they can be asked about the material. The students are allowed to work in groups or simply shout out answers to the questions on the screen. I intentionally use "giveaway" questions; those which are easy enough that students feel confident in answering them by shouting answers in the class. I also use a lot of yes/no questions as opposed to open-ended questions. For example: Does this molecule look hydrophilic? Would you expect it to dissolve in water?

The main point that I stress is that the time we have during the lecture is the time for making mistakes. To promote the culture of a conversation in such a high enrollment course, I employ a call-and-response method. As we encounter repeating themes in chemical reactions or nomenclature, I often ask the class to repeat some of the basic rules out loud. This brings them into the conversation and helps solidify their knowledge of the subject. Early on, I state that the first rule of the class is: *"Don't freak out!"* It is understood after the first few lectures that the key to tackling questions starts with a low level of anxiety. And so, when a difficult question appears on the screen, I often ask: "What is the first rule?" and the class responds in unison: "Don't freak out!" This helps engage the students and lower their anxiety level, allowing them to have a free mind to focus on answering the questions.

Another important point I always like to share is my own struggle with some STEM courses in high school and college. I share my personal experience of not understanding some of the more difficult topics, and I relay stories of how taking the chance to ask for help was what got me through the courses. This attitude change that promotes conversations resonates with the students as many are empowered to seek help when things are difficult because they feel that they can speak their concerns without being judged. They become more aware that both teacher and student share the same goal, namely student success.

So far, this strategy seems to help many students with succeeding in chemistry. This is reflected in their evaluations, as many explain how they were initially very nervous about the course, but found the subject to be more approachable. They also felt like, while the class was challenging, they were given the tools to succeed. Many also reflected on how they became engaged active participants in a discussion as opposed to being passive listeners, ultimately increasing their desire to participate in the class and work toward success.

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5

Failure Is an Option, and We Will Harness It to Learn

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Introduction

Over the past several years, I have taught the introductory physics courses on mechanics or electricity and magnetism to physics majors at two different schools, both research-intensive institutions, one large public university and one smaller private university. In physics, it is not uncommon for 40%-60% of our students to leave the major from their first year to graduation. These are students who declare their major prior to arriving, and the attrition occurs after the first two introductory courses. Many of the lost students are from historically excluded groups, including women, Black, and Latino or Hispanic identities who we desperately want to keep.

Here, I present some interventions I have developed that have helped to create an environment in the classroom where struggling, failing, and recovering are acceptable for students. Classes with explicit interventions have higher student attendance, especially among historically excluded groups, throughout the semester, and students who succeed in the class and are more likely to persist in the major (Arif et al.; Tibbetts et al.; McAllister and Irvine).

In this article, I will discuss practical advice for encouraging students to learn through failure and have a growth mindset to persist with difficult subjects, like physics. I should note that many of the mechanisms I use were developed from conversations with other caring educators, particularly the Cottrell Scholars (Research Corporation for Science Advancement), working with students, and not through exhaustive literature searches. I have attempted to include citations to support some of my work, although the methods may not exactly replicate or match that described in the literature.

1. Syllabus Language: On the first day of classes, we all go through our syllabus. I treat my syllabus like a contract, so everything needs to be explicit and students vote to ratify the language (Smith and Keller). My syllabus is long because in addition to having the logistics and the grading scheme of the class, I also lay out the ethos of how the class will run. An essential part of the ethos is a growth mindset and learning through failure and recovery (Steele; Canning et al.). In my syllabus, I spill a lot of ink discussing the importance of practice, failure, the cumulative nature of science, and some basics of how science works, including the importance of collaborations, and creativity (MacElroy). I have a section called "No geniuses allowed" where I discuss that hard work is the most important way to learn and become smarter (Leslie et al.). People are not born knowing physics – it is something you must work hard to learn.

The structure of the grading is set so that failure can be recoverable. I do not have high-stakes exams. All the exams together are only worth ~25% of the points for the class (Freeman et al.; Tanner). About 30% of the points come from homework – which they have a week to complete and can use the resources of the class and department, including the office hours, the teaching assistants, the peer-learning coaches (Otero et al.; Micari et al.), and the department's physics clinic, where any student can get help on any assignment all day long. About 44% of the grade comes from them showing up and doing the work in class, in their groups, and at weekly recitations (discussion sections with the teaching assistant to go over more problems and the homework). In making the grades this way, I am putting my points where my ethos lies – with hard work and attempts. They get credit for attempting, failing, and recovering. Their grade is not entirely reliant on high-stakes assessments that may be judging their fight or flight response more than their knowledge of physics. Please see the included example syllabus to see how I structure and discuss the course.

2. Values Affirmation and Empathy: On the first day of class, I ask students to fill out a personal survey. The survey is on paper and it asks a variety of questions, each with a different purpose. At the top are logistical questions, like their name, major, year in college, and expected graduation year. Next, I ask a series of values affirmation questions (Miyake et al.; Tibbetts et al.). I stage them as "getting to know you" questions, but I am having them identify their values and demonstrating that I also value those things. The questions are:

- Please tell me one thing about yourself that you think I need to know in order to teach you better. (Examples: "I learn best by …" or "I have a full-time job …")
- Complete the following statements and answer the following questions:
- I am a scientist because…
- What good can science do for the world and society?
- If I could study ANYTHING in the whole world, it would be ….
- How will it change the world or how we think?

- I want to learn physics because ….
- How do you feel about this class?
- Starting college has made me feel ….
- What kinds of things do you enjoy outside of class? Do you have hobbies, sports, etc?
- When I graduate from college, I want to ….

After these questions, from which I get a lot of insights about the students as people, I ask more sensitive questions such as if they have a lunch period before or after class (I provide food when the class overlaps lunchtimes, but this also helps students with food insecurity issues), if they have a laptop, and to reveal their self-identities (first-generation, veteran, LGBTQ, Black, international, transfer student, etc.) and designated pronouns. I find that structuring this personal survey in this manner opens the students up to giving me more information I can use to meet them where they are and create a better class for them. It also demonstrates my empathy for them as people (Arif et al.; McAllister and Irvine).

3. In-Class Support Structures: I employ several class structures, described below, to promote hard work and active engagement with the class. These prompt failures and enable immediate recovery, learning gains, and increased comfort with struggling.

3A. Flipped/Active Classroom: The class structure is a "flipped classroom" with active-learning in class because students cannot learn from failure without trying (Kishimoto et al.; Mzoughi; Låg and Sæle; Freeman et al.; Theobald et al.). I use an online system with pre-made videos that students watch prior to class (FlipItPhysics, Macmillan Learning). They also need to answer questions and tell me what they found confusing. In class, we go over only the parts with which they are struggling and get to the business of "doing physics" through group work. Every day there are problems to do in class with their groups. They get to try and fail at doing these problems with experts walking around helping them. The instructors in the room include the graduate teaching assistants and peer-learning coaches (Otero et al.; Kishimoto et al.). Because we can see them work on their problems, we can tell when the issue is one with mathematical skills or physics concepts. We can use this information to provide direct support or indirect help with on campus tutoring or other resources.

3B. Groups: As described, the students work in groups. How I form the groups is essential to their success to support students in their hard work and failure (Steele; Riestra et al.). The method I used was adapted from lessons learned from other successful instructors and psychology books on stereotype threat, such as *Whistling Vivaldi: How Stereotypes Affect Us and What We Can Do* by Claude M. Steele (Steele). To give the students comfort with failing, I group historically excluded folks together. As some identities are hidden, I use the first-day personal survey to put LGBTQ students or other persons together, so they can support each other and find people in class with commonalities.

For instance, I make groups with all women. Sometimes students notice, and only once did a single student object. I asked the student to try it out, and after a few weeks, they reported how happy they were with their groups. This person was a woman who had always worked exclusively with men, so she had never had the opportunity to work with women students. She was thrilled to find her group members supportive and hard-working with her.

When I ask Black students about how they feel about working with each other, most comment that they never had the opportunity before, and quite enjoyed working with other Black students in class. These students reported that they were more comfortable and able to create a group of people with whom they could work inside and outside of class.

The in-class groups are made to have three students in the group, including a strong student, a weaker student, and one in the middle. I use a long-standing pre-assessment, such as the Force Concept Inventory (Savinainen and Scott), on the first day of class to collect pre-course performance information and to help for the groups. I also add a mathematics assessment, as math ability is a major factor in performance in introductory physics courses. Students earn points for doing the assessments, but their grades do not depend on their performance. The same assessment is also done at the end of the class to assess learning gains, again without impacting their scores.

Perhaps the most essential ingredient to the success of these groups is the "intergroup grade" wherein the students grade each other at the end of the semester (Winchester-Seeto). A significant portion of their points for the course (~8-13%) come from this peer-grading. On the second day of class, I form the groups. Their first task, before they start on any physics questions, is to set expectations for the group and create a group grade rubric. Before creating the rubric, I have them answer the following questions as a group:

- A good group member will ....
- The most important thing a group member can do is ....
- It's not a big deal if a group member ....

Students typically discuss communication, showing up, contributing, honesty, and hard work. No one ever has an expectation that their peers will be geniuses or that they will know and give all the answers. These are common complaints in group work, and this activity relegates those issues.

After they address the questions, I ask them to create a rubric. They all come up with different schemes, but they always put points on the values they have discussed in the group. This pre-discussion sets a good tone for the group during the semester, encourages all students to show up because their groups are depending on them, and results in very fair grading at the end of the semester. I have never had to change a group due to bad behavior after doing this expectations-setting and basing part of the grades on their group performance. It is an essential ingredient to making group work functional in class.

3C. Cohort Building: Although it is important to give students a comfortable environment for failure when they are trying new things, and often failing, it is also important to normalize failure between groups. Thus, it is essential to mix the groups and allow everyone to see that everyone else is also struggling with the material. In my classes, I have done this by making time in class for grousing and advising about the major. These times are essential to allow all the students to hear about their struggles—to normalize failure and struggling. Historically excluded students working only with others of the same identity need to hear from students with stereotypes of high performance (white and Asian males) are not perfect and find the work difficult. At the end of the semester, I host a party and one of the topics is how this cohort of people will continue to work together to support each other in the following classes. Many times, the students will pledge to work together, so they can all make it through the physics major. Creating a sense of shared struggle is important to create a community among the students.

4. Recovery Mechanisms: Consistent hard work and failure is de-motivating. To enable recovery, I have several methods built into my class, although not all are explicit in the syllabus.

4A. Homework Online System: For entry-level physics, there are several online homework systems to allow faster and automated grading for large classes. The one I use is also an integrated flipped classroom system developed by physics education researchers from the University of Illinois Urbana Champaign (FlipItPhysics, Macmillan Learning). One of the things I like about these systems is that you can allow continued access to the problems. To help students with time management, the homework is due weekly. This is what most people do in physics courses. One difference in my class is that if you skipped or missed a problem, you can go back and redo it to still earn half the points back. These problems are open all semester until the final exam—giving the students time to go back and earn those points. Recovery requires work, but there are always options to improve your grade.

Because of the grading scheme, some of the students who perform best on the exams still have a surprising (to them) lower grade because they are not doing their homework. For these students, they have often seen the material before, and are avoiding the homework because they already know (or think they know) most of the concepts. Keeping the homework open until the end of class allows them a recovery mechanism, too, when they realize that their grade is suffering because they are not putting in the effort on their homework.

4B. Exam Re-Dos: One of the biggest places where students struggle is in exams. Students who demonstrate conceptual knowledge in class get into exams and freeze. As described in *Whistling Vivaldi*, they can experience anxiety resulting in a flight or fight response, causing the blood to leave the cortex (Steele). The cortex is where the physics thinking happens, so they under-perform on their exams.

To allow recovery and to demonstrate their knowledge, I allow students to redo a limited number of questions (1-3 on an exam with 8-10 questions) to earn back half the points they missed. For students with testing anxiety, they can demonstrate their knowledge without stress. For students who did not understand the concepts or how to solve the problem on the exam, they have another chance to learn the material. For students who perform well on the exam the first time, they do not have to do redos, and they consider this policy fair because the redos will never give back all the missed points. I have never had a complaint from low- or high-scoring students about exam redos. I do not put this policy on my syllabus, so that I can use it as needed.

Conclusion

Overall, the students are positive about the structures and methods I have employed as assessed from their final surveys. Although no one loves to struggle and fail, the fact that the failure does not define them is essential to increase their comfort with it, and to persevere in the physics major. In classes where I taught one of the first two courses, the number of physics majors at graduation for those cohorts increased compared to similar years in both academic institutions where I have employed these methods. The number of women and Black students also increased for these cohorts. For instance, when I taught this course as the first introductory course at a large public university, the incoming class had 19 women students in the class. Four years later, 14 completed BS degrees in physics and seven completed their degrees in astronomy (the introductory course feeds into both majors, and three were double majors). Many of these students cited my work in cohort building as the reason they persisted in the majors, and several are continuing to graduate school in physics or astronomy. I have not done any formal studies, but in exit surveys from the classes and the cohorts, they have a sense of community and pride in their struggles that helped them to persist to graduation. Future quantitative studies of these techniques would be welcome, but until then, I will continue to employ these methods. I hope these ideas will be helpful to others.

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Example Syllabus

Instructors

Professor Jennifer Ross
Email: *xxxxxx@syr.edu*
Office: 225 Physics Building
Lab: B112 Physics Building

Teaching Assistant: Sounok Ghosh
Email: *xxxxxx@syr.edu*

Peer Coach: Ava Breitbeck
Email: *xxxxxx@syr.edu*

Homework Session/Office Hours

Jenny: Tuesday evenings 5-6 pm,
Physics Clinic 104S, Physics Building

Jenny: Wednesday evenings 7-8 pm,
remote via ZOOM!

