TEACHING AND INSTRUCTION OF FACULTY IN HIGHER EDUCATION

By

Byron Hempel

A Dissertation Submitted to the Faculty of the

DEPARTMENT OF CHEMICAL & ENVIRONMENTAL ENGINEERING

In Partial Fulfillment of the Requirements

For the Degree of

DOCTOR OF PHILOSOPHY
WITH A MAJOR IN ENVIRONMENTAL ENGINEERING

In the Graduate College

THE UNIVERSITY OF ARIZONA

2019

THE UNIVERSITY OF ARIZONA
GRADUATE COLLEGE

As members of the Dissertation Committee, we certify that we have read the dissertation prepared by Byron Hempel, titled *Teaching and Instruction of Faculty in Higher Education* and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy.

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ACKNOWLEDGEMENTS

During the pursuit of achieving a Ph.D., I have been blessed to be supported and guided by many of my family members, friends, and colleagues. Although a Ph.D. is meant to be the ultimate individual and independent academic challenge, I could not have completed it without their assistance. In particular, Paul Blowers has been a wonderful mentor and guiding entity throughout the entire process. Without him, I would not have stayed as an Engineering Education PhD Student. Vicente Talanquer, Katie Southard, Young Ae Kim, and Jazmin Jurkiewicz were my core research support, providing guidance into the foreign territory of qualitative education research. Justine Schluntz was a major emotional support and intellectual contributor to my own teaching practices. Tori Hidalgo was a great research subject to have interviews and discuss the classroom; I greatly appreciate her insight and teaching practices as they helped put my own research and teaching into perspective. My faculty learning community members over the past two years (totaling four semesters of different groups) all contributed to generating different teaching ideas and techniques.

Over the past four years, my climbing partners have all been great emotional support groups for dealing with the ups-and-downs of a graduate education. I could not have emotionally made it through the program without their kind and loving support.

Last, but definitely not least, by family has been a strong support group. They may not have always been physically present in Arizona, but they were always nearby in spirit.

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Abstract

Within higher education at Research 1 (R1) institutions, there are a variety of different roles and positions within the university. In particular, faculty at an R1 school vary from having independent roles (such as tenure track positions, emeritus roles, and practitioner or educator positions) to mentored or sponsored roles (such as non-tenure track teaching or research positions and post-doctoral fellowships). Each subset of faculty roles contains areas of challenges and areas of opportunity. Of those faculty positions, careers that educate both undergraduate and graduate student populations in STEM are being pushed by many agencies to improve the quality of education to allow for increased student successes [1]–[8].

Our Chemical and Environmental Engineering Department managed to improve the retention of chemical engineers from 45% to roughly 90% over the span of a few years. The overarching research question this dissertation will address is how we can continue to improve the teaching of faculty members and spread the successes in the department to other disciplines. As the Association of American Universities would suggest, this dissertation will approach this retention success from the focal point of the instructor. Instructors encounter many challenges when teaching or incorporating change in their practices [9]–[15]. An abbreviated list of different challenges across teaching include: developing ways to promote higher order thinking [16], understanding the nature of group or team assignments [17], having an appropriate depth of content knowledge [18], disseminating curricula and pedagogy, developing reflective teaching and questioning personal beliefs [6], [19], use of information communication and technologies [20], [21], relations and adoption of professional communities [22], utilizing different teaching structures, such as using student learning initiatives [23], and adopting evidence-based teaching practices, such as using an interactive classroom [24]. With a plethora of different areas to spend time on, this dissertation will focus on:

1. Providing a manual of scalable instructional techniques for student retention which helped increase retention dramatically.
2. Qualitatively characterizing affective drivers that promote change in teaching practice to help instructors and professional development facilitators improve instruction
3. Assessing gender biases of students on teacher course evaluations in higher education to ensure there is equality towards instructors in terms of gender.

In essence, the perspective of the chapters looks at higher education from different viewpoints. This dissertation will have five main parts: 1) an introduction to the state of higher education from a broad perspective, 2) scalable and practice interventions faculty can deploy to increase retention and improve teaching practices from a teaching perspective, 3) an in-depth look at one instructor's affective factors to her teaching practices from a professional development perspective, 4) a look as potential gender biases in higher education as females may be discriminated against in end-of-semester reviews in a male dominated field giving insight from the student perspective, and 5) a look at the future of teaching faculty in higher education from a broader perspective on higher education.

Below are a list of the chapters found in the dissertation:

Chapter 1 - The Current State of Higher Education

Chapter 2 - Scalable and Practical Interventions Faculty Can Deploy to Increase Retention: A Faculty Cookbook for Increasing Student Success

Chapter 3 - Affective Factors that Influence the Implementation of Task vs. Lecture in a Large Introductory General Chemistry Course

Chapter 4 - Student Evaluation of Teaching in an Engineering Class and Comparison of Results Based on Instructor Gender

Chapter 5 – The Future of Teaching Faculty in Higher Education

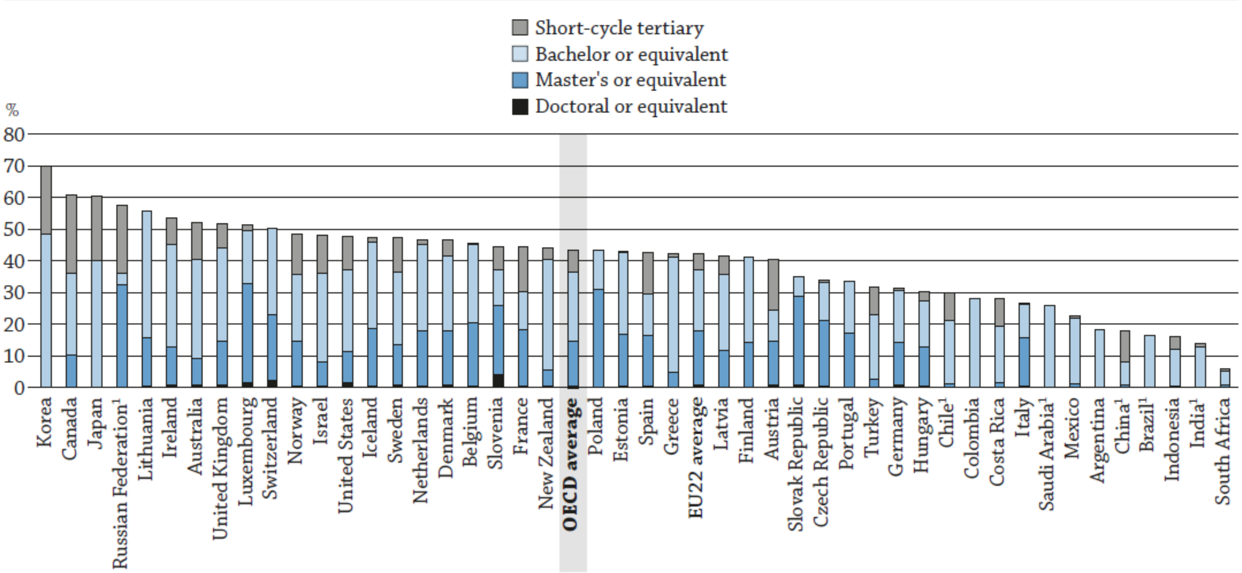
Chapter 1: The Current State of Higher Education

As the introduction to the dissertation, there are no published papers associated with this chapter. This chapter will introduce various aspects of higher educations and the need for quality instruction. As of the writing of the dissertation, this document will focus on three gaps in the literature to improve the quality of instruction of higher education while weaving in different threads of supporting research. The three chosen gaps of study are the use of different practices in the classroom from the perspective of growth mindset, self-efficacy, metacognition and belongingness; an in-depth case study observing how affective factors influence a teacher's decisions made in the classroom; and the use of a co-teaching model to identify gender biases among women in the male-dominated field of engineering, in particular a sophomore chemical engineering course.

1.1 Reports from Reputable Sources of the State of Higher Education

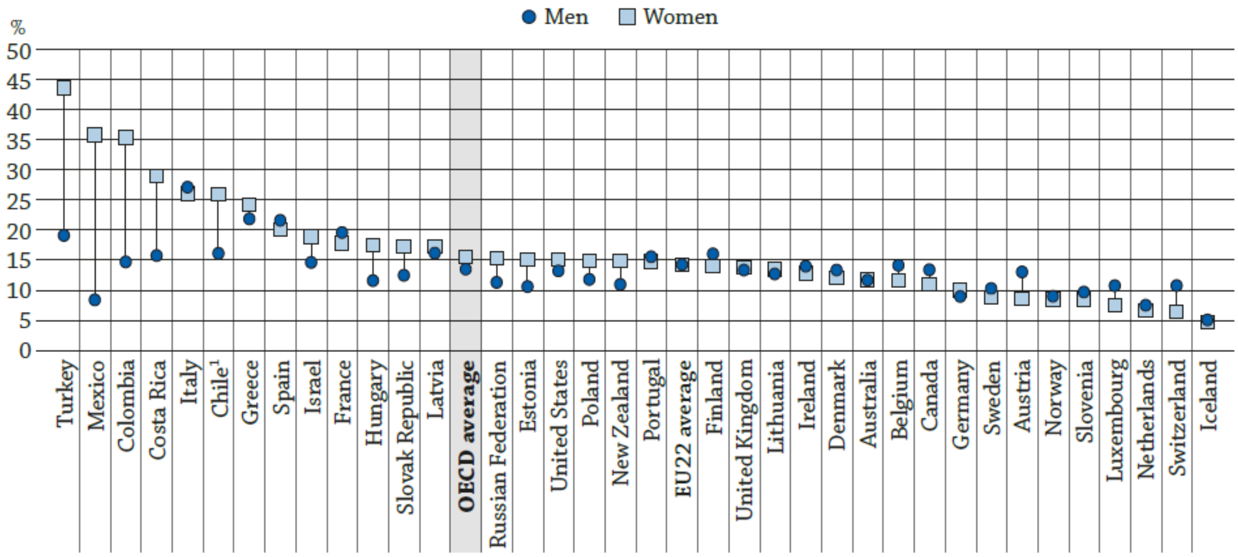
The Organization for Economic Co-operation and Development (OECD) is an intergovernmental non-partisan economic organization with 36 member countries with a focus to stimulate world trade (1). The OECD released a report in September 2018, ranking education across the member countries. Of the different categories, the United States (US) was ranked 13th in percentage of 25-34 year-olds with tertiary education, as seen in *Figure 1.1*; additionally, the US has a large percentage of 18-24 year-olds without employment or education or training, as seen in *Figure 1.12* (2).

Furthermore, the OECD report listed the percentage students who reported being aware or well-aware of environmental issues, by science proficiency level. Across the subjects of greenhouse gases, genetically modified organisms, nuclear waste, deforestation effects, air pollution, extinction of plants and animals, and water shortage, the US obtained scores close to or less than average across all domains compared to the OECD average (2).



Note: Some categories might be included in other categories. Please refer to Table A1.1 for details.
1. Year of reference differs from 2017. Refer to Table A1.1 for more details.
Countries are ranked in descending order of the percentage of tertiary-educated 25-34 year-olds.

Figure 1.1 - Percentage of 25-34 year-olds with tertiary education, by level of tertiary education (2017)
Taken from OECD (2).



Note: NEET refers to young people neither employed nor in education or training.
1. Year of reference differs from 2017. Refer to the Table A2.1 for more details.
Countries are ranked in descending order of the total percentage of 18-24 year-old NEET women.

Figure 1.2 - Percentage of 18-24 Year-Old NEETs, by Gender

Taken from OECD (2).

With the US being a major force on the international stage, various reports have been written which created diagnostics on the state of higher education, in particular STEM education. These reports were generated to give the US an idea of how to be more competitive on the international stage. Five reports created throughout the past 20 years discuss the status of higher education in the US, along with strategic plans being implemented. The first three reports focus on higher education in general, and the last two reports by the Association of American Universities focus more on scale and reform of undergraduate STEM education. For brevity, a brief summary of the following five reports are detailed:

1. Reinventing Undergraduate Education: Three Years after the Boyer Report (2001) (3) in response to the Boyer Report (1998) (4)
2. Report to the President: Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering and Mathematics (2012) (5)
3. Charting a Course for Success: America's Strategy for STEM Education (2018) (6)
4. A Five-Year Status Report on the AAU Undergraduate STEM Education Initiative (2017) (7)
5. Scaling Improvement in STEM Learning Environments: The Strategic Role of a National Organization (2018) (8)

The Boyer Report, distributed in 1998, detailed viewing the university as an ecosystem and proposed an Academic Bill of Rights as an agreement between students and the university to detail adequately the relationship and what was expected between the students and universities. The report further detailed 10 main ways to change undergraduate education (4). Those are to:

1. make research-based learning the standard
2. construct an inquiry-based freshman year
3. build on the freshman foundation
4. educate graduate students as apprentice teachers
5. remove barriers to interdisciplinary education
6. link communication skills and course work
7. use information technology creatively
8. culminate with a capstone experience
9. change faculty reward systems
10. cultivate a sense of community

The 3 year follow up to the Boyer Report, which was distributed in 2001 to 123 Research I and II Universities (91 responded), reflected that most universities have made efforts directed largely at the highest achieving students, leaving the middle and lower achieving students behind. Being able to influence the broader spectrum of students has been more difficult. Moving forward, *Table 1.1* and *Table 1.2* summarize the most recent actions universities have taken. Major observations from the response are summarized in six main findings. First, research universities were taking undergraduate education seriously. Second, institutions were still working on achieving their ambitions for the spectrum of undergraduate programs, rather than the best students. Third, the social sciences, humanities, and arts were falling behind the sciences and engineering in promoting undergraduate research. Fourth, oral communication and presentations were still not valued by universities. Fifth, in contrary to the lack of oral emphasis, the writing emphasis was largely set as a priority. Lastly, budgets were a limiting factor to expanding undergraduate programs faster. Education was not considered a top priority, and unless education becomes a priority, will evolve slowly (3).

Table 1.1 - The Most Important Actions a University Has Taken in the Last Three Years to Improve Undergraduate Education

Actions	**Number of Responses**	**Percent of Respondents**
Revising the general education curriculum, including increasing the emphasis on teaching writing, communication, and math skills	25	27%
Expanding undergraduate research opportunities or programs	19	21%
Creating or expanding freshman seminars	14	15%
Improving advising and academic support services	13	13%
Establishing or expanding learning communities	11	12%
Creating or strengthening a teaching and learning center	10	11%
Expanding writing programs	9	10%
Initiating planning projects and discussions	8	9%
Creating or expanding faculty development initiatives	8	9%
Creating new positions or administrative structures to support undergraduate education	8	9%
Expanding the use of information technology	7	8%
Offering faculty awards and incentives	6	7%
Expanding experiential learning initiatives	5	5%
Focusing more attention on undergraduate education	5	5%
Improving the first-year experience, including initiating a common reading requirement	5	5%
Expanding honors programs	4	4%
Developing study abroad programs	4	4%
Enhancing residential life	4	4%
Placing more emphasis on undergraduate education in promotion and tenure guidelines	3	3%
Developing interdisciplinary initiatives	3	3%
Implementing recruitment and retention initiatives	3	3%
Implementing collaborative learning initiatives	2	2%
Establishing or expanding block scheduling	2	2%
Other	5	5%
Total	183	

Taken from Reinventing Undergraduate Education: Three Years After the Boyer Report (3)

Table 1.2 - Single Most Important Action Your University Could Take to Improve Undergraduate Education

Actions	**Number of Responses**	**Percent of Respondents**
Changing faculty incentives and increasing the integration of research and teaching	14	15%
Hiring more faculty/decreasing class size	10	11%
Increasing integration within the undergraduate program	7	8%
Implementing administrative changes	7	8%
Revising the general education curriculum	6	7%
Improving curriculum and expanding inquiry-based and experiential learning	5	5%
Improving pedagogy	5	5%
Improving the first-year experience	5	5%
Improving programs that teach writing and other skills	5	5%
Preserving quality while accommodating enrollment growth	4	4%
Focusing attention on student learning and learning assessment	3	3%
Increasing student/faculty interaction, in- and outside the classroom	3	3%
Developing a capstone experience	2	2%
Improving advising	2	2%
Other	2	2%
Total	80	

Taken from Reinventing Undergraduate Education: Three Years After the Boyer Report (3)

The Report to the President: Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering and Mathematics (5) focused primarily on the first two years of college, as these two years were deemed a crucial stage in the STEM education pathway. The report provided ways for students to have the tools they need to excel and to diversity pathways to STEM degrees through such means as study skills, identification with STEM fields, and particularly math preparation. Five recommendations arose to achieve these.

1. The first recommendation was to catalyze widespread adoption of empirically validated teaching practices by increasing programs to help facilitate faculty adoption of evidence-based teaching practices, federal funding through National Science Foundation (NSF) grants, and request the National Academies to develop metrics to evaluate STEM education.
2. The second recommendation focused on changing standard laboratory courses with discovery-based research courses. This transformation would occur through using scientific research and engineering design courses for the first two years through the NSF program, along with allowing Federal research funds to allow students to join research faculty on their projects of interest.
3. The third recommendation was the launch of a national experiment to delve into the mathematics-preparation gap. Many students enter into higher education without the required mathematics preparation to take introductory STEM courses, thereby creating a "bottleneck" of students waiting to take higher-tier courses. The study would be supported through a national experiment of undergraduate education at NSF, the Department of Labor, and the Department of Education focusing on removing or reducing the mathematics bottleneck keeping many students from pursuing STEM majors.
4. The fourth recommendation is to diversify pathways to STEM careers. The report suggested sponsoring summer programs for high school students, making the transition from a 2 to 4 year college easier, establishing private industry ties with 2 and 4 years colleges to encourage learning standards, and improving data provided by government agencies to STEM students, parents and the greater community.
5. The last recommendation was to create a presidential council on STEM Education with leadership from academia and business to prove strategic leadership for STEM education.

Table 1.3 below lists the elements of successful STEM education programs seen throughout the US.

Table 1.3 - Elements of Successful STEM Education Programs

Program Focus	Evidence and Resources*
Intellectually engage students	
Teach science with evidence-based methods that engage students in creating and integrating knowledge	Springer, Stanne et al. (1999); AAAS (2011)
Focus on learning goals that involve both the process and content of STEM-related activities	AAAS (2011)
Involve students in research early, preferably as freshmen	Bartlett (2003); Carter, Mandell et al. (2009) Hathaway, Nagda et al. (2002); Hunter, Laursen et al. (2007); Kight, Gaynor et al. (2006); Kinkel and Henke (2006); Lopatto, Alvarez et al. (2008); Russell, Hancock et al. (2007)
Build alliances between community colleges and research universities to enhance the availability of research experiences to students at community colleges	Shaffer, Alvarez et al. (2010); Wei and Woodin (2011)
Facilitate study group formation and other structures that enable group learning	Burstyn, Sellers et al. (2004); Springer, Stanne et al. (1999)
Personally engage students	
Show relevance of STEM subjects to human and planetary problems	Donofrio, Russell et al. (2007); Buckley, Kershner, et al. (2004)
Provide role models of diverse backgrounds and life choices to inspire diverse students	Lockwood (2006); Stout. Nilanjana et al. (2011); Walton and Cohen (2011)
Provide opportunities for students to become part of STEM communities in classes, research laboratories, and STEM-related extracurricular activities	Kight, Gaynor et al. (2006); Peckham, Stephenson, et al. (2007)
Show students the diversity of careers in science	Campbell, Fuller et al. (2005)
Provide mentoring and tutoring to help students excel in STEM subjects	Muller (1997); Summers and Hrabowski (2006); Gilmer (2007)
Engage students' families in STEM-related academic experiences	Rodriguez, Guido-DiBrito et al. (2000); Ong, Phinney et al. (2006); Sy (2008)
Provide students with sufficient resources, including employment in laboratories and scholarships, to enable them to engage fully in academic life and the science and technology community	Barlow and Villarejo (2004)
Provide students with critical feedback and encouragement to give them realistic assessment of their performance in STEM subjects	Ovando (1994)
Build classroom communities in which students feel that they are being groomed for STEM fields rather than weeded out	Gainen (1995)
Build connections between higher education and industry to provide students with internships and exposure to potential career options	Gilmer (2007); Turner, Petzold, et al. (2011)
Provide undergraduate STEM pathways with access to role models by linking graduate training programs with undergraduate research programs	May and Chubin (2003)
Accommodate the needs of non-traditional students	Barlow and Villarejo (2004)
Educate faculty	
Provide faculty with training in teaching through campus programs, summer institutes, and programs organized by professional societies	Pfund, Miller et al. (2009); Yoon, Duncan et al. (2007)
Provide graduate students and postdocs with training in teaching through training grants and professional societies	University of Texas at Austin (2008); Bouwma-Gearhart (2007); Connolly (2008); Miller, Pfund et al. (2008)
Provide faculty with databases of learning tools and technology	University of Texas at Austin (2011)

Table 1.3 - Elements of Successful STEM Education Programs (cont.)

Assess outcomes (cont.)	
Assess understanding through diverse means, and articulate assessment with learning goals	Haudek, Kaplan et al. (2011)
Assess student retention in major	Wild and Ebbers (2002)
Measure achievement gap between various segments of student body and assess impact of interventions on gap	Haak, HilleRisLambers et al. (2011)
Evaluate teaching in terms of learning goals and how they are assessed and met	Felder, Rugarcia et al. (2000)
Improve learning assessment through technology development	Beatty (2004); Caldwell (2007)

*References for table at end of References for Chapter 1
Adopted from Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering and Mathematics (5)

In 2018, the Committee on STEM Education created a report titled "Charting a Course for Success: American's Strategy for STEM Education," a document presenting the Federal Government's "five-year strategic plan for STEM education, based on a vision for a future where all Americans will have lifelong access to high-quality STEM education and the United States will be the global leader in STEM literacy, innovation, and employment" (6). The report suggests this is achievable through a variety of different mechanisms, the three main being building a strong foundation for STEM literacy, increasing diversity, equity and inclusion in STEM, and preparing the STEM workforce for the future. The pathways through which this will happen are by developing and enriching strategic partnerships between educational institutions, employers and their communities, engaging students where disciplines converge, building computational literacy, and operating with transparency and accountability by having few boundaries to access to the information obtained and actions made.

Table 1.4 summarizes the different goals and pathways for bettering the American Higher Education system in order to increase retention and quality of educational experiences. Various resources are linked in this thesis to help stakeholders and those invested in higher education to evolve the educational system, such as "What Works in Education." This website provides educators with information about evidence-based decisions across all many different aspects in education, which can be found at the following URL: https://ies.ed.gov/ncee/wwc.

Table 1.4 - Goals for American STEM Education

Goals: 1. Build strong foundations for STEM Literacy 2. Increase diversity, equity and inclusion in STEM 3. Prepare the STEM workforce for the Future	
Pathways	Objectives
Develop and Enrich Strategic Partnerships	Foster STEM Ecosystems that Unite Communities
	Increase Work-Based Learning through Educator-Employer Partnerships
	Blend Successful Practices from Across the Learning Landscape
Engage Student where Disciplines Converge	Advance Innovation and Entrepreneurship Education
	Make Mathematics a Magnet
	Encourage Transdisciplinary Leanring
Build Computational Literacy	Promote Digital Literacy and Cyber Safety
	Make Computation Thinking and Integral Element of All Education
	Expand Digital Platforms for Teaching and Learning

Adopted from Charting a Course for Success: America's Strategy for STEM Education (6)

The Association of American Universities (AAU) produced "A Five-Year Status Report on the AAU Undergraduate STEM Education Initiative" in 2017 to encourage and support faculty in using evidence-based teaching practices effective in engaging students in STEM education and improving learning (7). This report followed a major initiative launched in 2011 to improve undergraduate STEM education across 55 universities and 450 faculty and institutional leaders by opening communication on the national scale to share educational information. According to the AAU, 90% of students who switched out of STEM fields cited poor teaching as a concern (7). As the previous three major national reports have described, the undergraduate landscape can use a major improvement in teaching and instruction; with the research on education already describing various innovations that can be implemented in classrooms, students should have access to and be given an education with the most effective teaching methods. However, the "biggest barrier to improving undergraduate STEM education is the lack of knowledge about how to effectively spread the use of currently available and tested research-based instructional ideas and strategies" (7). The AAU focused institutional change for both faculty and students, starting with pedagogy at the core, followed by scaffolding, and finally inducing cultural change. A goal is to be as excellent in teaching as universities in the US are in research.

The last report by the AAU titled "Scaling Improvement in STEM Learning Environments: The Strategic Role of a National Organization" focuses on how the AAU initiative in the previous report can reform undergraduate STEM teaching and learning on a much grander scale (8). Additionally, the AAU explored the role of a national association in undergraduate STEM and methods for doing so at scale. In order for the focus of this dissertation – instruction in higher education – to be applicable, an agency like the AAU needs to be involved in the diagnostic and dissemination process of educational practices to help institutions adopt and implement progressive practices. AAU chose to build on collaboration and networking to help with institutional change by overlapping the Research University STEM community, STEM Coalition, and STEM Improvement organizations with the AAU, AAU STEM Network, Project Sites Network and Subgroups. *Figure 1.3* illustrates this network. *Table 1.5* lists the key institutional elements and breaks pedagogy, scaffolding and cultural change into subcategories of points of focus.

Table 1.5 - Key Institutional Elements for Instructional Change in Higher Education

Institutional Element to Change	Points of Focus
Pedagogy	Articulated Learning Goals
	Educational Practices
	Assessments
	Access
Scaffolding	Provide Faculty Professional Development
	Provide Faculty with Easily Accessible Resources
	Collect and Share Data on Program Performance
	Align Future Facilities Planning
Cultural Change	Leadership Commitment
	Establish Strong Measures of Teaching Excellence
	Align Incentives with the Expectation of Teaching Excellence

Adopted from A Five-Year Status Report on the AAU Undergraduate STEM Education Initiative (7)

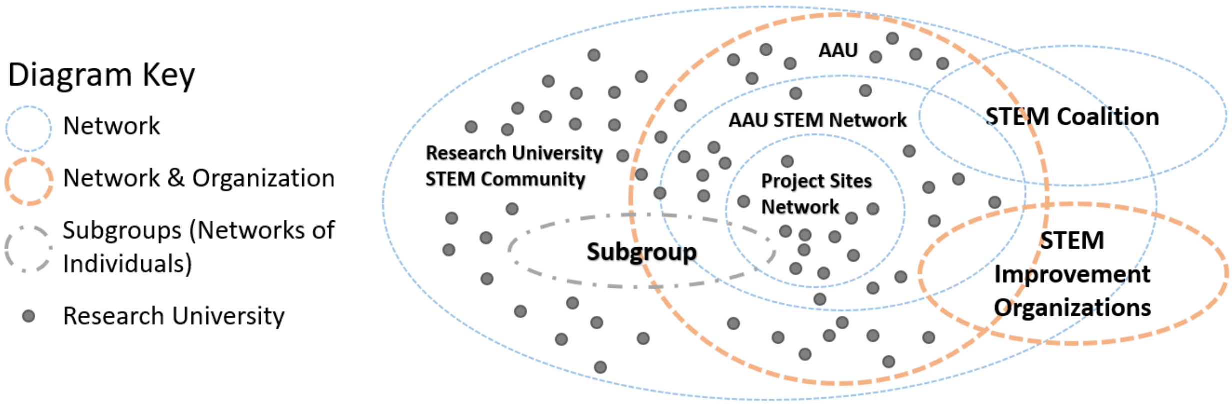


Figure 1.3 - Networking on the National Level for Institutional Change.
Adopted from Scaling Improvement in STEM Learning Environments: The Strategic Role of a National Organization (6).

In the recommendations of the AAU to organizations engaged in scaling change, the following suggestions are made:

1. Assess your strength and assets as well as limitations as an organization
2. using a systems approach is promising to scaling change
3. develop a multi-theory strategy for maximum impact
4. understand and intentionally plan influence strategies
5. carefully evaluate the framing and language used to communicate the change
6. use networks to scale change
7. apply strategies to facilitate learning and adoption, and examine barriers to learning in change processes
8. consider culture change at multiple levels
9. create distributed leadership to improve STEM education

Various peer reviewed publications also propose calls of action to transform STEM education. With the desirability for more higher education research, Froyd, Wankat and Smith identified five major shifts in engineering education (9). From the article, those five major shifts are:

1. From hands-on and practical emphasis to engineering science and analytical emphasis
2. To outcomes-based education an accreditation
3. To emphasizing engineering design
4. To applying education learning, and social-behavioral sciences research
5. To integrating information, computations, and communications technology in education.

As these shifts continue to occur or are emphasized, instructorship practices will continue to change to create a stronger educational experience for engineering students.

These shifts in teaching practices are reflected in the previously mentioned reports as well. Discipline-based education research (DBER) has focused on many issues important to engineering education, such as what and how content should be taught, accreditation, design, engineering education research, and technological implementation into engineering (9). It is important to note that conducting DBER and using DBER findings are not exactly the same. Singer and Smith suggests the two activities should be viewed as distinct but interdependent pursuits (10). By doing so, interested faculty and staff can either focus on the skills for performing the research, or implementing ways to apply the research outcomes. Singer and Smith also note that the DBER base of research is continuing to expand, from improving student ability to transfer learning, to enhancing a student's own thinking about learning (aka metacognition), to better understanding the role of various other affective domains in undergraduate science and learning. Talanquer also notes the expansion and base of DBER and STEM education reform (11). Talanquer further promotes collaboration, conceptual integration, diversity, development of expertise, and translation of research into practice.

Dennin et al focus on how to change the culture of higher education within departments to recognize and reward teaching at research universities (12). Many students change paths and degree foci as they progress through higher education, as seen in *Figure 1.4*.