Sounok: Monday mornings 10 am-12 pm,
Physics Clinic 104S, Physics Building

Ava: Sunday evenings 6-9 pm, remote via ZOOM!

Logistics

Course meeting times: Tuesday/Thursday
11 am-12:20 pm, 208 Physics Building

Recitation meeting time: Monday 6:45-8:05 pm,
208 Physics Building

Website: using Blackboard to post syllabus,
homework sets, homework solutions.
Logon with NetID and password

Faculty office hours: Tuesday evenings 5-6 pm,
Physics Clinic 104S, Physics Building Wednesday
evenings 7:00–8:00 pm, remote via ZOOM!

TA office hours: Mondays 10 am-12 pm,
Physics Clinic 104S, Physics Building

Coach help hours: Sundays 6-9 pm (ZOOM)

Textbook and Online Resources/Homework

Free Online Book: OpenStax University Physics Volume 1. *https://openstax.org/details/books/university-physics-volume-1* This is a FREE, online textbook. You can get a print version.

Online Videos/Questions: We will be using FlipItPhysics for online video lectures, quizzes, and homework. The cost is less expensive ($42) than other homework systems, and it has videos for you to watch and answer questions. If you don't like to watch videos, read the free book, but you still have to answer the questions. At the end of syllabus is an extra sheet with information on FlipItPhysics.
The enrollment code for this class is: xxxxx

EMAIL POLICY: The best way to get hold of me is email. Please start your subject header with "Physics 215" followed by a relevant phrase related to your question. If you don't include "Physics 215" in your title, I might miss your email. I will not respond if the information is contained within this syllabus, so please check here first. I am happy to setup meetings with you. I am also happy to chat about anything during the Evening Homework Sessions (see above).

DISCORD SERVER: We will use Discord as a messaging system to have conversations about class and to communicate broadly with quickly. It will have places to chat about class in general, homework, and other topics. It works great if people use it.

COURSE DESCRIPTION: This course is the first course in the sequence for physics majors. It contains a broad theoretical and experimental introduction to the study of physics using the mathematical skills of algebra, trigonometry, and calculus. Topics covered are: motion (kinematics) in one, two, and three dimensions over time, motion with varying acceleration, vectors, Newton's Laws of motion, circular motion, work, energy, center of mass, momentum, rigid body motion, moment of inertia, angular momentum, torque, and gravitation. Whenever possible, applications to physics more broadly, research topics, and other fields of science and engineering will be discussed to give the work in here more context and interest! I have reserved the last two weeks to go over a special topic that you can decide such as special relativity, orbital mechanics, or something else.

Example Syllabus Continued

LEARNING OBJECTIVES: The first-year majors' courses are an essential preparation for your four-year metamorphosis from student to physicist. Thus, it is important that we create a good foundation of basic language, conceptual understanding, analytical skills, and experimental skills that you will continue to learn, hone, and use throughout your time as a physics major. My goal is to impart the following:

- Construct and use analytical (mathematical) models or representations of the real world in order to explain, analyze, and predict physical phenomena (especially related to electricity and magnetism).
- Reason through new problems logically, creatively, and independently.
- Identify fundamental principles, theories, and concepts related to electricity and magnetism.
- Interpret information in the form of mathematical expressions (formulas or sets of formulas) and graphical expressions (graphs, tables, schematics).
- Ability to draw inferences and make predictions from mathematical and graphical expressions.
- Use algebra, trigonometry, and calculus to solve problems analytically.
- Estimate and reflect on your answers to problems either mathematically or graphically in order to determine if your solution or result is reasonable for physical phenomena of electricity and magnetism.

LECTURES AND ACTIVE LEARNING: This course is taught in an active learning style because studies have shown that this style is the best and most effective method to teach you. In order to do this, we will use the FlipItPhysics, where you will watch videos (please read the relevant chapters of the OpenStax text, if you don't like videos) and answer questions. FlipItPhysics has a space for you to leave questions, if something was confusing. I will use those questions to create a short lecture at the beginning of class to clear up misconceptions. After that discussion, you will work on problems in class. The idea is that you will actually be *doing physics* in class with the teaching staff (TA, coach, faculty) present. This will allow me to help you learn the concepts and good problem-solving techniques. Your homework should be easier and faster, if we do it this way. This work is meant to help you understand the physics.

Why are we doing class this way? Numerous studies have shown that active learning format classes teach you physics better. Because, honestly, as much as I would like to think I am an awesome "lecturer" you will probably only get about 15 minutes of information from an 80-minute lecture. That would be a waste of everyone's time. You really learn physics when you try it. So, we are going to move the learning part to the classroom, and the information getting part (lectures/reading) to mostly outside the classroom. As with learning any new skill, you also need to practice (like shooting hoops), so your practice part will be both in class and as homework.

RECITATION: This class has a recitation section on Mondays 6:45-8:05 pm. The TA will be there and he may give an extra lecture, do some problem solving, or work on some "doubt clearing" with you. Attendance is required, and you will get points for attending. Recitation will start on Monday, September 13. There are 12 recitations for the semester. You are required to come to 10 of these 12 sessions. Points will be given for attendance.

MATH SKILLS: The co-requisite course for this class is: Calculus I (Differential Calculus). You must have a good working knowledge of basic arithmetic, algebra, geometry, and trigonometry. We will also be using the concepts of vectors, differential calculus, and integral calculus in this course. I will review math concepts and teach new math to you (this is true for all physics courses, so don't worry!). If you have concerns about the mathematics we are doing, please come see me and make sure you come to evening office hours on Tuesdays (5-6 pm) and Wednesdays (7-8 pm).

HOMEWORK: There will be several types of assignments for this course.

Online assignments will be done in FlipItPhysics. (*https://www.flipitphysics.com/*) The first assignment is due before the second class on Thursday, September 2, so make sure you can get into the system today. Online assignments will be automatically graded in FlipItPhysics online system. The thing I like about FlipItPhysics is that it is pretty intuitive. The enrollment code for this class is: xxxxx

FlipItPhysics prelectures: The prelectures are short videos with embedded questions. You have to watch the video to access the question and you need to do the question for credit. If you don't like watching videos, you can read the book while the video plays, but you still have to answer the questions to get your points. There are 20 prelectures where you can earn

Example Syllabus Continued

points. I will count the best 18 of 20 prelectures.

FlipItPhysics checkpoints: After watching the lecture, you need to take the checkpoint quiz. This short set of questions will help the instructors (the TA, coaches, and me) to know what you understood and what was still confusing to you. We will alter the in-class work based on your answers. I will also write mini-lectures to address gaps in knowledge based on these checkpoints. There is the ability to leave a question or comment in the checkpoint. Please use this option, if you are getting confused or worried about something. There are 20 checkpoint quizzes where you can earn points. I will count the best 18 of the 20 checkpoint quizzes.

FlipItPhysics homework: Every single lecture has an associated homework. The homework assignments will be due Fridays at 9 am. Each homework assignment will automatically open in FlipItPhysics one week prior to the due date. The portion of the homework you complete by the due date will be graded. If you do not complete the homework by the deadline, you can still access, try, and complete the homework problems for up to 50% credit before the end of the semester. In other words: You can complete the homework anytime before the end of the semester for 50% credit. If you don't get the homework done by the first deadline, you should absolutely still do it!! First, you will get points for doing it, and second, you will still need the practice for your midterm and final exams!

Long answer homework: I have found that when all the homework is online, many students don't learn how to write a good, long-answer solution to their problems. In order to address that, one question each week will be long answer where you will need to write out the full solution and it will be graded by the TA or the professor. Your exams will be long-answer format, so this is important practice to make sure you get all your points on your exams.

What's the point? The key to learning any new skills or concepts is to practice. The point of the homework is to give you that practice. It is not because I like to torture you. It is because I want to give you an opportunity to try and fail in a productive way. Like practicing a sport. Failing on homework should be OK and should teach you something. After the first deadline, you will still have every opportunity to try these problems and practice getting the right answer. Although our culture does not admit it, physics is hard work and takes a lot of practice—not so much genius. It is a skill to solve physics problems, like any other skill. You will get better with practice.

Skills: As a skill, you need practice, but you also need to practice the right way. You should always use a paper and pencil to do your homework—even if it is on the computer. We will be working on good problem-solving skills in this class. These will last you a lifetime—no matter what field you go into. Even a restaurant owner has to solve "word problems" to make her restaurant a success. The skills you learn in physics to solve problems are broadly applicable to all fields that have quantitative problems to solve!

Best Practices

Work in groups. I expect that you will work with others in a group to solve the problems on your homework. The homework (especially the long-answer questions) will be significantly harder than the exam questions.

Start the homework early. You should at least open, look at, and try the problems the day they open! I cannot stress this enough. The homework on FlipItPhysics will open a week before the deadline. They are due twice a week (because we have two in person classes each week). If you get behind, still try to catch up, since you can still earn points for your homework being late. We will have Homework Sessions Tuesdays (5-6 pm) and Wednesday (7-8 pm) instead of daytime office hours. I expect you to have started the homework and come with questions. If you have not started the homework, come to the homework session anyway and get started there!

Get help! There are lots of opportunities for you to get help on your homework in Monday recitation, Tuesday and Wednesday evening homework sessions, Monday TA office hours, Sunday coach help hours, and anytime in the physics clinic, making an appointment with the coaches or TA, or in class! We will also be using the Discord server to serve as an online resource for connecting to help solve problems. Make sure you sign up, ask questions, and answer the questions of others, too! The TA and coach will be checking the Discord server regularly.

In Class Work There will be daily in class work**.**

Warm-up questions: We will start with a warm-up question every day in class (Tuesdays and

Example Syllabus Continued

Thursdays). It will be worth points, so make sure you get to class on time and get working on it. It may be a logic puzzle, math warm up, or conceptual problem on the topic we are studying. We have 24 class periods with warm-ups, but I will only count the best 20. You can miss four warm-ups due to anything. If you are out for an extended period, and miss more than four warm-ups, you will need to be a valid excuse to get them waived from your grade.

Group work: In class, you will work with your assigned group each day on daily worksheets. I will try to make them short enough that we can follow-up and go through the solutions before you leave the class that day. If you finish your group work early, please start on your homework. You should be working with your groups on these problems. If you think you get it, help others. You may use the provided smaller white boards or get up and use the chalk or white boards in the room to work out the problems. Remember to work together both on in class work AND your homework. There are 24 days when we will do regular daily work (not taking an exam). I will count 20 toward your grade. You can miss four in class group work assignments due to anything. If you are out for an extended period, and miss more than four group work assignments, you will need to be a valid excuse to get them waived from your grade.

Turning in work: Everyday, you will turn in your warm-ups and group work exercises for credit. Use the color folder at your table to turn in your work. The TA will pick up the folders at the end of class and grade your work. Please remember to take out your graded work, or it will be thrown away.

A note about group work: This class will require you to work in groups. Scientists of all stripes routinely work in groups and collaborations—it is vital that you become accustomed to responsible participation. Being able to be productive and work in a group is a skill set that ALL employers expect and need. You and your group must learn to work together, sharing the workload, collaborating during problem solving, and involving all members in discussions and experiments. It is in your best interest to make sure that every group member pulls his/her own weight. Instructors will observe your group to determine the level of involvement of all members.

In order to help your group work well together, we will create a group rubric, and you will be allowed to score your group members in their participation using that rubric at the end of the semester. The score your group gives to you will count toward your final class grade (see below).

EXAMS: This course will have a total of FOUR exams: three midterm exams and one final exam. These exams will be given in class. Each will cover one section of the course in FlipItPhysics. The exam dates are already listed on FlipItPhysics calendar. All exams are cumulative. The final exam date and time are subject to change. The point of testing you this often is to make the exams lower stakes. The more grades I collect, the less each one will impact your grade. Each exam will be worth 100 points, but I will only use the best three of the four exam grades. If you are happy with your exam scores going into the final, you don't have to take the final exam. If you are bad at exams, and you freak out on an exam, you can make it up by performing better on future exams.

Midterm exam dates:
Tuesday, September 28th, in class
Tuesday, October 26th, in class
Thursday, November 18th, in class

Final exam date (subject to change):
Thursday, December 16th, 3-5 pm, in classroom

MAKEUP EXAMS: will be given early for verified exam conflicts. Please notify Jenny of conflicts as soon as possible, preferably two weeks, but no later than one week, before the scheduled exam. No post-exam makeups are scheduled. Verified extenuating circumstances will be considered individually, as appropriate.

OUT OF CLASS ACTIVITIES: Although physics is super fun, I want to make sure you discover other aspects of Syracuse University and the surrounding area this semester. Thus, some of your class points can be earned by attending and reporting on other activities. Do three of these activities to earn points in class for five extra points each: (1) attend a meeting of the Society of Physics Students, (2) visit the Barnes Center to work out, (3) attend a department colloquium (Thursdays 3:30-5 pm), (4) join a student club for music or sports, (5) go for a walk or a hike at Green Lakes Park or Clarke Reservation, (6) attend the cohort advising for physics, (7) visit the physics clinic, (8) find and hang out in the undergraduate physics majors lounge, or (9) other—submit to see if it qualifies.

Example Syllabus Continued

LAB: The lab for this course is required. You must co-register for the laboratory course PHY221 (1 credit hour) unless you passed it previously or your program does not require it. Your grade in PHY215 may be withheld if you don't co-register for the laboratory. PHY221 will provide you with hands-on experience with the physical phenomena discussed in this course (PHY215) and introduce you to the measurement process. The PHY221 course is graded separately. Your TA for your lab section is in charge of PHY221 and your grade for that portion. If you are having issues with PHY221, please contact me, and I will help to facilitate the interactions.

PHYSICS CLINIC: Physics Clinic is operated in room 104S of the Physics Building. Hours are posted on the door and online. They are nominally open 9 am to 9 pm (depending on staffing). The clinic is staffed by graduate Teaching Assistants who can help you with this course. Preferably come to the clinic when the TA assigned to this class holds their office hours, Mondays 10 am-12 pm (subject to change).

ABSENCES: This course is designed for you to come to class and participate. That being said, life happens, and we all have other stuff going on. I understand that. Because of that, I have designed the assignments so that you can miss a certain number without affecting your grade.

There are 20 prelecture and checkpoints. I will count 18 of the 20 prelectures and 18 of the 20 checkpoints. They open a week in advance, so you have plenty of time to complete them before the 9 am deadline.

There are 24 class meetings that will have a warm-up question and in class group work that will both be collected for a grade. I will use 20 of the 24 of each of these assignments. You may miss four warm-ups and daily work without an excuse for the semester.

There are 20 homework assignments in FlipItPhysics, typically given as two topics per week. Turning the assignment in on time allows you to earn full credit. But you can turn them in up until the final exam (5 pm on Thursday, December 16, 2021) to earn up to 50% credit. I will use the best 18 of the 20 homework assignments. There will be ten weekly long-answer Homework assignments due in class on Fridays. Solutions to these problems will be posted one week after they are due. I will use nine of the ten long-answer homework assignments as grades for the class.

There are 12 recitation meetings on Monday evenings 6:45-8:05 pm, 208 Physics Building. You must attend 10 of the 12 recitation sessions.

There are three midterms and one final exam. I will count the best three out of four exams. Exams are scheduled far in advance. No late exams will be given without valid proof of extenuating circumstances.

If you miss a class because of illness, you do not need a note unless you have already missed four classes. If you are having a lot of difficulty coming to class, eating, sleeping, or generally functioning, I will send your name to the dean of students to help you. I want you to be able to earn points and a grade based on your ability to do physics—not based on something out of your control. That wouldn't be fair. Fairness is very important to me.

RELIGIOUS OBSERVANCES POLICY: SU religious observances notification and policy recognizes the diversity of faiths represented among the campus community and protects the rights of students, faculty, and staff to observe religious holidays according to their tradition. Under the policy, students are provided an opportunity to make up any examination, study, or work requirements that may be missed due to a religious observance provided they notify their instructors before the end of the second week of classes for regular session classes and by the submission deadline for flexibly formatted classes.

For fall and spring semesters, an online notification process is available for students.

STUDENT SUCCESS: Your success in this course is important to me. I will use the Orange SUccess site to help your advisor understand your performance in this class, and any other issues you may have. I might use it to refer you to advising or let them know I am seeing some skill deficiencies that we can improve through tutoring. The point is to keep your entire advising team in the loop about your advancement while at Syracuse University, so we can help you succeed. Orange SUccess is also linked to the dean of students office, so they may also contact you.

Throughout the semester, your instructor will communicate with Student Success & academic advisors regarding your progress in the course. If you are contacted, please consider scheduling appointments such as tutoring or academic advising and talk with your professor. Referrals are not punitive and are meant to assist you in connecting with resources at SU.

Example Syllabus Continued

PUBLIC HEALTH: The University has already sent you the general things we expect students to do to protect public health. In our class specifically:

- If you are required to wear a mask, the instructor has been notified, and they will gently remind you to do so.
- When we are at a RED alert level, we expect you to wear a face covering when indoors or when interacting with others outdoors. This includes every space within the physics department including the classroom, hallways, offices, main office, and the Physics Clinic.
- When we are at a BLUE alert level, we expect you to wear a face covering when in class and in the Physics Clinic or office hours (not on Zoom). We recommend you wear a face covering anytime you are indoors.

These guidelines may change during the semester to reflect changing conditions and knowledge; we will let you know if this happens. If you forget your mask, instructors will likely have extras; ask us, and we may have one for you. If a student is unwilling to do their part to preserve public health in in-person classes, then we will ask them to leave the class. As in class participation is a major part of the class, this could affect your grade in the class.

What to do if you are not feeling well. One of the most important things you can do is to stay home if you are sick. Go to get a free COVID-19 test at Kimmel Hall. COVID testing times are:

Monday, Tuesday, Thursday: 10 am-3 pm
Wednesday : 12-7 pm
Friday : 8:30-10:30 am
Sunday: 10 am-2 pm

If you are sick with anything, please make sure to get an excused absence. As with any other excused absence, you will be allowed to make up your work within the framework of the class.

We often have a culture of trying to "push through" when we're not feeling well, saying things like "Yeah, I am sick, but I will be okay—I can still go to class". While this sort of perseverance in general is a good thing, coming to class when you are sick puts other people's health at risk. So, if you have any symptoms at all, stay home.

What to do if you are seriously ill. If you have an illness or injury that interferes with your ability to do work in our class, talk to us! The Center for Disability Resources helps students with short-term injuries and illnesses—concussions, broken bones, etc. If you are sick or hurt, we will work with you and with CDR to do whatever we can to accommodate your condition.

What happens if the instructor is sick? If any of your instructors contract COVID-19, we will do our best to get a substitute instructor for you as soon as possible. If this happens, however, we cannot risk a spreading set of cases in our class. In this case, we may switch to an online session for the times when the instructors cannot be in person.

ONLINE ETIQUETTE: When interacting with your colleagues over the internet, there are a few simple things you can do that will make life easier for everyone and keep the environment friendly:

- First, make sure you are aware of what you are transmitting. (If you're sending video over the internet, for instance, make sure you're wearing appropriate clothing!) Treat online classes with the same gravity that you would treat classes in person.
- If you are in a larger group, keep your microphone muted unless you are actively talking to your colleagues; this is especially important if you are in a noisy place or if you are using a built-in microphone on a laptop or cellphone.
- If you are using a platform such as Zoom that allows you to change your name, please modify your name to include your personal pronouns e.g. "Jenny Ross (she/they)". If you are referring to someone whose pronouns you do not know, it is always appropriate to use they/them.

INCLUSION: Everyone in this class is an equally valued member of this university and our community. We expect you to treat your classmates as honored colleagues in the collective endeavor we are all involved in—to understand the natural world and use that understanding to improve our society.

Bias against or denigration of anyone in our class because of their gender or how they express it, their sexual orientation, their religion, their national origin, their race or ethnicity, or a disability they may have will not be tolerated. If you are the target of this sort of bias or if you witness it, please report it directly to the instructors and we will take swift action. If you don't feel comfortable talking to instructors, you may report it anonymously to the Physics Department feedback form.

Example Syllabus Continued

COURSE GRADES will be based on the numerical score obtained by combining the Exam Scores and the Homework Scores.

Item	Points	Break down	Percent of Grade
Prelecture/Checkpoints	90	18 x 5 points each (complete grades)	~7.7%
Weekly Homework	270	18 x 15 points each (there are two per week) (up to 50% credit if turned in by Dec. 16)	~23.0%
Weekly Long-Answer Homework	90	9 x 10 points each (best of 9/10)	~7.7%
Daily Warm-Ups	60	20 x 3 points each (best of 25/29)	~5.0%
Weekly in Class Work	100	20 x 5 points each (best 20/24)	~8.5%
Recitation Attendance	100	10 out of 12 recitations attended	~8.5%
InterGroup Grade	150	You score each other in your group	~12.8%
Midterms and Final Exam	300 total (100 each)	3 x 100 points each (best 3/4) (~8.5% each)	~25.5%
Out of Class Activities	15	3 x 5 points	~1.2%
Total Points	**1,175**		**100.0%**

GRADE SCALE

A	A–	B+	B	B–	C+	C	C–	D+	D	F
100-94%	93-90%	89-87%	86-84%	83-80%	79-77%	76-74%	73-70%	69-67%	66-60%	< 60%

HOW TO THINK ABOUT YOUR GRADE: Think about it like a video game. You are starting with zero points in the class, and you are working to earn as many as you can to get a max score of 1,175. We are not taking points away from you when you get a grade—we are adding points to your total that you have earned.

ACADEMIC HONESTY

For homework assignments, you can (and are encouraged to) work with other students in the class, but you cannot directly copy answers from them. If we identify homework with exactly the same answers including formatting and errors, that is a violation of academic integrity.

It is a violation of the academic code to seek or give assistance during the exams. The instructor is the only person you can communicate with during the tests. Please do not make any changes or marks to the graded exams, if you want to preserve a right to appeal grading mistakes.

Syracuse University's academic integrity policy reflects the high value that we, as a university community, place on honesty in academic work. The policy defines our expectations for academic honesty and holds students accountable for the integrity of all work they submit. Students should understand that it is their responsibility to learn about course-specific expectations, as well as about university-wide academic integrity expectations. The university policy governs appropriate citation and use of sources, the integrity of work submitted in exams and assignments, and the veracity of signatures on attendance sheets and other verification of participation in class activities. The policy also prohibits students from submitting the same written work in more than one class without receiving written authorization in advance from both instructors. The presumptive penalty for a first instance of academic dishonesty by an undergraduate student is course failure, accompanied by a transcript notation indicating that the failure resulted from a violation of academic integrity policy. The presumptive penalty for a first instance of academic dishonesty by a graduate student is suspension or expulsion. SU students are required to read an online summary of the university's academic integrity expectations and provide an electronic signature agreeing to abide by them twice a year during pre-term check-in on MySlice. For more information and the complete policy, see the Academic Integrity Policy.

EXPECTATIONS: I expect that you are committed to doing the work to understand the material of this course. I also expect that the level of work each person needs to commit for each part will vary from

Example Syllabus Continued

person-to-person and from topic-to-topic. The role of the instructors (Jenny, TA, coaches) is to act as your coaches to guide you in your learning. Ultimately, the learning process belongs to you alone. Consider your learning much like how you would learn a new physical skill, such as shooting hoops, playing an instrument, or a new dance move. You should practice on your own and you can self-assess your progress. I will help you, but I cannot do it for you, just as Simone Biles's gymnastics coach does not jump on the beam to show her how it is done—I cannot really show you how to do these things. You just have to try, fail, and try again.

Some students find this type of teaching annoying because they want to lean back and let the professor drone on in lecture classes. These students often think I am not working because they are doing all the work. This is simply not true. Instead of lecturing to all, but missing learning moments for most, I am coaching you each one-on-one to make you all stronger. I may challenge you differently in order to bring you each individualized instruction. The other reason why I know this type of teaching is more work for me (not less, as it might seem) is because many professors also find this type of teaching difficult. It is far easier to write lectures and deliver them to sleeping students than to have to think on your feet and answer questions on the fly to help you.

Practice. In order to become an expert at something, you need to practice for 10,000 hours. In any physics class, we typically expect 10 hours of work per week on each class. Depending on your level coming into this class you may not need to spend ten hours per week on this class, or you may need to spend more. The class is 14 weeks long, so that is approximately 130-150 hours per class. By the time you complete the physics major, you will have taken 8-10 lecture classes. The minimum Physics major doesn't make you an expert in physics, but doing a Ph.D. will give you those expert hours (5-6 years working 40-60 hours per week). You can estimate all these hours and see for yourself. Regardless, in order to learn, master, and ultimately become and expert, you need to practice. The goal of the homework, in class work, and other problems is to give you the practice you need to master the work. That is a major benefit of the Active Learning Style.

Failure. There is no problem with trying and failing, as long as you learn something. In fact, in science, your goal is often to test a model, theory, or hypothesis and try to get it to FAIL. When it fails, and how it fails, teaches us something. Thus, as scientists, we strive for failure. We do not work to "prove" anything. That is a one-way ticket to false truths, we work to disprove models, theories, ideas. Trying to prove theories leads to results that are not reproducible and falsifying data. These do not help science move forward. We learn far more from good, solid, scientifically reliable failure than we do from FAKE proof. For instance, in physics, Newtonian mechanics works for many problems, but not all. Instead we need relativity. Without relativity, we cannot have satellites or other communications that move at the speed of light. In fact, Newton got it wrong—he failed, but his failure still works in many cases and is still taught today. Some people get caught up in failure, success, grades, being a hero, but in science, there is really no such thing. So, be brave, try your best, failing is just nature's way of telling us what is real and true.

Cumulative nature of science, learning, teaching. If you notice, all the exams are cumulative. This means that they cover all the materials up to that point in the class. So, Exam 1 covers the materials in homework 1-3, Exam 2 covers the materials in homework 1-7, Exam 3 covers 1-9, and the final covers everything. Physics, and science in general, is cumulative. We cannot separate what we learn in the second half from what we learn in the first half any more than you would be able to do that for a foreign language.

In fact, the way we structure our entire physics major curriculum (all the classes you take) is set up to build one on top of the other. When you learn quantum mechanics, they will assume you understand and remember what you learned in this course! The concepts carry forward, and you learn them deeper, with new mathematical tools, and it reinforces the concepts and skills you learned from previous courses. Our curriculum is iterative, much like real science, so you will also see several topics several times in new contexts and with new jargon and concepts attached. Keeping in mind the big picture as well as the local activities you are doing in your current class will help you to understand why we do things the way we do.