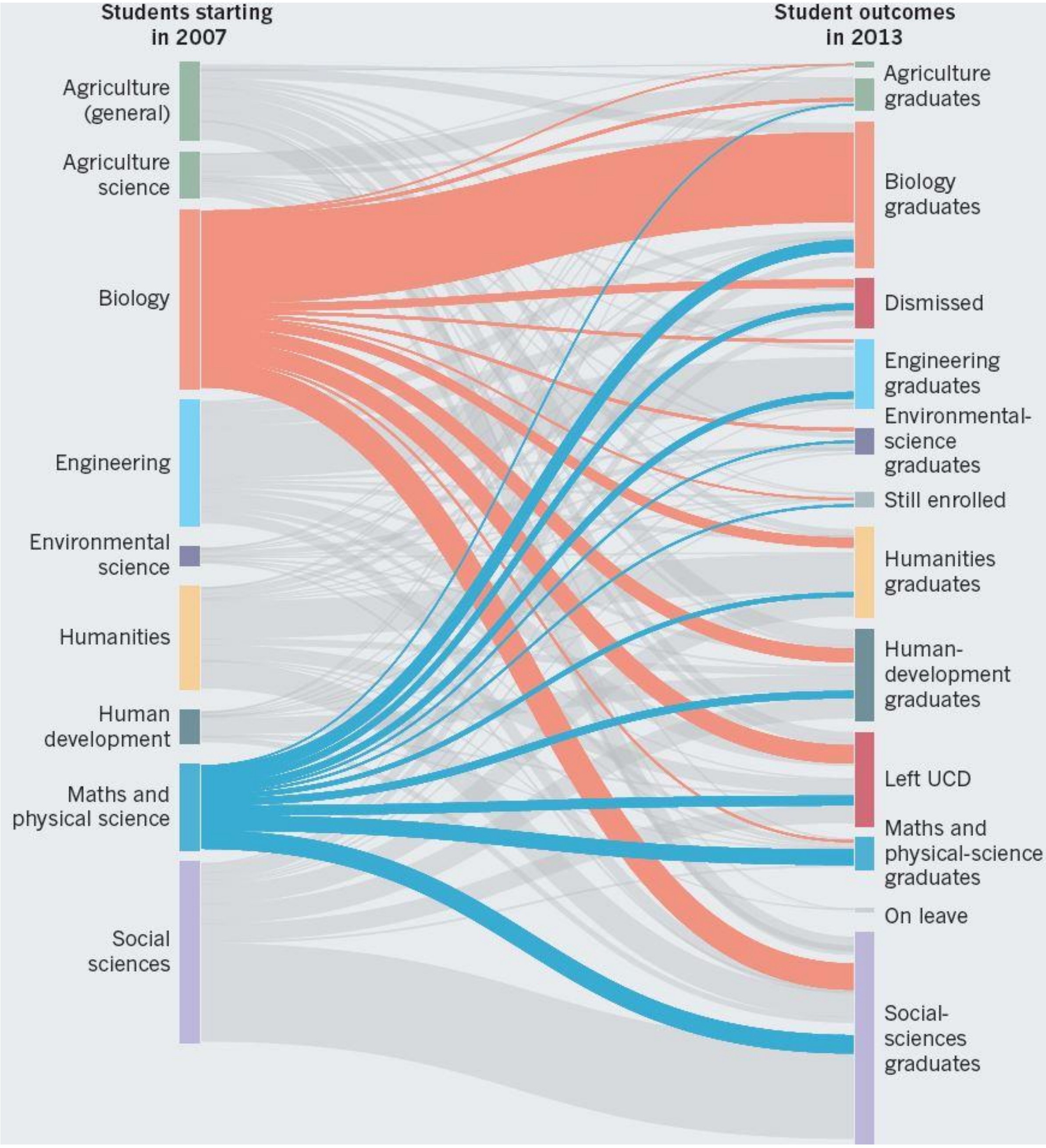


Figure 1.4 - Path of Students through Major Degree Types

Taken from Miller (13). Pathway of students through major degree types from 2007 to 2013 (or until graduation) at UC Davis.

Figure 1.5, *Figure 1.6*, and *Figure 1.7* for these three assessments are presented below. Kennedy and Odell also define attributes of STEM programs to engage all students, focus on engagement, and discuss assessments in progress (15).

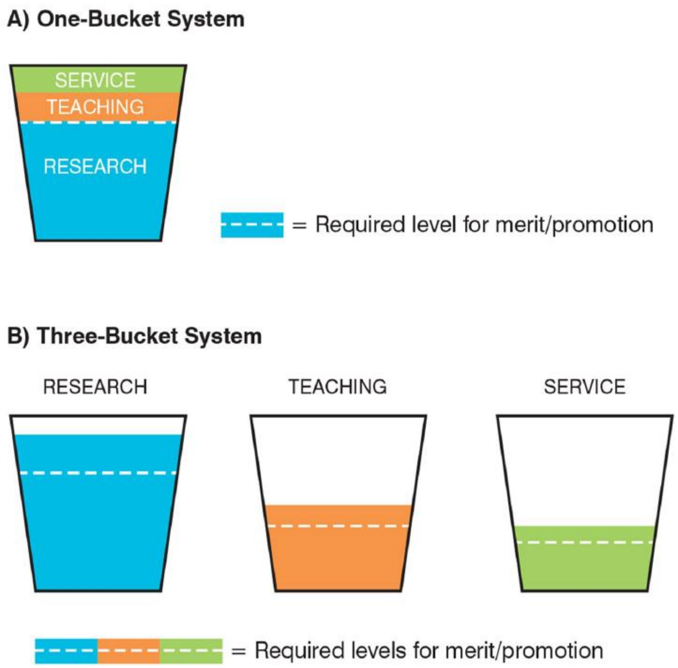


Figure 1.5 - Three Bucket System of Merit for Faculty

Taken from Dennin et al (12). In the one bucket system, faculty only need to reach a certain threshold to gain promotion or merit. As such, research could be the only component that a faculty member pursues to gain merit. With a three bucket system, the levels for merit or promotion encompass additions to the three aspects of faculty: research, teaching and service. As such, time, energy and resources from faculty need to be distributed accordingly.

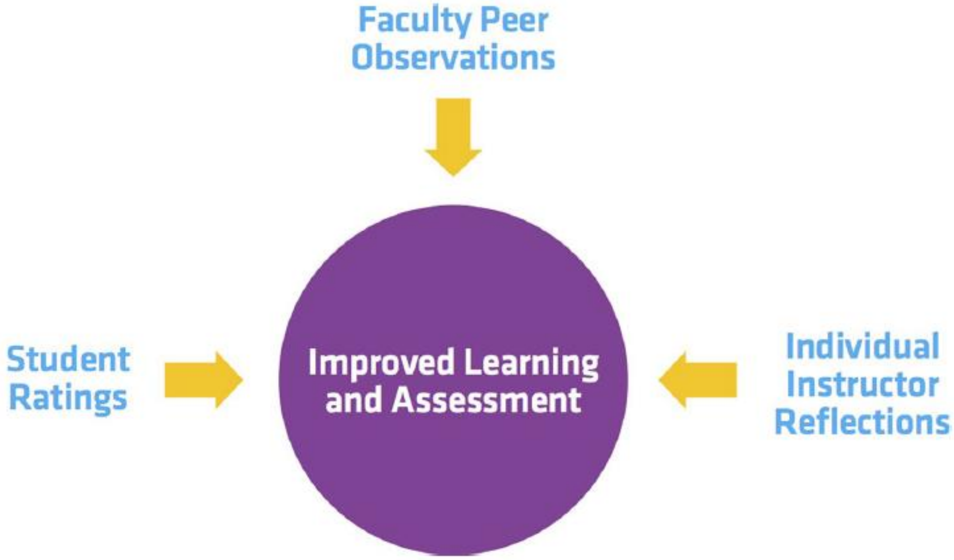


Figure 1.6 - Teaching Quality Framework

Taken from Dennin et al (12). The three different inputs for determining and assessing teaching.

	Below Expectations: 1-2	Meets Expectations: 3	Exceeds Expectations: 4-5
Expectation levels align with KU's promotion and tenure rating scale.	**(1) Poor: Consistently at this level** **(2) Marginal: Some teaching at this level**	**(3) Competent**	**(4) Professional: Some teaching at this level** **(5) Advanced: Consistently at this level**
Goals, content, and alignment • What are students expected to learn from the courses taught? • Are course goals appropriately challenging? • Is content aligned with the curriculum?	• Course goals are unclear, inappropriate, or marginally related to curriculum • Content and materials are outdated or unsuitable for students in the courses • Range of topics is too narrow or too broad • Content is not clearly aligned with curriculum or institutional expectations	• Course goals are articulated and appropriate for curriculum • Content is current and appropriate for topic, students, and curriculum • Course topics include an appropriate range • Standard, intellectually sound materials	• Course goals are well articulated, high quality, and clearly connected to program or curricular goals • Content is challenging and innovative or related to current issues and developments in field • Topics are of appropriate range and depth, with integration across topics • High quality materials, well-aligned with course goals
Teaching practices • How is in-class and out-of-class time used? • What assignments, assessments and learning activities are implemented to help students learn?	• Teaching practices are not sufficiently planned or organized, or are poorly implemented • Practices are not well executed; little development in methods despite evidence of need • Students lack opportunities to practice the skills embedded in course goals • Student engagement is variable	• Teaching practices are well planned and organized • Standard course practices carried out; follows conventions within discipline and institution • Students have some opportunities to practice skills embedded in course goals • Students consistently engaged	• Activities are well planned, integrated, and reflect commitment to providing meaningful assignments and assessments • Uses effective, high-impact or innovative methods to improve understanding • In- and out-of-class activities provide opportunities for practice and feedback on important skills and concepts • Students show high levels of engagement
Achievement of learning outcomes • What impact do these courses have on learners? • What evidence shows the level of student understanding?	• Insufficient attention to student learning–quality of student learning is not described or analyzed with clear standards • Evidence of poor student learning; low level of skill/understanding is required or achieved without clear attempts to improve	• Clear standards for evaluating the quality of student understanding • Typical student achievement for courses at these levels	• Standards for evaluating student understanding are connected to program or curriculum expectations, or use authentic assessments • Efforts to support learning in all students • Quality of learning supports success in other contexts (*e.g.*, subsequent courses or non-classroom venues), or is increasing over successive offerings
Classroom climate and student perceptions • What are the students' views of their learning experience? • How has student feedback informed the faculty member's teaching?	• Classroom climate does not promote civility or discourages student motivation and engagement • Consistently negative student reports of teacher accessibility, interaction skills • Poor sense of learning among students • Little attempt to address concerns voiced by students	• Classroom climate promotes civility • No consistently negative student ratings of teacher accessibility, interaction skills • Most students indicate progress with their learning • Instructor articulates some lessons learned through student feedback	• Evidence that classroom climate is respectful, cooperative, and encourages motivation and engagement • Student feedback on teacher accessibility, interaction skills is generally positive • Students perceive that they are learning important skills or knowledge • Instructor is responsive to student feedback in short- and long-term
Reflection and iterative growth • How has the faculty member's teaching changed over time? • How has this been informed by evidence of student learning?	• No indication of having reflected upon or learned from prior teaching or feedback	• Continued competent teaching, possibly with minor reflection based on input from peers and/or students • Articulates some lessons learned from prior teaching and feedback	• Regularly makes adjustments to teaching based on reflections on student learning, within or across semesters • Examines student performance following adjustments • Reports improved student achievement of learning goals based on past course modifications
Mentoring and advising • How effectively has the faculty member worked individually with UG or graduate students?	• No indication of effective mentoring or advising students (but expected in department)	• Some evidence of effective advising and mentoring (*define as appropriate for discipline*)	• Evidence of exceptional quality and time commitment to advising and mentoring (*define as appropriate for discipline*)
Involvement in teaching service, scholarship, or community • In what ways has the instructor contributed to the broader teaching community, both on and off campus?	• No interaction with broader community about teaching, including involvement with teaching-related committees • No evidence of keeping up with reports on effective teaching • Practices and results of teaching are not shared with others • Actions have negative impact on teaching culture in department or institution	• Some involvement in teaching-related committees, or engagement with peers on teaching (*e.g.*, teaching-related presentations or workshops) • Participates in department-level curriculum decisions	• Regular involvement in teaching-related committees, engagement with peers on teaching (*e.g.*, teaching-related presentations or workshops) • Occasional (or more) local or external presentations or publications to share practices or results of teaching • Contributes to department or university curricular planning or assessment • Advanced–Scholarly publications or grant applications related to teaching

Figure 1.7 - Rubric for Department Evaluation of Faculty Teaching

Adopted from Dennin et al (12). The rubric can be used to determine if teaching and instruction are up to par in the world of higher education.

1.2 Modern Theory on Learning in General

With the call from national organizations to improve higher education as just discussed, we must next look at the current modern theories on learning, in general. By understanding how learning works, we can mold instruction around learning theories to best allow for student growth in the classroom. Various theories exist on how humans learn, and how they learn best, but the main overarching theme is that learning requires energy and dedicated practice to effectively produce long-term results. On an individual basis, learners tend to have differences on how they prefer to study for retention of material, but the theme is the same: an appropriate amount of targeted effort consistently applied to the use and examination of content is the best way to learn topics.

In the literature, we see individualized learning supported in various ways. How People Learn II: Learners, Context and Cultures (HPLII) describes three main ways in which individuals can compose their own learning through: metacognition, executive function and self-regulation (16). Metacognition has been studied extensively and is defined by McGuire et al as "thinking about one's own thinking" and "monitoring and controlling one's mental processing" (17). As a result of this self-monitoring, the cognitive processes can then regulate cognitive and affective behavior. Arising from psychologists and neuroscientists, executive function is described by Nyroos et al. as "a generic ability to deliberately organize and act on information in order to attain planned goals" (18). This higher-order processing further allows individuals to plan, sequence, initiate and sustain different behaviors towards an objective, allowing room for feedback to make adjustments. HPLII defines self-regulation as "learning that is focused by means of metacognition, strategic action, and motivation to learn. Self-regulation is seen as involving management of cognitive, affective, motivational, and behavioral components that allow the individual to adjust actions and goals to achieve desired results" (16).

Ericsson describes that skill-based activities require long hours of practice; doing the activity involving the skill is what bring about gains in learning. Even though different training regimes may accelerate the skill induction, shortcuts will not lead to long-term acquisition (19). As an example, Benjamin and Tullis showed that repeated opportunities to retrieve facts spread out over time, location, and learning contexts – also known as retrieval practice – allows for an increase in information stored in long-term memory (20). Chapter 2 of this dissertation will expand upon teaching practices and theories used in the classroom. Additionally, having students learn various learning theories or strategies and applying them to different settings will allow for a more holistic education. *Table 1.6* gives examples of different settings in which students may find themselves. By applying the theories behind metacognition, executive function, and self-regulation, students interact with the world and learn in a more efficient and productive manners.

Table 1.6 - Examples of Autonomous and Mandated Learning in Formal and Informal Settings

Learning Context	Example
Self-directed (autonomous) development in an informal environment.	• Keeping up to date with news and events by reading news articles • Going to a local science museum
Self-directed (autonomous) development in a formal environment.	• Taking online courses, such as Code Academy to learn about different computer languages • Taking a certification course, such as a Wilderness First Responder course
Required (mandated) development in an informal environment.	• Receiving mentoring from older students or professors in the academic environment • Reviewing internship requirements for a desired company.
Required (mandated) development in a formal environment.	• Taking courses or review work for the professional engineering license. • Taking CITI training prior to submitting an Internal Review Board application

Adopted from How People Learn II (16).

1.3 Social Learning Theory

To further build on this dissertation's discussed theory of learning in the modern classroom, we will build upon the concept of social learning. As classrooms have moved to more of a collaborative environment, educational researchers have embraced sociocultural theory; in particular, the notion that all learning is a social process shaped by and infused with interactions within a cultural context (21–23). A main takeaway from the literature is that everyone (from all age categories) brings the unique experiences they have in life to their learning opportunities. The uniqueness of experiences creates an extremely complex and diverse set of influences students have in the classroom, as demonstrated by Bronfenbrenner and Boss et al (24–26). Classrooms tend to have different levels of influences on the individual which can be imaged as concentric rings, starting with the individual, moving to the family, then outward to the school, peer groups, workplaces, and to broader social and institutional settings, with different ideologies, laws, customs, and value systems. An individual gains experiences over time, and all these can influence the current state of the individual based on contextual settings, as seen in *Figure 1.8*.

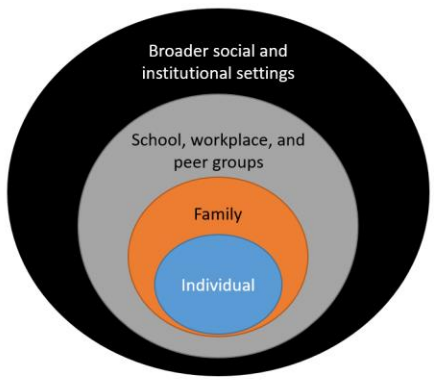


Figure 1.8 - Hierarchy of Social Learning to the Individual

Adopted from Bronfenbrenner (25).

From the perspective of the instructor, as students proceed through their undergraduate education, the students also learn by modeling an instructor's behavior, attitudes, and/or emotional expressions. Students may or may not express the behavior or skill, but they do absorb the practices that instructors exhibit. This is known as "no-trial learning" as coined by Bandura (27). Bandura states: "Thus, in this mode of response acquisition, imaginal and verbal representations of modeling stimuli constitute the enduring learning products of observational experiences," meaning that by simply observing others, be it through mental representation or from listening, we can model and learn different skills (27). In the classroom, this means that instructors should practice what they preach and be strong role models for students. Additionally, as teachers and parents often claim that students seem to pay more attention to their peer groups than authoritative voices (28), the instructor needs to set norms of behaviors for students to follow (29). This can allow for high-quality peer learning, using the students as resources for each other, rather than just the instructor as the guide (30). Take problem solving as a skill in the classroom as an example. The skill is facilitated when both the classroom environment, the mindsets guided by the instructor, and the students are all on the same page. With a salient mindset, and the flexibility of cultural mindsets as seen by peers being strong influencers, the cognitive functioning and adaptability of students can build off of each other, creating a well-defined skillset to problem solve as a group (31).

In essence, we are social creatures. The cultural setting we are in shapes all aspects of our learning, from the wiring of the brain (see this chapter's Neuroscience section) to the way that the scholarly settings organize learning opportunities. There are various types of learning as seen in the learning theories sections, and all are supported by a community of learners which engage with content in a collaborative setting. In particular, the social settings allow for developing expert knowledge through viewing the different perspectives that all students bring to the classroom. Sophisticated learning tasks and introducing novel problems for students to solve allows for the individual students' beliefs, values, interests, and identities to play a central role in learning. As learners are immersed in these contexts, we can see a growth not only cognitively, but perceptually as well (16).

1.4 Mindset Shifts for the Modern Classroom

As the theories and practices are being published concerning the modern state of learning, instructors should begin to shift their focus in the classroom. To be responsive to the new theories, the classroom will need to shift away from being teacher-centered arena into student centered environments (32). Instructors will need to consider the theory behind retention of material. Various memory-relevant instruction techniques are shown in *Table 1.7* (33). The atmosphere of the classroom will need to change. For instance, Ames and Archer suggest that a shift will need to be made to move students to a balanced amount of both a performance mindset and a mastery mindset (34) and this is exemplified in *Table 1.8*.

Table 1.7 - Memory-Relevant Instructional Techniques

	Definition	**Example**
Instructional Techniques		
Strategy Suggestions	Recommending a student adopt a method or procedure for remembering or processing information	"Look at the process flow diagram if you are having trouble remembering how the pipes are connected."
Metacognitive Questions	Requesting that a student provide a potential strategy, a utilized strategy, or a rationale for a strategy they have indicated using	"How did you know which equations to use for solving the mass and energy balances? Where is your control volume?"
Instructional Techniques Co-occurring with Deliberate Memory Demands		
Instructional Activities	Requesting information from member and the presentation of instruction information by the teacher	"Today we are going to solve a distillation process. What is the first step to solving any engineering problem?"
Cognitive Structuring Activities	Requesting information from memory and teaching instruction that could impact the encoding an retrieval of information, such as focusing attention or organizing material	"Mass flowing through a system is modeled the same way as what other systems? Where else do we find double integrals to solve an engineering system?"
Metacognition	Requesting information from memory and the provision of solicitation of metacognitive information	"Is this an open or closed system? What strategies did you use to figure that out?"

Adopted from Grammer et al (33).

Table 1.8 - Achievement Goals and the Classroom

Climate Dimension	**Mastery Goal**	**Performance Goal**
Success Defined as…	Improvement, progress	High grades, high normative performance
Value Placed on…	Effort/learning	Normatively high ability
Reasons for Satisfaction…	Working hard, challenge	Doing better than others
Teacher Oriented toward…	How students are learning	How students are performing
View of Errors/Mistakes…	Part of learning	Anxiety eliciting
Focus of Attention…	Process of learning	Own performance relative to others
Reasons for Effort…	Learning something new	High grades, performing better than others
Evaluation Criteria…	Absolute, progress	Normative

Adopted from Ames and Archer (34).

Moreover, instructors need to modify the perception of difficulty that students may have of content material. Instructors and experts have been working with the content typically for years, being knowledgeable individuals in the field. As such, various simple topics that may not be otherwise thought of a difficult may be extremely difficult for students to comprehend on their first pass. The instructor may not realize that novices do not have the same perception and mastery of the material that experience bestows. Faculty shifting their perception will allow for more appropriate cognitive loads on students, and a better learning environment in general (16). With a growth mindset adopted by the faculty and shared with students, we can see conceptual change, a rather difficult and elusive task instructors face in the classroom. Conceptual change entails the learner to have a sense of dissatisfaction towards a new concept, but combined with the need to understand they can change how they approach the content. In addition to the unease a student may feel with content, an available replacement conception that was intelligible or plausible is necessary to allow for the accommodation of the new conception into what the student knows and can use. However, the additional conception has to be non-contradictory and understood by the student, believable, and allow for solving of problems. With a supportive classroom and a comfortable area to allow for drastic conceptualization changes, the alteration to conception can be permanent, temporary or tenuous to detect (35). With a mastery mindset, students can continue to push their conceptual understanding of the world, and push themselves appropriately to become distinguished scholars.

One method towards building an inclusive, student-centered classroom is transitioning from a transmission environment in the classroom (the instructor largely transferring content to students) to an inferential learning environment. This is a setting in which students construct knowledge and understanding by working with material rather than being told what they should know. The application of content builds on the modern theory in learning by allowing students to practice self-regulation, metacognition and executive function as they work their way through problems or tasks. However, inferential learning is most effective when the learner receives guidance on the thinking needed to address concepts. The instructional guidance helps prevent strong negative affective factors of high levels of frustration and helplessness, which hinders learning (36, 37). Allowing students to work freely without any assistance does not improve learning outcomes as students' emotional states are not conducive to learning (38). Nevertheless, the process of working with material, making mistakes (and successes), and having proper cognitive and emotional guidance is what allows learners to grasp content. Immordino-Yang states "It is in the detours and missteps as well as in rediscovering the path that students experience rich emotionality, accumulate valuable emotional memories, and develop a powerful, versatile emotional rudder. In a time of heavily used standardized testing and curricula packed to the brim, this idea might sound unorthodox. But from an affective neuroscientific perspective, the direct and seemingly most efficient path turns out to be inefficient, leading too often to abundant factual knowledge that is poorly integrated (and therefore ineffective) in students' real lives." (39).

Another strategy of a student-centered education involves having a problem-based learning atmosphere. This form of learning instills flexible knowledge use, builds on problem solving skills, self-directed learning, collaboration, and intrinsic motivation (40). Classrooms using those techniques should be deployed more as the upcoming generations of students enters into higher education with a new set of needs that include the necessity of technology and collaboration in the future job market. For instance, the rise of Smartphones (see Technology section later in this chapter) and the addition to the devices has created a much higher likelihood of distraction in the classroom (41). Having more engaging classes that can align students to future careers and their perception of employability (42) creates a cyclic effect that builds on their educational experiences. Incorporating skills and practices into the traditional engineering education from the vocational, hands-on training can help students have a better working knowledge of systems as well (43). Immordino-Yang suggests that simply having knowledge does not guarantee success outside of higher education. She suggests pushing students more in the rational domain, encouraging students to develop knowledge that will transfer into the real-world, not simply developing the ability to solve a textbook problem (44). This can be achieved through problem-based learning, if applied correctly. The components of a process to do this for engineering design courses is shown in *Figure 1.9*, taken from the National Research Council (45).

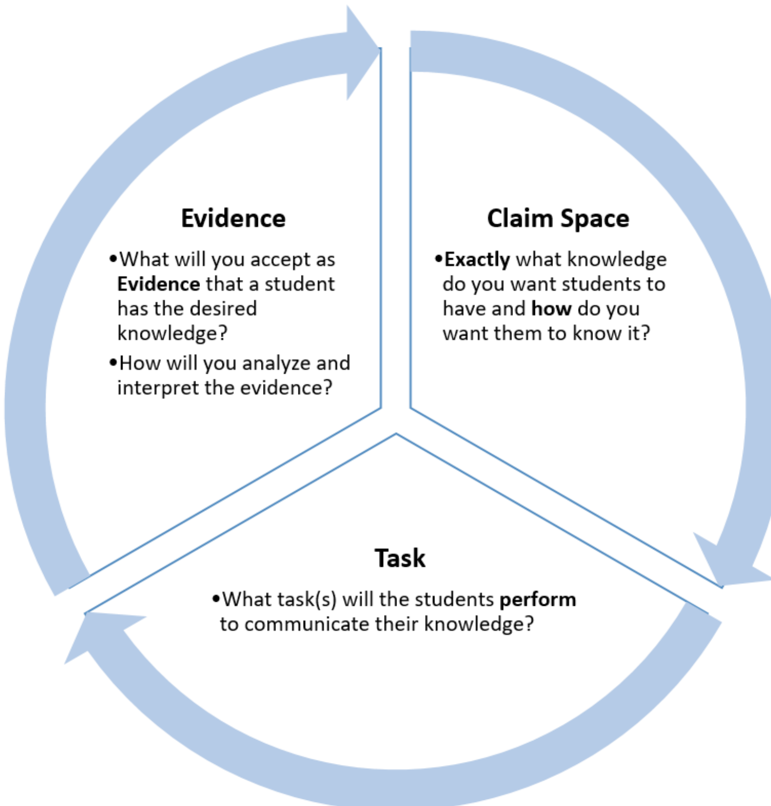


Figure 1.9 - The Components of Design for Higher Education Courses

Adopted from National Research Council (45).

1.5 Cognitive Neuroscience

1.5.1 Introduction

Cognitive neuroscience blends the two disciplines of cognitive psychology and neuroscience. Cognitive psychology elaborates on how students tend to have deeply rooted conceptions and ideas that are not congruent with science views, or are in contrast to those views, sometimes known as misconceptions. Neuroscience deals with the structure and function of brain. Ideally, just as computers have hardware as physical entities that allow for the running of software, the brain has networks of connections that allow for thought to occur. By joining findings in neuroscience and cognitive psychology, we can build on two different domains to improve student education in conjunction with science education (35).

With various improvements in teaching practices, such as utilizing active learning in collaborative learning spaces, quality of instruction in higher education is seeing a rise in proficiency (46). With the advent of modern teaching practices, there are proposed relations with education and cognitive neuroscience and scientific backing for why the various practices work (47). In particular, recent research in imagination and mind wandering support the use of various types of teaching styles to facilitate learning and allow for students to receive a holistic education. However, the link between education and cognitive neuroscience has not always been strong , in particular when misconceptions or miscommunications between the research fields arise (48–50). However, with more research being produced and active members of the scientific community working to dispel the misconceptions, the link between education and neuroscience is becoming stronger.

1.5.2 Background

The brain is by far the most complex organ in the human body, containing around 15-33 billion neurons and 49-65 billion glial cells with varying amounts of connectivity between each cell (51). These connections are considered transient and plastic – the more they are stimulated, the more the neurons will adapt, creating more or stronger connections with neighboring neurons and increasing efficiency of signal transduction (52, 53). Previously, sequestered areas of the brain were thought to provide the functions of the brain; however, recent findings are showing that networks of brain cells across the cranial space are what comprise different functions from the brain. As such, various regions of the brain can be activated to provide different major functions. See *Figure 1.10 - The Various Major Networks in the Brain, Two Different Views* from (54, 55) to see large-scale resting-state networks and their between-network relationships.

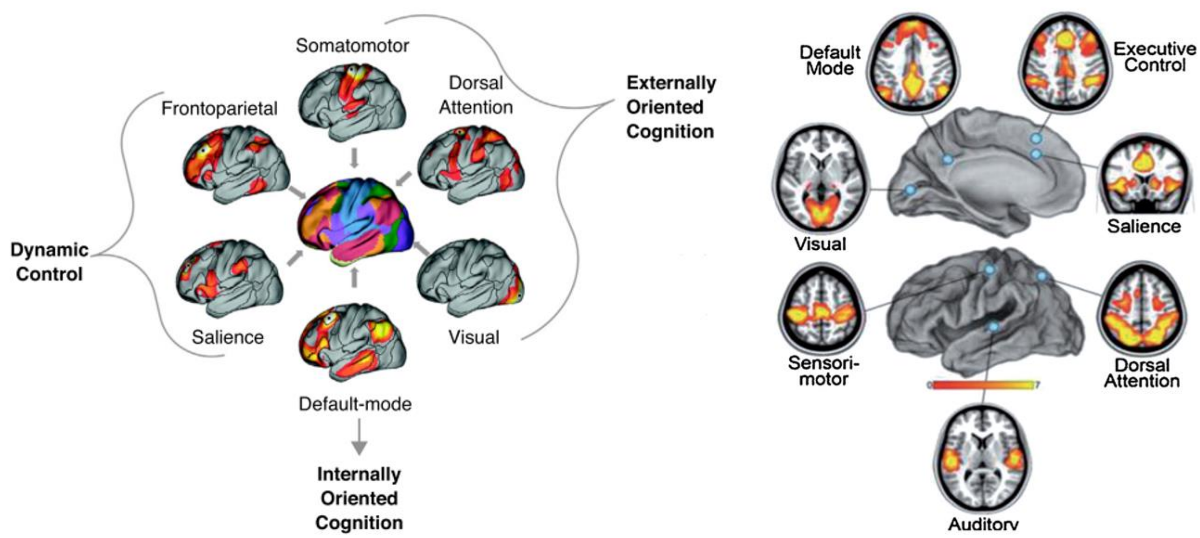


Figure 1.10 - The Various Major Networks in the Brain, Two Different Views

Taken from Whitfield-Gabrieli & Ford and Zabelina & Andrews-Hanna (54, 55).

For the purpose of this section, the focus will be on the default mode network (DMN) and the frontoparietal network, also termed the executive control network (ECN). The advancement of analytical techniques, in particular functional magnetic resonance imaging (fMRI), have allowed for much greater insight into cell activation within the brain. Describing the theory behind fMRI is beyond the scope of this chapter, but introductory information can be found in (56).Various databases now exist which provide various images and interactive models of scans of human brains from fMRI. For an interactive 3D model of the brain using meta-analyses from hundreds of papers, the default mode network can be found here (57), along with a plethora of other networks and keywords, at neuosynth.org. These various areas of the brain are linked via white matter that can be imaged by diffusion tensor imaging (DTI). A review of DTI and further images can be found at (58) and (59). *Figure 1.11* is an image taken from DTI (60).

The conceptual space relating different types of thought also plays a role in education and the link with cognitive neuroscience. With considerations for both deliberate and automatic constraints on the conceptual spaces, the brain can perform various functions, as seen in *Figure 1.12* taken from (61). With these different spaces, various parts of the brain activate for different tasks. Traditional views believed the executive control network and default mode network were negatively correlated. This antagonist function essentially means that as the ECN begins a task or focuses on external demands, the default (or resting state) network would lower activity to allow for the executive functioning to have optimal thought resources allocated to it. However, an analysis by Beaty et al illustrated various clusters activating during poetry generation and revision (62).

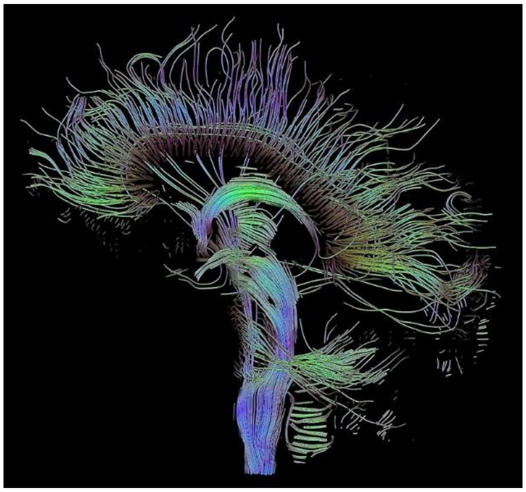


Figure 1.11 - Tractographic reconstruction of neural connections via DTI
Taken from University of Utah (60).

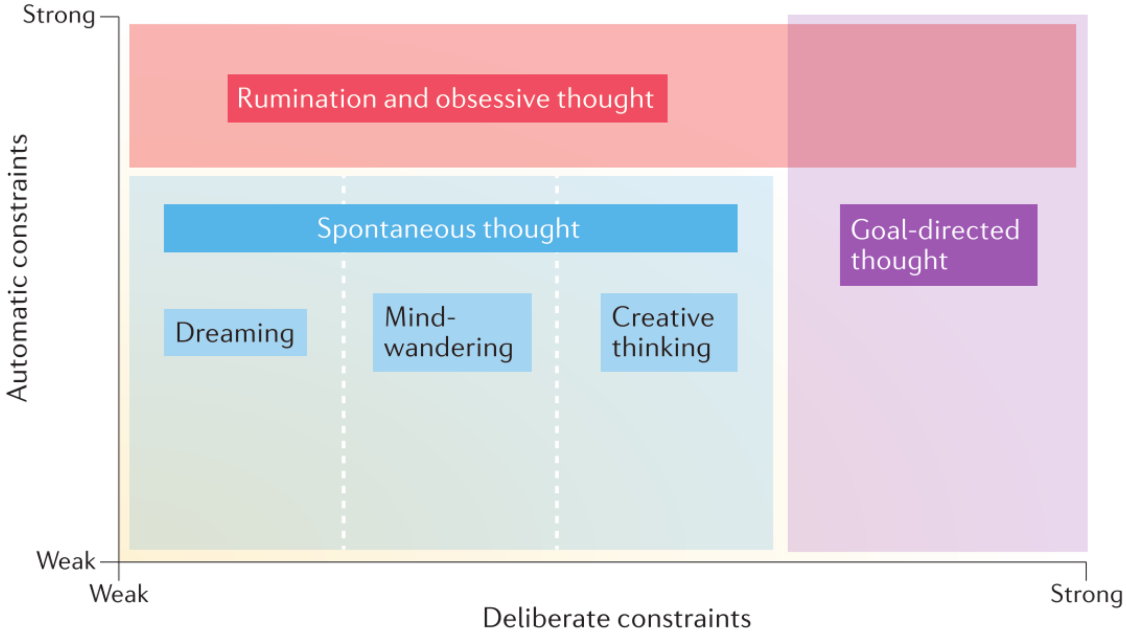


Figure 1.12 - Different Types of Thought in Relation to Conceptual Space
Taken from Christoff et al (61).

By understanding the basic functions of the brain and how the networks interact with each other, cognitive neuroscience and education can work together to provide a better educational experience for students in higher education. For instance, if students are only task centric, they will likely have difficulties working with highly imaginative or creative mindscapes. This leads from the belief that the networks that are not used as much do not develop as effectively as the frequently used networks. By allowing for usage of all of the brain's networks, students can see universal improvement in cognitive function. However, for best practices, the different areas should not be tasked simultaneously. A direct correlation exists between intelligence and DMN connectivity and the ability to switch the networks on and off; for most task centric goals, a healthy individual with greater connectivity only taps into his or her overall intelligence with the ability to moderate network activation (54, 63).

1.5.3 A Wandering Mind – but at What Cost?

Mind wandering (MW) refers to a shift of attention away from an ongoing task and/or from events in the external environment, towards the processing of self-generated thoughts about a different time and place, which often occurs without meta-awareness (64). A recent study found that the ratio of deliberate to spontaneous MW was positively correlated to motivation to perform the task, indicating that subjects may be especially prone to intentionally MW when they are not engaged by the task (65). In terms of educational practice, this would require an educator to design meaningful tasks for students. An early idea regarding MW is that it occurs because individuals have goals and concerns that extend beyond the present moment (66).

For most educators or professionals in the education environment, mind wandering is seen negatively. In the traditional view, MW takes away from the ability to focus on a task and continue diligently towards a long term goal (67). In the online environment, researchers found that interpolated memory tests reduced mind-wandering and improved learning of lecture content (68). However, the stipulation that using the DMN to mind wander negatively effect's person's cognition is short-sighted. Individuals with stronger DM connectivity when the brain is at rest score higher on measures of cognitive abilities like divergent thinking, reading comprehension and memory (69). These individuals are not using the DMN to improve the executive function on tasks; they simply have greater connectivity outside of the task.

By allowing space for the DMN to function outside of a task oriented session, the DMN can grow and improve (65). As most cognitive operations do have a dualistic nature for activating the two main networks, it could behoove students to be able to reduce mind wandering during specific tasks or assignments involving intense amounts of focus. In particular, extensive and time constrained standardized testing does not favor students who mind wander while taking the tests. To help with this, mindfulness and other metacognitive approaches have been used to build the working memory capacity (WMC). Counter to the long-standing assumption that mental aptitude is largely fixed across the life span (also known as having a fixed mindset (70)), recent work has indicated that extensive practice on tests of WMC can generalize to improvements in IQ and that IQ can either improve or deteriorate throughout adolescence (67). Other studies have shown that a wandering mind is an unhappy mind (71).

If educators understand the notion of having different networks and that developing those networks is important for long-term cognitive growth, time can be allotted to allow for DMN activation and ECN activation. Students can also gain the skill of utilizing the different networks optimally. By understanding that creativity functions best without high cognitive demands, an appropriate environment can be established to allow for optimum creativity (72, 73).

1.5.4 Misconceptions between Education and Neuroscience and the Need for DMN Activation

With the logical link between education and cognitive neuroscience, one can see why well-intended individuals in education seek to link research in cognitive neuroscience and integrate findings into teaching practices. However, misinterpretations of findings brought into educational practice – deemed "neuromyths" – are relevant in modern discourse. Such faulty interventions originate from misinterpretations of genuine scientific facts and are promoted by wishful thinking of individuals who hold a "sincere but deluded fixation on some eccentric theory that the holder is absolutely sure will revolutionize science and society" (74). Some thought-leaders have suggested that the longstanding prevalence of neuromyths in the classroom indicates the need for caution when including neuroscience in educational thinking. What is needed is a bridge between the cultural difference between the disciplines to help mitigate any already standing neuromyths and preventing any more from happening in the future. A brief list of a few of these neuromyths are:

1. Not drinking 6-8 glasses of water causes the brain the shrink
2. Students learn most effectively when they are taught in their preferred learning style
3. Individuals tend to be "right" or "left" brained
4. Having multiple intelligences, or a singular learning style

5. Oversimplification of the relationship between genetics and intelligence provides a perfect opportunity for introducing biases from which misunderstandings then develop
6. From 0 to 3 years of age is a critical period during which the great majority of brain development occurs and after which the trajectory of human development is chiefly fixed
7. Heckman Economics, suggesting that the earlier the investment in a student's education, the greater the return
8. The dualistic non-plastic mind–brain model in which the brain cannot be influenced by the mind
9. Insight into the relationship between reward (e.g. dopamine) and declarative memory formation
10. Involving teenagers and their decision making process: "because the frontal lobes are involved in controlling impulses and making good decisions, adolescents often fail to fully consider the consequences of their actions until it's too late. They are all gas and no brakes!"

An in depth analysis of these issues can be found here (74).

Most educational efforts center on delivering a specific amount of content to student, often times in too short of a time frame. As a result, most educational settings are filled with continuous task or lecture-centered objectives. However, in the long-term, this may hinder the development of creativity for students. Many educators fail to realize that rest is not idleness and that there are many benefits to down time – for social and emotional functioning and for academic achievement both in and out of class (69). Immordino-Yang et al also report "[periods of down time help] with active, internally focused psychosocial mental processing, such as tasks involving self-awareness and reflection, recalling personal memories, imagining the future, feeling emotions about the psychological impact of social situations on other people and constructing moral judgments." As seen with the introduction, the whole brain is not involved with attention to tasks and the external environment, but instead just a few networks are engaged at a given time.

As a component of the brain's networks, the DMN seems to be recruited for processing that pertains less to factual knowledge state and more to simulation and evaluation of abstract social, emotional and moral implications. There are also various anecdotes of people having enhanced problem solving after mind wandering episodes are prevalent (75). Mind wandering could be linked to enhanced creativity, especially if a particular task or problem has been encountered before. In the classroom, this could relate to a "grand challenge" or overarching goal the class is attempting to solve. *Figure 1.13* illustrates the phenomenon of increased creativity for tasks if mind wandering is allowed (75).

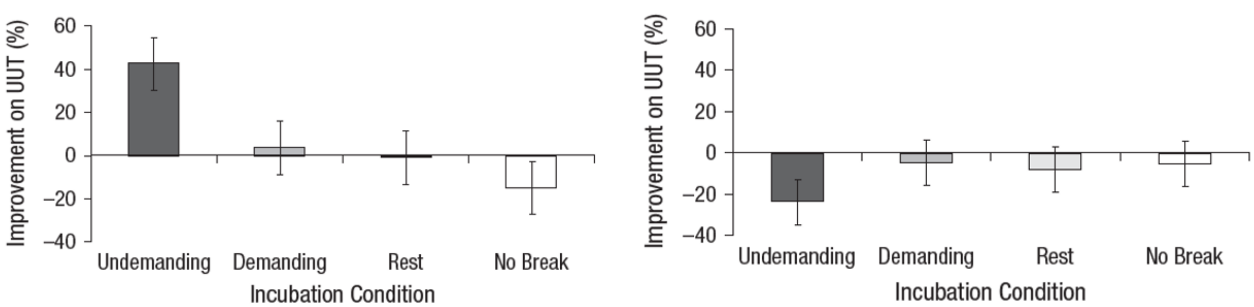


Figure 1.13 - Improvement in Unusual Uses Task (UUT) uniqueness scores for repeated exposure problems (left) and new exposure problems (right) as a function of incubation condition. Adopted from Baird et al (75). The UUT followed the incubation condition.

The study by Baird et al also raises another relevant finding: different levels of performance arise depending on how demanding (or lack thereof) a task is to help promote learning, in particular, creativity. With a previously encountered subject, an undemanding task (such as folding laundry or doing dishes) allows for the "sweet spot" of mental stimulation and incubation of ideas to allow for creativity to thrive. However, for a new topic, such an undemanding task is detrimental. Functionally, in a classroom setting, using the balance between cognitive load and rest could be integrated with simple time management. As mentioned previously, taking a constructivist approach deems that students build from prior knowledge as they work to actively accumulate new information to make sense of the current learning situation. With the cognitive load being largely demanding, in order to assimilate the knowledge, a need for pauses or breaks after exercises for students to digest information is created. Structurally speaking, the break allows for a better network of connections to form in students brains. By allowing for brief spaces of time for the integration of material, students could see an improvement in retention of material (67).

In terms of applicability to students, as the job market continues to evolve as an ever changing entity, having the ability to creatively solve new tasks is paramount to giving students an adequate education. Content knowledge is important; however, using higher level thinking (as seen in Bloom's Taxonomy (76)), will benefit students significantly more than rote memorization of facts. As a result, a narrowing – but deepening of understanding – needs to arise from specific lesson, as seen by the depth versus breadth argument with content coverage (77). In other words, rather than cover 100 topics superficially, academia needs to focus on fewer topics critically. This not only allows for greater retention of the learned content, but skills developed during this time can be transferable to new topics, further allowing students to be empowered to self-educate (78, 79).

Outside of task performance, students also gain critical thinking and socially relevant skills outside of the purely academic environment. The DMN is associated with building emotional awareness, in particular, empathy. Gotlieb et al state that students, after performing reflective writing tasks: "Furthermore, the ability to construct a detailed simulation of social events may actually increase empathy and pro-sociality. Conversely, possessing low levels of empathy is associated with being a school bully perpetrator and bullying victim, and being bullied is associated with less academic achievement" (63). Although physical or palpable bullying is not as evident in high educational settings, microaggressions can still arise that can go unnoticed by the academic community (80–83).

By giving students to time and space to allow for DMN activation, instead of constantly performing tasks or requiring students to passively listen to a lecture, many benefits for students can arise. With even brief pauses or breaks, such as allowing students to contemplate a question before requesting a response, the brain is allowed to function across multiple networks. Having students reflect on material and giving students times of open thought may not be the solution to all of education's problems, but allowing for a sequential multiple network activation, students may improve their focus, attention, and level of motivation (84).

Teachers may feel pressured to help their students learn a large amount of information as quickly as possible, and at least initially, students may be slow to attain mastery of any given content. However, neuroscience suggests that in the long run, learning may be more effective if teachers judiciously build opportunities into the curricula for students to develop skilled intuition, or the ability to transfer a "feeling" about a topic into a cognitive argument. Without the development of sound intuition, students likely will not remember the material over the long term. And even if they do remember specific content in an abstract sense, they will have difficulty applying the content to novel situation. (39)

1.6 Ending Statement

Throughout this chapter, we have seen the need for improvement in the quality of instruction in higher education. From most faculty's perspective in higher education, motivation for students (and faculty) is an intrinsic factor. Just as an instructor's teaching needs to vary depending on the level at which they are educating students, the level of assumed motivation needs to be pedagogically applied to the learners. Most students are not motivated by an instructor's performance, but instead what they desire to be as a profession. There likely is a subset of high performing students who are deeply intrinsically motivated. These students would succeed no matter who was standing at the front of the room and which activities they were asked to complete. However, this singular groups of students is not the whole picture. Many of our students have areas of other concerns besides their intellectual growth and obtaining the best grades possible. Mental health issues, to caring for their families at home, to navigating their social worlds are just the tip of the iceberg of challenges that students face on a daily basis. Students may be paying tuition dollars to earn a job-focused degree and then carry on with the rest of their lives and have not a care in the world for the broader scholar we are trying to turn them into. The debate can continue as whether or not this is the students' prerogative. However, as we will see in chapter 2, if instructors implement some scalable and effective strategies described and consider the affective factors of implementing these strategies in chapter 3, even reluctant students may find themselves more engaged than they ever expected they could be (85).

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Chapter 2: Scalable and Practical Interventions Faculty Can Deploy to Increase Retention: A Faculty Cookbook for Increasing Student Success

Two joint manuscripts submitted for publication are the focal points of this chapter. The two-part paper series are found in Appendix A and Appendix B. They were submitted to the International Journal of STEM Education on May 30th, 2019.

2.1 Introduction

As seen in Chapter 1, there is a loud cry for improvement in undergraduate education from many sources. Part of this attention to a need for change involves the skills and strategies instructors use in the classroom. Current literature contains many deployable interventions, and some contain verification on why the focus on teaching practices work (1–10), but few contain an in-depth or wide-spread guide on how to best improve teaching practices on an easy to implement scale. The two part paper titled "Scalable and Practical Interventions Faculty Can Deploy to Increase Retention: A Faculty Cookbook for Increasing Student Success" (found in Appendix A and B as "Part 1" and "Part 2") submitted to the International Journal for STEM Education, includes teaching practices that span four major domains of non-cognitive interactions in the classroom, whereas most papers will cross two domains at most (11–14). The four affective domains used to guide the formulation of that paper are: growth mindset, self-efficacy, metacognition and belongingness.

The intention of this two-part paper series is to provide faculty members with a set of easy to deploy, scalable, low cost interventions that were found to be successful by student-centered instructors in the Chemical and Environmental Engineering Department and Mechanical Engineering Department at the University of Arizona. The paper provides support for each teaching practice in Part 1, along with personal support and implementation strategies for the teaching practices in Part 2. The rest of this chapter delves further into the various topics that support the need for the paper and also explores greater depths of the theoretical background to make the case for the various teaching strategies.

2.2 Emotions

As mentioned in part one, humans are social creatures. Within the perspective of the social domain, we must look at the individual and the individual's response to different stimuli which can be experienced in higher education. In the past, scholars generally assumed that emotion interferes with critical thinking and that knowledge and emotion are separate (15). Following this trend, engineering education researchers have tended to think of only the cognitive demands in the classroom, rarely thinking about the non-cognitive aspects. Goldberg and Somerville did not make the realization that all relevant change variables are emotions until they embarked on a journey to write *A Whole New Engineer* (16). In fact, they have a revolutionary chapter in their book titled: "The Emotional Breakthrough." Goldberg and Somerville said

> "We came to recognize that our initial thinking about the keys to education reform [seen by Olin College and iFoundry] was wrong. The key variables weren't pedagogical. They weren't financial. They weren't curricular. They weren't research. They weren't any of the usual things we've always talked about as the engines of change. The variables were deeply emotional and cultural" (17).

The authors recognized that the buzz words around educational change – such as content knowledge, learning outcomes, active learning, etc. – were insufficient to describe reform. Instead, efforts for reform were found in the emotional side of change; words such as "trust," "joy," "connection," and "openness." They created a formula for the "authentic transformation" that led to real and lasting change if the prescribed instructors adopted the formula (16):

$$\text{Unleashing} = \text{Trust} \rightarrow \text{Courage} \rightarrow \text{Initiative} \rightarrow \text{Failure} \rightarrow \text{Authentic Learning}$$

Note that the basis of this equation will be the foundation for all conceptual change in this chapter. In order for authentic learning to happen, we must first build trust with the practice or with the instructor. Courage is needed to move out of a comfort zone and extend beyond personal limitations in skill or knowledge. As we will find with implementing a growth mindset, failure is integral to the learning process. Mistakes allow for a strong pathway to learning (17). For the rest of this chapter, we will refer to the non-cognitive aspects as affective factors, which are also commonly represented as the emotional side of learning. As we will see in Chapter 3, this is much more complicated than we are implying for simplicity's sake here.

How People Learn II, a report from National Academies Press, describes emotions as developing the "neural substrate for learning by helping people attend to, evaluate and react to stimuli, situations and happenings" (18). Damasio and Immordino-Yang both claim that emotions are a critical and universal component of thought, and function as an emotional rudder which steers behavior, thought and learning (19, 20). Immordino-Yang further makes the claim that neurobiologically, a healthy brain will not be able to remember information that does not have some sort of emotional attachment to the individual, as this would be a waste of processing information resources (21). Emotions are a central process to all learning function: they help learners set learning goals, know when to keep working or stop, identify when a solution pathway "feels" right or not when solving problems, and in filtering out what is important or not. The emotional drivers are seen in the classroom – students work harder and are much more invested in topics in which they are emotionally interested. In particular, when content and skills are connected to a student's motivations and future goals, instructors see a much greater work capacity, resilience and overall grit (22). For instructors to tap into a student's grit, emotional intelligence needs to be understood and built upon. As Sottilare, DeFalco and Connor claim, instructors must understand (or at least be able to manage) emotions for helping students be academically successful, and it is important to detect, identify and manage learner's emotions (22). Emotions that hinder learning, such as anxiety, uncontrolled anger or frustration, and confusion, can dramatically undermine learning. These deplete cognitive resources while activating brain regions correlating to fear and escape, as we will see in the cognitive neuroscience section (23). To combat the negative emotional states, the Study of Social and Emotional Learning defines five main areas that students integrate to allow for a positive and productive educational experience. These areas are social skills, public spirit, identity and agency, emotional regulation and cognitive regulation, as seen in *Figure 2.14* (24).

Not only do instructors see a wide variety of emotions in the classroom, they also observe different frequencies of each type of emotion. Throughout the majority of classroom settings, students report that anxiety was the one emotion that was most frequent, from around 15% to 25% of all emotions reported in studies by Pekrun et al (25). Diving deeper into the study by Pekrun et al, this anxiety was seen not just before exams, but also while in class or while studying. This is likely due to achievement pressure and the fear of failure felt by the students. Applying this consideration to instructors' practices, the classroom setting needs to address the psychological well-being of students to create methods that help students cope with the demands they face, and provide a safe place in the classroom for students to emotionally regulate. Aside from the focus on anxiety, students in Pekrun's study also reported feeling roughly "equal amounts of positive and negative emotions, from enjoyment of learning, hope, pride, and relief, as well as anger, boredom, and shame. In addition, there were accounts of several less frequently reported emotions (e.g., the social emotions of gratitude, admiration, contempt, and envy)" (25). Gendolla and Brinkmann, in light of this work, propose that those in positive moods will be optimistic about handling the difficulties of a classroom environment, have a higher self-efficacy, more rapport with peers, demonstrate greater allocation of effort, and will persist longer than those who experience negative emotions more frequently (26). Faculty having a high emotional understanding will have more insight into the state of the classroom climate and be able to potentially take actions that cause more positive emotions.

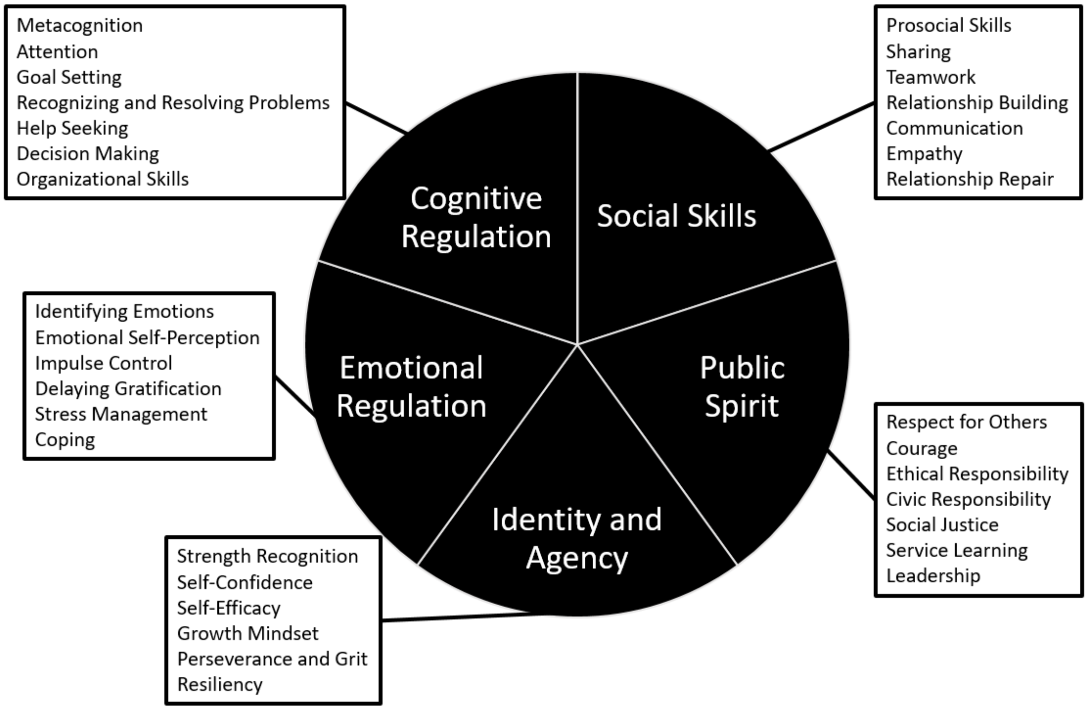

Figure 2.14 - Integrated Social and Emotional Learning

Figure adopted from Frey, 2019 (24).

2.3 Cognitive Neuroscience

Cognitive neuroscience points in the direction of integrating both cognition and emotional processing. Panksepp and Biven show that the brain networks supporting emotion, memory and learning are all greatly intertwined (27). Using functional magnetic resonance imaging (fMRI) in relation to performing different cognitive tasks, along with qualitative methods of research, the connected nature was found across many disciplines, even highly "unemotional" fields, such as mathematics (28). To further understand cognitive neuroscience, we need to have a basic understanding of the structure of the adult brain. Chapter 1 of the dissertation highlighted the major networks of the brain, as well as the neural connections via diffuser tension imaging. With the different network processes occurring continuously, and sometimes simultaneously, we can start to anatomically see different structures in the brain. *Figure 2.15* illustrates major components of the brain. The brain has a thick outer cap, the cerebral cortex, that processes much of our experiences. The cortex has two hemispheres and four functionally different lobes. Various regions towards the center and lower parts of the brain govern fluctuating emotional and hormonal reactions, also termed subcortical structures because they lie beneath the cortex (29).

Different parts of the brain were originally thought to have specific functions, either cognitive or emotional (31). The subcortical structures were thought to govern emotional processing and the cortex governing cognitive processes, each independently. However, Kiverstein and Miller report that this separation does not hold up to recent findings and that emotions and cognition are essentially inseparable processes in the brain. When humans perform tasks that engage emotional and cognitive processes, the two areas of the cortex and subcortical structures are in constant and continuous interaction (32).

Narrowing in on the cellular structures within the brain, we see that the neural connectivity is constantly changing and reforming through repetitive use and adaptation, a term coined neurological or synaptic plasticity (33, 34). This specific adaptation to imposed demands allows for a direct link to educational practices. For instance, when the discussion of depth versus breadth of content coverage comes into debate, Geake and Cooper suggest that depth should win out. Learning requires repetition that allows new pathways to become reinforced, maximizing long-term retention (35). Weimer also supports this claim through her book “Learner Centered Teaching: Five Key Changes to Practice” (36). A depth mindset leads to teaching that promotes repeated testing, such as retrieval practice, and having many low-stake exams. With repetitive stressors on neural connectivity, instructors can further promote the fundamentals of a course to better prepare students for future demands. On the contrary, skimming over topics or skills in order to meet a content coverage quota results in shallow learning. Students are unlikely to retain that information in the long run, especially after the course ends (37).

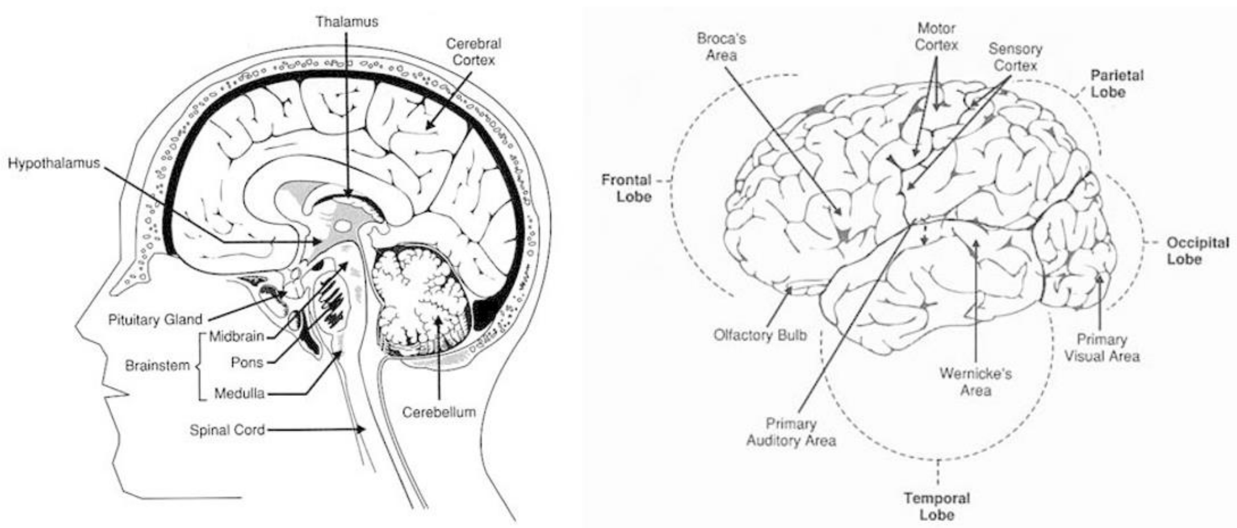

Figure 2.15 - Major Components of the Brain

The above figures were adopted from Torbra and Ackerman (29, 30). (Left) The brain’s outer appearance is due to the wrinkled and deeply folded cerebral cortex, which handles the vast signals responsible for perception, movement, and mental processes. Below the cortex are other specialized structures: the thalamus, a relay station for senses, and the hypothalamus, a structure joining the nervous system and the endocrine system, linking emotions and physical feeling. The pituitary gland, in communication with the hypothalamus, produces hormones for function regulation, from growth to reproduction. The pons and the medulla, two major elements of the brainstem, channel nerve signals connecting the brain and sensory organs, controlling vital functions such as breathing and deliberate movement. The anterior of the brain is the cerebellum, coordinating skilled repetitive movements and maintaining posture and balance. (Right) The brain is split into a left and a right hemisphere by a deep groove running from the front to the back of the head. In each hemisphere, the cerebral cortex falls into four main divisions (lobes) divided by noticeable folds in the surface. Although some processing load is shared, each lobe generally has one or two specialized functions. The frontal lobes house the motor area and Broca's area, which handles the production of speech. Planning and constructing the world are also attributed to the frontal lobes. In the parietal lobes, the cerebral cortex receives the signals from sensation and processes them; the temporal lobes are concerned with memory, hearing, and, in Wernicke's area, with the ability to understand language. The occipital lobe manages the processing of vision. The olfactory bulb is tucked just under the frontal lobes, dealing with the sense of smell. Note the proximal nature to the temporal lobe, and the generally accepted association between smell and memory.