Example Syllabus Continued

Of course, we can always improve our teaching and curriculum in the department, so if you can think of something that would make this class or the physics major better, please don't hesitate to let me know. I am the department chair. You can also talk to Prof. Jay Hubisz (director of undergraduate studies and lead academic advisor). Getting to know the leadership in the department is a good way to affect change for yourself and your peers for years to come.

Science and being a scientist. Finally, many of the questions and hands-on work both in class and the laboratory are open-ended. I may not know all the answers. Being a scientist is not about knowing the answers … it is about knowing how to find the answers. As a card-carrying physicist, I have confidence that I know how to find the answers through direct trial and error experimentation. My job in this class is to teach you how to find the answers for yourselves. The answers may or may not be available on the internet. You will get the thrill of discovering how science works, if you follow the process and make the discoveries in class and in lab for yourselves (as a team).

Collaborations. Another stereotype of scientists is the "lone scientist." Scientists do not work alone. They do not work in a vacuum (not even astronauts). They work with others in collaboration. You are in groups in this class and in lab because learning to collaborate is an essential element to learning and doing science. Even a theorist coming up with a new theory must talk to people, get the idea out there, and test the predictions with experimentalists.

Creativity. One of my biggest pet peeves is how society doesn't associate science with creativity. Part of the reason is in how we teach (standard) science classes. We often teach that there is a "right" and a "wrong" answer. For those of you who like this aspect of science (the ability to be right), I have good and bad news. The good news: your homework problems will still have a right answer. The bad news: cutting edge science, which is still under debate, may not. This is where a lot of scientific ingenuity and creativity comes into play.

No geniuses allowed. Finally, people also think that you must be brilliant to be a physicist, but instead you must be smart. They are not the same thing. Smart people are observant, make conceptual connections, think creatively, and are hard working. You must practice your craft. Many seemingly "brilliant" people are actually very hard working, acquiring knowledge through practice, failure, and retrying, in order to appear brilliant when the occasion arises. I encourage you to work on these skills: hard work, creativity, observing, making connections, thinking conceptually. These are skills, and they can always be improved with practice, and they can be applied broadly.

I am really excited about teaching you in this course. I endeavor to do things in the class to help you struggle well, so that you learn. It is the most important part to me—that you learn. I am here to coach you. Also, I am admittedly human, so if I make a mistake, please let me know (with kindness). I am looking forward to working with you all!

Day 1: Personal Survey

Please fill out this survey and turn it in at the end of class.

I want to know who you are and why you are here, so I can educate you better.

Who are you?

Name:

Select one: ◯ Freshman ◯ Sophomore ◯ Junior ◯ Senior

Major: Expected graduation year:

Please tell me one thing about yourself that you think I need to know in order to teach you better.

Examples: "I learn best by…" or "I have a full-time job…"

Complete the following statements and answer the following questions.

I am a scientist because …

What good can science do for the world and society?

If I could study *anything* in the whole world, it would be…

How will it change the world or how we think?

I want to learn physics because …

How do you feel about this class?

Starting college has made me feel …

What kinds of things do you enjoy outside of class? Do you have hobbies, sports, etc.?

When I graduate from college, I want to …

This class starts at 11:00 am and goes until 12:20 pm—which is over lunchtime.
Do you have time for lunch after this class? ◯ Yes ◯ No

Do you have your own laptop? ◯ Yes ◯ No

I would like to teach you the best I can. In order to do that, I would like some information about you.

Please answer what you are comfortable answering.

Self-designated gender and preferred pronouns:

Do you have any of the following identities/status (that you would like to disclose)?

◯ Veteran ◯ LGBTQ ◯ Black ◯ Latinx

◯ First generation to go to college ◯ International

◯ Community college transfer ◯ Other transfer ◯ Other

Day 1: Personal Survey Continued

In Class Group Work

Names:

Thursday, September 2, 2021: Due: at the end of class in your folder.

GROUP WORK:

Groups That Work.

Today is the first day that you will work in your new groups. In order to help you get along, we will do more than just getting to know each other—we will decide for ourselves what makes a good group and set the goal that this group will run functionally.

As a group, complete the following statements.

1. A good group member will...

2. The most important thing a group member can do is...

3. It's not a big deal if a group member...

Use your discussion and answers above to create a rubric (grading scheme) for how you want to evaluate each other in your group. I will use all the rubrics together to come up with a single rubric the entire class. At the end of the semester, you will grade each other (worth ~13% of your class grade) on your group work.

If you want, you can come up with a name, mascot, or color for your group.
If you do that, please let me know what it is here.

Diagram out your rubric here. I will return this to you at the end of the semester to you, so you can use the rubric to assign your grades to each other. Try to be as clear as possible, so you can use the rubric to evaluate yourself and each other fairly at the end of the semester.

6

Reflection and Mindset Activities in an Introductory Physics Sequence

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I. Introduction

The Department of Physics and Astronomy at Bucknell University has been implementing a series of reflection activities in our two-semester introductory sequence taken by STEM majors in all branches of science, mathematics and engineering. There are several goals to these activities:

- **To have students reflect on the values** that are important to them and how their studies at Bucknell (particularly in physics) may help them realize these values and make a contribution to society. The original motivation for the introduction of values reflections was a study (Miyake, 2010) that claimed a reduction in the gender gap for achievement in introductory STEM courses when students were asked to reflect on their values, even if seemingly unrelated to the course material. A focus on values along with the use of culturally relevant examples and problems can also help to promote engagement by underrepresented students in the course.
- **To give students an opportunity to reflect on their strengths and to express their concerns about the course.** By reflecting on their strengths, we hope partially to help reduce the effects of impostor feelings among students who might feel that they are somehow not competent enough (or as competent as their peers) to be able to succeed in the course. And there are studies (Ramirez, 2011) that indicate that giving students an opportunity to express their concerns can actually improve performance on timed exams.
- **To have students reflect on what strategies and approaches will help them succeed.** These reflections happen both at the beginning of the semester and again after the first midterm exams to give students an opportunity to reflect back on their approaches during the first month and to encourage them to refine their strategies and approaches moving forward. Including discussion and peer-to-peer sharing here normalizes that reflection and sharing resources is an important value within the course.

- **To make students more aware of the various resources that are available to them to help them succeed.** These resources include office hours, regular help sessions offered by the department, example videos posted on the course web pages, and tutoring and study groups offered by the Teaching and Learning Center at Bucknell.
- **To better connect the course material to the real world.** This is potentially important not only to help motivate the students to engage in the material, but asking students to consider how the physics principles apply to real-life situations also helps elucidate lingering misconceptions.
- **To emphasize a growth mindset over a fixed mindset.** Numerous studies indicate that a particularly troublesome aspect of introductory STEM courses is a widespread misperception among students that achievement in STEM courses is determined by some innate talent (fixed mindset) – e.g., how "smart" you are – rather than a realization that understanding grows with effort and practice (growth mindset).
- **To reduce bias among the students in course evaluations of instructors of different genders, races and cultures.**
- **To improve a sense of belonging among underrepresented students in the course.**

We have not yet conducted a careful assessment of the success of these efforts, relying instead on the scholarly research already conducted by other academics promoting similar approaches.

PHYS 211 and PHYS 212 ("Classical and Modern Physics I and II") are calculus-based, introductory courses with separate lab components. These courses differ from most introductory physics courses with the inclusion of significant exposure to topics in modern physics, with three weeks of relativity, four weeks of quantum mechanics and two weeks of elementary particle physics and cosmology. PHYS 211 covers classical physics, relativity and thermodynamics and is taken by virtually every science, mathematics and engineering student at Bucknell with a typical enrollment between 300 and 350 students. PHYS 212 covers electricity and magnetism, waves and interference, quantum physics, and elementary particles and has a typical enrollment of around 200 students.

PHYS 211 and 212 are both team-taught courses with multiple components and multiple instructors. The structure of both of these courses includes two large lectures each week on Tuesdays and Thursdays (with the class separated into two lecture sections each day), followed by smaller problem sessions (with ~25 students each) on Wednesdays and Fridays. The lectures introduce concepts, with several conceptests (Mazur, 1997) to keep students engaged and provide feedback to the instructor. There are minimal examples of worked problems in lecture as well, supplemented by three to five video examples posted online. The Wednesday/Friday problem sessions support the material discussed in lecture from the previous day. Students work collaboratively on a set of assigned problems in each problem session, with support from a faculty problem session instructor. The team of problem session instructors (which always include the faculty teaching the main lectures) meets weekly to discuss the course and to work collaboratively on exams for the course.

There are three midterm exams during each semester, taken on a Thursday evening in place of one of the lectures. Consequently, there are three problem sessions on the Fridays that follow that are not centered on new material. Most of the reflection activities occur during these three post-exam problem sessions. Each of the problem session instructors are given instructions (tip sheets) to assure reasonable uniformity in the experience for the students.

II. Reflection Activities in PHYS 211

There are four reflection activities in PHYS 211, one at the beginning of the semester and one each in the problem session the day after the three mid-term exams. In addition to the reflection activities, each of the three post-exam problem sessions also feature a 10-minute interactive "preview exercise" to get the students thinking about concepts that will be relevant to the next unit.

A. Initial reflections about values, strengths and concerns: On the first day of class, students typically fill out a written survey that begins to address issues of values. In the fall of 2019, for example, the survey was as follows:

PHYS 211: Day 1 Survey

Fall 2019

In your opinion (answer each on a 1-5 scale).

1. Physics is ... (1 = incredibly boring/dull, 5 = really interesting):

2. Physics is ... (1 = completely irrelevant for anything of importance to me, 5 = very relevant and important):

3. Physics is ... (1 = extremely difficult, 5 = very easy):

4. What is/are your favorite musical group(s) (fill in the blank):

5. For each of the following choices, circle one to show your preferences.

a. Cats or dogs
b. Big city or small town
c. Squids or giraffes
d. Family or career
e. *Star Wars* or *Doctor Who* or *The Last Airbender*
f. Large income or job satisfaction
g. *Game of Thrones* or *The Walking Dead* or *The Bachelor(ette)*
h. Intelligence or kindness
i. *The Hunger Games* or *Harry Potter* or *Station Eleven* (books)
j. Respect or friendship
k. Fidget spinners or chocolate
l. Enjoying your career or helping other people
m. Baseball or football or soccer (what everyone else calls "football") or basketball
n. Rock concert or movie

PHYS 211: Day 1 Survey Continued

6. Why are you taking PHYS 211?

7. Feel free to add any comments that you think are appropriate—or any comments that you think are inappropriate—on the back of this sheet.

This survey (or something similar) was originally used for the faculty teaching main lectures to learn a bit about the students in the course. But the survey might also have beneficial impacts on the students. This is the first opportunity for students to reflect on values that are important in their lives. The values questions (e.g., "Enjoying your career or helping other people") are interspersed with seemingly less serious questions (e.g., "Squids or giraffes"), originally put in simply for fun. But recent scholarship has indicated that even questions like these can have an important impact by humanizing students in the course. (The importance of humanizing students was discussed in Mini-workshops 2 and 3 in the "Inclusivity in Introductory STEM Courses" series; see Chapters 2 and 3.)

The written survey is followed up the next day in the first problem session with a more extensive written reflection:

Personal Reflections

PHYS 211 Problem Session: August 28, 2019

Name:

Problem Session Instructor/Time:

Please answer the following questions with your own opinions—there are no right or wrong answers. Only your problem session instructor will see your responses.

1. What do you consider to be your strongest characteristic (for example: "I love learning new things," "I work well with others," "I'm a great athlete," "I'm a hard worker,"...) ? How do you think that strength will help you succeed in PHYS 211?

2. In what ways do you think attending problem session and completing all the assigned and hand-in problems will help you succeed in PHYS 211?

3. Do you have any thoughts (hopes, concerns, etc.) about taking this course that you would like to share with me?

4. How do you envision your life 15 years from now? What kind of balance would you like in your life between family, friends and work?

5. What do you think you will learn in PHYS 211 that will be useful to you in the future (both short-term and long-term)?

6. What do you think you will learn in PHYS 211 that will help you contribute to your local community, the world and society as a whole?

The first question asks the student to consider their strongest points with a goal of having them think about themselves in a positive manner in terms of their potential for success in the course (impostor syndrome). The second question is targeted with the goal of having the student consider the importance of continual course attendance and a regular and consistent work ethic will help them succeed (growth mindset). The third question is intended to help facilitate a conversation between the student and professor and to give the professor an idea of any issues that might impede their students' ability to succeed in the course.

The back of the form (questions 4-6) are the values reflections that were motivated by the 2010 study by Akira et al. The goal is to have the student not only reflect on what matters to them most in life (continuing from the survey from the previous day) but also to consider how this course might help them to achieve those goals.

Each problem session instructor is able to view the responses from their students. The written responses are saved and are returned to the students later during the semester as part of the reflection exercises that happen after two of the mid-term exams.

Although we have not properly assessed the impact of this particular exercise on student attitudes and performance in the course, we have found that the students are very thoughtful and conscientious in writing their responses to these questions. We tell them in advance that they will receive five points if they put in a reasonable effort into writing their responses, and that there are no incorrect responses. We have been doing this particular reflection exercise since the Fall of 2016. To date, every student who has attended this first problem session has received 5/5 for this exercise.
The first problem session also includes time for students to work collaboratively on the assigned problems for that day. We also hand out a kit of toys that the students will use as part of some of their homework assignments.