As we further delve into the functioning of the brain, we must introduce a new topic: cognitive load theory (CLT), as effectively described by Sweller (38). Sweller proposes that students’ limited working memory is spread among “three sources of tax on working memory resources: germane (resources dedicated to the development of new learning), intrinsic (resources divided among the number of tasks and their complexity), and extraneous (resources divided to distracting or interfering thoughts or processes). CLT argues that these taxes on working memory resources are additive and that to aid student learning we should intervene to free up as much working memory as possible for germane and intrinsic purposes, usually by reducing extraneous load." CLT thus accounts for the limited nature of an individual's working memory and not overloading this in the classroom. Huk and Ludwigs strongly promote that when considering the cognitive load theory, affective factors must also be woven into the usage of working memory (39), and this idea is supported by the previous topics in this section.

One example of neuroscience supporting the need for faculty to have emotional awareness is understanding the workings of stereotype threat, for both instructors and students. Briefly, stereotype threat is being at risk of confirming, as self-characteristic, a negative stereotype about one's group (40). Neurophysiological evidence shows that under threatening conditions, such as those that may be experienced when confronted with stereotype threat, the prefrontal cortex lowers in activation (meaning the neurons are not firing as often, implying lowered functioning), thus impairing the executive control network and working memory (41–43). Walton and Spencer showed that with effective support (such as reversing the stereotypes around non-Asian ethnic minorities and women in quantitative fields), instructors can reverse this effect as seen in *Figure 2.16* (44). Additionally, through functional magnetic resonance imaging, (fMRI), higher levels of activation can be found in the amygdala, suggesting a fear response (40, 45–47). If a threatening feeling propagates on the short term into felt emotions, it can result in students feeling upset, distracted, and anxious, among other unfavorable emotions, which impedes learning (48). In the long-term, stereotype threat becomes a self-fulfilling prophecy and individuals begin to believe they can no longer be successful in a domain of performance, further exacerbating educational achievement gaps (44, 46, 49).

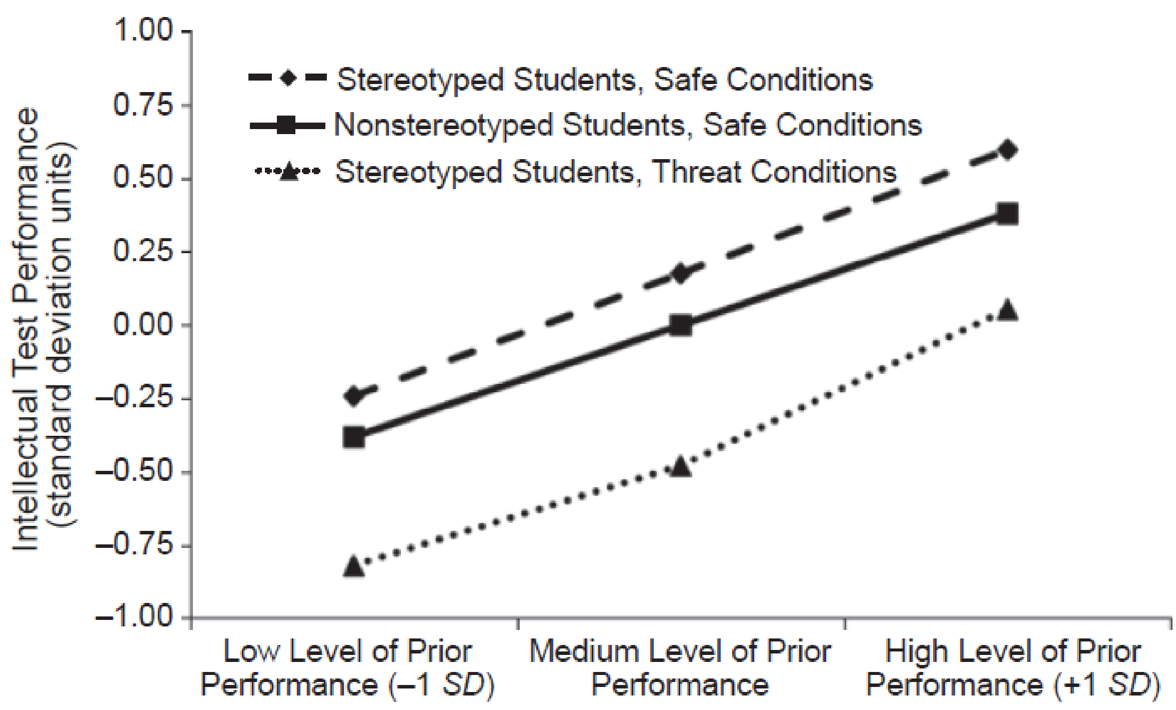

Figure 2.16 – Effect of Supportive, Safe Conditions in Reducing Stereotype Threat

Taken from Walton and Spencer (44). In the graph we see three different conditions: two control groups of 1) students without a stereotype threat and in safe conditions and 2) students having the potential for stereotype threat, but in safe classroom conditions. When comparing the academic performance between the controls and the stereotyped students in threatening conditions, we see a noticeable drop in performance above and beyond the levels of prior performance. In other words, regardless of how successful a student has a been historically, if they fit into a stereotype and are in threatening conditions, they will generally perform worse than student in safe conditions, stereotyped or not.

2.4 Strategies to Support Learning

As mentioned in chapter 1, conceptual change for individuals, including instructors and students, does not come easily. In order to influence educators to make a conceptual change, we need to further explore conceptual change itself. Duit et al. suggest there are two types of conceptual change for most common analyses which are 1) weak knowledge restructuring, assimilation or conceptual *capture* and 2) strong/radical knowledge restructuring, accommodation or conceptual *change* (50). The need for the latter is paramount for lasting change. With the different paradigm shifts – both weak and strong – that need to happen in the classroom, there are a variety of different strategies and classroom designs to allow for the most effective learning environments.

Various authors, such as Benassi et al., Dunlosky et al., and Pashler et al., have reviewed research on the effectiveness of strategies that support learning (51–53). These studies looked into practical applications that are generalizable strategies to promote long-lasting learning and problem solving ability while supporting comprehension and application of knowledge. A common thread through the publications are five main strategies to use in the classroom:

1. Retrieval Practice, where the individual has to recall information, preferably without using notes
2. Spaced Practice, where the student breaks up studying into smaller, manageable chunks over time
3. Interleaved and varied practice, where the learner changes topics between study sessions
4. Summarizing and drawing, where individuals synthesize information into their own words
5. Explanations, where the student uses elaborative interrogation, self-explanation or teaching to help solidify material. This is to the benefit of both students and their peers who may be on the receiving end.

These strategies are reinforced through other literature (54–57). In relation to STEM classes, and in particular engineering courses, there is a very strong argument for utilizing problem-based learning as a means of content delivery (58–61).

Teaching other people content has been found to foster effective learning in the ones doing the teaching, not just the recipients (62–64). When learners prepare to teach their peers, they must construct explanations, just as they do in elaborative interrogation and self-explanation activities. With the open-ended task of instructing peers, students can find a direct means of finding where they lack content knowledge and thus reinforce what is already understood (65, 66). Having the "power" to instructor other peers allows students to feel responsible in a way that is not as easily possible in a traditional lecture (67). The shifts to students giving mini-instructions transitions the students from being simply passive recipients of knowledge to active participants in their learning.

Improving the learning environment does not need to be complicated or highly complex. Very simple changes in the classroom or in the expectations required of students can alter the quality of knowledge acquisition. For instance, Mueller and Oppenheimer studied note taking of college students (68). The study tested students conceptually over lecture material, comparing students who took notes via laptop and those that took longhand written notes. They found that verbatim transcriptions (associated with the use of laptops) were associated with lower retention of the lecture material compared to summary notes (associated with the use of longhand written notes). The same was the case for taking notes via laptop: students were no better at synthesizing material than a control group. By simply promoting handwritten notes or providing notes with blanks for students to fill in that promote engagement with the material, instructors can increase comprehension of material. Mueller and Oppenheimer believe longhand notes were more beneficial because they forced students to process the information and reframe the material in their own words.

As demonstrated by the example above, technological advancements over the past three decades have dramatically influenced the educational landscape. *How People Learn I* noted that technologies may be used to:

1. Incorporate real-world problem solving into classroom curricula
2. Scaffold students' learning, usually through pedagogical technique to appropriately introduce topics
3. Provide students and teachers with more opportunities for feedback, reflection, and revision

4. Build local and global communities of individuals who are invested and interested in learning
5. Expand opportunities for teachers' learning.

Since that report was published, new technologies have been developed and researchers have expanded our understanding of how digital technology can most effectively be used to foster learning (54). The opportunities allowing for learning and instruction to happen through technology are termed affordances (69). Affordances help students in the modern work environment, but are not enough in themselves to face the future challenges; the application of them is needed. Future employees need more than a simple background in the sciences to handle complex technologies, social systems and ever-evolving subject matter (70–72). Deeper learning, mediated by technological advances, involves understanding complex concepts and systems, along with the ability to integrate information from multiple documents and experiences (73). Integrative systems learning is a necessity for students to master in order to move into the next modern area of problem solving, reasoning, inferential thinking, and transfer of knowledge to new situations (74).

In addition to different teaching practices, the instructor can further improve the learning environment by first understanding what students are trying to achieve in the classroom. Why are the students in their classroom? It is not always easy to determine students' goals, especially as the goals can shift throughout the semester in response to events and experiences. However, assessing why students are in the classroom can allow for a more directed approach to teaching and instruction, more so than just assuming that every student is simply attending class for a high letter grade (75, 76). This level of "awareness support" can be expanded upon by encouraging students by addressing their engagement, persistence and performance. *How People Learn II* suggests the following to improve student motivation (18):

1. Helping students to set desired learning goals and appropriately challenging goals for performance
2. Creating learning experiences that students value while supporting their sense of control and autonomy
3. Developing students' sense of competency by helping them to recognize, monitor, and strategize about their learning progress
4. Creating an emotionally supportive and nonthreatening learning environment where learners feel safe and valued.

The Spark of Learning provides one strong piece of advice working through the various practices and changes that have been threaded throughout the dissertation: to be vibrant, which in Cavanagh's terms means "being vibrantly yourself" (37).

The two-part paper presented in Appendices A and B will describe all of the various teaching practices that we use in the Chemical and Environmental Engineering Department that seek to address the greater theoretical foundational improvements suggested from neurological and cognitive sciences.

2.5 Future Research Opportunities

With the creation of the two-part paper, a wide variety of doors have opened onto how the current research I have done can expand into future endeavors. First and foremost, a critically relevant topic to research would be how each teaching practice influences the classroom experience and student successes differently, which can be approached both quantitatively and qualitatively. Quantitatively, through an ideal ANOVA approach (77–79), all interventions would be assessed in a controlled, randomized study to understand the effect on student success and experience. However, with limited class sizes and controls, clusters of intervention can be assessed in a controlled, randomized study to understand the effect on the educational experience. However, this task will be relatively difficult and challenging to conduct as classrooms have a large number of confounding factors that are difficult to control. From a study design perspective, bias and the confounding factors are limited by 1) using a simultaneous control group, 2) randomization, and 3) blinding. Precision, which will help by detecting small effect sizes and lowering "noise," is increased by 1) replication, 2) balance, and 3) blocking (80–82). Using these principles, primary studies can be developed to help build the base of effective study groups.

Generally speaking, in education research, performing meta-analyses and having a large sample size are used to help confront the issue of confounding variables. Hence, the need to follow the aforementioned principles are necessary as meta-analyses are only as good as the studies on which they are based. For instance, Lazowski and Hulleman performed a meta-analysis of 92 effect sizes of student motivators with 38,377 participants to quantify the influence certain variables in the classroom have on student outcomes (83). The studies measured authentic education outcomes (e.g., standardized test scores, persistence at a task, course choices, or engagement) and showed consistent, small effects across intervention type. The findings lead to the understanding that nearly any intervention towards student motivation (supported by literature) does improve the classroom environment and outcomes. As seen in *Table 2.9*, the larger the effect size, the great the positive impact on student learning. An important note was that the magnitude of differences was based on the study design: randomized designs had smaller effect sizes than quasi-experimental designs (83). The implications are that the design of future studies needs to be randomized to account for what could be a potential bias in teaching methods.

Table 2.9 - Summary of Effect Sizes of Student Motivation from Lazowski and Hulleman

Theory	Description	K	Average	95% CI
Transformative experiences	Reframing the learning experience as an application of the content in a way that enhances everyday value	4	0.75	[0.33, 1.16]
Self-determination	Satisfying students' three core needs (autonomy, relatedness, competence) is essential for promoting motivation and well-being	11	0.70	[0.53, 0.87]
Interest	The development and deepening of interest in specific topics and academics is influenced by situational and individual difference factors	2	0.69	[0.30, 1.08]
Goal setting	Specific, difficult task goals produce higher commitment and performance than vague goals that are easy to attain	1	0.67	N/A
Implicit theories of intelligence	Students' beliefs about whether intelligence is fixed (i.e., entity mindset) or is malleable (i.e., incremental mindset) influence goal striving, persistence, and performance	6	0.56	[0.31, 0.80]
Attribution	Students' explanations for success or failure influence subsequent achievement behavior	13	0.54	[0.37, 0.71]
Self-confrontation	Students' perception that their behaviors and values differ from their self-conception motivates change	1	0.54	N/A
Possible selves	Students' conception of what they might become (both desired and feared) serves as an incentive for future behavior and a way to evaluate current behavior	3	0.49	[0.19, 0.80]
Multiple theoretical perspectives	Studies having multiple perspectives on student learning.	23	0.41	[0.29, 0.53]
Expectancy-value	Student motivation is determined most proximally by success expectancies and perceived task value	7	0.39	[0.18, 0.59]
Achievement goals	Students' goals for engaging in an activity shape how they approach, experience, and react to achievement situations	4	0.38	[0.09, 0.67]
Self-affirmation	Students who perceive that they are in danger of confirming a stereotype about their group experience increased anxiety and reductions in performance	8	0.38	[0.19, 0.58]
Need for achievement	The importance of mastery, high achievement, and besting others to reach one's full potential	1	0.36	N/A

Table 2.9 - Summary of Effect Sizes of Student Motivation from Lazowski and Hulleman (cont.)

Theory	Description	K	Average	95% CI
Social belongingness	The degree to which students perceive they belong and are connected to others can influence their learning outcomes	5	0.35	[0.07, 0.63]
Self-efficacy	Students' perception that they can successfully complete the specific tasks and activities required for learning promotes learning outcomes	N/A	N/A	N/A
Achievement emotions	Emotional experiences in school emanate from students' perception of control and value for academics	N/A	N/A	N/A
Total		92	0.49	[0.43, 0.56]

Adopted from Lazowski and Hulleman (83). K refers to number of studies; Goal setting, need for achievement, and self-confrontation theory could not be included in moderator analyses for Theoretical Framework because only one study was coded for these theories. If two or more theories contributed to the development of the intervention, then the study was coded as multiple perspectives. Achievement, emotions and self-efficacy only contributed to studies coded as multiple perspectives.

The need for the qualitative side of research on understanding students and their thought processes is paramount. For instance, in a study by Pekrun et al, the authors claim:

> The qualitative accounts given by our participants also enabled us to detect phenomena that otherwise would have gone unnoticed. A case in point was students' meta-emotions, that is, their feelings about their own emotions. For example, a number of students gave detailed accounts of experiencing anger about being anxious before exams. In some of these students, this anger helped them to find ways to cope with the anxiety, thus implying that meta-emotions may facilitate students' coping with negative emotions, something educators may wish to consider when trying to assist students in dealing with their affective experiences (25).

As the previous sections have discussed, future research can qualitatively look at more of the emotional side of instruction outside of the four domains and further focus on *why* different instructional practices have increased student retention in the Chemical and Environmental Engineering Department. In particular, a topic that was largely hinted at but not explored in Part 1 and Part 2 of the submitted manuscripts was diving into the motivations of engineering students. Additionally, Gerhardt strongly promotes a shift in teaching practices to adjust to the changing student population (84). With the incoming generation of millennials, students reported having a desire for sociability, further demonstrating the need for classrooms to have interaction, collaboration, relationships, and communication with their instructors—in the classroom and beyond. Gerhardt also makes the claim that the Millennial generation in the United States has been raised with parenting and teaching styles that highlight individual attention and team cohesion, further supporting the need for a collaborative atmosphere.

A longitudinal study from the Chemical and Environmental Engineering Department as scholars progress would be largely beneficial to understand the growth and maturation of students. In particular, as instructors potentially begin using the various evidence-based teaching strategies (see *Table 2.10* for examples), seeing the change of a cohort of engineering students across the domains of DEW rates, affective support and qualitative measures, such as personal satisfaction, would allow for other universities across the United States adopt the various teaching practices that seem to be working so well for our department. Additionally, the described practices in the two-part paper are not exhaustive. There are new ideas and implementations that occur every semester; small tweaks or changes that allow for a better fit of the instructional practices to the classroom dynamics indicate a growth mindset to teaching that should be encouraged among all faculty. As time progresses, there will be many more interventions waiting to be discovered and implemented in the classroom that will lead to more student success and higher learning gains.

It is important to note that the landscape of higher education is vastly changing. The current generation of students is highly connected through social media. Understanding the impact of nearly instantaneous social media connection on instruction, and how instruction could appropriately respond to the varying needs of students, will be beneficial to the future of STEM fields. In addition to understanding these impacts, students need to learn how to best use them for their education. Mamaril states: "engineering educators and program evaluators should be concerned with not only developing students' skills but also with their beliefs about their skills, especially when working with undergraduates encountering difficulties" (85). Mamaril calls for future research to help practitioners understand how engineering self-efficacy beliefs progress as students age, especially as the learning environments continue to evolve. Interventions, such as the ones found in the two-part paper in Appendices A and B, can then be implemented to further help boost student self-efficacy. A second implication of Mamaril's paper implies that most studies are suitable for use when students' desireable outcomes are closely linked with grades; however, skill-specific measures might be useful predictors for out-of-classroom assessments. Marmaril makes note that over 75% of the variance in engineering major GPA's remained unexplained by the predictors in their model; this level of variance of GPA suggests that self-efficacy, though important, is not the only predictor of engineering GPA (85). The wide variety of affective factors impacting student success may explain more of the variance in the prior studies cited here, and needs further research. Current research into the application of the affective side of education will likely see an increase in meta-affective learning in science (86).

Table 2.10 - Types of Active Learning that have been Demonstrated to Enhance Learning

Types of active learning with feedback	Examples of studies that demonstrate enhanced learning*
Small group discussion and peer instruction	Anderson et al. (2005); Armbruster et al. (2009); Armstrong et al. (2007); Beichner et al. (1999); Born et al. (2002); Crouch and Mazur (2001); Fagen (2002); Lasry et al. (2008); Lewis and Lewis (2005); McDaniel (2007a, 2007b); Rivard and Straw (2000); Tessier (2004 and 2007); Tien et al. (2002)
Testing	Steele (2003)
One-minute papers	Almer et al. (1998); Chizmar and Ostrosky (1998); Rivard and Straw (2000)
Clickers	Smith et al. (2009, 2011) Capon
Problem-based learning	Capon and Kuhn (2004); Preszler et al. (2007)
Case studies	Preszler (2009)
Analytical challenge before lecture	Schwartz and Bransford (1998)
Group tests	Cortright et al. (2003); Klappa (2009)
Problem sets in groups	Cortright et al. (2005)
Concept mapping	Foncesca et al. (2004); Prezler (2004); Yarden et al. (2004)
Writing with peer review	Pelaez (2002)
Computer simulations and games	Harris et al. (2009); McDaniel et al. (2007); Traver et al. (2001)
Combination of active learning methods	Freeman et al. (2007); O'Sullivan and Cooper (2003)

Adopted from "Report to the President: Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering and Mathematics" (87). See Part 1 and Part 2 paper series in Appendix A and B for greater explanation of different types of active learning.
*References in table follow after the References for Chapter 2.

To conclude and restate the essence of the papers in Appendices A and B: to support teacher growth, teachers should be actively engaged in their own learning (88, 89) and reflect upon their own understanding and practice (90) with a strong content component to professional development (91, 92). By having instructors continuously building on their practices, higher education will only improve.

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Chapter 3: Affective Drivers that Influence the Implementation of an Instructor's Teaching Practices in a Large Introductory General Chemistry Course

The manuscript associated with this chapter can be found in Appendix C. This manuscript is a case study focusing on one instructor's affective drivers towards her implementation of teaching practices. It will be submitted to the *International Journal of Science Education* by 8/30/19.

3.1 Introduction

Through the past two chapters, we have seen the need for change in higher education and have highlighted various teaching practices whose implementation could enable more students to excel in higher education. However, change – for both students and instructors – is not always easy. This chapter will delve into the affective factors, which are described in the next section, which should be contemplated when instructors consider adopting teaching practices. A few sample affective drivers that may arise when implementing different teaching practices include (but in no way are limited to): frustration with past student outcomes, dissatisfaction with teaching performance, anxiety around getting out of a comfort zone, joy from seeing student learning, positive feedback from a department head, and believing in one's ability to successfully implement a new strategy.

The emotional landscape of an instructor can take a lifetime to fully understand; however, this chapter claims that by understanding a few fundamental areas of affective domains, we can better promote and build upon instructor's own history and experiences to improve their teaching practices. As we have seen in the reports from Chapter 1 and claims by *How People Learn II* in Chapter 2, we see that every individual brings their own experiences to the learning environment (1). This means that not only are students influencing the classroom experiences with their own unique histories, but that instructors, too, bring their own beliefs and life experiences into the classroom.

Ask any high school student or individual who has not attended college to explain what their perspective on the college environment is like. You might find that a common assumption involves depicting a classroom that is a dry, sober setting with the unemotional distribution of facts. The instructor might be described as standing with their back to the class, droning on about various obscure topics. Cavanagh claims that if we want to truly motivate our students, we would do much better by focusing on targeting their emotions (2). The papers and books mentioned in the previous chapters also made similar claims about learning being emotional and social. Thus, recent changes involve creating classrooms vastly different from the lackluster setting described by those unfamiliar of the college classrooms (3–5).

As the previous chapters mentioned, the student landscape is changing and the experience is vastly different from a few decades ago (6, 7). But what about the instructors' landscape, and how is this change affecting them? The following chapter sections will take a different perspective than the general approach to an instructor. As instructors learn different teaching practices, they, too, become students of education. To look at this different perspective – of the instructor as a student – we must assume that instructors themselves have the same difficulties that students face when learning new concepts or ideas. Chapter 2 introduced a simplified version of *affect*; we now will dive deeper into the literature and terminology of the non-cognitive domain on humanity.

3.2 Affect

In the previous chapter, we claimed that the cognitive and non-cognitive parts of the brain are connected structurally in the brain and are closely linked, usually running in parallel (8, 9). To focus on understanding the non-cognitive domains, we will start broadly with understanding *affect* and *affective drivers,* and then dive deeper into the components that make them up. The following excerpt is taken from the paper "Affective Drivers that Influence the Implementation of Teaching Practices in a Large Introductory General Chemistry Course" found in Appendix C:

> Depending on the perspective taken and area of study, affective drivers, sometimes referred to contextually as affective factors, have various definitions found in the literature. English Language Sciences describe affective factors as entities that relate

to the learner's emotional state and attitude toward a certain goal (10). Southerland et al. simply describe them as emotions, motivations and beliefs (11), while Cela-Ranilla and Cervera list them as simply feelings (12). Dornyei and Hurd both refer affect to the emotions, feelings and attitudes that individuals bring to the learning experience and the role these play in motivation (13, 14). More generally, affect is a work that encompasses not only emotional states but also many other experiences that involve pleasure, displeasure, and physiological arousal (eg. motivation, physical pain) and which doesn't assume that our various emotions are discrete and separate entities (2). One largely studied example of an affective driver is a teacher's self-efficacy (15). However, this tells only a part of the story of teachers' approaches to their practices, especially with reform and adoption of different practices (16, 17). Examples of affective drivers that could influence an instructor's use of teaching practices are: being motivated by some combination of anticipating rewards, experiencing fear of censure with not doing well, experiencing innate curiosity about a topic, or feeling the desire for future career success.

To further explain the classification of affective drivers in terms of the subcategories of emotions, moods and motivational states, we can begin to understand what is meant by affective drivers. Emotions, such as anxiety, are complex, multifaceted phenomena that combine feelings (experiential elements), physiology (heart racing, labored breathing), and expression (body language and facial expressions) (18). Some view emotions as distinct prepackaged programs, like apps on one's computer while others argue that emotional experiences are instead complex, interrelated systems of body, brain, and mind. Emotions and emotional regulation are still relatively new fields and are still being clearly defined by research (19). For this paper, we will apply the idea from Gross that emotions generally predispose us to approach rewarding experiences and avoid punishing situations. Emotions are exquisitely sensitive to modulators such as situational context and relevant past experiences (19). Emotions are generally short lived that have a direct object and direct goal, while moods are longer lasting, from hours to days, and may not have an exact contextual factor. Motivational states also have much in common with emotion: they involve goals, invoke approach or avoidance behavior, impact neurochemistry and hormonal responses, and have evolutionary significance (2). Varma, McCandliss and Schwartz point out that education has traditionally treated motivation, emotion, social factors, and learning as discrete, separate concerns in the classroom, whereas neuroscientific findings increasingly suggest that the reward system governs all four of these processes (20). As such, the discussion of the affective drivers will incorporate these different components into the analysis of the instructor's discussion of her classroom.

To allow for simplicity of writing, this paper will use "emotions" as synonymous with the closely related terms of "mood" and "motivational states" unless otherwise noted. *Table 3.11* expands upon positive and negative associated emotions commonly associated within academic environments (21). To integrate these ideas, D'Mello and Graesser asked students to track their emotions during a computer tutoring program (which later helped build Affective AutoTutor (22)) to model and predict a learner's state of engagement or flow (23). During the tutoring session, students felt oscillations between confusion-engagement/flow, boredom-frustration, and confusion-frustration. Learners returned to a flow state of engagement if their emotional equilibrium was restored through thought, reflection, and problem solving. With the equilibrium established, positive emotions such as delight arose. With this example, we see that as learners proceed through acquiring new skills or concepts, the affective side becomes an integral influencer. Applying this concept to instructors, we can predict that they, too, will feel similar emotions trying out different teaching practices or simply applying traditional practices in novel situations.

Table 3.11 - The Domain of Academic Emotions: Examples

	Positive	Negative
Task-related and self-related		
Processes	Enjoyment	Boredom
Prospective	Anticipatory Joy	Hopelessness
	Hope	Anxiety
Retrospective	Joy about Success	Sadness
	Satisfaction	Disappointment
	Pride	Shame and Guilt
	Relief	
Social		
	Gratitude	Anger
	Empathy	Jealousy and Envy
	Admiration	Contempt
	Sympathy and Love	Antipathy and Hate

Taken from Pekrun (21)

In addition to the emotional side of learning, the affective drivers of motivation (not significantly discussed in the paper found in Appendix C) have had a significant amount of research attention and support (24–27). *How People Learn II* describes motivation as "a condition that activates and sustains behavior toward a goal" (1). Järvelä and Renninger consider motivation, interest, and engagement as distinct and complementary influences on learning; motivation involves a complex blend of the environment, cognition, and effect. Furthermore, motivation is distinguishable from other similar states, such as interest, goal orientation, grit, and tenacity (28). This affective factor allows for life-long learners to flourish in both informal and formal learning environments. Murayama et al. believe that motivation is one of the main influencers that explain achievement gaps in education (29). Additionally, motivation can be externally driven through contextual rewards and punishments, or to a greater extent, intrinsic reasons. In terms of learning new skills, intrinsic motivators nearly always are more powerful than extrinsic motivators; having an inner drive to always evolve, for instance, tends to outweigh punishment and reward systems for long-term growth (1).

Motivation to learn is thus influenced by many factors. Individuals can construct multiple goals stemming from life and school experiences to build motivation; this sense of purpose can be fostered when they have a sense of belongingness and promote a sense of agency (as seen in Chapter 2 of this dissertation). Gehlbach demonstrated how a sense of belongingness improved 9th grade student achievement when the students felt like they could relate with their teachers (30). In other words, the connection made between the student and instructor helped improve motivation to learn through their affective and social interactions. *How People Learn II* compiled much of the research and found the following (1):

1. Learners tend to persist in learning when they face a manageable challenge (neither too easy nor too frustrating) and when they see the value and utility of what they are learning.
2. Children and adults who focus mainly on their own performance (such as on gaining recognition or avoiding negative judgments) are less likely to seek challenges and persist than those who focus on learning itself.
3. Learners who focus on learning rather than performance or who have intrinsic motivation to learn tend to set goals for themselves and regard increasing their competence to be a goal.
4. Teachers can be effective in encouraging students to focus on learning instead of performance, helping them to develop a learning orientation.

Therefore, as an instructor begins to adopt new teaching practices, they must be placed in an environment which adequately challenges and supports them, must focus on the learning aspects for themselves, and find ways to set their own teaching goals..

Motivation, just like emotions, moods, and other affective factors, can be seen as an emergent phenomenon regarding learning. Motivation can be present at one moment for an individual, and then suddenly dissipate. As seen in the previous section, this is supported by literature, and the learning environment can help sustain a learner's curiosity and interest, thus helping maintain motivation over the long-run (31). The contextual component in which motivation is considered has importance as well. Having a motivational systems perspective – seeing motivation as a transient psychological mechanism and process – will help a learner understand the process they are going through (32). Additionally, expectancy-value theories, as discussed by Wigfield and Eccles, looks at how learners choose goals depending on one's self-efficacy and the value of actually completing the task (33). With the different theories in mind, we can influence instructors to adopt novel practices by ensuring the practices are useful for effective teaching and instruction. Furthermore, the adopters can understand that the practices can align with one's identity or sense of self, while making teaching enjoyable, and promoting buy-in to get instructors invested in pursuing educational improvements. Eccles and Wigfield also demonstrated that learners of any age exert more energy and perform much better when they expect to succeed at a task; this also is reinforced over time as learners become more skilled and cyclically improve over time (34).

As another perspective from expectancy-value theories, self-determination theory hypothesizes that learner behaviors are influenced by autonomy (the urge to control one's own life), competence (the urge to experience mastery), and psychological relatedness (the urge to interact with, be connected to, and care for others), which are all often major components to intrinsic motivation (35–37). Applying the self-determination theory to instructors, we could see an increase in faculty intrinsic motivation to change their teaching practices when they willingly approach instructional improvements, and perceive they have a high level of autonomy while doing so. Using external motivators, such as financial rewards or punishments for failing a task, is not the best solution to building intrinsic motivation for change and improvement in the long run. Deci et al. have shown extrinsic rewards can harm intrinsic motivation in a meta-analysis of 128 educational experiments across all ages and follow up review (38, 39). In the short-term, external rewards can help with encouragement and persistence, so long as the rewards do not undermine the sense of autonomy and control of behavior (40, 41).

With the several frameworks for viewing instructor development, one can assume that various perspectives of motivation mix with an individual's affective states. This means those involved with professional develop have a complex decision-making process. The mix of different emotions can either hinder or promote teaching practices, as seen in the paper found in Appendix C. However, those in professional development (or faculty looking to self-improve) still need to understand the emotional factors leading staff and faculty take action to change their teaching. Self-love (42), a universal human motivation, is one explanation proposed by many theorists, but this goes beyond the scope of this dissertation. Virtually all theories of human motivation signify a central role to a general need for positive self-feelings (43). In the words of Immordino-Yang and Damasio, "most, if not all, human decisions, behaviors, thoughts, and creations, no matter how far removed from survival in the homeostatic sense, bear the shadow of their emotive start" (44).

3.3 Neuroscience Support for Affective Domains

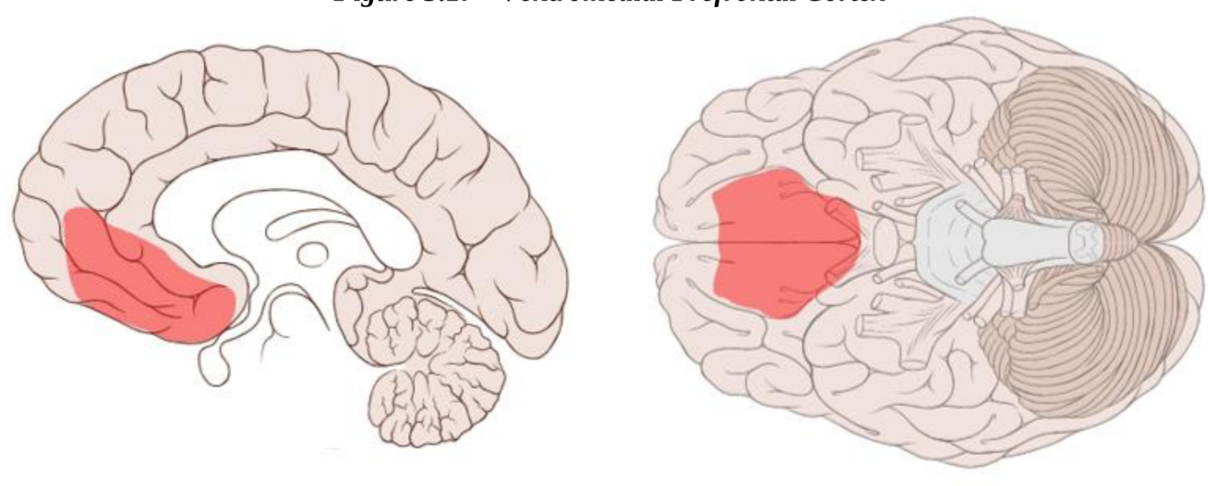
The discipline of affective neuroscience has been on the rise since the late 2000s (45). As we saw in the previous chapter, neuroscience research evidence shows that the emotional and cognitive brain are not, as traditional accounts would have us believe, separate systems pulling us in opposite directions. Neural circuits overlap each other in the brain and are responsible for both the emotional and cognitive, and the biochemical origins for each are very similar (46). Evolutionarily, this makes sense because both emotions and cognition label certain experiences and skills as important and make different items critical to both attend to and remember in different situations for survival. From the integrated framework, the neural mechanisms underlying emotion, motivation, and learning are so intertwined and relevant to the classroom that highly skilled instructors (2) need to consider each.

The use of emotions to make decisions has been a debated topic as well. Mikels et al. demonstrated that affective strategies may be just as effective as normal deliberative decision strategies.

By having participants consciously focus on feelings versus details over choices that varied in complexity – such as when students trusted their gut feelings – their results indicated superior objective and subjective decision quality for complex decisions (47). However, as many individuals have experiences when second-guessing themselves on exams, subsequent deliberation after a decision resulted in reduced choice quality. As an instructor, I can attest that numerous students and peers have lamented missing multiple-choice questions because they second-guessed themselves, and would have gotten more correct answers had they "followed their gut." Likewise, simple accounts of emotion's influence on decision-making become more complex with the addition of a number of qualifiers (such as local environment and different cognitive strategies), demonstrating that emotions are likely the guiding hand in every decision we make (48).

Larger and more rigorous studies followed to find out how different areas of the brain affected the decision-making process. One area in particular, the ventromedial prefrontal cortex (VPC, see *Figure 3.17* below), which is associated with processing risk and fear, was studied to find the influence on decision-making using different psychological tests, such as the Wisconsin Card Sorting Test (49). The VPC area also plays a role in the inhibition of emotional responses since the VPC is critical in the regulation of the amygdala as well as the decision making and self-control domains (50). Immordino-Yang reports that advances in social and affective neuroscience link "body and mind, self and other, in ways that only poets have described in the past. They dissolve traditional boundaries between nature and nurture in development, underscore the importance of emotion in 'rational' learning and decision-making" (51). The advances linking the cognitive and affective domains recommend exploring everything from mind wandering or daydreaming (as previously mentioned in Chapter 1) to intense and effortful internal focus (where individuals spend a great deal of energy solely working with one to a few different items). Affective neuroscience would lead us to examine effortful internal focus as potentially important for making meaning of new information and for refining creative, emotionally relevant connections between complex ideas, something critically important to an instructor learning new teaching practices (52). Therefore, constructive internal reflection, if studied self-reflectively, could flesh out and validate the dimensions of internally focused thought. Applied further to instructors, the constructive self-reflection could be a strong case for creating space for time of reflection to further build teaching skills.

Figure 3.17 - Ventromedial Prefrontal Cortex



Ventral view of the Brain | Media view of the Brain

Taken from Patrick J. Lynch, medical illustrator (53)

3.4 Professional Development and Growth in and for Faculty

Threaded through this dissertation is the strong notion that learning has an incredibly strong social component. The relationships with other individuals provides two main principles: providing a support network and having a variety of perspectives in which to grow. The local social aspect of teacher change needs to be acknowledged. Although there are benefits to getting different perspectives from individuals outside of a department, Porter et al. found that having teachers from similar areas enables conversations and discussions that increased teacher change (54). Additionally, simply having a variety of teaching practices to implement in the classroom does not inherently indicate that the practices will be incorporated effectively or that they are appropriate for the instructor (55). If a route of professional development is taken to build on one's teaching practices, high-quality, efficient and educated individuals are needed to facilitate effective change (56).

To continue the topic of professional development, rational approaches have limitations because affective measures are not taken into consideration. Without consideration of emotional connections, intentional conceptual change is difficult to occur (57). Sinatra and Pintrich have emphasized the importance of affective factors in conceptual change. The affective factor of motivation involves establishing conducive learning environments and most teachers value social and group learning (58). Teachers attempting to adopt new strategies who ignore the social and affective aspects of personal and group learning may limit conceptual change in themselves (59). Therefore, it would be fruitful to merge conceptual teaching practice change into theories on the significance of affective factors (57).

Therefore, we must consider the affective side of an instructor, as well as their background, beliefs and identities as they enter into the challenging arena of growth. Gawronski found that implicit attitudes are influenced by affective associations more so than cognitive evaluations (60). Just as many students hold various conceptions and schemas with science, instructors may hold similar beliefs about teaching styles and practices (57). In addition to understanding the mechanisms of teaching, instructional age of the instructors matters. In a study by Luft looking at changing inquiry practices and beliefs, beginning teacher groups changed their beliefs more than their practices and the experienced teacher group changed their practices more than their beliefs (61). According to Desimone, to change teaching practices, professional development should target changing the beliefs and attitudes of the instructor to result in teacher learning (62). To further build on this notion that cognitive and affective factors need to be considered when instructors are changing teaching practices, we can briefly consider self-esteem. Global self-esteem has two main aspects: cognitively based self-evaluations and affectively based feelings of self-regard, and both need to be addressed to induce change (63).

Regardless of the state of the instructor, a long-term view should be taken. Vosniadou and Ioannides claimed that a gradual process, based on everyday experiences, are continuously enriching and restructuring conception (64). Replacing a conception does not mean that the old conception is forgotten; the learner has to potentially reinstate new models later, especially if old conceptions retake prominence (65). To promote conceptual change of instructors, there are limitations to taking any singular view or position; often, multiple positions may need to occur, sometimes simultaneously, to allow for lasting improvements (57).

Grosslight et al. proposed having three main levels on how individuals think about the world and the paradigms that exist for understanding the world. Grosslight states: "The first level describes having a 1:1 ratio of how a model and the world are related; in other words, the model is an exact replica of how the world works. The second level contains models that remain real world entities rather than representations of an idea, but is a means of communication rather than idea exploration. Level three, where experts reside, are thinking tools that can be manipulated by the modeler to suit epistemological needs" (66). Through professional development, instructors will find change desirable if they are at the third level of understanding the different teaching practices, their usages, and how they can be applied. Growth towards this level happens through practice. With instructional age and after various efforts are made to try different practices, mental representations will begin to connect the disparate facts into a more effective mental structure of how classrooms work (1). However, throughout this process, an emphasis needs to be placed in that apparent conceptual changes are context-driven rather than conceptual status changes. In other words, the perception of understanding may give a "false-positive" on understanding when in an incongruous setting. An example would be feeling a mastery over using retrieval practices in the classroom, only to find that questions pertaining to past content stayed relatively low on Bloom's Taxonomy, and did not challenge student's conceptualizations appropriately. To help identify the influence of a contextual setting, Mortimer proposes using conceptual profiles as a means to track and understand growth in the new belief or thought (67).

Biases of various types should be considered throughout the professional development process, in particular, the social bias. Salthouse demonstrates that knowledge accumulates through both learning new information within direct experiences and from constructing new knowledge based on reasoning and imagining (68). Additionally, a person's identity – their sense of who they are – is the lens through which individuals make sense of experiences. Identity is tied into social roles or social characteristics, which can further influence perception. Engaging in activities that promote a sense of belongingness with others in the social structure tends to alter an observations as well (69–71). Within the professional development circle, this means that an instructor's identity can be dynamic, malleable, and sensitive to the developmental environment (70, 72). As the instructor progresses their knowledge base, through all of the different aforementioned aspects, their thinking also becomes biased by only having the lens of their social structure. However, we need to note that biases may be either beneficial or detrimental to learning. Having a bias is a natural side effect of knowledge acquisition, often implicit and unknown to the individuals who hold them (1). This "consequence of cultural fluency," as Mourey et al. would describe the phenomenon, helps the instructor know what to expect in the classroom. And these biases can either promote or hinder the acquisition of new skills; the biases can be intrinsically empowering, or undermining. For instance, an instructor could fully believe in the use of think-pair-share as an instructional technique in the classroom. The strategy could be the primary means to promote student engagement and collaboration, and can work very well when used effectively (73). However, relying on only one tool could be largely limiting to teaching practices. The familiarity with only one practice could impede motivation and interest in continuous growth and development. In particular, if the instructor knows that learning a new skill would be difficult, it would be extremely hard to convince the instructor to adopt or test out different strategies, which may be more effective in different situations (74, 75). As a result, the biases need to be addressed in order to create and offer high-quality, efficient and evidence-based professional development.

3.5 Case Studies and the Need for Small-N Studies in Engineering Education

The practice of engineering research tends to focus on providing the community of researchers with large-N studies, where the N indicates the sample size. This allows for a higher chance of reproducibility, generalizability, and power of result to be applied throughout the various engineering disciplines. However, this practice can overlook the value of small-N studies which allow for the deep examination of phenomena in real-life contexts (76).

The need for qualitative research methodologies, especially in the traditional "hard sciences" of quantitative research, is desirable as it is widely underrepresented due to lack of training for faculty and students (77). The goal of qualitative research is to understand human behaviors and their underlying processes. Following a traditional trend, quantitative data can be amassed through highly representative and generalizable studies with large sample sizes. Conversely, case studies in particular are useful in observing phenomena in their natural context, without the researcher's direct influence on the data. The aims of case studies are not so much 'to prove' a particular approach is effective, which requires a large sample research design, but to analyze how a research question can evolve in a concrete situation (78). Of the various components to consider with using case studies, this section focuses on the strength of the single-individual methods, their structure and validity, as well as their applicability to engineering education and other fields of research.

Case studies are qualitative in nature, as the sample size tends to be too small to apply statistics that are generalizable in nature. In order to determine if qualitative methods are appropriate for a certain research project, it is important to first analyze the characteristics of the experiment; namely: the research question, the researcher's own experience, and the intended audience. Qualitative research aims to answer questions such as "What is occurring? Why does something occur? How does one phenomenon affect another?" (79). The goal of qualitative research is to better understand human behavior and experience through empirical, rigorous observation (80). The paucity of these methods in engineering education research is not due to validity in answering these questions, but to the experiences of the researchers and audience (79). Most research in engineering education is conducted and presented to engineering faculty, who have largely been trained in a post-positive perspective (there is only one truth in research to be discovered), which lends itself to quantitative experimentation and analysis. Qualitative research aims to answer how phenomena occur in their natural setting, while quantitative research aims to confirm a hypothesis through controlled and experimental variables. However, the broad range of topics in engineering education allows for a diverse set of analytical methodologies. Thus, more qualitative research should be presented in this field, when applicable, to specific research questions (79). However, research does not need to be solely qualitative or quantitative in nature. In particular with engineering education, a mixed methods approach can be used to help strengthen findings for the designed research questions. Ultimately "what is most fundamental is the research question. Research methods should follow research questions in a way that offers the best chance to obtain useful answers" (79).

While qualitative research design is extremely dependent on the specific question and circumstances surrounding the experiment, a general outline for conducting qualitative research can be developed. A first consideration should be the goal of the research project. For instance, what does the research intend to achieve? A conceptual framework should also be developed to answer what exact phenomenon is taking place in this environment. With this information, a fundamental research question can be derived (i.e. what does the researcher intend to learn from the experiment). To answer the research question, the researcher must plan a rigorous methodology and clearly list what they intend do in the study. Finally, the researcher must assess the validity of investigation and clearly outline any and all error that may be inherent in any data collected. With this setup, the researcher can then begin to understand the meaning and particular contexts present with the subjects of the experiment. By understanding the process by which events and actions take place, the researcher can begin to make causal explanations for the underlying phenomenon (80).

Table 3.12 - Research Design of Affective Drivers

Consideration	Example from Affective Drivers in Appendix C
Goal of the research project	Understand the different affective drivers that lead an instructor to make different teaching decisions in the classroom.
Conceptual framework	1. Perspective: Postmodern/post-structural 2. Concepts: Affect and Affective Drivers 3. Framework: Based on application of Teacher-Centered Systemic Reform Model and competing factors
Fundamental research questions	1. What affective drivers influence teaching decisions and practices? 2. How do these affective drivers influence teacher decisions and practices?
Methodology	Classroom observations, semi-structured interviews based on observations, all focusing on instructor of interest
Validity	Feedback from research team on claims and assumptions

There are many benefits to qualitative research that have been noted already. Specifically, process theory is used to see people's situations, events and processes and the connections between them (80). Qualitative research is best suited for understanding meaning, context, and process flow of the research environment, and is thus better suited for identifying unanticipated phenomena and developing causal relationships. A basic outline for qualitative research design can be developed by formulating the following: the goal, conceptual framework, research questions, methods, and validity. This can also be done by answering the questions: Why are you doing the study? What do you think is going on? What do you want to understand? What will you actually do? And how might you be wrong? (80).

Case studies capitalize on observation of phenomena in their normal contexts by taking place outside of the laboratory where the researcher has absolute control. Instead, research is conducted in the natural environment, where research subjects behave naturally in a largely unmodified environment. Study subjects are not chosen as statistically representative populations, but rather data is collected via in-depth analysis of typical or special cases. Conducting case study research is an iterative process through several discrete phases; namely: design, data collection, analysis, reporting, and review. The design phase should follow the outline for general qualitative research. The design phase should clearly define the Goal/Objective (What to achieve), the Case (What is studied), Theory (Frame of reference), Research Question (what to know), Methods (How to collect data), and Selection Strategy (Where to seek data). Once these primary questions are answered and the researcher has a clear view of the project design, data collection can begin.

There are three degrees of qualitative data collection. First degree data is collected through direct methods where the researcher is in direct contact with the subject(s) and data is recorded in real-time. Second degree data collection uses indirect methods where raw data is collected without interacting with the subject(s). And finally, third degree data is collected during independent analysis of work artifacts from already available or compiled data.

Data analysis of the information obtained can be done using a number of tools and methods, including, but not limited to, descriptive statistics, correlation analysis, development of predictive models, and hypotheses testing. Similarly, there are various reporting structures suitable for case study publications. A linear-analytic report structure is often used, beginning with presenting the problem, followed by describing related work, then methods, analysis, and giving conclusions, all in sequential fashion. Other structures include:

1. Comparative (repeating a case two or more times to compare two or more points of view)
2. Chronological (best suited for long-term studies)
3. Theory-building (presents case as a part of an overarching theory)
4. Suspense (converse of linear-analytic by reporting conclusions then backed by evidence)
5. Unsequenced (used when reporting general characteristics of a set of cases).

Finally, a formal checklist can be used to review and revise the report. The final step allows verification of the presence of the steps and sufficient detail to the previous steps (81).

As with any research or science, the quality of a study must always be analyzed. In quantitative research, this is usually measured by reliability and validity; however, the concept of reliability as a criterion for qualitative research can mislead the audience to conclude that a study no good. Because there cannot be validity without reliability, though, providing evidence for the former can be enough to establish the latter. Thus, the effort to evaluate qualitative research requires a focus on the validity of the work. In order to attain validity, it is paramount to eliminate bias and increase the researcher's truthfulness about the primary claim of some phenomenon. Triangulation presents an adequate and commonplace practice for estimating validity of one's work. Triangulation is a procedure where researchers search for convergence among a variety of sources of information to form a theme in the study. Triangulation has become an important methodical practice in qualitative approaches to control bias and establish validity. Other validation methods that are used in traditional scientific research tend to be incompatible with qualitative research. Triangulation may include the collection and analysis of different data; however, this does not imply a fixed method for all research. Methods must be chosen by the researcher to fit the criteria of the study specifically (82). Different types of validity design can be found in *Table 3.14* below.

Table 3.13 - Various Design Types Found in Engineering Education

Design Type	Timing of quant and qual Phases	Relative Weighting of quan and qual Components	Mixing – when quan and qual phases are integrated	Notation
Triangulation	Concurrent	Equal	During interpretation or analysis	QUAN + QUAL
Embedded	Concurrent or Sequential	Unequal	One is embedded within the other	QUAN(qual) or QUAL(quan)
Explanatory	Sequential, quan then qual	Usually quan is given priority	Phase 1 informs Phase 2	QUAN -> qual
Exploratory	Sequential, qual then quan	Usually qual is given priority	Phase 1 informs Phase 2	QUAL -> quan

Taken from Borrego (79). Quan = quantitative, qual = qualitative.

It is evident that qualitative and mixed methodologies, and more specifically case studies, are useful when answering unique research questions in engineering education. One example of a case study used in education research is "Supporting presence in teacher education: The connection between the personal and professional aspects of teaching" by Meijer et al. (83). In this study, the instructional development of a single teacher over the course of a year was observed and put into the theoretical framework of discrete phases of the "Core Reflection" approach. The purpose of the study was not to prove that Core Reflection was effective, but rather to show how the process could be applied in a concrete example. Thus, the specific research question and goal lent themselves to the use of mixed methods and qualitative analysis (83).

3.6 Future Research Opportunities

The present study, which investigates the different affective factors that influence the implementation of teaching practices in a large introductory general chemistry course, can be expounded upon in various ways. The paper in Appendix C hinted at the instructor teaching other courses. Future research could delve into the other courses that the same instructor teaches to allow for examples of how her beliefs, identities, and affective states influence her teaching approaches in an entirely different context. Also, different decision-making theories could be explored, such as the expected-utility theory, subjective expected utility theory, and cumulative prospect theory (48). The application of these different theories could lead to different perspectives on the decisions that Dr. Hidalgo made in and outside the classroom.

As qualitative research has its pros and cons compared to quantitative research, the generalizability of the results and conclusion will be highly specific to Dr. Hidalgo's educational situation, given that this is a case study (84). However, this study went into great depth into the thinking and beliefs of the instructor compared to other generalizable research. Additionally, focusing on only one instructor was different from other studies which tend to have more instructors over longer periods of time, but with less frequent interviews/observations of the instructor(s) (85–90). The goal of this research was to allow for others in academia – be it instructors, policy makers, administration positions, or others – to have greater insight into the inner workings of an instructor who is passionate about teaching. The research will help in promoting student success by helping other faculty members negotiate the difficult decisions that are based on inputs they receive while teaching. The research could further expand by seeing how other instructors' affective areas are influential to the level of influence for task vs. lecture. These new findings could look at different teaching practices through the perspectives of other instructors.

A topic that was threaded through this chapter is the idea of perception and biases. The instructor of interest occasionally had students tell her perceptions about the class that did not reflect her own perspective of what was happening in the classroom. For instance, she was recorded saying that she believed the lecture on a particular day was sub-par. However, students would tell her otherwise later. This leads to critical disconnect between instructor perception and student / team perceptions. Using a tool like the Academic Emotions Questionnaire (AEQ), future research could collect data of the instructor and compare the students, both those taking the course, and the team that she uses for support, and see where correlations may lay between perceptions (21).

Having a simplified self-reported background to Dr. Hidalgo may not be sufficient to have the most in-depth understanding of her psyche. Past research shows that different cultures have different factors that come into play when determining the impact of different motivations towards teaching practices (43). Carey, and many others who have explored the relatedness of learning and culture, suggest that a person's social experience affect biological and neurological processes that support cognition, perception and learning (91–95). A longitudinal study of Dr. Hidalgo would also allow research to see how different interactions, experiences and age affect her teaching practice over time (96).

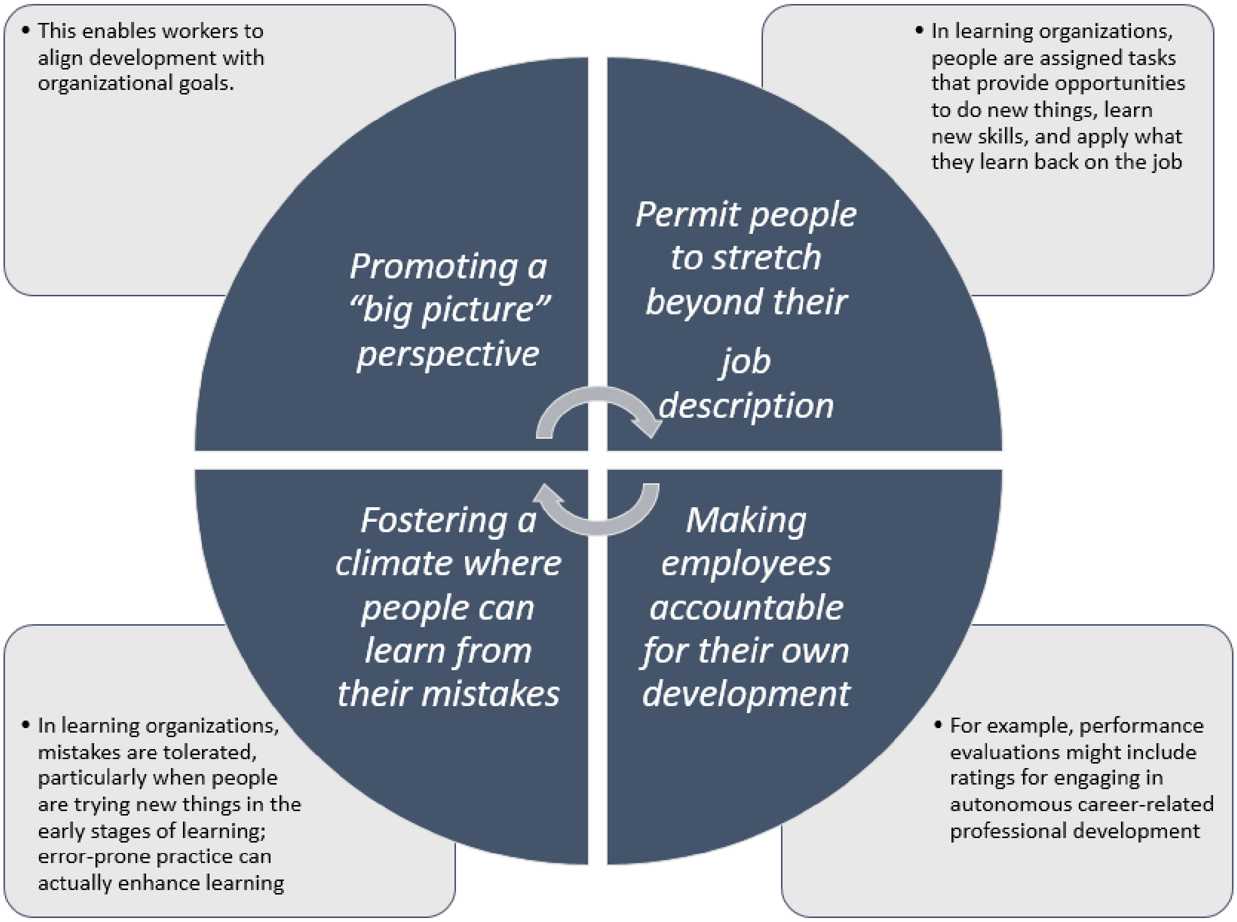
The effects of emotion labor – the perceived sum total of emotional input and burdening – is an area to be explored as well. Taxer and Frenzel evaluated a group of secondary school teachers and assessed both their hidden and their surface emotions. They reported: "teachers who reported frequently genuinely expressing their positive emotions were efficacious, felt related to their students, were mentally healthy, satisfied with their jobs, and had low levels of emotional exhaustion, whereas teachers who reported frequently genuinely expressing their negative emotions had low teaching self-efficacy beliefs, poor mental and physical health, were emotionally exhausted and unsatisfied with their jobs" (88). This area of research could be used to further see how different instructors handle being authentically and emotionally genuine in the classroom and those that withhold and bury different emotions while in the classroom.

Professional development itself was not explored in this research; however, the research presented in Appendix C has a potential impact factor with future professional development research. Tannenbaum found that the organizational environment plays a key role in employee development (97). Blume et al. also found three elements in the work environment that are critical to growth (98). *Figure 3.18* and *Figure 3.19* below illustrate the main findings for effective work environments.

Figure 3.18 - Main Ways to Improve Professional Development

Adopted from Blume et al. (98). Environmental support for training, including peer and supervisor support; Transfer climate, in the form of implicit cues in the environment that using what is learned in training on the job is expected, such as peers who actively transfer their new knowledge; organizational constraints, such as lack of autonomy and other situational factors

Figure 3.19 - Methods for Creating an Environment for Long-Term Growth



Adopted from Tannenbaum (97).

The research presented in Appendix C is not only a way to understand to an extent the inner working of one faculty member, but as a launching point into further teacher change research.

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Chapter 4. Student Evaluation of Teaching in an Engineering Class and Comparison of Results Based on Instructor Gender

The published paper is located in Appendix D; the paper was published in Chemical Engineering Education, Vol. 52, No. 2, Spring 2019.

4.1 Introduction

Regarding faculty positions at American institutions, criteria for pay and promotion in higher education assumed that good teaching and good research go hand in hand (1). As such, having a sufficiently good research program was an adequate performance standard that could be used to reward professors with tenure, often placing little value on teaching and instruction (1). With the trend in higher education shifting to having teaching faculty and departments shifting more influence on teaching in tenure and promotion for full professors, various factors can be considered to ensure that quality education is delivered to students. Thought has been given to using different performance measures to access teacher performance (2), but evaluations tend to become strongly skewed to focus on examinations as teachers start preparing classroom materials. Achievement-based models for both teaching and learning that are effective, affordable, fair, legally defensible and politically acceptable need to be created to allow for a more holistic assessment of teaching (3). Currently, one of the main, and often only, forms of evaluation of teaching is end-of-semester student evaluations of teachings (SETs) (4). At the University of Arizona, they commonly are called Teacher-Course Evaluations (TCEs). With such a large domain of instruction review being placed on only one form of evaluation, the importance of having an unbiased and fair evaluation of teaching is paramount. An ideal case would involve having the entire student population respond to the TCEs in an adequate and responsible period while students have a clear remembrance of the course. Additionally, each of the questions on the TCE would not provoke any unforeseen biases, and the evaluation process would accurately determine the effectiveness of the instructor.

However – and practically speaking – the ideal case is an unlikely event on all accords. In particular, when we factor in the ideas from previous chapters about affective factors for student success, there exists a plethora of different motivations for students to complete a TCE. Anecdotally, and as seen by Dommeyer et al, when no incentive is given by the instructor to the students, response rates tend to fall to 50% or lower (5). Some instructors tend to offer incentives to students, such as bonus points or the ability to exempt a grade, to promote the completion of TCEs. Unfortunately, there is not a high degree of intrinsic motivation from the average student to complete a teacher evaluation. When no incentive is given, only the highly motivated students respond, and generally out of moderate to strong emotional response to the course or instructor; additionally, students feel motivated to respond if they feel they can provide meaningful feedback to the instructor (6–8). When incentives are given, students in the author’s courses have reported that they rushed to complete their TCEs, even though the university and instructor(s) remind students of TCEs well in advance before they are due. On a student’s priority list, giving feedback on instruction tends to fall short compared to the variety of other obligations students face near the end of a semester. The lowered priority students place on completing the evaluations is evident from their very concise responses on open ended questions. Therefore, the amount of time students allot for completing the TCEs (and lack thereof) tends to effect quality and quantity of submissions.