B. Exam "wrapper" after the first midterm: At the beginning of the problem session the day after the first midterm exam, the students are given the following sheet and are told to write responses to the first three questions on the front but not to turn the page over; i.e., they should respond only to the first three questions.

Follow-Up Reflections

PHYS 211 Problem Session: September 20, 2019

Name:

Problem Session Instructor/Time:

Please answer the following questions with your own opinions—there are no right or wrong answers.

1. Having been in PHYS 211 for a month now, have there been any changes in your views about what you need to do to succeed in this course?

2. Studies have shown that human intelligence isn't "fixed" but rather grows with activity and hard work. How might this kind of "growth mindset" relate to success in PHYS 211?

3. What resources, tools, and approaches during the past month have worked for you?

The students are given 5-10 minutes to write their responses (basically, however long it takes). The first question is intended to prompt the students to reflect about what has and has not worked for them during the first month of the course. The second question introduces (briefly) the concept of fixed versus growth mindsets and asks them to consider how a growth mindset would help them succeed in the course. (There is a much more significant exercise on fixed versus growth mindsets in the second course in the introductory physics sequence; see below.)

The students are given about five minutes to discuss their responses to the third question with other students at their table. The discussion is then broadened to the entire class. The instructor asks each table in turn to shout out a resource/tool/approach that someone at that table found useful. Each response is written on the board. This continues table-by-table until no one has any responses that have not already been mentioned. The goal of this exercise is for the students to hear ***from each other*** the different approaches and resources that can help them. Again, we do not have hard assessment data about the effectiveness of this approach, but the philosophy is that students tend to be more receptive when their peers suggest an approach or a resource than when the professors say this.

From our experience, since 2016 we have found several cases of students who have commented something to the extent of "Oh, I didn't know about the TLC study groups" or "Oh, those are useful?" The responses are mostly exactly the kinds of things that we hope that students will find important, e.g., attend all classes, do most of the assigned problems in advance of problem sessions, go to office hours to talk with the professors, take advantage of study groups and tutoring from the Teaching and Learning Center, go to weekly "Help Sessions", etc. Occasionally (but not often), a student might respond with something that could potentially be unhelpful, e.g., "Look on the internet for example problems." In situations like that, we typically try to redirect; e.g., "Well, there are example problems on our web pages—we have made videos which a lot of students find helpful. But you have to be careful with random internet pages because there is a lot of very unhelpful information out there."

After the full class discussion, the students are asked to flip the page over and write their responses to two questions on the back:

Follow-Up Reflections Continued

4. What aspects of your approach to you intend to keep doing for the rest of the semester?

5. What changes (if any) should you make in your approach going forward?

These questions provide the students with an opportunity to refresh their plans for their approach to the course, hopefully with any additional ideas that they might have gotten from their peers. Every student who puts a reasonable effort into this exercise gets 5/5 points. As with the first exercise, every student who has done this since 2016 has received full points.

C. Values revisited and bias: There are two parts to the reflection activities that happen in the problem session the day after the second midterm exam in PHYS 211. Each student is given a copy of the values reflections that they wrote on the back side of the sheet from the first problem session (questions 4-6 from the second activity in section A above). During the first ten minutes of the problem session, they are asked to look at what they wrote and then respond to the following:

Reflection Writing About Values and PHYS 211

PHYS 211 Problem Session: October 25, 2019

Name:

Problem Session Instructor/Time:

The following is a list of techniques, approaches and topics that we have covered so far in PHYS 211.

Techniques and Approaches

- Being methodical about your work and showing how you arrive at your answer.
- Working with ratios and checking dimensions.
- Your work ethic toward this course and time management.

Specific Topics

- Kinematics: working with position/displacement, velocity and acceleration.
- Vectors and vector addition
- Newton's 2nd Law ($F_{net} = ma$)
- Work and kinetic energy
- Non-conservative work and conservation (or lack thereof) of mechanical energy
- Conservation of momentum
- Relativistic notions of time and distance
- Relativistic energy and momentum
- Rotations

Reflection Writing About Values and PHYS 211 Continued

1. Choose two or more of the above techniques and/or topics and discuss how what you have learned about these in PHYS 211 has changed the way that you view the world in any way (e.g., topics that make you think "cool!" or make you notice things in the world around you, or perhaps change the way you do your work or think about your future.) In your response, don't just list the topics but also describe your specific reaction to these topics.

2. Look back at the back of the reflections sheet that you wrote during the first problem session. Again, choose two or more of the listed topics on the front and write how these techniques, approaches or topics might help you succeed in your future career and/or help you to contribute to your local community and to the world as a whole? Again, don't just list the topics; describe **how** what you have learned in PHYS 211 will help in the future.

3. After the first exam, you briefly wrote about any changes that you would make to your approach for succeeding in PHYS 211. If you had planned on making changes after the first test, did you effectively make those changes? If so, how, and if not, why? If you did not plan to make any changes after the first test, did your strategies continue to work for you? Did you make any adjustments or additions to your approaches?

Again, the goal is to connect what they are doing in this course to the values that are important to them in their lives. During this silent writing, there is a thermodynamics demo evolving in time (the "preview exercise") which is shown when the students have finished.

The rest of this problem session is used for an activity that is ostensibly about end-of-semester course evaluations and what students should be considering when filling these out. Students are always asked at the end of the semester to evaluate their instructors and their courses, but they almost always do so without any guidance, other than a brief, one-minute speech by whomever is proctoring the evaluations, which has virtually no impact on the students. This exercise both asks students to discuss what constitutes a good course and a good professor, and also addresses the prevalence of bias in course evaluations.

The students are first given 5-10 minutes to write responses to the following two questions on the front of a handout:

Discussion for PHYS 212 Problem Session

October 25, 2019

Name:

Problem Session Instructor/Time:

At the end of every semester, students fill out evaluations for all of their courses. In anticipation of that, please respond to the questions on the front of this sheet. We will discuss the responses together as a class.

1. In general, what are your responsibilities as student in a course (not just PHYS211, but for any course)?

2. What defines an "excellent course" for you? What defines an "excellent teacher"?

When they have finished writing their responses, there is a class discussion, with students stating their responses to both questions out loud, while the problem professor writes the responses on the board. (If there is time, it is good to start with table discussions before having a whole-class discussion, but that often isn't possible since this is one of two activities for this problem session.) The students are then asked to flip over the page:

Discussion for PHYS 212 Problem Session Continued

Course evaluations provide useful feedback to your instructor and the university on your learning in a course. They are a **professional evaluation** of your learning in a course and of the teaching provided by your instructor. If you want your evaluation to be taken seriously, you should provide thoughtful responses.

Questions:

When are comments about an instructor's physical appearance or clothing appropriate on an evaluation?

When are comments about an instructor's personality or accent appropriate?

Over the past several years, numerous studies have been conducted showing that student evaluations of teaching are biased with respect to race, gender, ethnicity, and even beauty. *(Study by Boring, 2017)*.

An example this is shown in some interesting visualizations here: *http://benschmidt.org/profGender*

Go to the website above and try searching "organized," "annoying," "brilliant," and "funny." Try some of the words that you used to describe an excellent course or excellent teaching. Do you notice any trends?

The point here: we all have biases. This can often be a difficult topic to grapple with as scientists, doctors and engineers, because we'd like to believe that we are objective and that race/gender/sexual orientation etc. could not affect our judgement *(These questions are variations of an activity written by Moses Rifkin.)*. The web site *https://implicit.harvard.edu/implicit/demo* has some interesting tests to examine your implicit biases. Relevant to today's discussion, you might want to try the Race IAT or the Gender-Science IAT.

Question:

How might implicit biases hinder the success of aspiring scientists, doctors or engineers, particularly for women or people of color?

The instructor discusses the text at the top, then—if there is time—there is a class-wide discussion of the questions above the line. There have been some very interesting discussions among the students in response to these questions. As an example, in one class the students discussed whether it is appropriate or not to comment on a professor's accent. (They concluded that the issue was whether or not the professor could be understood, not whether they had an accent. "There are plenty of professors without accents whom I can't understand.")

We then talk about bias, using the Benschmidt website to motivate the discussion. This is a website that counts the number of times that any particular word is used in online course evaluations from *"ratemyprofessor.com,"* categorizing how often those words are used for male and for female professors, also broken down by subject. The results are quite striking: there are clear differences between the frequency of words used for male and for female professors in particular.

The professor brings up the web page and shows the class the results for a few words. We then give the students the opportunity to shout out other words to try. It usually ends up being a fun way to get across a really important point; i.e., that we all have biases. When discussing this with the class, we usually point out that having biases doesn't make us "bad"—we're human and humans usually have biases. But it's helpful to be aware of them.

We have had students who have commented to us after this particular exercise that it helped them to be aware of these kinds of biases and to have a better appreciation for their responsibilities when writing course evaluations. And some of the students are very appreciative of this activity. "This is the first time in any of my courses that we have ever had a conversation about issues of bias in course evaluations."

D. Physics "Scattegories": The third post-exam activity happens near the end of the semester, so we try to make this activity as enjoyable as possible. (The students have been working very hard, so it is nice to end on a fun note.) The activity is a competition between the students, grouped into teams of four students each. The goal of the activity is for students to consider "real-life" applications of the material that we have been studying. This is important not only in terms of connecting the course material to the students' values and gives them the opportunity to make the material culturally relevant to them (see Chapter 3 for a discussion of cultural relevance), but the process also elucidates some misconceptions that students sometimes still have about the concepts at the end of the semester.

Once the groups are formed, the students are given 10-15 minutes to write responses on the following sheet (both sides):

PHYS 211 Competition

November 22, 2019

Group Members:

You will be given 10-15 minutes to come up with one example of each of the following physics principles in "real life" (i.e., in an application and/or in the world around you). State the example in the space provided, and briefly explain how this example demonstrates the principle. Each group will then share their answers with the entire class. You will be given one point for each pertinent example (if it really is, in fact, an example of the principle). You will get a bonus point for each real-life example that none of the other groups has come up with.

- Newton's 2nd Law ($F_{net} = ma$)
- Work, kinetic energy and mechanical energy
- Conservation of momentum
- Relativistic position and time
- Relativistic energy and momentum
- Oscillations and resonance
- Thermal energy of solids and liquids
- Ideal gas law
- Gas processes that do work
- Microstates, macrostates and entropy
- Heat engines

During the rest of the problem session, the responses are presented and scored in a whole-class discussion. The instructor picks a concept randomly (we don't go in order on the sheet), asking each group to state the example that they have written down for that concept. The instructor decides if the example is, in fact, a valid application of the concept. And when all of the groups have responded, the instructor decides which responses are the same and which are unique (and worth an additional point). The discussion can be quite entertaining – the members of the group have to be prepared to justify why their example is valid, and they typically argue why what they have (e.g., "a marble roller coaster") should be considered as different from another group's response (e.g., "an amusement park roller coaster"). The instructor then goes on to a different concept, scoring as many concepts as there is time.

We typically have the instructor make all of the decisions ("a benevolent dictatorship"), but if there is a tie at the end, we'll often use another concept as a tie-breaker between the leading groups, with the rest of the students voting for which example they think is more interesting. The winning team is then given a simple prize, e.g., a candy prize and/or puzzle erasers or inexpensive goofy LED toys.

III. Reflection Activities in PHYS 212

There are three reflection activities in PHYS 212, one each in the problem session the day after the three midterm exams. And as is the case in PHYS 211, In addition to the reflection activities, each of the three post-exam problem sessions also feature a 10-minute interactive "preview exercise" to get the students thinking about concepts that will be relevant to the next unit.

A. Reflections after the first midterm exam: As in PHYS 211, the problem session after the first exam in PHYS 212 is devoted to reflections about the students' approach in the course. But the approach is different in PHYS 212. Instead of talking specifically about resources and approaches, the reflections ask the students to consider what success really means in the course – without referring at all to grades.

During the first 10 minutes, the students (silently) write responses to two questions on the front of the following handout:

Reflections / Post Exam #1

PHYS 212 Problem Session: February 7, 2020

Name:

Problem Session Instructor/Time:

Please answer the following questions with your own opinions—there are no right or wrong answers.

1. Without referring to grades or test scores, describe a good outcome for a student in PHYS 212 (and 211). (E.g., "At the end, (s)he is able to ...")

Reflections / Post Exam #1 Continued

2. Based on your experience so far in PHYS 212 (and 211 if you took it), describe a student who is likely to achieve the outcome that you described in question #1. Do not name any specific people, and do not refer to any abilities (e.g., "She's good at math"). Instead, discuss what a student does to achieve a good outcome in PHYS 212.

The second question is phrased in a manner to emphasize the connection between a student's approach and success in the course (growth mindset) rather than a student's *abilities* (fixed mindset).

After the students finish writing their responses to these two questions, they discuss their responses with other students at their tables (typically groups of four students). There is then a class-wide discussion, with each table in turn saying (out loud) one item for each of the two questions, with the instructor writing these responses on the board. The responses continue on a table-by-table basis until no one has anything to add that isn't already on the board.

In our experiences, the discussions about these two questions have been excellent, with students expressing good "outcomes" and a student who is likely to achieve these outcomes much in the same way that we (the instructors) would, but it is likely more effective for the students to express these views to each other rather than simply hearing from us.