Concerning the questions, students tend to rank instructors on both factors that the professor can control and somewhat on those that they cannot. Mason et al found that professor characteristics dominated the determinants of performance, as well as the professor-specific areas (9). For instance, students rewarded instructors for using class time wisely, encouraging analytical decision-making, being prepared for class, and being pedagogically knowledgeable. However, students gave negative scores for what the instructor may not have had the power to control, which include lower grades, teaching difficult courses, a pace not preferred by students, failing to stimulate interest in the material also led to lower instructor scores (9).

Anonymity is a common practice with evaluations so that faculty cannot retaliate against students by linking responses to individual students. Even with the anonymity of the submission, different factors affect student honesty on responses. By making the submissions anonymous, Hopkins argues that there is less merit in the response, as personal accountability is lost (10). However, with anonymity comes a higher response rate. Psychology and the social sciences have found that masking the identity of respondents for nearly any sensitive material tends to dramatically increase response rates (11, 12).

The population of the participants can result in variations with the data obtained. For instance, one could expect a different response type between freshman/sophomores and junior/seniors as the epistemological beliefs of students changes over time (13). In addition, the expectations students have of the instructor, along with gender-role beliefs, play a significant role in the student evaluations. Fitting a stereotype tends to promote positive reviews from students, along with a mixture of displayed masculine and feminine qualities (14, 15). This creates a serious consideration for committees that evaluate promotion, contract decisions, or tenure: students appear to evaluate likability and competence for men and women on somewhat different bases. With behaviors directly related to teaching being constant, friendliness can increase female evaluations but not male evaluations; and in general, female instructors are expected to excel in masculine (e.g. competence) and feminine characteristics (e.g. warmth) (16).

It is likely that student responses may contain subtle or unmentioned bias against an instructor. For instance, Anderson and Miller tell of an anecdotal story where an Asian-American woman was reviewed and denied tenure due to negative SETs (17). The professor thought this was due to gender and racial biases; however, her SETs did not mention anything about her ethnicity or gender. Were the students biased against this professor? This is unclear, but having the knowledge that this bias is possible can lead to more awareness that the potential for bias during review is possible (4).

The paper found in Appendix D, submitted and accepted by the journal Chemical Engineering Education, delves into whether students show bias against a female instructor in the male-dominated field of chemical engineering. The results help clear up a largely confounding literature base, and provide a framework to build future research topics along the same lines.

4.2 The Use of a Co-Teaching Model in Higher Education

The paper presented in Appendix D discusses briefly the use of a co-teaching model to not only converge the two instructor's teaching practices, but also to help develop both instructors' teaching practices. The use of peer-to-peer instruction in the classroom has been identified by Angela et al. as a best activity that students engage in as a means for collaborative learning, including first-generation college students, low-income college students, and underrepresented students of color (18). If we extend this to the perspective of an instructor, and then modify the activity to fit as a form of faculty professional development (19), we can help instructors improve their teaching practices through faculty or staff peer-to-peer instruction. In the K-12 area, co-teaching models have established principles to include cooperation, communication, mutual planning, training and agreement about subject matter (20–22). Friend et al. describe co-teaching as having evolved from special education to the modern classroom, where two professionals with equivalent licensure share instructional responsibility and accountability for part or all of the school day (23).

Confusion exists around the topic, and the label, of co-teaching. Friend suggests that the term "apprentice teaching" be used to denote when a student or pre-service instructor is co-teaching in the classroom with an experienced instructor (23). For instance, Chizhik et al. describe that co-teaching could build student teacher self-efficacy when a student reported: "My [classroom] teacher made me feel like we were co-teaching. Like we are equals. She is expecting me to step up" (24). Another student states, from Bartlett et al. "The co-teaching with professor and practitioner was a great strength and the Change class was one of the more valuable classes I've sat through" (25). Friend suggests the students label the collaboration as apprentice teaching rather than co-teaching as there is a power and conceptual knowledge difference between the instructor and student.

Most instructors teach by themselves in a solo-teaching model (26). The co-teaching model could foster an environment that allows for transformative shifts in teaching practices. The resulting teaching evolution would be fostered by allowing the feedback of another equally qualified instructors (27). Dow and Thompson suggest that co-teaching should be evaluated through "intensity of effort through co-teaching" in which educators work together to build "maximum intellectual strength in themselves". Educators working together support large amounts of the weight of the curriculum and instruction, help students with retrieval of material through multiple repetition, and exert effort during the planning, implementation, and evaluation of ongoing instruction (28). However, in the traditional model of co-teaching involving a general education and special education teacher, Austin found that general education co-teachers were perceived as doing more work; additionally, co-teachers who had access to the collaborative practices, preparation, and supports considered them less valuable in practice than in theory as they were not deemed as helpful as expected (29).

Therefore, an equal balance of work between the participants is critical for the success of co-teaching throughout a semester, or if deemed beneficial, long-term for an extended set of years. In some teaching institutions, all instructors, regardless of years of instruction, were required to attend a pre-semester meeting and co-teaching workshop and collaboratively work on improving their teaching and learning (30). *Figure 4.20* and *Figure 4.21* found below and modified from Bitting and Arthurs (31), illustrate the foundation of teaching and learning at the university, as well as how the co-teaching model will contribute to the body of knowledge in terms of teaching and learning practices.

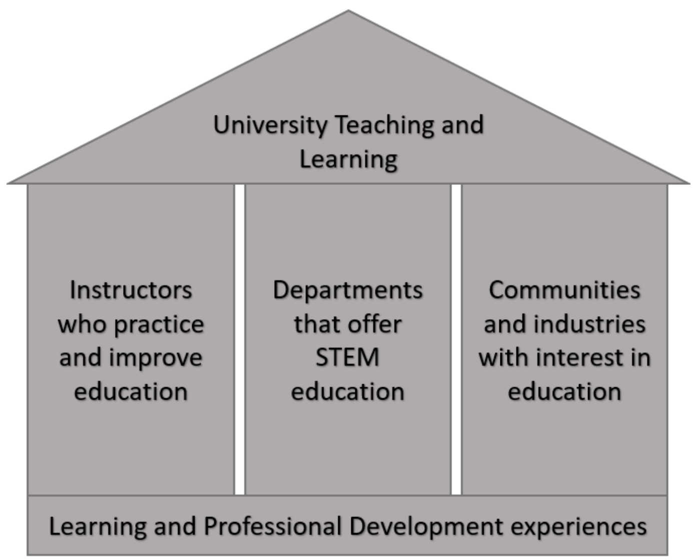

Figure 4.20 - Foundational Structure of the University Teaching and Learning
Modified from Bitting and Arthurs (31). Under the university, instructors, departments and communities/industries all support the teaching and learning of students. There is a foundation in learning and professional development experiences.

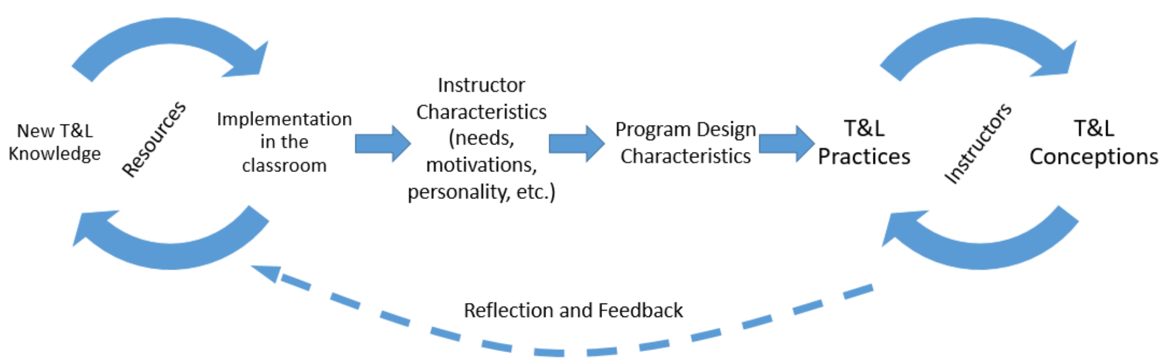

Figure 4.21 - Feedback Loop for Co-Teaching Knowledge

Modified from Bitting and Arthurs (31). Through the knowledge base of teaching and learning (T&L), the different practices can be implemented in the classroom. By applying the teaching practices through different instructors, and within a framework of program designs, the instructors give feedback to the original source of resources (be it a professional development specialist, a factulty learning community, a knowledgeable instructor who serves as a reference, etc) to build more universal knowledge.

Graziano demonstrated that in their 5-year-old institution (at the time), the co-teaching model allowed for individualized instruction, easier scaffolding of learning techniques by instructors, and better monitoring of students' understanding that can promote equitable learning opportunities (32). Ploessl et al. provide co-teaching practice techniques to enhance interactions between the special educator and general educator. Note that similar parallel structures could be implemented in a more generalized faculty-faculty co-teaching model in higher education, and these are seen in *Figure 4.22* and *Figure 4.23* found below (33).

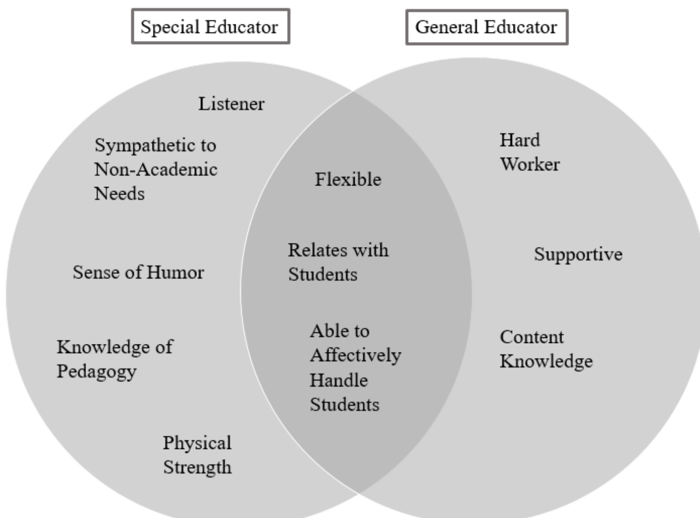

Figure 4.22 - Strengths within the Co-Teaching Model

Adopted from Ploessl et al. (33)

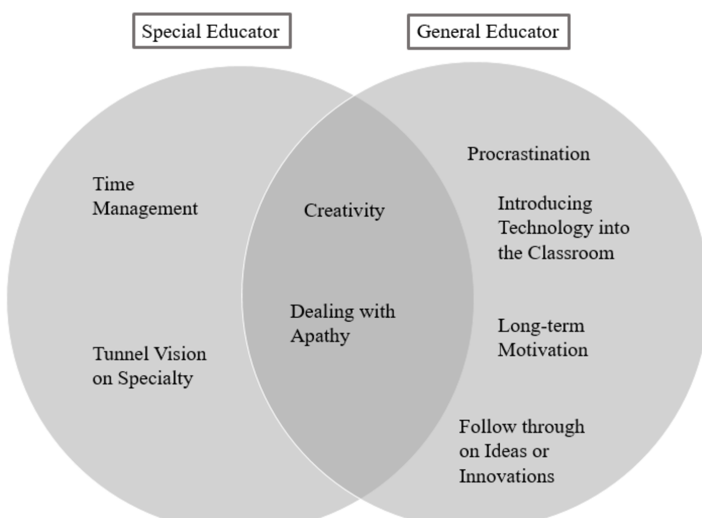

Figure 4.23 - Areas for Growth in the Co-Teaching Model

Adopted from Ploessl et al. (33)

Keep in mind that with special education, different assets are needed to run a classroom effectively, such as the Special Educator having "physical strength" or "sense of humor" to help regulate the classroom.

The idea of faculty-faculty co-teaching models is not new. Henderson et al. concluded that their physics co-teaching model was a cost-effective model that effectively promoted evidence-based instruction in new faculty. *Table 4.14* and *Table 4.15* found below taken from Henderson et al., list the course elements promoted through co-teaching, as well as the alignment of the course elements with different educational practices.

Table 4.14 - Course Elements Adopted and Promoted through Co-Teaching

Course Component	**Course component, Co-teaching**	**Course Component, one semester later solo-teaching**
Encourage students to read text before class	Reading assignment—students asked to submit a question about the assigned reading as well as to discuss an example problem from the reading assignment. Typically due Monday evening—submitted via WebCT	Reading quiz—WebCT quiz covering important aspects of the reading. Typically due Monday evening.
Use of class time	During class time there may be short lectures (5–10 min) when new topics are introduced. But, most of the class time is spent with students working in assigned groups (and, usually, white boards) on instructor-assigned activities. Activities varied from conceptual questions to quantitative problems—all were designed or chosen to encourage discussion and thought about the physics topics and discourage rote learning. The instructor(s) moved around and interacted with groups. When the instructor noted that many of the groups were finished or stuck, he would hold a whole-class discussion. This would start by calling on a group (typically at random, but sometimes chosen based on observations).	
Assignment of groups	At the beginning of the semester, students are assigned to groups of 3–4 based on where they live (as homogeneous as possible) and their performance in the prerequisite math course and conceptual pretest (as heterogeneous as possible). Gender was also considered, but given less weight than the first two factors. Students remained in these groups throughout the semester	
Online exercises	Each week 6–12 exercises were assigned. These consisted of conceptually oriented questions (often multiple-choice) or relatively simple calculations and were typically due on Wednesdays at class time. Grade recorded is average of up to four chances.	Used for reading quizzes
Online homework	Students were each responsible for completing their individual assignments on WebCT (although they were explicitly encouraged to work together). Each week four problems were assigned. These were similar to mid-level problems found in standard textbooks (they involved multiple steps and were specifically chosen to not be easily solvable by rote) and were typically due on Thursdays at class time. Grade recorded is average of up to four chances	Online HW was optional
Written homework	Each group of students was responsible for turning in a written solution (using the problem solving format) to each of the four WebCT problems.	Each student was responsible for turning in a written solution for six to ten HW problems.
Problem solving framework	Students required to include the following aspects of a problem solution in their written work: General Approach (big picture description of how to solve the problem, including relevant physics principles), Procedure (details about how to solve the problem, including specific steps), and Implementation (working out the details and evaluating the result). The use of these three aspects was modeled by instructor during class.	The three aspects of a problem solution were emphasized in class but not required in student solutions. Student solutions were expected to start from basic principles and show reasoning.
Use of main ideas	The important physics concepts covered during the course were broken into 21 main ideas that were explicitly categorized, frequently referred to in class and provided to students on exams. All problem solutions were expected to be based on one or more main idea.	

Table 4.14 - Course Elements Adopted and Promoted through Co-Teaching (cont.)

Course Component	**Course component, Co-teaching**	**Course Component, one semester later solo-teaching**
Testing	Each week a quiz or exam was given. The weekly quizzes focused on the material covered during the week. Every third week, there was an exam that focused on the material covered during the previous three weeks. Each quiz and exam had a similar format. There were two to four conceptually-oriented short answer questions and one multi-step quantitative problem that required a solution using the problem solving format. There was also a final exam with three multi-part conceptual questions and three problems. Complete written solutions were available on WebCT shortly after each examination.	
Quiz Corrections	After graded quizzes were returned, students had the option to complete a quiz correction assignment. The purpose of the assignment was to have students reflect on their quiz mistakes in light of the instructor solution and construct generalized physics knowledge. Quiz correction attempts resulted in an increased quiz grade of 50% of the lost points if done well and no change in the quiz grade if done poorly.	Not used

Adopted from Henderson, et al. (34)

Table 4.15 - Alignment of co-teaching activities within the cognitive apprenticeship framework

	Modeling	**Coaching**	**Scaffolding**	**Articulation**	**Reflection**	**Exploration**
Alternating being in charge of class	X	X				X
Weekly reflection meetings	X	X		X	X	
Course structure			X			
Access to previous materials			X			
Teaching on own						X

Adopted from Henderson, et al. (34)

4.3 Future Research Opportunities

After submitting this paper and it being accepted, many future directions can be explored that build off this research. In particular, the instructors studied in the paper have more semesters of data to be analyzed. The male instructor has continued to co-teach with other female faculty members and has co-taught with a transgender faculty member, allowing for the potential for future comparisons.

An area that would further allow for the understanding of student biases that may arise could look into affective factors influencing TCEs. What drives a student to have biases towards or against an instructor? How do the biases affect their learning? By understanding the reasoning behind why a student would unconsciously (or consciously) give a female instructor a lower rating than a male instructor in a male dominated field, or vice versa, could help determine ways to alleviate instructor rating differences and create a more fair environment for instructors and students.

To further support future research goals, having a bigger population size of instructorships would be ideal. As with any research topic, the larger the sample size, the larger the power of the results, and the more generalizable the results can be. Another way to build on the research would be to continue to improve the co-teaching model presented in “Student Evaluation of Teaching in an Engineering Class and Comparison of Results Based on Instructor Gender” to allow for a robust system of comparison between instructors, in particular if the instructors were closer in age or teaching experience. However, from my understanding, neither age nor teaching experience have been confirmed as being a significant factor in terms of overall teaching ability. The co-teaching model can be promoted by the "active learning" movement in higher education. As research is evolving towards understanding the benefits of active learning, showing the benefits of being student-centered or having engaging class periods. Such things as formative assessment and problem-based learning will benefit those who stay current with the research and will inherently have the potential for better teaching practices than those who do not. Newer faculty tend to have a higher degree of motivation to improve in teaching and instruction that older, tenure track instructors (35). Especially if faculty join a learning community, the newer faculty can be push to learn new techniques and implement them in the classroom (36). More research could also see if age or teaching experience effect evaluative results, in particular with the changing teaching focus in higher education.

Future research could also extend out to a female dominated fields and see where the relationship lies between student biases and the gender of the instructor. Beyond gender, future research could tie ethnicity or race into the mix. As mentioned in the introduction, an Asian-American woman was potentially ranked lower due to the assumed biases of white male majority students. Assuming she was ranked lower than male counterparts due to these biases, what affected that score more: the gender portion or the ethnicity portion? Alternatively, was it a mixture of both? Extending even farther out from ethnicity and gender, one can wonder what other traits about an instructor influence student perceptions. For instance, do teaching style or charisma of the instructor effect the evaluations of teachers? Even dating back to the 1970's when teacher evaluations were being more prolifically implemented, the debate raged on that ratings would favor an entertainer over the instructor his gets their material across effectively in a dry manner (1). The future of this research will continue to evolve as we gain further insight into perceptions of students and how they view instructorships.

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Chapter 5: The Future of Teaching Faculty in Higher Education

As the conclusion to the dissertation, there are no published papers associated with this chapter.

5.1 Summary of Dissertation Chapters

The past four chapters detailed different aspects of higher education. Each chapter had different threads through them, but all were in relation to being an instructor in higher education. Each chapter had various topics that listed where to dive deeper in order to conduct for future research.

Chapter 1 began by outlining six major documents which called for change in higher education. Those documents were:

6. Reinventing Undergraduate Education: Three Years after the Boyer Report (2001) (1) in response to the Boyer Report (1998) (2)
7. Report to the President: Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering and Mathematics (2012) (3)
8. Charting a Course for Success: America's Strategy for STEM Education (2018) (4)
9. A Five-Year Status Report on the AAU Undergraduate STEM Education Initiative (2017) (5)
10. Scaling Improvement in STEM Learning Environments: The Strategic Role of a National Organization (2018) (6)

In essence, there are various facets in which to focus on to improve in higher education. Chapter 1 then continued to describe modern theory on learning in general, from social learning theory, to mindset shifts needed in higher education. Following these sections, an introduction to cognitive neuroscience was presented.

Chapter 2 presented the two-part paper "Scalable and Practical Interventions Faculty Can Deploy to Increase Retention: A Faculty Cookbook for Increasing Student Success" found in Appendices A and B. These papers were designed as an easy reference for faculty or staff in an instructor role. Chapter 2 introduced emotions of students through affective domains, and how they can begin to be integrated into higher education. Additionally, further implications from cognitive neuroscience were explored. Various other strategies, not specifically presented in the paper, were also presented, along with future research opportunities surrounding implementing various teaching strategies shown to increase student success.

Chapter 3 presented the paper "Affective Factors that Influence the Implementation of Teaching Practices in a Large Introductory General Chemistry Course" found in Appendix C. This paper detailed how the teaching practices, and the decisions that an instructor makes in the classroom, are largely influenced by the affective states and drivers the instructors experience. The chapter further explored the concept of affect, argued for neuroscience support towards including more affective thought into instruction, and discussed ways for professional development and instructor growth to improve. Additionally, a special topic on the use of qualitative research, in particular the use of case studies, was presented. Future research opportunities were offered, opening the doors to either dive deeper into the instructor of interest, or expand outwards to other instructors.

Chapter 4 presented the paper "Student Evaluation of Teaching in an Engineering Class and Comparison of Results Based on Instructor Gender" found in Appendix D. This paper explained how gender can influence student evaluations of teaching, in particular when the instructor is in an opposite-sex dominant field. While controlling for a large number of aspects of instruction, a male and female instructor co-taught a course and results from their end of semester evaluations were compared. Chapter 4 emphasized the importance of appropriate assessment of instructors, as well as the different biases that can be found in higher education. The chapter also introduced different co-teaching models. Future research opportunities could look into the motivational factors of the students, as well as to gain a higher number of comparison to make this type of study reproducible. Additionally, the co-teaching model used in that study can be expanded upon and shared with the academic community.

In summary, the higher education landscape is changing. With the student population becoming more diverse and inclusive than a few decades ago, the instructorship needs to take into consideration the various complexities that arise as a result. New technologies and methods of instruction are continuously progressing to allow for a holistic education. Not only does the quality of instructorship need to improve to fulfill national standards for higher education, but the methods to monitor the quality of instructorship needs to progress. By considering the affective side of both students and teachers, in conjunction with the cognitive side of instruction, teaching and learning in higher education can evolve into a highly effective means of creating the next generation of successful students.

5.2 Future Directions

"To learn" is an action verb describing a dynamic process where students adapt to unique circumstance and experiences (7).

This thesis has demonstrated that teaching and learning have a plethora of different components to consider in order to create effective educational experiences. From a neuroscience perspective, learning involves the orchestration of a variety of interconnected networks. Every topic or skill learned in higher education uses multiple parts of the brain to lead to learning with the integration of various areas. The molecular-physical functioning of the brain backs the need to ensure that different brain networks are utilized to allow for a holistic education. On a more macroscopic scale, we see that the different brain systems support social, cognitive, emotional and cultural functioning. By focusing on the individual factors internal to students and factors external to students, instructors can develop a complete picture of learning (8). From a social and emotional perspective, learning cannot be fostered unless these disparate areas are addressed or incorporated into classroom experiences. Students may still be able to persist without a faculty member's direct understanding of the various interplays between the different factors; however, recognition of how they influence learning will allow for a higher quality, supportive, and impactful education (9).

When we look at the affective factors influencing not only student motivation, but instructor motivation, we can see that intrinsic drivers are critical to becoming life-long learners (10). As a recap, life-long learners require an inherent interest in a topic, but also prolonged motivation and persistence. Instructors can build curricula by tying the different ways in which a course or topic benefits students into a complete and coherent experience (11, 12). Individuals have unique sets of influences that they have experienced, changing the way they perceive and interpret the world and their role in it (13). The social and emotional dispositions of students influence how they approach tasks, and must be considered as well (14). Moreover, the culture of students can be a heavily variable factor – the emphasis on individualism or of focus on the community may influence how the learner thinks in the classroom and what they are motivated by (15).

With these thoughts in mind, we can proceed forward with future research directions. In addition to the areas of future research described in the previous four chapters, there are other areas to explore, not only through research, but also through professional development and classroom implementations. How People Learn II (HPL2) suggests two broad areas in which to focus future research: "understanding and embracing variability in learning and the potential uses and impacts of technology for learning" (8). With the variability in learning component, we can connect internal mechanisms of learning with the other factors of contextual variation, including culture, social context, instruction, and age. The various factors suggested from HPLII are categorized below.

5.2.1 Study Populations

As mentioned in the third chapter of the dissertation, simple case studies and small-N studies can be a significant addition to the Scholarship of Teaching and Learning. However, in addition to being able to dive deep into the contexts of a few select individuals or courses, the creation of large-N studies would be highly beneficial to higher education. The generalizability and robustness of results could be improved by looking at a multitude of populations. This dissertation mostly focused on teaching and instruction in higher education, but extending out to K-12 and non-academic learning environments could further contribute to understanding how learning can vary. Diversity studies and other multi-gender, ethnicity and age populations could help with the power of using the results of the research in terms of real-life situations. The end goal of such studies would be to affirm or contest different practices that have worked anecdotally or on a small scale.

5.2.2 Interest in Learning

Although Chapter 2 described a variety of different strategies instructors can use to increase student motivation, learning more about situational interest could largely benefit instructors. As we saw throughout the past four chapters, the affective side of an individual's experiences can be hugely influential to the buy-in for engaging in and mastering a particular topic. Understanding the interplay between intrinsic and extrinsic motivators could greatly improve the quality of education delivered by instructors, along with having the ability to positive influence the emotional side of students. When these factors help with sustaining interest, mindset and learning progress over time. Recognizing how they influence the allocation of effort and time could be fundamental to classroom planning and implementation.

5.2.3 Role of Identity in Learning

In Chapter 3, the dissertation investigated and instructor's personal factors and how they influenced her beliefs and identity in relation to her teaching practices. Research could extend into the student realm by looking at ways a student's beliefs about their cognitive abilities influence learning. In Chapter 2, we saw different interventions that can affect the goals, mindsets, study practices, self-efficacy, and feelings of belongingness for students. Research could also look into the specific learning experiences, not just in the Chemical and Environmental Engineering Department, but branching out to other departments or disciplines. An interesting concept to study would be the malleability of the learning identities, especially as students move through higher education. Can instructors influence the sociocultural norms associated with a student's identity to create a positive impact? How are the departmental cultures integrated into the student's view of themselves as learners? Understanding the answers to these questions would allow educators to better tailor the learning experience so the instructor could provide the general body of students with a quality education.

5.2.4 Motivation to Learn

As hinted in Chapter 3, motivation has a variety of different theories (such as expectancy-value and self-determination theory) and perspectives to take to understand different individual's drive for learning. However, a more unified higher-order understanding of motivation, albeit complex and intertwined with various factors, would help to understand the role of motivation in learning. Such factors could include psychological processes, social interactions, and cultural aspects. As the University of Arizona has become a Hispanic Serving Institution, with a diverse background of students, research could explore the boundary conditions of where motivational techniques could be applied and under what circumstances to enable more students to persist and move towards graduation. How could a model of motivation help promote students to become life-long learners to create highly impactful graduates that can solve the Grand Challenges of the world (16)? As How People Learn II states: "Most research on motivation has focused on psychological processes and dyadic or group interactions between peers or between students and teachers during instruction and in the context of a specific activity or task" (8). Future research can build from the different motivational review articles from Davis et al and Lazowski and Hulleman (17, 18).

5.2.5 Self-Regulated Learning

Transforming students that are not already self-regulated learners into independent learners could be one of the most influential abilities to foster in students (19, 20). To improve the development of this skill set, HPL2 states that the following are needed (8):

1. Studies that explore the development of self-regulation across time and across domains and disciplines
2. Studies that examine effective instruction in self-regulation in respect to individual development
3. Studies of environments that lend themselves to the autonomous discovery and development of a broad repertoire of self-regulated strategies.

Results from studies that investigate these changes would help with the applicability of self-regulation and the shifts to becoming autonomous learners in higher education. Future research would tie how self-regulation supports educators when building content knowledge over the course of a student's undergraduate or graduate career. Furthermore, different practices and interventions might need to be constructed to help transfer self-regulated learning practices into the classroom.

5.2.6 Influence of Learning Environments

As mentioned in Chapter 2, the classrooms used by the authors were largely collaborative learning spaces. These areas allowed for the implementation of many teaching strategies that otherwise would not work in a traditional, auditorium-style seating arrangement. As such, further study is needed on how the physical layouts of the learning environments, when combined with appropriate practices, influence learners' sense of belonging, adaptability, agency, and learning outcomes. Additionally, the contextual and personal factors in a classroom come into place with the "feel" of the classroom. With these components in mind, and by looking at the various objectives in learning, research could help understand how students can remain motivated and positively influenced in higher education classroom, particularly those with low success rates. For instance, a case study looking at how collaborative learning classrooms, in comparison to a traditional lecture style room, can allow for better usage of language in the classroom centered around belongingness could be effective at determining the effect size of "language used in the classroom" (see "Scalable and Practical Interventions Faculty Can Deploy to Increase Retention: A Faculty Cookbook for Increasing Student Success" in Appendix A and B under "Intentional Use of Language to Improve the Classroom Climate"). A hypothesis to be tested is: when using intentional language to build growth mindset, self-efficacy, metacognition, and belongingness, the effectiveness of such language is more effective in a collaborative learning space than a traditional classroom.

5.2.7 Learning across the Lifespan

As mentioned in the future research from Chapters 2 and 3, longitudinal studies to see the long-term effects of different teaching practices are critical to understanding which interventions will make the most impact on students. Large-scale pilot studies that span education from infancy to older adulthood would better understand the complete picture where the highest return of investments are for educators. For instance, how should an introductory instructor treat an 18-year old student fresh out of high school versus a 35-year-old parent coming back to school to build a better life by continuing their education? The median age of the U.S. population is increasing (21) and in general globally (22), thus research is needed on ways to optimize interventions to maintain student retention, cognition and brain health to maintain a well-educated population. The developments of an open-access database at the national level with student data could allow for retroactive and future studies to best find improvements and optimizations with the learning process (5). Having a shared data source to mine for causalities would allow for researchers to collaborate easier with each other and share significant findings concerning learning across the lifespan.

5.2.8 Learning Disabilities

With the rise of Universal Design of Learning (23) and advances in neuroimaging methods, the potential to substantially improve the ways learning disabilities are defined and diagnosed can be substantially improved. However, little integration has occurred between the field of neuroscience and studies of interventions for enabling students with diagnosed learning disabilities to become successful in college classes (8). As we will see in the next section, technology will be a major player in the educational story of those with learning disabilities. As learning disabilities are being explored more (but not extensively enough) (24), the accommodation of students with a variety of needs can be fulfilled. An important note is that the resources that students with learning disabilities use can also largely benefit those without diagnosed or understood learning disabilities (25).

5.2.9 The Future Use of Technology

As any modern instructor has seen in their classrooms, the use of technology by students has exploded over the past decade. In particular, with the rise of laptops and use of smartphones (26), availability of sophisticated teaching practices and use of formative assessment can be capitalized. Learning across the life span can be supported by technology, and best practices in the classroom vary widely among instructors (27). As we saw in the neuroscience section in Chapter 1, inappropriate use or disregard of the technology may be hindering students in multiple ways (28). With the increase of technology in the classroom, there is no reason why instructors cannot use the advances to help tailor instructor to better use evidence-based teaching practices (29). However, understanding the relationship between the integrated use of technologies to improve teaching and learning and technologies needs to be explored. There is a conversion phases between those who did not grow up in the digital age and those that have (30–32). Yet, practicing researchers have found that pre-digital age individuals can adopt to new technologies, such as smartphones, if they are willing and have the correct motivation (33, 34). With various case studies on technology coming out (35–40), comprehensive, systematic meta-analyses of research on the impacts of different multi-functional learning technologies can provide better guiding for instructors to reach desired learning outcomes. Looking at the relationship between social media and the academic environment can be explored as well. Are platforms like Facebook and Twitter good methods of connecting students to each other for collaborative learning? As we have threaded throughout the dissertation, learning is social; therefore will the appropriate use of social media allow for the greatest benefit to students? In terms of the learning environment, HPL2 reports that some evidence (but not enough to guide practice reliably) suggests that technology-based learning in informal settings can enhance achievement in school (8).

Another unexplored topic would be looking at the study of memories and retrieval practice (41). Future research could understand how memories are reconstructed, in conjunction with the different learning environments present in higher education (42). Such results on how reconstruction occurs could help with instructors incorporating different practices into the classroom and structuring how the class time is used (43). However, the interplay between the students' emotions and affective states could be hard to capture in parallel to assess the amount of learning in a course.

5.3 Final Remarks

Between the chapters presented in the dissertation, and the call for a deeper understanding of the incorporation of the emotional environment into the classroom, one could easily think that instructors need to dramatically transform their classrooms. This dissertation is not meant to suggest that instructors should tailor every moment of a student's education as if it were a coherent 4-year experience. Much of a student's education involves dealing with the unknown, failing, and sloughing through tedious tasks. Frustration, as we have seen in Chapter 3, often occurs. However, negatively emotional experiences are likely essential to learning. The emotional realm of students should not be avoided, but observed, appreciated and considered when making instructional decisions. Of the upmost importance is to provide a challenging, productive, and supportive environment for students to grow and flourish – if students decide to put the effort forward. A goal of higher education involves pushing students to the limits of their skills to create a future generation of minds to combat the upcoming Grand Challenges (16). Coddling students does not help them learn to work through adversity or push through difficulties. Overprotecting students through the academic process does not let them find their own inner strengths and the understanding that they can persevere. Therefore, the right integration of affective support and rigor needs to be applied.

Instructors should remember that not all fields of study are interesting to all students, and sometimes the students must simply push through to complete a course. As Cavanagh would suggest, instructors should remember that "When dealing with people, remember you are not dealing with [simply] creatures of logic, but creatures … of both logic and emotion, and that logic itself is emotional" (10).

Humans' drive to understand is powerful. Students will impose their own perceptions and experiences to build their own realities so what happens around them is congruent with their beliefs. This inclination has the potential to be a prevailing objective for learning if directed at suitable tasks and activities. Instructors have the opportunity to build learning environments to best provide new experiences for student to be able to understand the world around them. By comprehending the world around them and applying critical thinking skills learned in higher education, the future generation of students will likely create innovative processes and products to combat the major challenges in the world. Conversely, if instructors do not engage students appropriately, and provide artificial, decontextualized tasks, students will disengage and only learn to deal with academia as a game to beat. Such strategies will be conceptualized as simply "doing school" (8). Furthermore, allowing for discussion and the social interactions in the classroom will engage and challenge learners in the ways they need for growth.

In summary, this dissertation emphasizes that throughout their life span, students continue to learn and grow. Their choices, motivation, contextual factors and capacity for meta-cognition, influence how much and how well they learn and are able the transfer of skills to the world outside of academia. Additionally, active engagement largely predicts long-term growth. Learning outside of academia occurs through the learner's motivation, interests, and opportunities. Complex work that is demanding and challenging to an appropriate extent, physical exercise, social engagement, and adequate sleep are all associated with lifelong learning and healthy aging.

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Conclusions

There are a few main points that this dissertation would like to disseminate. Broken down by chapters, these are the highlights of each chapter. In essence, these lists are the culmination of each section and the abbreviated main take away points.

Chapter 1 – The Current State of Higher Education

1. The United States Department of Education and leaders in higher education can increase support for teaching and instruction to support the education of students. These students are our future leaders, workforce, and decision makers. They require and deserve the most effective methods of instruction in STEM education.
2. The United States needs to catalyze widespread adoption of empirically validated teaching practices by increasing programs to help facilitate faculty adoption of evidence-based teaching practices, federal funding through National Science Foundation (NSF) grants, and request the National Academies to develop metrics to evaluate STEM education.
3. Elements for instructional change involve pedagogy (such as articulating learning goals, having educational practices, adequate and fair assessments, and access from all types of students), extend into scaffolding (providing professional development for faculty, along with easily accessible resources, collecting and sharing data of program performance, and aligning future facilities planning) and culminate with cultural change (such as leadership commitment, establishing strong measures of teaching excellence, and aligning incentives with the expectation of teaching excellence).

Chapter 2 – Scalable and Practical Interventions Faculty Can Deploy to Increase Retention: A Faculty Cookbook for Increasing Student Success

1. There are wide varieties of effective teaching practices that enhance a student's learning experience compared to a didactic lecture that is not engaging. By delving into the affective factors of learning, we can promote a variety of different social and emotional learning goals. Students can build upon cognitive regulation, social skills, public spirit, identity and agency, and emotional regulation to become better well-rounded individuals.
2. Four high-impact affective factors involve promoting a growth mindset,building student self-efficacy, developing student metacognition skills, and creating a sense of student belongingness. By integrating these four affective factors together, and applying them with different instructional practices, we can modify those practices to allow for an impactful classroom that leads to student retention and developing quality graduates of higher education.
3. By practicing self-reflection after selecting different teaching practices, instructors can more readily identify teaching practices that align with their core identities as instructors. Additionally, if a faculty member is aware of a general weakness in their instructional practices, they can take action to target that weakness for continued improvement. Through reflection, the design and management of the classroom environment can be shaped to suit the instructor and still meet the needs of the students.

Chapter 3 – Affective Drivers that Influence the Implementation of an Instructor's Teaching Practices in a Large Introductory General Chemistry Course

1. In the case of instructors deploying new teaching practices, the script is flipped: the instructor is now a student of different educational techniques. Therefore, we should consider both the affective (values, motivation, attitudes, stereotypes, and feelings) and cognitive (synthesis, recollection, comprehension, evaluation, analysis) domains of the instructor as a learner as they try using new teaching methods.
2. Each instructor adopting different practices is unique; they will have a variety of different affective drivers that have an impact on how they grow as a practitioner and adopt different methods of instruction. To help facilitate the growth of an instructor, these drivers need to be considered to have a more streamlined and effective environment for the instructor.
3. When considering the instructor in the case study of Chapter 3 (found in Appendix C), we found that she had two main categories of drivers: internal (focusing on her internal affective state) and external (how she impacts those around her, in particular, the students). Should she want to implement different teaching practices, such as those found in Chapter 2, she would want to consider how they align with her affective drives, and use that perspective to find the most personally viable practices.

Chapter 4 – Student Evaluation of Teaching in an Engineering Class and Comparison of Results Based on Instructor Gender

1. As we improve the quality of instructorship, evaluating the condition of instruction can be an elusive task. A variety of measures should be taken to get a holistic appreciation for an instructor. Often, the simple and widely used approach is to analyze solely the student evaluations of teaching as a source of instructor quality. In a male dominated field such as chemical engineering, the landscape of the literature does not allow for any solid or conclusive evidence for or against gender biases against female instructors.
2. The study presented is a step towards eliminating the different confounding variables found in the literature and provides a structure to conduct future studies. Although this work was a case study without generalizable results, the co-teaching model used in the study will allow for a classroom that helps eliminate the variables that tend to make conclusive claims elusive. Future work could pursue answering more question.
3. For the course under study, the data suggest there was a bias against the female instructor. However, to become more generalizable and stronger in future studies, researchers will need to control for instructor age, years of experience, and other factors. Preferably, new faculty who have minimal teaching experience and reputation would be compared after a few semesters of co-teaching. Different males and females should be used to further allow for a greater statistical power of results.

Chapter 5 – The Future of Teaching Faculty in Higher Education

1. There are still wide varieties of areas to study to advance higher education. Different areas of future research include:
    - Diversifing the study populations of interest
    - Understanding the interplay between intrinsic and extrinsic motivators
    - Studying the role of identity in learning
    - Delving into higher-order levels of why students have different motivators to learn, and using those to capitalize on and grow student interest
    - Promoting self-regulated learning
    - Understanding the influence of learning environments
    - Understanding how learning across the lifespan is influenced and changes over times
    - Learning how to appropriately address learning disabilities
    - Managing how to integrate the future use of technology
2. The emotional realm of students should not be avoided, but observed, appreciated and considered when making instructional decisions. Of the upmost importance is to provide a challenging, productive, and supportive environment for students to grow and flourish – if students decide to put the effort forward. A goal of higher education involves pushing students to the limits of their skills to create a future generation who can address the upcoming Grand Challenges as defined by the National Academies of Sciences.
3. Coddling students does not help them learn to work through adversity or push through difficulties. Overprotecting students through the academic process does not let them find their own inner strengths and the understanding that they can persevere. Therefore, the right integration of affective support and rigor needs to be applied.

Appendix A

Scalable and Practical Teaching Practices Faculty Can Deploy to Increase Retention: A Faculty Cookbook for Increasing Student Success: Part 1

Abstract

Student retention in college is often expected to be handled by advisers, staff, and administrators. The university classroom—specifically, the pedagogies and practices that are utilized there—is a largely untapped resource in our quest to increase student success and retention. Instructional faculty are the only members of an academic institution that students are required to interact with regularly. For most courses offered in higher education, the contact time between faculty and students is typically three hours per week; faculty can have a significant impact on student outcomes in that time. This paper discusses low-cost, scalable teaching practices that span the affective domains of growth mindset, self-efficacy, metacognition, and belongingness. These teaching practices helped increase student retention by 30% in an entry-level core engineering course at our institution. Our institution is a newly designated Hispanic-Serving Institution that is also a land- and space-grant university, a Research 1 university, and a member of the Association of American Universities (AAU). The total enrollment is approximately 45,000 undergraduate and graduate students. The techniques described in this work can be deployed either simultaneously or in discrete sets to help students remain engaged in the educational process and successfully graduate. Because teaching is a universal practice, the teaching practices can be deployed in nearly every discipline and at every academic level, and most are independent of which instructional modes are being used, e.g., active learning vs lecturing, large vs small classes, or online vs in-person delivery. The specific implementation and effectiveness of the teaching practices may differ in each of those contexts, but improvements in student success and retention can be expected. We strongly recommend that a reflective process be deployed throughout implementation of the different teaching practices. This will allow for personal and professional growth in the instructor as they deploy the techniques while also improving the efficacy of the techniques themselves over time as they are refined for the local teaching environment.

Introduction

Statistics on Why Students Leave College and STEM Fields

The current state of degree attainment in higher education is concerning. The U.S. Department of Education reported in 2015 that nearly half of all students who begin college do not graduate within six years. Future employers will require higher education as information and technology begin to dominate employment markets [1], [2]. Students who receive a bachelor's degree have lower rates of unemployment and earn approximately one million dollars more than a high school graduate over the course of a lifetime [3]. By 2020, Georgetown Public Policy predicts that two-thirds of jobs will require postsecondary education or training [4].

When focusing on STEM education, national agencies such as the National Academy of Sciences, National Science Foundation, and U.S. Department of Education call for improvements [5]–[7]. Approximately 30% of students pursuing a bachelor's degree entered a STEM field in 2003-2004. However, between 2003 and 2009, 50% of those students and nearly 70% of students pursuing an associate's STEM degree left higher education or switched to non-STEM majors [8]. With so many students dropping out entirely or switching to non-STEM majors, it is imperative that we reform our teaching practices. Teaching practices need to become more student centered to provide educational experiences and settings that promote the retention of capable students in these rigorous fields.

Student-Faculty Relationships are Critical to Student Success

Research has shown that most engineering students leave engineering due to deficits in one or more of the following four areas: academic and career advising, high school preparation, engineering structure and curriculum, and faculty relations [9]. This paper focuses on faculty relations because, historically, universities have relegated retention issues to staff and advisors. The importance of faculty influence on student retention is an under-researched and under-explored area. Specifically, faculty-student relations can be shaped through the adoption of specific teaching practices that instructors can use to increase student retention. Research supports the claim that student-professor relationships are vital in promoting the success of engineering students [10], [11]. One explanation for this is that, on average, faculty spend the most time with students, compared with staff, administrators, and advisors. For most courses offered in higher education, this time is at least three hours per week; for research mentoring, the faculty contact time can increase dramatically [12]. Classroom interactions between students and faculty have a significant potential to influence students' graduation path [13]. Yet, when considering instruction by faculty, engineering students reported that the quality of instruction in engineering was lower than in their non-engineering courses [14], [15]. A 2017 study by Gandhi-Lee et al. found that most faculty are unaware of actions that positively influence STEM recruitment and retention. Gandhi-Lee et al. promote professional development to better train faculty in identifying changes needed to support STEM student recruitment and retention [16], [17].

Four Domains for Improving Retention

Faculty interactions with students can contribute to increasing retention rates. One way to address this is to improve teaching practices. We suggest focusing on four areas of instructional practice that may create more successful learning environments.

We challenge faculty to modify their teaching practices to support the following outcomes in four specific affective domains:

promote a growth mindset
build student self-efficacy
develop student metacognitive skills
create a sense of student belongingness

Descriptions of the Four Affective Domains

Growth Mindset

Growth mindset has developed out of Dweck's work with entity and incremental theories of intelligence [18]. Dweck postulated that growth mindset was important to student persistence and success [19]. Additionally, Heyman, Martyna, and Bhatia showed that many engineering students have fixed mindsets about their intelligence—they believe that intelligence cannot be changed or improved with practice or training [20]. As a result, many engineering students enter higher education with performance goals and expectations of striving to earn good grades rather than with the goal of mastering the content. Students who develop a growth mindset are able to accomplish goals and focus on long-term improvement rather than short-term rewards [21]. Conversely, students with performance goals typically decrease the amount of time and effort spent on difficult tasks to focus on the short-term reward of grades [22].

Based on the extensive research supporting growth mindset, some have called for mini-lessons on growth mindset through a student's education that encourage students to understand and transition to a mastery focus [23]. With a growth mindset, students control their own learning and understand that intelligence can increase over time with effortful practice [24]. Rendon further supports this notion by showing that even the most vulnerable non-traditional students can transform into powerful learners through academic validation [25]. Thus, instructors can use teaching practices to transition their students' fixed mindsets into growth mindsets.

Self-Efficacy

Students with high levels of self-efficacy are less likely to drop out of college [26]. Self-efficacy is an aspect of social cognitive theory defined as "the exercise of human agency through people's beliefs in their capabilities to produce desired effects by their actions" [27]. As with growth mindset, self-efficacy is domain-specific. Students may have high self-efficacy in one discipline that does not necessarily transfer to a related discipline. Four proposed sources of self-efficacy are mastery experiences, emotional/physiological states, social persuasion, and vicarious experiences. Social persuasion and vicarious experiences are the most impactful [28].

Prior research has demonstrated a systematic link between the use of innovative teaching practices and increases in student self-efficacy [29]. For instance, collaborative groups improve self-efficacy regarding task achievement because group members challenge peers to cope with difficult content and group dynamics [30].

In particular, teaching practices that increase self-efficacy can help non-traditional and at-risk students. Underrepresented minorities often have lower levels of self-efficacy compared with their peers. This suggests that targeted changes in self-efficacy teaching practices will lead to higher levels of retention for these groups [31]. The same is true for first-generation college students, women in male-dominated fields, and students with a low socioeconomic status [31], [32]. Increases in self-efficacy can lead to higher levels of persistence in their designated majors and benefit society by retaining capable students [33], [34].

Metacognition

Metacognition involves an awareness of, and thinking about, one's own thought patterns [35], [36]. Researchers have demonstrated that students who achieve academic successes are better able to pay attention, analyze, and adjust their approaches to learning compared with less academically successful students [37], [38]. One important component of metacognition is the ability to plan, monitor, and evaluate learning. This is called self-regulated learning[39], [40]. As Zimmerman stated, self-regulated learning is about transforming "mental abilities into academic skills"[41]. Considering concepts such as Bloom's taxonomy [42], students' success can be fostered through direct instruction that challenges them to move from using lower-order to higher-order thinking on Bloom's scale.

Promoting student metacognition includes instruction that explicitly helps students learn how to retain information, apply information to new situations, and skillfully and creatively solve new problems. In introductory chemistry courses, metacognition assisted students in attaining deeper understanding of concepts and helped them become more expert problem solvers [43], [44]. McGuire showed reflective thinking can be practically and successfully introduced to students [45].

Belongingness

The concept of belonging, or fitting into one's environment or group, was developed in the higher education context in response to observing the many students who leave college. In particular, Tinto's proposal that leaving higher education is due to a lack of social integration has broadly informed the field [46]. Current research suggests that one's sense of belonging in an academic context influences individuals in at least three ways: academic motivation, academic achievement, and well-being [47].

Walton and Cohen implemented a successful practice to frame perceived adversity, such as social discomfort, as nonthreatening. They presented quotes from academically older students sharing uncomfortable experiences that they overcame, which increased new students' sense of belonging [48]. This teaching practice helped lower the minority achievement gap and increased minority students' grade-point averages. Additionally, minority students self-reported improved health and well-being. With open communication, teachers and students can foster a vital relationship that positively influences students' capacity and motivation for critical reflection and learning [49].

Burns and Lesseig studied how infusing empathy into the design of lessons would influence student interest in STEM and STEM careers and develop a sense of belongingness [50]. Preliminary results suggest that infusing empathy teaching practices into classes may have a positive and rewarding impact on interest and belongingness for males and females. Sense of belongingness helps explain the gender differences in retention rates and the success of students in STEM and in health care, elementary education, and domestic spheres, with males preferring STEM fields and women preferring the other domains [51]. Such gender stereotypes can be broken through practices that allow students to feel welcome in their chosen major [51]. We note that there has been little to no research on non-binary or other self-reported gender identification and its impacts on any of the affective domains.

Interrelatedness of the Affective Domains

Growth mindset, self-efficacy, metacognition, and belongingness may act synergistically or antagonistically. For instance, with a self-efficacy teaching practice, Marra and her colleagues indicated that women showed positive increases in self-efficacy, even though women also show a significant decrease in feelings of inclusion while they stay in engineering programs. This suggests an antagonistic relationship can be possible with belongingness [52], [53]. Stump et al. showed the relatedness of self-efficacy, belongingness, and growth mindset through a bivariate correlation analysis. Their results showed that students' intelligence beliefs correlated with active learning strategies. Additionally, self-efficacy, reported use of collaboration, and incremental beliefs (growth mindset) about intelligence predicted students' reported use of knowledge-building behaviors. Many studies have shown that mastery training toward a growth mindset helps improve student self-efficacy and vice versa suggesting that the two could be synergistic [54]–[56].

These effects are not always universal. For instance, Rhee et al. used growth mindset and belongingness teaching practices in a freshman engineering class to improve students' exam performance. While both practices helped students with their exam performance compared with a control, belongingness was the most impactful compared with growth mindset. However, the results were not uniform across all students. Among women, the growth mindset teaching practice resulted in lower course performance compared with the control and belongingness groups. Among men, the belongingness teaching practice resulted in higher course performance than in the growth mindset and control groups. Additionally, the teaching practices did not differentially affect course performance among underrepresented minorities. Among non-underrepresented minorities, the belongingness teaching practice led to more improvement in course performance compared with the growth mindset and control conditions [57].

Note on Implementation

Wormeli suggests that the best educators, like engineers, embrace systems theory and focus on multiple areas for improvement in teaching practices, as opposed to many simple factors working in isolation [58]. When implementing the strategies described below to cause shifts in the four affective domains for students, we suggest focusing on one or two teaching practices per semester for a given course. As suggested by Elmore, systematic, scalable change can realistically happen by pushing in a few strategic places and then observing the results [59]. In addition to promoting a growth mindset in students, we suggest that instructors foster a growth mindset in themselves about their own teaching practices, which allows instructors to gain practice with the process of developing a growth mindset and thus lead students by example. Skill sets take time to develop and become innate, but with practice and active use, the acquired skills become easier to implement.

The techniques and practices described below may help other faculty members implement these practices in their own classes. Our goal is to provide a comprehensive list of practices that have shifted our retention of students in chemical engineering from 60% to 90%, well beyond prior retention results [60]. We suggest that the evidence-based teaching practices described below may allow for an improved, more inclusive learning environment compared with the traditional classroom. The learner-centered teaching strategies are based predominantly on research showing their effectiveness across the STEM disciplines. The relevant data supporting these teaching practices have come from numerous different disciplines, including the learning sciences, cognitive psychology, and educational psychology [61], [62]. A growing body of research within specific scientific teaching communities supports and validates our approaches to teaching [62].

When implementing change, faculty are more likely to put effort into pedagogical reform if they understand the goal of the reform, are committed to improving teaching practices, and believe in its success to retain capable students [63], [64]. Even if faculty are motivated to change their teaching practices, their main implementation barrier is lack of time [65]. Shifts in practices require shifts in how instructors define their own teaching practices, and much like student misconceptions, dislodging old teaching beliefs can be difficult [66]. There may be teaching situations in which the instructor may not consider student affect or experience, and these may be the most critical moments in which to do so. Formative assessment is an aspect of teaching that allows instructors to understand where students are in their learning and subsequently make changes in their teaching. If formative assessment reveals that groups of students are struggling to grasp a concept, some instructors might assume that there is "something wrong" with the students, a view sometimes referred to as the student deficit model. This model infers that these students, otherwise equal to their peers, are somehow lacking intellectually. An alternative to the deficit model, the dynamic model, calls on instructors to consider individual characteristics of students that might alter their experience of the learning environment and hinder their conceptual learning [67].

This paper provides practical examples that faculty can use to improve teaching effectiveness and student retention. We structure our descriptions of the practices below using the framework of growth mindset, self-efficacy, metacognition, and belongingness. The following table lists numerous teaching practices and indicates which affective domain is addressed by a given practice. The subsequent description of each practice contains citations to studies in which these practices were studied or described.

Table of Teaching Practices that Can Influence Student Retention through Growth Mindset, Self-Efficacy, Metacognition, and Belongingness.

In Table 1 below, we identify a number of classroom practices that instructors can implement to improve student success. Future research needs to explore the effectiveness of each implementation across disciplines, quantify improvements in student success, and qualitatively measure changes in student perceptions within each affective domain.

Table 1: Teaching Practices that Can Influence Student Retention through Growth Mindset, Self-Efficacy, Metacognition, and Belongingness				
In the Classroom				
Teaching Practice	**Growth Mindset**	**Self-Efficacy**	**Metacognition**	**Belongingness**
Active Learning	√	√	√	√
Formative Assessment	√	√	√	√
Using a Student Response System	√	√	√	√
Intentional Use of Language to Improve the Classroom Climate	√	√	√	√
Teaching Learning Strategies to Students	√	√	√	√
Modeling Behavior	√	√	√	√
Pre-lecture Quizzes		√	√	√
Use of Learning Assistants		√	√	√
Use of Real-World Problems		√	√	√
Music in the Classroom		√	√	√
Student Teams		√	√	√
Student Teams: Underrepresented Minorities and Women		√		√
Incrementally Solving Problems in Class			√	√
Cold Calling on Students		√		√
Learning Student Names		√		√
Job Openings and Internships		√		√
Lecture Capture			√	√
Class Structure				
Syllabus Practices	√	√	√	√
Soliciting and Using Feedback from Students Mid-Semester	√	√	√	√

Modifying Classroom Layouts		√	√	√
Grading on a Straight Scale	√		√	√
Regular-Interval Homework	√		√	
Group Homework and Exams			√	√
Requiring Attendance			√	√
Cumulative Exams and Quizzes		√	√	
Sharing Rubrics		√	√	
Posting Proficient and Distinguished Student Work	√	√		
Rapid Feedback on Exams and Homework		√	√	
Estimating Time Taken on Assignments			√	
Listing Class Objectives			√	
Outside of Class Events				
Student-Faculty Interactions	√	√	√	√
Informal Events for Students	√	√	√	√
Promotion of an Inclusive Cohort			√	√
Encouraging Office Hour Attendance			√	√

Classroom Practices

Overview

The table above shows the effect that various classroom practices can have on students. Here, we describe the reasoning behind the practices and why they work. In part 2, we frame this section of the work with our own trajectories in teaching practice to show how implementations were tried, improved, and what our next steps will be [68]. This demonstrates that we are re-engineering our classroom practices each semester based on the framework of the four affective domains: growth mindset, self-efficacy, metacognition, and belongingness.

Active Learning

The lecture format (teacher-centered) has been the primary method of instruction on college campuses since their inception. However, a variety of educational theorists have emphasized the need to take a more learner-centered approach to instruction [69]. Active and evidence-based instructional methods have repeatedly been shown to have positive impacts on student outcomes [70], [71]. These teaching methods affect the areas of growth mindset, self-efficacy, metacognition, and belongingness.

Rodriguez et al. found that when converting a Process Control class to an active learning environment, after the first year, students showed much higher motivation in the course, along with higher participation and better grades. The students displayed a growth mindset, and the change in classroom design promoted a sense of belongingness [72]. Soffa pointed out that the use of collaborative active learning leads to higher student self-efficacy [73], as did Wilke [74]. Wilke used active learning in a study of student characteristics in a human physiology course for non-majors, finding that even though the amount of content explicitly taught to students was reduced, students demonstrated similar, if not better, academic achievement compared with the traditional lecture control group.

In the area of cognition, students report more learning when active instructional methods are used [75]. Volet and McGill found that students applied more concepts when they were exposed to active teaching methods [76]. Bell and Kozlowski observed that students who were exposed to active learning approaches showed improvements in self-regulatory approaches to learning [77]. Bernold et al. relied on slightly older arguments about learning styles to claim that students who have different learning styles are discouraged from remaining in college due to a mismatch between lecture and learning style [78], although those theories have become less favored recently [79]. Additionally, students in active learning classes have a greater sense of belongingness in their field of study [80], [81]. The Bill and Melinda Gates Foundation funded research looking into the psychology of students. Dweck et al. found that academic tenacity increased with social belonging fostered by the active learning classrooms [82].

Formative Assessment

Formative assessment involves refining teaching practices based on an assessment of current levels of student performance [83]. The use of formative assessment in the classroom touches concretely on all four domains: growth mindset, self-efficacy, metacognition, and belongingness.

Concerning growth mindset, at a college for female students, Soffa collected data in three entry-level science classes. Soffa found that using clickers allowed students to check their understanding and created opportunities for students to experience success and develop a mastery mindset [73]. Lang discussed in Small Teaching how using formative assessment as part of deploying activities in class can build a growth mindset; with the right implementation, the activities also foster metacognition by requiring students to do retrieval practice [84]. In his book, Ellis found that the ways instructors used formative assessment and responded to students were more important to learning gains than what the teachers asked the students through summative assessment [85]. The result of the formative assessment was building the mindset that answering questions – correct or incorrect – in the classroom allowed students to continue to develop their understanding of the content.

Specific formative assessment practices have also been investigated. Talanquer et al. discussed the importance of asking why students give explanations the way they do in order to diagnose and correct student misunderstandings and to better interpret their statements [86]. Formative assessment like this not only allows instructors to accept a correct answer as proof of understanding but also promotes a more positive attitude toward error management [87]. Students felt that formative assessment led to validation of being a significant individual, which is one element of self-efficacy [86]. Pierce and Fox, as mentioned in a previous study, found similar results [88]. Skinner and Belmont suggested a link between using formative assessment and creating a sense of motivation for learning in students, which in turn affects metacognition and self-efficacy [89]. Decristan et al. studied the use of formative assessment in elementary school science classes and found students felt more belongingness from the increased belief that they were in a more supportive classroom [90]. This study also found that tasks involving higher cognitive load could be used when formative assessment was deployed. Best practices in formative assessment elicit student reasoning to increase the students' metacognitive abilities [91]. Student scores on tests were higher when formative assessment was used, indicating positive impacts on student metacognition [92], [93]. Also, students were predicted to have higher self-efficacy, agreeing with Soffa's conclusions [90].

Using a Student Response System

Student response systems are a technological subset of formative assessment allowing instructors to solicit and use student feedback. Inherently, using a student response system can have an impact on all four domains. Soffa advocated using clickers, a type of student response system, to positively impact growth mindset and self-efficacy by creating opportunities for students to experience successes with low-stakes self-evaluations, promoting students' motivation to challenge themselves and have confidence in their ability to solve tasks [73]. Hoekstra and Mellborn found that the use of clickers fostered class discussions and suggested that this had an impact on metacognition by increasing self-explanation [93], as did Black and Wiliam [94]. Lang argued that solving problems in class would foster metacognition because students benefit from seeing solved examples [90]. Clickers are a way of providing students with the ability to check their understanding in real time as they solve problems. The clickers provide rapid feedback to students that increases learning potential [95]. In order to foster belongingness using clickers, Turpen advocates using them for low-stakes scores, like for attendance, and not for high-stakes grades. The latter would lead to high academic achievers dominating the discussions while others are silenced [96]. Tanner and Seidel advocate in-class clicker questions not only for the reasons above but also to verify implementation of different activities and assessments as productive or not [97]. Various other sources promote student response systems as a method of improving belongingness and growth mindset when used correctly [81], [98].