When the discussion is finished, the students flip the page over and write responses to the following questions:

3. For each of the following, give a score from 1-10 (1 = very low priority, 10 = highest priority) to indicate how important you feel the item is in terms of what you get out of PHYS 212:

a. Learning and mastering the specific principles of electricity and magnetism, waves, quantum/modern physics and elementary particle physics: ________

b. Learning and mastering problem-solving techniques: ________

c. Being able to explain physics principles and techniques to other people: ________

d. Learning/understanding how basic physics principles relate to practical applications: ________

e. Understanding the physics principles that explain how the universe operates (including life) and/or developing an appreciation of how amazing the laws of the universe are: ________

f. Being able to understand how everyday things work: ________

g. Developing an appreciation for how science is done: ________

h. Seeing something new and interesting that you have never seen before: ________

i. Developing a sense of awe about something that you always see but may have taken for granted: ________

j. Developing an appreciation for how elegant mathematical principles can shed important light on how the universe operates: ________

k. Developing good work habits: ________

l. Experiencing physics as an experimental/empirical discipline: ________

m. Becoming reasonably proficient at basic experimental techniques: ________

n. Becoming more curious about the universe: ________

o. Other (please specify):

Reflections / Post Exam #1 Continued

4. What do you consider to be the single most important thing that you hope to get out of taking PHYS 212 (other than "a good grade")?

5. What do you think of when you hear the word "wave?"

(Question #5 is part of the preview exercise for the upcoming unit on waves and interference.)

The responses to questions 3 and 4 vary significantly between the students, which is not surprising considering the variety of backgrounds and interests of the students. It is interesting for the instructor to see what each student considers to be most important about the course, but the exercise is more important in terms of getting the students to think about the reasons why they are taking this course (other than a requirement for their major). This connects back to the "values" reflections from PHYS 211.

B. More extensive discussion of growth mindset after second midterm exam: In the problem session the day after the second exam, the students initially write responses to the six questions on the front of a handout sheet:

Post Exam Activity

PHYS 212 Problem Session: March 7, 2020

Name:

Problem Session Instructor/Time:

For each of the following statements, circle the choice below that best indicates how much you agree with that statement.

1. No matter how much talent you have, you can always change it quite a bit.

Strongly Agree | Agree | Somewhat Agree | Somewhat Disagree | Disagree | Strongly Disagree

2. Some people can never be good at math.

Strongly Agree | Agree | Somewhat Agree | Somewhat Disagree | Disagree | Strongly Disagree

3. If you are smart, things should come "naturally" for you.

Strongly Agree | Agree | Somewhat Agree | Somewhat Disagree | Disagree | Strongly Disagree

4. Your intelligence is something about you that you can't change very much.

Strongly Agree | Agree | Somewhat Agree | Somewhat Disagree | Disagree | Strongly Disagree

5. Anyone can learn physics if they work hard enough.

Strongly Agree | Agree | Somewhat Agree | Somewhat Disagree | Disagree | Strongly Disagree

6. You can learn new things, but you can't really change your basic abilities.

Strongly Agree | Agree | Somewhat Agree | Somewhat Disagree | Disagree | Strongly Disagree

As with most of these exercises, the issue really isn't so much us trying to find out what the students initially think about fixed vs. growth mindset issues, but for the questions to get the students start thinking about these issues.

After the students finish the front of the sheet (which only takes 2-3 minutes), the problem session instructor shows the class a two-minute video about fixed vs. growth mindsets *(https://www.youtube.com/watch?v=M1CHPnZfFmU)*. We then have a classwide "brainstorm" where the instructor asks the students "What are the personality traits of a fixed mindset?" and "What are the personality traits of a growth mindset?" From our experience, the discussion frequently starts off slowly, so it helps to have the instructor prime the discussion with questions along the line of "Well, here is an example of a fixed mindset. How might someone with a growth mindset respond to this?" E.g., "A fixed mindset – if you fail at something, you might say, 'Well, that means I'm bad at it.' How might you respond if you fail at something if you have a growth mindset?" After a couple of those nudging cases, the students tend to start speaking up more.

We then have the students discuss specific scenarios. Each table of students is asked to pick one positive and one negative example from the following list and discuss how they might react to the situation if they had a fixed mindset and how they would react if they had a growth mindset:

Post Exam Activity Continued

Scenarios: Each table choose one positive and one negative scenario. Discuss how you might react to the scenario if you had a fixed mindset, and how you might react if you had a growth mindset.

- **NEGATIVE:** Your research advisor just told you your analysis was completely wrong, that you'll have to go back and redo it.
- **POSITIVE:** You just got an award on your first research poster.
- **NEGATIVE:** Your friend is going through a bad breakup with a romantic partner.
- **NEGATIVE:** You missed the deadline on your research paper.
- **POSITIVE:** You just aced all of your physics classes.
- **NEGATIVE:** You didn't get into your preferred graduate school.
- **POSITIVE:** Your grade on Exam 2 is better than Exam 1.
- **NEGATIVE:** You scored below the average on a biology exam.
- **NEGATIVE:** Your friend is very upset because they failed a research paper.

Each table then presents their scenarios and fixed/growth mindset responses to the class. In some cases, the instructor then discusses cases from their past in which they responded to some situation with a growth mindset.

The students then flip the page over and respond to the following two questions:

Post Exam Activity Continued

1. Think about a particular situation you have encountered (it could be academic, social, career, family, etc.) that you approached with a fixed mindset. For example, have you thought "I'm bad at…" or "I'm good at…" in a situation? Describe your fixed-mindset approach to the situation, and the ways in which a growth mindset could help you.

2. What are some examples of things that you would like to do in PHYS 212 to foster a growth mindset in yourself and/or others?

This particular activity is one that we have done only since 2020, so we don't have as much experience with it. And we ultimately think that it would be better to do this in the first semester of the course rather than waiting until halfway through the second semester of the introductory sequence.

C. Physics "Scattegories": The third post-exam activity in PHYS 212 is the same as the third post-exam activity in PHYS 211—a friendly competition (with simple prizes) in which students are asked to relate the concepts in the course to real life.

PHYS 212 Competition

April 10, 2020

Group Members:

You will be given 15 minutes to come up with ONE example of each of the following physics principles in "real life" (i.e., in an application and/or in the world around you). State the example, and briefly explain how this example demonstrates the principle. Each group will then share their answers with the entire class. You will be given one point for each pertinent example (if it really is, in fact, an example of the principle). You will get a bonus point for each real-life example that none of the other groups has come up with.

- Coulomb's Law for Electric Forces
- Electric Potential
- Biot-Savart Law or Ampere's Law
- Magnetic Forces
- Faraday's Law of Inductance
- Electromagnetic Waves
- Standing Waves
- Wave Interference
- Diffraction Through an Opening or Around an Obstacle
- De Broglie's Relation for Wavelength of Objects
- Photons and the Photoelectric Effect
- Emission and Absorption of Photons
- pn Junctions
- Quantum Mechanical Spin and Magnetic Moment

The goals of this exercise are the same as for the last activity in PHYS 211, and the process is the same.

IV. Continuing Changes in These Courses

By no means do we consider our efforts to be complete in these courses. We are continually looking for ways to improve the course, particularly in ways that will hopefully reduce inequities – which are clearly still a factor – between students from different backgrounds. Starting in academic year 2022-2023, we will be enhancing our efforts to improve disparities in feelings of belonging among underrepresented students in the course. (These activities will draw heavily from the research of Chandralekha Singh, discussed in Chapter 2 of this book.)

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7

Teaching Students How to Navigate Setbacks in STEM Undergraduate Learning Contexts

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Overview

FLAMEnet (Factors affecting Learning, Attitudes, and Mindsets in Education network) is a NSF-funded Research Coordination Network that was started in 2017 to cultivate the next generation of resilient, challenge-seeking STEM innovators. The network brings together STEM instructors, education researchers, psychology researchers and academic leaders to build upon intrapersonal frameworks such as mindset, fear of failure, coping, sense of belonging, etc. FLAMEnet supports resource development and the dissemination of interventions focused on understanding how intrapersonal factors can be leveraged to improve educational practices within STEM undergraduate learning environments.

The network originally focused on the role of failure in science and science undergraduate education. Indeed, a hallmark disposition of a scientist is the skill to view failure as an opportunity to learn, display resilience, adaptively cope and persevere (Harsh, 2011, Laursen, 2010, Simpson, 2017, Sawyer 2019, Henry 2019). Ambiguity and uncertainty must similarly be embraced as a necessary part of the scientific process. The development of such a disposition requires mindful practice (Thiry, 2012, Gin 2018) and thus there is a real opportunity to view failure as an epistemic experience (Simpson 2017). At the same time, many college students do not welcome their first academic challenge or failure. Students can find failure difficult, feel discouraged, develop fear of failure, and turn to maladaptive coping strategies (Shepherd 2009, Henry 2019). Thus, it is critically important that we support students in navigating failure events such that they grow in ways that nurture challenge-seeking and adaptive coping strategies and reduce fear of failure.

Recognizing a dearth of interventions designed to help students effectively practice and hone these skills, FLAMEnet drew from the literature largely in K-12 work, to develop a theoretical framework exploring undergraduate students' approaches to academic challenge and response to failure in undergraduate STEM learning environments (Henry, 2019). Based on this framework, participants in the 2018 FLAMEnet workshop created two interventions designed to support adaptive coping strategies and reduce fear of failure in the context of undergraduate laboratory and lecture courses. These interventions have since been expanded and refined through feedback from network members and conversations among the steering committee. Templates for the two intervention streams are provided below with the hope that this information will lower the barrier for others to use/develop similar activities to support their students. Google Form copies are available upon request.

Intervention 1: Research Reflections/Digital Communication

Implementation context: Implemented in lab or course-based undergraduate experience (CURE) courses where students routinely encounter research failures (e.g., a failed DNA extraction), challenge, or ambiguity.

Brief description: Students are prompted to reflect on their responses to research failures or challenges in written form throughout the term. Near the end of term, students use these reflections as inspiration to create a digital communication product (*e.g.* video, podcast) sharing insights about how to learn from failure with their peers. The goal is to encourage a growth mindset, mastery goal orientation, and productive coping skills. Digital communication assignments from one year can be shown to students in the subsequent year to enable peer-to-peer communication regarding the importance of failure as a part of the learning process.

Details: Interventions are designed to be implemented at a point in the lab class in which at least some students are encountering failure, ambiguity and/or challenge. Interventions can include the text outlined below. Google Form copies of these research reflection activities are available upon request.

Research Reflection 1

Overview. As with all of your college courses, in this class you will be challenged to learn and apply knowledge and concepts in novel ways. The [domain] specific knowledge you obtain will be important for excelling in this course. However, the specific skills you develop during this course, including how to face challenges and overcome failures, may be even more important than what you learn from your immediate successes. Research on education and achievement shows that reflecting on these skills helps students to improve and leads to higher academic achievement and well-being in the long term. Thus, this assignment provides you with an opportunity to reflect on and improve your strategies and capacity for dealing with scientific challenges or failures that may arise in the future. The final component of this assignment will also enable you to help future students in this course by offering your advice and perspective on overcoming challenges.

This assignment involves both individual and team components. Your individual work will help you to generate a high-quality final project with your team; the effort you put into individual assignments will make the team assignment more fun and personally beneficial.

Working individually, you will...

1. Complete three short written exercises in which you reflect on your experiences of failure and/or challenges during this course, and …
2. A final synthesis of your experiences with failure and/or challenges in the course that draws on the previous three reflections.

Your instructor will provide you with these prompts throughout the course and you will be expected to submit them via [Course Response System or survey link].

Working in teams, you will…

3. Create a digital communication (e.g., a movie, brief podcast, or other digital media) for future students to help them successfully navigate the obstacles or failures that may be experienced **during this class**. This assignment will be provided to you [x] weeks before the end of the [unit or semester].

* If by chance, **everything** works 100% perfectly for you on the first try, please write about realistic obstacles one might have encountered in this course and how you might have responded in those situations.*

Writing Prompt 1

- Please describe any research-related challenges, failures and/or unanticipated results that you encountered during [class today or this week]. These can include challenges or failures during data collection and analysis (including lack of data or experimental output), difficulty in interpreting data, or any other challenges associated with your research practices. Please only discuss experiences that directly involve planning and implementing experiments or analyzing data for this lab (i.e., do not discuss taking quizzes or exams). *(Open Response)*
- Describe the thoughts and feelings you experienced in response to this experience. *(Open Response)*
- Please describe the actions you took after encountering the challenge. Were these actions helpful or unhelpful, and why? *(Open Response)*

Research Reflection 2

- Describe a potential research-related challenge that may occur in the upcoming [two weeks].
- Describe the actions you might take in response to this challenge. What is your rationale for taking the potential actions you have described?

Research Reflection 3

- Please describe the challenges, failures, or unanticipated results you encountered during the past [two weeks] in this class. Did you encounter any of the challenges you predicted in the last writing prompt? Did you have any unexpected challenges?
- Describe your thoughts and/or feelings in response to these experiences.
- Please describe the actions you took after encountering one of these challenges.
- Did preparing for anticipated challenges change your thoughts, emotions, or behaviors when responding to this new challenge; if so, how?

Research Reflection 4

- Write a one-page reflection (~250 words) that responds to the three questions below.
- Reviewing your responses to the previous three prompts may help you complete this assignment.
- Describe your behavior, attitudes, and/or coping strategies in response to anticipated or unanticipated obstacles in this class. How did your response to challenges, behavior after challenges, and attitude with regard to challenges change over the course of this semester?
- Describe which of your traits and attitudes were most important for your success in this class?
- Describe how your experiences in this class will inform your attitudes and responses to challenges and failures in the future.

Final Project

You have now completed the majority of [course research project] and it is likely that you have experienced some of the same challenges that professional researchers face on a daily basis. As a final component to this project, we are asking you to create a digital communication product sharing your experiences dealing with challenges, obstacles, and failures in this class in order to help future students have success in this course. In thinking about the content of this communication (i.e., the overall message you will communicate), consider the following questions and frame your digital communication with a minimum of three of the questions below:

1. What role do you think failures and challenges have in science?
2. How did you approach unanticipated obstacles in the lab? In what ways did you modify your approach to overcome these challenges and ultimately achieve a desired outcome in your research?
3. How did viewing unexpected obstacles as potential learning experiences change how you will approach scientific failure and challenge in the future?
4. How would you encourage a new student who just experienced a failure or encountered an unexpected challenge in this class to change their perspective or reframe the failure?
5. What attitudes do you think are most productive when encountering obstacles and challenges in this course or in scientific research in general?

Remember, you do not have to address all of the questions above in your communication, but please frame your communication using at least three of these questions. You should construct a digital communication product that creatively expresses your thoughts and experiences regarding these questions. We encourage you to think beyond a simple interview format for this assignment.

Project formatting:

In thinking about the *format* of this communication (i.e., how you will communicate your thoughts and advice), consider the following options:

Free video editing software programs

- Openshot (Windows, Mac, Linux)
- Videopad (Windows, Mac)
- iMovie (Mac)
- Movie Maker (Windows)

Free animation programs:

- Moovly (free online trial)
- Raw Shorts (free online trial)
- Pencil (Windows, Mac, Linux; 2D)
- Blender (Windows, Mac, Linux, 3D)

Your final product should:

- Be 2-5 minutes long
- Include a separate "credits" section in the form of a word document detailing the role of each team member
  *Note: All team members **do not** need to appear on-camera in body or voice. As long as the team agrees that an individual contributed to the final product in a meaningful way (represented by placing them in the "credits"), they will receive credit.*
- Be responsive to the topic of growing as a result of failures and obstacles, using the prompt questions or your own reflections
- Addresses **at least three** prompt questions
- Be appropriate for an audience of your peers (students in this course)
- Demonstrate competency and creativity in format and content

Citation: Intervention developed by members of FLAMEnet, funded by NSF RCN UBE Awards# 1827160 and 1919953.

Additional engagement opportunities: If you have the bandwidth, it can be useful to respond to each student's reflection with encouragement and/or comments about the role challenge/failure/ambiguity played in your own development as a scientist. This can help build instructional immediacy and trust, while also normalizing the role of failure as a stop along the way to success. Moreover, aligning course objectives and grade assessment with troubleshooting and thoughtfully completing these reflections will serve as an incentive for students to engage in this activity and signal to students that you value their growth as holistic learners. You can even include a question along the lines of "what did you learn about the role of challenge/failure/ambiguity in research" on a final report! Finally, sharing the digital reflection with the class at the end of the semester and/or at the start of the following semester can be yet another valuable way to celebrate failure as a step along the way to success.

Intervention 2: Assessment Reflection

Implementation context: Implemented in any courses with exams or quizzes, typically lecture courses.

Brief description: Students are prompted to review incorrect answers from an exam and also answer prompts designed to help them develop a plan for improvement on subsequent exams. The prompts and messaging throughout the assignment are specifically designed to encourage a growth mindset, mastery goal orientation, and productive coping skills.

Details: Interventions are designed to be implemented after each learning assessment (e.g. exam) and include the text outlined below. Google Form copies of these Assessment Reflection activities are available upon request.

Assessment Reflection 1

Overview: This activity will help you to reflect on your recent assessment and explore strategies that work best for you in mastering the material for this course. A key idea of this activity is that we can learn how to succeed by understanding what went wrong when we made a mistake. When we identify what went wrong, we can make a plan to address inaccurate or incomplete thoughts and to build our knowledge and intelligence in a specific area. In this case, by looking back at your exam and thinking about why you had difficulty with certain questions, you can adapt your future work habits and approaches and seek the kind of feedback that will help you change your learning strategies and to improve your success in this class, and in future classes.

Assignment Duration: You will have approximately 15 minutes of class time to work on this assignment in class today. Use that time to review your exam answers. Finish the rest of the reflection thoroughly, thoughtfully, and sincerely. Please come to our next class meeting prepared to discuss the questions with a peer.

Part I. Reflecting on overall assessment performance:

1. Please indicate how you feel about your performance on this assessment. *(Options: very bad, bad, neutral, good, very good)*
2. How confident are you that you can improve your performance on future assessments? *(Options: not confident at all, not confident, neutral, confident, very confident)*
3. Explain why you feel this level of confidence. *(Open Response)*
4. Reflect on how your assessment made you feel. Were you surprised? Satisfied? Disappointed? What did you do to cope with these emotions? *(Open Response)*

Part II. Working to correct specific questions:

1. Identify a challenging question that you got correct/received full credit for. If you did not get a question correct/receive full credit, pick a question that you could at least partially answer with your current knowledge. Question #: *(Open Response)*
2. Describe the process through which you came to know the information or develop the skills that allowed you to answer the question correctly. (Consider your thoughts and behaviors during class, while working on assignments, and during your exam preparation.) *(Open Response)*
3. Identify a question that you got incorrect or did not receive full credit for. If you did not get any incorrect answers, pick the most challenging question you got correct or received full credit for and answer the question below. *(Open Response)*

4. Write the correct answer below with an explanation for why it is the correct answer. *(Open Response)*
5. Reflect on why you may have missed this question or why it was particularly challenging. What actions could you have taken that would have helped you to learn this material or better approach the question, and thus answer it correctly on the exam? *(Open Response)*

Part III. Preparing for future learning in this class:

Why are wrong answers so useful? Wrong answers represent opportunities for you to learn and gain knowledge and intelligence since they illuminate areas you haven't mastered yet. This mastery comes from working to understand why a wrong answer cannot be the correct answer and the process by which you can arrive at the correct answer. Through this activity, you will learn how to learn from your mistakes. This is an important skill for scientists, as even highly experienced researchers frequently make mistakes and experience failure.

Now that you have reflected on both correct and incorrect questions from this [exam\quiz\assessment], it is time to come up with a strategy that will help you to learn the material so that you can master future content in this class and become proficient in [Name of class or Class topic]. This can include *using evidence-based strategies.* Research has shown that we learn more when we repeatedly put effort into engaging with all aspects of a topic. The following strategies have been shown to help students learn content and truly master what they know (i.e., be able to apply it or build upon it in real-life situations).

- Teaching content to others.
- Asking oneself "why" or "how" questions about content and answering them. Writing explanations from one's own memory.
- Making a map of concepts that are linked to one another (concept-mapping).
- Generating your own exam-style questions and answering them.
- This can also include using tips from resources available on the internet about the best ways to study STEM subjects; for instance, you can find great examples here: *http://www.learningscientists.org/posters* and *https://www.penguinprof.com/uploads/8/4/3/1/8431323/what_works_what_doesnt.pdf*

Describe three specific steps that you will take between now and the next assessment to grow your knowledge and understanding to improve your performance and confidence. In addition, briefly explain why you believe each change will help. Include at least one of the suggested strategies from above in your plan. If you feel your current methods were satisfactory for academic success, comment on why you think this and describe your methods here.

1. Goal A: *(Open Response)*
2. Goal B: *(Open Response)*
3. Goal C: *(Open Response)*
4. How confident are you that this plan will work for you? *(Options: not confident at all, not confident, neutral, confident, very confident).*
5. Share your plan with a partner and discuss what you might improve in order to master class content. Summarize your discussion in a few sentences in the space below. *(Open Response)*
6. Would you be willing to share this study plan with the class? Your name and other identifying information will be removed from your assignment. *(Open Response)*

Citation: Intervention developed by members of FLAMEnet, funded by NSF RCN UBE Awards# 1827160 and 1919953; adapted from Lovett 2013.

Assessment Reflection 2

This is similar to Assessment Reflection 1, with the following modifications:

Overview: Congratulations on completing [Exam/Quiz/Assignment 2]! This activity is similar to the one you completed after [Exam/Quiz/Assignment 1], and it is designed to help you continue improving your learning skills by reflecting on your thoughts about your [exam/quiz/assignment] performance. The key idea of this activity is the same as before; that mistakes simply indicate where you are right now and point to opportunities for learning, and that dissecting what went wrong and not being afraid to engage with your failures or mistakes lets you adapt your approaches to improve your learning and maximize your success.

Part I: Additional questions:

1. To what extent did the first debrief exercise help you as you prepared for and took this [exam/quiz/assignment]? *(Options: not at all, a little bit, somewhat, greatly, it was essential).*
2. Explain your answer with specific comments on how well you executed your plan from the first debrief exercise.

Part II: Add the following introduction:

Remember, understanding why a wrong answer cannot be the correct answer and how you can arrive at the correct answer is where learning really happens. As an example, consider the relationship between practicing a musical instrument and proficiency. When you practice, it's not just the act of practicing itself that makes you more musically proficient. It's the fact that you evaluate yourself and receive feedback on how the music you produce sounds. As you respond to this information, your body and brain develop neural pathways which help you to increase your knowledge and skills.

Part III: Modify as follows:

Now that you've completed reflections on your current study habits and have a better understanding of why you had trouble with specific content from [Exam/Quiz/Assignment 2], it's time to revisit your plan of action to use this knowledge to improve your skills and abilities for future exams. Your plan should guide you in deciding how you will both work harder and employ smarter strategies to build new neural connections that will enhance your performance in this class!

Recall that during the first Assessment Reflection, you reviewed evidence-based strategies that will help you learn content and truly master [insert Course or topic]:

- Teaching content to others
- Asking oneself "why" or "how" questions about content and answering them
- Writing explanations from one's own memory
- Making a map of concepts that are linked to one another (concept-mapping)
- Generating your own exam-style questions and answering them

1. Since completing the previous debrief, what have you learned to do differently to prepare for an [exam/quiz/assignment] in this course? *(Open Response)*
2. How was your performance on [exam/quiz/assignment 2] compared to [exam/quiz/assignment 1]? *(Options: higher, lower, the same)*
3. Propose a reason for this difference. Was it related to your study strategies? Your confidence? Something else? *(Open Response)*

Describe three specific steps that you will take between now and the next assessment to grow your knowledge and understanding to improve your performance and confidence. In addition, briefly explain why you believe each change will help. Include at least one of the suggested strategies from above in your plan. If you feel your current methods were satisfactory for academic success, comment on why you think this and describe your methods here.

4. Goal A: *(Open Response)*
5. Goal B: *(Open Response)*
6. Goal C: *(Open Response)*
7. How confident are you that this plan will work for you? (*Options: not confident at all, not confident, neutral, confident, very confident).*
8. Share your plan with a partner and discuss what you might improve in order to master class content. Summarize your discussion in a few sentences in the space below. (*Open Response)*
9. Would you be willing to share this study plan with the class? Your name and any other identifying information will be removed from your assignment. *(Open Response)*

Citation: Same as Assessment Reflection 1.

Assessment Reflection 3

This is similar to Assessment Reflection 2, with the references to assessment numbers modified as necessary. The final questions can be modified to be more forward-thinking (for example, "describe steps you will take in your future STEM courses to grow your knowledge in the course subject and understand and improve your performance and confidence).

Additional engagement opportunities: If you have the bandwidth, it can be useful to a) respond to each student's reflection with encouragement and/or comments, and b) remind students of their action plan ~two weeks before their next assessment. This can serve as a reminder and also increase accountability while also building instructional immediacy and trust. Moreover, aligning course objectives and grade assessment with thoughtfully completing these reflections will serve as an incentive for students to engage in this activity and signal to students that you value their growth as holistic learners. You can even include a question along the lines of "what did you learn about yourself as a learner this semester" on your final exam!

Measurement validations: The two interventions outlined above were developed based on the premise that supporting adaptive coping strategies and reducing fear of failure will help students leverage failure and ambiguity experiences as an opportunity to build resilience and develop adaptive coping skills. In turn, these students will be more prepared to encounter failure and setbacks as they search for tenable solutions for the increasingly complex problems of our modern world. To determine whether these (and other) interventions indeed support students in this important growth, FLAMEnet developed validated measures of coping and fear of failure (Henry 2021, Henry 2022). For both these attributes, items that were anticipated to be a good measure of undergraduate students' coping and fear of failure were gathered and then tested for validity in undergraduate STEM context via exploratory factor analyses, confirmatory factor analyses, and cognitive interviews. The resultant items were confirmed to effectively measure fear of failure and coping in diverse populations, including PEERs (persons excluded due to ethnicity or race). If you wish to measure the effect of your lab course on students' coping and fear of failure, we encourage you to use the measures outlined in the publications (see Henry 2021 and Henry 2022).

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8

Toward a Community of Belonging in Introductory Physics

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MIT, a STEM-focused university with substantial undergraduate populations of both women and underrepresented/minoritized (URM[1]) students, has a unique opportunity to address the dramatic underrepresentation of these students in U.S. bachelor's programs in physics (*https://ncsesdata.nsf.gov/home*). Unlike other universities, where the K-12 pipeline is a tempting scapegoat, at MIT we cannot claim that lack of participation in the physics major is due to inadequate mathematical preparation or disinterest in STEM fields.

A rich body of research highlights how fostering a sense of "belonging," or the feeling of being a welcome and contributing member of a community, is key to allowing a diverse undergraduate population of STEM majors to flourish *(https://www.aip.org/sites/default/files/aipcorp/files/teamup-full-report.pdf)*. This chapter describes work I have done, together with MIT course staff and experts in social psychology and educational research, to investigate a social belonging intervention in the introductory physics courses, as a means to increase recruitment and retention of these students within the MIT physics major. Crucially, this intervention framework aims to shift *the culture of the entire class,* rather than focusing on the thought processes of individual students.

The introductory physics sequence is a requirement for all MIT undergraduates, with the courses targeted by this intervention serving ~800 students each semester. As each instructor teaches two sections of ~50

[1] MIT defines a member of an underrepresented minority as a U.S. citizen or permanent resident who self-identifies as Black/African-American, Hispanic/Latino(a), Native American or Alaska Native, Native Hawaiian, or other Pacific Islander. We caution that we are limited in our conclusions by the demographic data that the registrar does, and does not, collect.

students each, we were able to compare feelings of belonging in sections where instructors led the belonging intervention (treatment) and in sections where the same instructor instead led a discussion of general study skills (control). Physics is among the largest undergraduate majors at MIT, with ~200 majors (sophomores, juniors, and seniors) enrolled in a given year. This work thus holds the promise of making a large impact within the university, and allows for meaningful statistical assessment of effects.

Who Belongs in the MIT Physics Major?

The data at MIT support that the experience after arriving at MIT is dissuading certain student demographics from pursuing a physics major, despite their initial interest. Using pre-admission questionnaires, we see that the number of students who graduate with a major in physics is smaller than the number of students who indicate they intend to major in physics before arrival at MIT. This result alone is not surprising – when applying to MIT, most high school students are familiar with physics, but not familiar with biochemical engineering, neuroscience, or many of the other attractive topics pursued at MIT – and is not necessarily a problem.

However, this drop is dramatically sharper for women than men; for first-generation students than other students; and for URM students than white students. In other words, once at MIT, far more of these students are discouraged from joining the physics major than are encouraged to join. As a result, women, for example, are close to half of the undergraduate population, but only ~25-30% of physics majors in a given year.[2]

It is difficult to argue that such dramatic differences are due solely to student capability. MIT is an exceptional place, recruiting from the most mathematically and scientifically well-prepared students in the world. Any student admitted to MIT is capable of completing the physics major curriculum, if they desire. Indeed, for example, women's average grades are no different than men's in the introductory physics courses 8.01 and 8.02.

The concept of belonging gives one lens onto the possible causes of this worrying trend. Belonging is not an abstract concept, but tied to the concrete academic behaviors that we encourage in our students. Belonging influences how students engage with resources when faced with inevitable struggles. It influences whether they form study groups, attend office hours, or approach professors with questions. A culture of belonging encourages intellectual bravery, where all are unafraid to learn from each other and our mistakes and struggle through to new understanding together.

Belonging in the Introductory Physics Courses

Two semesters of introductory physics are required of all MIT undergraduates,

[2] In quantifying this problem, we use five years of anonymized data for the graduating classes of 2014-2018.

with the majority taking the general courses 8.01 (mechanics) and 8.02 (electricity and magnetism). The format of 8.01 and 8.02 interweaves short standard lectures with extensive group problem work, where feelings of social belonging are critical to success. With ~800 students, typically in their first year, each semester, these courses are a pipeline for recruiting into the physics major. Although ~30 students each year instead take 8.012 and 8.022 (a more mathematically rigorous, lecture-based version of this sequence), the majority of students and the majority of physics majors take 8.01 or 8.02.

To understand how our MIT physics classrooms influence belonging, we looked more closely at student experiences within 8.02. This course is taken by most students during their first year, as they are still settling into the MIT experience and preparing to choose an academic major. As our colleagues at MIT's Student Support Services attest, for many students 8.02 is a defining experience, inducting students into "the MIT way of thinking."

The status of student belonging was measured using surveys formulated in collaboration with professor Rene Kizilcec of Cornell University—an expert in scalable interventions to broaden participation in STEM—that were administered at the end of the course in Spring 2018 and 2019. These surveys contained 22 questions, including general prompts on the importance of physics, the utility value of the class, and students' general experience in the class, as well as targeted questions on students' sense of belonging, such as "Sometimes I felt like an outsider in the class," "People like me are good at physics," "I felt comfortable asking questions in class," and "I felt like I belonged in the class.'"

In these surveys, women showed statistically significant lower measures of belonging in 8.02. A statistically significant disparity is not prevalent across other demographics, such as URM or first-generation students. However, some students speak of experiencing isolation and unease within our classrooms, extreme enough to dissuade them from continuing in physics.

Importantly, these surveys also highlight that even students who are not identified as women or URM do not, on average, show high measures of belonging in 8.02. Building an infrastructure of belonging into our classrooms thus has the potential to improve learning outcomes for all students.

Belonging Intervention Framework

In Spring 2021 (remote, synchronous learning) and 2022 (in-person classes), we incorporated a 30-minute affirmative intervention into the first day of 8.02, with the hope of demonstrating an impact on student belonging within the particular context of MIT. Previous research validated that such a discussion can significantly improve the average grade in large introductory physics and biology courses for all student demographics, with particularly strong benefit for women and non-white students *(https://journals.sagepub.com/doi/full/10.1177/0956797620929984)*. The format of this discussion was adapted from scripts provided by one of the co-authors of this work, Chandralekha Singh, University of Pittsburgh, an expert in research on equity and inclusion in undergraduate physics education.

At a community level, this exercise changes community conceptions of competence and adversity and instills social norms around help-seeking and mutual support. As shown in the figure below, at the individual level, this helps interrupt negative recursive thoughts and behaviors – in which a lack of belonging causes students to disengage with sources of support, thus further decreasing feelings of belonging – and replaces them with constructive behaviors such as engaging with peers and instructors.

The framework of this intervention is simple: on the first day of class, instructors guide a discussion that normalizes that struggle is both common and surmountable:

1. Instructor frames discussion: First, the instructor frames the discussion by explaining, "It can be easy to feel overwhelmed and to ask yourself, Do I really belong here? Am I smart enough to make it? These kinds of experiences are normal at MIT. Everyone goes through them, and they get better with time." Instructors are encouraged to share examples from their own lives.

2. Writing activity: Next, students write brief reflections on the experiences they have found difficult or challenging at MIT so far.

3. Quotes from former students: Student volunteers then read aloud a collection of short quotes from former students explaining how they first struggled to feel like they belonged in 8.02, but eventually learned to engage with resources and succeed. The following two examples illustrate the personal and specific nature of these quotes.

> "I came into 8.02 pretty confident that I would do well because I had basically memorized everything while in high school and managed to pass. Then I got a C on my first midterm and I was so devastated. Some of my friends never came to class but got straight As and here I was spending more than six hours a week outside of class trying really hard but still not making it. I went to my professor's office hours and just broke down crying because I felt the pain of working so hard but not seeing any results. I thought maybe MIT wasn't for me. To my surprise, I felt so much better after. I told myself that I just couldn't give up at this point. I kept asking even more questions to make sure I wasn't just getting the psets correct but that I actually understood it so that no matter how much the question was twisted I would be able to do it. In my next test, I moved from a C to a 99%! I was just so thankful to my teachers and the TAs in class who were there 100% of the way; cheering for me at the finish line. NEVER hesitate to reach out to them for help or just to share how you are feeling. They actually care and want to see you succeed!"

> "About five weeks into the semester, I felt pretty hopeless about my ability to do well in 8.02. I had missed the first week due to medical reasons. I struggled to keep up while also catching up. I felt embarrassed to ask for help, especially when it seemed like everything came so easily to my friends and other classmates. I also had to deal with the anxiety of possibly not passing the class, which made me

even more reluctant to reach out; I felt alone in my struggles. After I received a fifth week flag, I set up a meeting with my professor and went over some of my difficulties. I immediately felt relieved that it wasn't actually that bad to talk to someone about how I was having a hard time, and my professor was incredibly helpful. By the end of the hour meeting, I felt less embarrassed to ask for help. Looking back, I realize I had a rough semester, but the thing that saved me was reaching out. Looking back, I realize I should've reached out sooner, because not only did it help me understand the material, but it also helped me see that I wasn't the only one struggling so hard!"

4. Small group discussion: Students are then prompted to discuss these quotes with each other, first in small groups and then as a larger class, focusing in particular on the question of why sometimes students feel alone in their struggles. In particular, they are prompted to discuss, "What are some common themes across several of the quotes we read? Why do you think that sometimes students don't realize that other people are also struggling with the course?"

5. Follow-up reflection: Finally, one week later, students are given an at-home assignment to write advice to a future 8.02 student who is worried about struggling in the course.

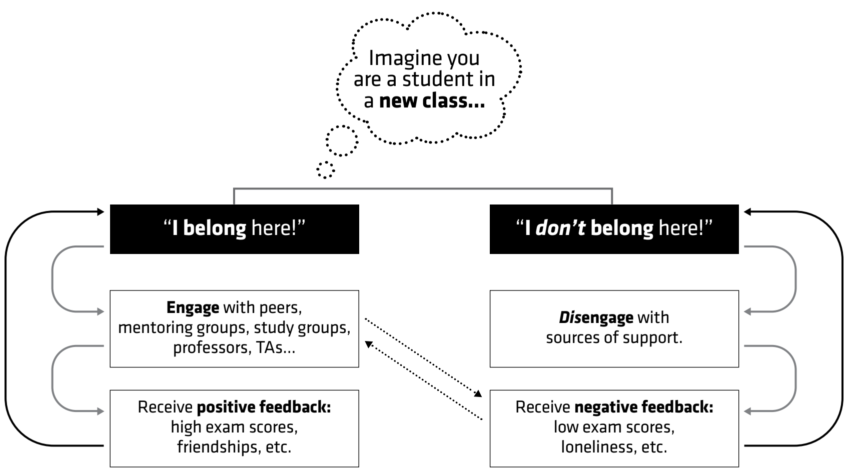

Figure: At the individual level, this exercise aims to interrupt negative recursive psychological processes, moving students from destructive thought patterns and behaviors to constructive responses.

Assessing Intervention Impact

The same surveys discussed above are used to assess the impact of this intervention on student belonging. In both of the semesters where this intervention was launched, each of the eight instructors taught two sections of 8.02, allowing for a control and treatment group. In one section, instructors led the belonging intervention (treatment), while in the other section they led a discussion of general study skills (control). Instructors were invited to participate in this study, but not required. Anonymized student IDs are linked to these two groups, allowing for correlation with demographic data and tracking of short-term outcomes via course grades and end-of-semester surveys and long-term outcomes via registrar data of intention to pursue a physics major, declaration of a major, and graduation with a major.

Although the analysis of this data is still ongoing, the experience of the students, instructors, and course staff has been so positive that it is now planned to make this intervention a permanent feature of the first day of 8.02. The quotes below illustrate some of this positive impact.

- **Student Perspective**

  "It was the class where I felt most connected. The group assignments helped a lot, but also from the very beginning of the semester, they talked about things related to Imposter Syndrome. It made the instructor feel more approachable, since he took the time to show he cared about students' health. In the first week of class, he showed us a Venn Diagram which pointed out how we just assume that other students know a lot more than we do. It helped me see that with my negative thoughts, there was a flaw in my reasoning. On many occasions, this was a safeguard against falling into that negative line of thinking, where I was doubting myself."

- **Instructor Perspectives**

  "At the beginning of the intervention, I was paying more attention to the timing and just trying to get any sense of what the students were thinking and feeling. Then it came time for me to share a personal story, and at least my feeling changed; I remembered that time when I was a Freshman in college realizing that everyone around me had gone to a better high school or had more educated parents and just seemed to know more about how to tackle the work, and I felt that sense of being overwhelmed and anxious. Hiding behind the Zoom windows, there were certainly students here who had a similar feeling right now! I love teaching 8.02 because I especially enjoy working with the students for whom physics is not their main interest. I am able to remind myself of what it was like to not know physics and not know calculus. But this intervention helped me go beyond the content. Not only was I able to forge a stronger bond with my students by being really vulnerable myself on the first day, telling my students something personal from my past, I was also reminded of what it was like to be that student and that helped me have additional empathy."

  "It was the first time after class on the first day that I had students (all women) coming up to me to introduce themselves and tell me how excited they were for the class. This only happened in the section where I did the intervention. I would love to continue doing this exercise. I really felt it brought us all together, and I felt way more connected to my students than I normally would in a large lecture setting.

  "There was lots of participation in the wrapup discussion. They seemed very open to it. Many students stayed after the class to chat with me informally; none stayed after in the other section."

- **Course Staff Perspective**

  "Before the semester began, we had an 8.02 instructor team meeting where Kerstin presented the idea behind this intervention, giving some grounding statistics about who drops out of our major and the gender difference in the sense of belonging within previous semesters of our course. The sense of interest shown by the instructors during that presentation was palpable. There were many questions, and even in subsequent meetings, instructors would refer to the ideas presented. While we do sometimes acknowledge that 8.02 is not everyone's favorite class at MIT in discussions of how to ensure student participation does not evaporate at the end of the semester, we were now talking more explicitly about the idea that students might not be engaging at the level we desired because of the feelings they have about the class. Everyone thought it was a good idea to emphasize in class the importance of seeking help. From my perspective, even if the intervention did nothing to help the students, it did a great deal to help the teaching staff!"

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