Intentional Use of Language to Improve the Classroom Climate

Intentional use of language can have direct positive impacts on students and their beliefs. However, careless language can be devastating. Through instructor use of appropriate messaging, students can be motivated to build a growth mindset, increase their self-efficacy, develop more metacognitive strategies, and have a greater sense of belongingness. When faculty use language intentionally, they create an inclusive environment for all students to be successful. One intentional use of language is to verbally and explicitly create safe spaces for students to ask questions. Deil-Amen points out that it is hard for students to ask questions, [99], and the onus is on the instructor to help facilitate effective question-asking strategies. Tellhed et al. observed that belongingness improves when language is warm and inviting, particularly for women in engineering [51]. Daempfle advocates avoiding sarcastic or ridiculing language when attempting to foster belongingness [100]. Meyers gives various techniques to help prevent negative emotions and conflict in the classroom [101].

One area for helping students develop a growth mindset is to build error training into class language [87]. Error training is explicitly stating to students that making errors leads to cognitive changes that are a part of learning. Heimbeck et al. found that by having an error framework, cognition improved and increased subsequent learning [87]. Chillarege also pointed out that allowing errors to be a positive experience leads to higher performance later [102]. Targeted praise, like observing that a student has expended effort resulting in learning a concept, has been suggested to increase growth mindset [103].

Bell and Kozlowski advocated for using language that focuses on mastery goals instead of performance goals [77]. This can increase student self-efficacy when students receive confirmation that they successfully completed a task. McGuire made similar comments about self-efficacy with verbal confirmation of mastery [45]. Finally, Phan found mastery goals lead to deeper processing and an increase in learning strategies [104].

Belongingness is also influenced by the language used in the classroom. Walton and Cohen sought to improve the minority achievement gap in their college freshmen by aiming to lessen the psychological perceptions of threat on campus. This teaching practice was targeted at underrepresented minorities and successfully halved the minority achievement gap in the study population. The teaching practices prevented the students from seeing adversity on campus as a hindrance to their belonging [48]. Vogt observed that faculty distance—the disconnect between an instructor and a student—lowered self-efficacy, academic confidence, and GPA. Strong integration had a positive effect on self-efficacy, allowing for higher motivation and effort on school work, suggesting that students benefit when engineering faculty find ways to become personally available to students [105].

Teaching Learning Strategies to Students

Explicitly teaching metacognitive strategies to students strengthens student success. Paimin observed that undergraduate students do not recognize needed strategies in new contexts [106], and helping them transfer techniques, or exposing them to new ones, helps them become better learners. While some faculty believe they should be solely teaching students content and not how to learn [107], [108], Daempfle argued that deliberate teaching of metacognitive strategies is important, especially to first-year students [100]. Santos Lanaan said that teaching learning strategies explicitly helps break down barriers and make faculty more approachable [109], helping to fostering student belongingness.

Tei and Stewart sort metacognition into two main areas: knowledge about aspects of the learning situation (including self-capabilities and limitations) and self-regulatory activities to produce comprehension. At the beginning of a study session, successful learners have specific purposes or goals, structure reading material and content effectively, purposefully extract significant or useful information, and self-assess knowledge gained [110]. To address these issues, Dunlosky et al. [111], Weinstein et al. [112], Roediger and Pyc [113], McGuire et al., and Sprenger [114] all offer concise materials on different effective learning strategies based on metacognition.

Self-Explanation and Self-Regulation

Using active and collaborative learning in class facilitates self-explanation, which McGuire [45] and others [115], [116] have noted helps students learn content. Tileston advocates giving lists of steps that must be done to complete a problem as procedural knowledge [117]. Brahmia echoed this from increases in learning in physics where time spent developing reasoning increased the success of underprepared students [118]. VanLehn, Jones, and Chi claim that students who explain examples to themselves learn better, make more accurate self-assessment of their understanding, and economically use analogies while solving problems, building self-efficacy and metacognitive strategies [119]. Various other self-explanation and self-regulation strategies can be found in the work of Bielaczyc, Pirolli, and Brown [115].

Retrieval Practice, Spaced Practice, Elaboration, and Concept Mapping

Lang advocated that retrieval practice is effective [84]. This is when you ask students to struggle to recall content and not just look up an answer. If this technique is paired with spaced practice [120], students see a benefit in their studying [111]. As an example, students benefit more from spreading five hours of studying over one week then the same five hours all at once. Elaboration has been used to help students dive deeper into content and build understanding [121]–[123]. Concept mapping has been advanced as a means to increase learning before exams [45].

Modeling Behavior

Instructors actively modeling behaviors and practices from each of the four domains helps students who are struggling to adopt such practices themselves. For example, instructors can display growth mindset in the classroom, giving an example of how they want students to adopt such behavioral patterns [124], [125]. Balwant et al. showed that instructors can improve student leadership skills through context-specific approaches, which breaks leadership skills down into different dimensions and provides models of how to approach novel situations [126]. In a clinical qualitative study by Howe and Monin, when an expert displayed exemplary behavior, individuals who feared negative devaluation paradoxically turned off the very people they are trying to inspire [127]. In the classroom, this would translate to a flawless instructor: one who never makes mistakes and has endless content knowledge. Instructors do not need to always display their shortcomings, but displaying self-regulation promotes metacognition by example and belongingness through relatability to students [39], [40]. When instructors use the four affective domains to guide their teaching practices—in particular, applying a growth mindset toward courses—studies show an improvement in course design, implementation, and student satisfaction [128]. Although this shift to exemplifying the four domains to students can be daunting for some faculty, the transformative potential for classroom instruction far outweigh the risk and uncertainty [129].

Pre-lecture Quizzes

Pre-lecture quizzes (sometimes referred to as pre-quizzes) are another method of providing rapid feedback to students. Pre-quizzes can be implemented in learning management systems to eliminate the need to use class time to administer them. Research has shown that pre-quizzes contribute to the development of metacognitive skills and belongingness. Lang argued that this practice increases metacognition by engaging students with the content even before it is covered in class [84]. McGuire pointed out that most students do not read the pre-class assigned readings and therefore come to class unprepared [45]. In response, focused pre-lecture quizzes can create the need for active pre-reading, pushing students to arrive better prepared for class. Because individuals have a base of content knowledge coming into a classroom, teams make better progress on tasks, work more effectively together, and overcome collaborative inhibition through error correction [130].

Use of Learning Assistants

There are a variety of different uses and functions for learning assistants (LAs) in higher education. These undergraduate or graduate students generally aid students through direct interaction inside and outside the classroom. LAs ideally support students' learning by asking guiding questions, pressing for elaboration from students and challenging student (mis)conceptions; they can also help with running supplemental lectures outside of normal scheduled course time [131], [132]. Outside of instructional support, there are other benefits to using learning assistants in classes, such as increased vicarious self-efficacy by having the former students functioning as role models [133]. Student self-efficacy increases when students have positive, successful role models similar to themselves [73]. The learning assistants also model effective student behaviors, which helps develop metacognitive strategies [134].

Decisions faculty make in recruiting learning assistants can create positive impacts on students taking a class. Transfer students report they want to interact with students who had transferred into an institution, building a sense of belongingness [31][135]. Trujillo and Tanner said that students in a class would have greater belongingness when they are able to see what the "norm" for success is [136], which is why recruiting a diverse pool of learning assistants is important. MacPhee et al. discussed how self-efficacy and belongingness are fostered by talking about how professionals from diverse backgrounds are successful [31].

Use of Real-World Problems

The use of real-world problems in and out of class has also been shown to positively impact students' beliefs and successes. The National Academies Press reports that "[engineering] first-year courses that engage students in teams to solve real-world engineering problems have been shown to increase student persistence in the field" [137]. Soffa reported that students who solve real-world problems have higher self-efficacy [73], a claim also supported by Meyer and Marx [138]. Sivarajah et al. found that using real-life cases for differential diagnosis in radiology boosted student self-efficacy because the students' aggregate group diagnosis was very similar to that of an expert radiologist [139]. McKenna and Yalvac point out that engineering faculty strongly support contextualizing the information by giving real-world examples. This allows students to apply the information to solve complex problems, boosting metacognitive strategies [140]. Trujillo and Tanner discussed how using real-world problems at the start of class would engage students more and lead to higher levels of student belongingness [136]. Deil-Amen found and promotes a similar result [99].

Music in the Classroom

With the use of music in the classroom, we have found an increase in student self-efficacy, largely through a reduction in student anxiety. McGuire et al. advocate for the adoption of practices that reduce stress to enable success and build student confidence [45]. Tanner confirmed in her work in a large biology class that playing music humanized the environment and that students positively commented on how music impacted their comfort with being in the classroom with her [141], building a sense of belongingness. While some faculty may be averse to adopting teaching practices that address student emotions such as anxiety, Elliott et al. and Seinfeld et al. illustrated how music can reduce the response to stress-inducing activities, such as competitive sports and the fear of heights [142], [143], functionally improving self-efficacy. Fukui also showed that music can help facilitate the neurogenesis, regeneration, and repair of neurons [144], while Meng et al. and Xing et al. observed cognition improvements in rats and mice exposed to music while they were learning how to perform different tasks [145], [146].

Student Teams

Placing students in teams for class activities can lead to many positive outcomes, particularly with self-efficacy, metacognition, and belongingness. Self-efficacy increases when students work in teams because they can vicariously learn from their peers and build the confidence to complete tasks [147]. Creating teams and building competence beliefs helps all genders with classroom success [51]. Building student teams fosters small-group explanations, which increase metacognition through self-explanation [84]. Peer interactions create the opportunity for rapid feedback as students explain to and ask questions of their classmates [95], increasing metacognition as well. Various other sources promote the use of student teams as a method of improving belongingness [130], [148] and metacognition [82], [117].

Not only are metacognitive skills fostered, but having students work in teams can also foster increased belongingness by intentionally developing each student's social network within their cohort [149] and creating a peer support network [100], [150]. French et al. [151] discussed the importance of building a network, and van den Bogaard showed how this support significantly affects student success [152]. Students with more social support are less likely to transfer [153]. Dika and D'Amico suggested that cohorts of similar majors could foster social and academic integration and increase belongingness [154].

Student Teams: Underrepresented Groups and Women

Certain student demographics benefit even more from small groups. For instance, Diel-Amen found that in-class interactions with other students is especially important to transfer students [99] and that formal study teams enables them to integrate into the university both socially and academically. Transfer students reported difficulty in meeting the same people on different days in large classes compared with the smaller classes they transferred from [135]. Other research shows that students from low socioeconomic backgrounds need opportunities to engage with other students in the classroom, which may be the only time they spend on campus [155]. Female students and underrepresented student groups feel less integrated [156] and are more likely to drop out, reinforcing the benefit of small groups.

Group dynamics are important to consider when designing groups. As Rosser explains, "if the dynamics of race and gender are understood and used effectively, group work may enhance the learning for all students, especially women and men of color. Even more important, if these dynamics are ignored or misunderstood, group work may actually inhibit or detract from learning" [157].

One strategy for building belongingness is to develop criteria when building teams. Tellhed observed that having more than one member from an underrepresented group on a team can create self-efficacy through vicarious mastery [51]. Another strategy for building teams is to balance preparation and skill sets to lead to higher learning gains for everyone on the team [158]. Britner and Pajares suggested that at-risk students benefit more when they work with those who are slightly ahead of them in ability, possibly through vicarious mastery experiences [134]. One final strategy to note is having the instructor pick teams instead of allowing students to choose them. Aggarwal and O'Brien found that social loafing is not reduced in self-picked groups [159]. Additionally, workers in jobs will rarely get to choose their own teams, and having the instructor choosing teams prepares students for future employment opportunities. For a best-practices paper, see the work of Gueldenzoph and May [160].

Incrementally Solving Problems in Class

Solving problems in class is a mainstay in many engineering and science classes, and many faculty use example problems to demonstrate the mental steps and details in calculations. The literature describing this technique largely focuses on the metacognitive domain. Tileston mentioned that using a wide variety of problems would improve procedural knowledge and increase metacognitive strategies [117]. Metacognition regarding the transfer of ideas from one context to another is often chaotic and open to ambiguity [87], which suggests that faculty could intentionally choose problems that scaffold ideas and increase student abilities in this transfer process. In particular, this also helps with the error management process, as mentioned earlier in the paper [87], [135].

Cold Calling on Students

Cold calling on students involves the spontaneous (although sometimes planned) selecting of a student or group to answer questions presented in class. This technique can be viewed negatively by students, but has benefits according to Hoestra and Mollborn [93]. They argue that this reduces anxiety because students feel relieved when they see others are also not understanding. They also hear explanations in their own language that can help them with building up to understanding the content like a professional. Dallimore et al. showed how cold calling in the class increased students answering voluntarily and increased comfort with participating in class discussions [161]. Using cold-calling to warm up the class can help benefit larger classroom discussions as well [162].

Learning Student Names

Learning students' names helps build a warm climate in the classroom. Fostering belongingness and helping students feel like they matter becomes more difficult with large classes. Pascarella and Terenzini observed that if faculty are interested in students [163] and have warm interactions with them [84], then student success is more likely. Personal interactions between faculty and students have also been suggested by Boon to lead to higher self-efficacy [164]. Jimenez Soffa, in more general terms, said that high levels of faculty concern lead to the best classroom experiences [73]. Similarly, Brahmia reported that staff who knew the names of female students increased their feelings of belongingness [118]. On the practical side, Tanner found that just the willingness to try to learn names in a three-hundred person biology class led to a personal connection with students and fostered connections [141].

Job Openings and Internships

Within engineering, it is well understood that having an internship increases employability post-graduation [165]. To increase hire-ability and the likelihood of being accepted into a job or internship, various factors go into the hiring or approval process. Word of mouth, staff word of mouth, and employee referral programs all provide employers with methods of selecting potential employees [166]. By encouraging students to apply for desired positions and get into contact with future employers, the likelihood of hiring increases. Women find greater success using formal job searches when looking for jobs in a male-dominated field as opposed to a word-of-mouth approach [167]. Student also gain a metacognitive and self-efficacy boost from participating in an internship, as students learn to relate to material better, keep a macro-level view of content, understand the important details, and build confidence in one's ability to succeed [168].

Lecture Capture

Lecture capture has been explored as a tool for supporting student learning, but little has been examined regarding its use in the context of the four areas of focus. Traphagan found that students reported webcasts helped them control how they learned [169], indicating metacognition would be fostered. Hall and Ivaldi also found through a qualitative study that students said the recordings gave them control over their learning [170], which also implies metacognitive processing. Cilesiz's research found that students reported that recorded lectures helped them work smarter [171]. Leadbeater et al. found that roughly 75% of students watch recordings of lectures. Approximately 5% of those students are underrepresented minorities highly dependent on the recordings, in particular those with dyslexia and those from a non-English-speaking background [172]. Danielson posited that lecture recordings would create an intimacy between faculty and students, suggesting belongingness [173]. Joseph-Richard found that faculty took advantage of the formative assessment opportunities from using their own recordings to spot student difficulties [174]. If possible, personalized videos of the lecture content, such as having the instructor's image in recordings to create a stronger social presence, transfer better than simple recordings of a lecture [175]. With the availability of lecture capture, it is imperative to advise students about effective time management strategies, or students could negatively impact their learning by repetitively watching a lecture, expecting passive learning [176]. Results from Owston et al. suggest that academically strong students view recordings significantly less often than weaker students; high achievers fast forwarded to view certain sections of recordings only once, whereas low achievers view the entire recording multiple times [177]. Karnad provides an in-depth report on student use of recorded lectures [178]. Research providing a practical guide to lecture capture, as well as how to overcome the associated challenges, can be found in Newton et al. [179].

Class Structure and Syllabus Decisions:

Introduction

The decisions that faculty make before they even enter the classroom set the tone for many student experiences and may be even more important than what happens in the classroom. These decisions include how points are allocated between different activities and deliverables, how the grading scale is chosen, and the level of detail communicated to students. This section describes how different syllabus decisions influence the four affective domains.

Syllabus Practices

Having a clear syllabus with concrete expectations is important for student success [45], [84], [90]. We argue that the structure of and content within a syllabus affects metacognition because students can modify what they do in response to a clear syllabus and its requirements. The language used can build belongingness by setting the class tone from the start [180]. By including inclusive language, the syllabus can create a welcoming environment for students, avoiding the chilly climate that often discourages at-risk students [181]. Universal design allows all students to feel welcomed and have the ability to succeed in college, further enhancing belongingness [182]. Best practices for a syllabus have been outlined by Slattery and Carlson, [183] and a brief guide by Burgstahler helps those wishing to implement universal design [184].

Soliciting and using Feedback from Students Mid-Semester

To further build on the student-faculty relationship, literature suggests promoting open communication between the students, instructors, and instructional team. This has a direct impact on belongingness in the classroom. Feedback plays an impactful role in and beyond higher education: we learn faster and more efficiently when we understand how well we are doing and have a sense of what can be improved [185]. Feedback from students typically comes in the form of student evaluations of learning, teacher–course evaluations, course experience questionnaires, or other surveys administered at the end of a semester [186]. However, end-of-semester feedback typically is not optimal for a student's experience in the classroom.

Tanner discussed how soliciting feedback mid-semester and then responding to it fostered a "we" type of communication that eschewed adversarial interactions [141]. Tanner and Seidel also mention that giving a forum for student feedback in the second week, mid-semester, and multiple times before formal student evaluations may help an instructor deal with student concerns and reduce student resistance to teaching practices [that semester] [97]. However, if feedback is requested and not acted upon or addressed (note that changes do not have to be made, but at least acknowledged), students will have an adverse reaction and experience a decrease in their sense of belongingness [187].

Modifying Classroom Layouts

Classrooms can be designed such that individual students can develop into highly skilled professionals, especially in jobs involving high levels of collaboration. Different classes require varying layouts and designs to create ideal learning spaces [188]. Physical environments play an important role in shaping human social interaction in the classroom, which can influence the feeling of belongingness [189]. This involves using rooms that create small-group environments, make collaboration in teams feel natural, and take the focus away from the instructor and move it to the students. Even a few learning experiences in these classrooms – if well designed — can have a lasting impact on a student's education and self-efficacy [190], [191]. Graetz and Boliber describe ideal classroom characteristics to guide future classroom design from a psychological perspective [192].

Grading on a Straight Scale

One choice that faculty make regarding class structure is the grading scale, which can be normed, criterion, pass/fail, or mastery. As described by Wormeli, "a grade is supposed to provide an accurate, undiluted indication of a student's mastery of learning standards. It is not meant to be a part of a reward, motivation, or behavioral contract system [58]." Practically speaking, however, the methods of grading inherently effect the underlying approach instructors take to course development [193]. Because having a normalized ("curved") grading scale inherently promotes competition between students, by switching to a criterion, or straight, grading scale, an instructor can promote collaboration among students [194]. Santos Laanan commented that use of a straight grading scale can encourage belongingness, particularly for transfer students, who found competition alienating, resulting in a negative experience [109]. Using a straight scale also affects cognition. Student performance decreases when learners are asked to demonstrate high performance compared with others [102]. Boon pointed out that grading on a curve, rather than straight scale, enhances a less-desirable performance orientation instead of encouraging a more-desirable mastery orientation [164]. By using a straight scale, students are not in direct competition with each other and can further develop a growth mindset.

Regular-Interval Homework

Many college classes, particularly upper-level classes, have no assigned homework with due dates and grades. Lang argues that requiring regular homework promotes the practice of spaced retrieval rather than students defaulting to massed practice [90]. Lang also argues that the decision to have regular homework leads to metacognition and self-efficacy by providing direct practice in the types of skills that students may be tested on. Townsend and Wilson argue that regular homework provides feedback to students so they can self-regulate their learning [135], building on a student's self-efficacy as students feel more confident after practicing content problems. Nilson also supports homework as a means for fostering self-regulation to strengthen students' self-awareness and learning skills, which can promote the use of metacognitive strategies [36]. Wormeli demonstrated that assessment of and feedback on homework, rather than such practices as refusing late work and refusing students the ability to redo work, are the most effective ways to teach accountability [58].

Group Homework and Exams

Assigning homework due at regular intervals benefits students' learning. A longitudinal study by Felder et al. showed taking responsibility for completing coursework, such as homework, significantly and practically predicted student success in chemical engineering courses [60]. Also, requiring group homework contributes positively to a student's education. Fass and Tubman pointed out that group homework increases belongingness and cognitive competence (metacognition) [195]. Gadgil and Nokes-Malach suggested making group problems complex so collaboration is optimal [130]. Whitt et al. [196] and Bell and Kozlowski [77] pointed out that cognitive outcomes and self-esteem improvements (among other factors) from peer interactions were higher compared with individuals working alone and that belongingness also increased with elevated task difficulty. Finally, Trujillo and Tanner said that student belongingness increases when students engage with content outside of class, such as when completing homework together [136].

Requiring Attendance

Historically, compulsory attendance in higher education has had mixed reviews on whether or not it supports student learning, especially when lecture notes or recordings were available to students [197], [198]. St. Clair makes the point that when looking at the top-performing students, there is a mixture of students who were recorded as being present and absent for classes. Attendance is only one of many different voluntary behaviors student exhibit to succeed in higher education [199]. Meanwhile, Dey found that attending class had a significant and positive effect on exam performance, in particular for males, non-whites, transfer students, students with a lower-than-average GPA, and students with poor performance on prerequisites [200]. Andrietti observed mixed results, suggesting that the positive effect of attendance may be the result of unobservable student traits, which we suggest could be influences from the four domains [201]. The main difference between the studies discussed is the style of teaching used in various types of classrooms. Traditional classrooms appeared to have little to no correlation with classroom attendance; active classrooms tended to produce a significant relationship between attendance and grades.

Requiring attendance offers some logistical challenges to faculty, depending on the technologies available, their comfort level using those technologies, or other teaching supports available. However, research has shown that requiring attendance can help transfer students more than other groups of students because they feel lost when no one tracks their presence [135], particularly when compared with the smaller classes they may have been in before they transferred. Cilesiz also reported that students felt motivated to attend when there was a grade associated with attendance [171].

Cumulative Exams and Quizzes

Using cumulative assignments or exams can lead to retrieval practice and other metacognitively beneficial activities [84], [202]. The testing effect on exams allows for spacing of information and retrieval practice [203], [204]. Peterson showed that in the flipped classroom, daily quizzes with a few cumulative questions allowed for higher students' satisfaction and beliefs of success in the classroom, leading to higher self-efficacy [205]. Guirguis found that the cumulative case-based quizzes in pharmacotherapy courses also built on students' belief in their own success and retention of content [206]. When the use of "reflection questions" for metacognitive practices is implemented in the classroom, the retrieval practice gained allows for students to enact the various metacognitive strategies described by McGuire et al [35], [207].

Sharing Rubrics

There are various descriptions of the purpose of rubrics, providing practical uses grounded in literature. Universally, well-designed rubrics serve three essential functions for faculty: facilitating evaluation of student work based on criteria, defining qualities of work, and providing a scoring strategy for that work

[208], [209]. A study by Wollenschläger et al. showed that rubric feedback after evaluation of student work is effective when given performance improvement information [210]. Receiving suggestions on how to improve performance provides a checklist of intermittent steps that can further guide students as they repeat and complete the assignments. Additionally, both in-class feedback and rubrics can aid in student learning [211]. One potential avenue to explore in the future is to co-create rubrics with students to build on self-efficacy and metacognition [212].

Posting Proficient and Distinguished Student Work
Methods of increasing student self-efficacy can easily be built into the class structure. One method of giving students verbal and mastery experiences simultaneously is to post good student work as the answer key and to email the students whose work was selected to let them know. Britner and Pajares advocated this as a mechanism of confirming for students that their work was very strong [134]. Wormeli suggests posting both proficient examples of student work as well as "non-examples" to build a growth mindset and self-efficacy for students [58].

Rapid Feedback on Exams and Homework
Providing rapid feedback on exams and homework is another class structural decision that has an impact on student success. Futak suggested that doing this would increase metacognition and self-efficacy by providing more feedback to students [213]. Additionally, by making the process more efficient, more practice can take place in the student's education. We can expect an increase in growth mindset by providing feedback in a timely manner, rather than much later, when the content has potentially lost some of its relevancy. One easy way to help provide faster feedback is to provide a rubric to facilitate easy, consistent, and fair grading [214] and to allow students to see what is expected of them [215].

Estimating Time Taken on Assignments
Engle and Tinto pointed out that when instructors are explicit about the length of time a task will take, it helps all students, lower socioeconomic status students and first-generation college students in particular. Providing a time estimate allows students to manage their time and to determine whether they are taking too long to finish an assignment. Time estimates are an inclusive practice that can help marginalized students become more successful [155]. Newhall, a specialist in learning disabilities, explains that while many students have issues with time management, students with learning-based disabilities, such as attention deficit/hyperactivity disorder and dyslexia, may greatly underestimate the time it takes to complete assignments. As such, listing the time that it takes for the average student to complete an assignment could improve the metacognitive strategies of students with disabilities, helping them plan accordingly to complete homework [216]. Bernold et al. noted that most students lack time-management skills when they start engineering [78] and that listing how many minutes each task would take can help normalize student effort. Meyer and Marx [138] found that a fraction of students who leave engineering were not ready for the time demands that studying would require, and being detailed would help those students better allocate effort.

Listing Class Objectives
Learning objectives are designed to provide expectations for students and prepare instructors for framing a classroom [55], [217], [218]. Some sources suggest placing learning objectives at the beginning of a course or as pre-class content [139], [219]. Lang [84] and McGuire [45] both separately suggest that faculty clearly list the class objectives as they are being covered rather than at the beginning or end of the class. We agree and believe that this will help students use metacognition to judge whether they could apply similar concepts to other areas of the course material.

Outside-of-Class Practices:

Introduction

A final category of practices faculty can use to increase retention and student engagement is out-of-class experiences. Being accessible to students outside of the classroom is a less obvious way to increase student success, but having a supportive interaction with a faculty member outside of class can be a highly enriching experience that influences a student's academic career. Because learning takes place beyond the formal classroom, space can be made outside of class to interact with students. There are social and motivational benefits to simply acknowledging students on and off campus [220]. Strauss and Terenzini found that after performing a regression analysis on over 4000 students and controlling an array of students' precollege characteristics, both students' classroom and out-of-class experiences make statistically significant and independent contributions to student learning on analytical and group skills [221]. Additionally, Einarson and Clarkberg surveyed over 900 faculty at large, highly selective research-intensive universities. They found little support for two of the most prevalent self-reported explanations for lack of faculty involvement outside the classroom: (1) competing time demands and (2) a lack of institutional rewards or support for out-of-class interaction [222]. With out-of-class connections, all four of the domains can be fostered for students through positive interactions with faculty. We would like to note that these relations with students are professional interactions and are ones that would not have the same level of intimacy as one would expect in a personal relationship.

Student-Faculty Interactions

In a qualitative study of students who left engineering, some students reported that they wished they had stronger relationships with faculty [138]. These relationships and interactions can help validate students in their college experience, helping students (in particular, non-traditional students) relieve personal doubt about learning and life in higher education [25]. Trujillo and Tanner pointed out that faculty rarely have time to get to know their students outside of class, other than in office hours [136]. Faculty getting to know students increases students' feelings of belongingness and self-efficacy. Additionally, Nadler and Nadler found that empathy, credibility, and gender of the student and instructor all influence the amount of out-of-class communication that occurs: the greater the empathy and credibility of the instructor, the more likely a student would interact with them outside of class. Same-gender preference for out-of-class communication was found as well [223]. We advocate collecting student information and pictures prior to the semester so that interactions can be intentionally nurtured.

Another way of fostering interactions, in addition to learning names (discussed in the Classroom Practices section above) and facts about students, is to invite groups of students to platonic social outings like sporting events, having lunch with a lottery of students, or doing activities, like biking, together. Because time is a precious resource for faculty, students can be integrated into pre-existing faculty events or activities. The extent to which this happens is instructor dependent, and involving students should not necessitate drastically altering faculty lifestyles. In some cases, more interaction with faculty may not be better. Kuh found that student-faculty interaction helps learning only when it encourages students to devote greater effort to their education—in other words, when the contact is substantive [224]. Some interaction is helpful, though. Nadler and Nadler found that students who stayed in college reported significantly more contacts with faculty outside of the classroom than did students who eventually dropped out [225].

Informal Events for Students

Deil-Amen pointed out that having informal lunches with students, for instance, can lead to increases in academic and social integration, along with increased belongingness [99]. On this front, Cross and Vick specifically advocated that faculty should reach out to women first and invite them directly because they often feel left out of interactions with engineering faculty [153]. Carroll provides strategies to enhance informal interactions with all students, including those with disabilities [226]. Terenzini et al. suggest faculty meet students for coffee or meet with students after class [227]. The interaction, as mentioned above, needs to have some sort of substantive content, not just involve casual interactions with students. There is little to no effect on learning gains or effort with strictly casual interactions [224]. Suggested focal points are mutual feedback about the class, discussing grades and assignments, delving into ideas related to the course, discussing career plans, working or talking about a committee or project the student could or is involved in, and discussing or allowing students to get involved with research.

Promotion of an Inclusive Cohort

There are various benefits when students build a cohort of classmates to help bridge the academic and social gap between the time spent in class and outside of class [228]. Additionally, students in learning communities spend more time together in both social and academic contexts, helping students learn and make friends while enhancing the quality of student learning and increasing persistence [229]. In part because of the group work that we build into our courses and the exposure to multiple groups during the semester, our student have consistently formed a strong out-of-class cohort for the past three years. Large groups of students from our discipline regularly congregate and work on course content and material in one of the campus libraries. Students that otherwise would not have taken the initiative to get to know their cohort are now meeting others from class, and we helped build this student network. As the network grew, students found that they could congregate in the library, collaborate on work, and help each other learn difficult concepts.

Encouraging Office Hour Attendance

Office hours are a formal setting to allow students to have a scheduled time with faculty members. Fusani, along with Marin and Myers, suggests that faculty regularly and actively encourage meeting outside of class, highlighting their availability, particularly to support at-risk students [230], [231]. Tanner discusses incentivizing students going to office hours by making the first visit worth points toward their grade if students spend ten minutes in discussions about their performance in class and in receiving feedback [141]. When implementing this technique in freshman and sophomore courses, we believe the students should meet with the instructors, not undergraduate or graduate learning assistants supporting the course, for this initial meeting. During these meetings, there will be opportunities to share our own failures or challenges in core classes and describe how we overcame those, which can contribute to the development of a growth mindset with students. We also have the opportunity to discuss relevant and targeted metacognitive strategies with each student.

Final Notes and Discussion

As you can tell from this work and the implementation discussion in Part 2 [68], we exhibit growth mindset ourselves as instructors. In Part 2, we describe how we iteratively improve our own teaching practices through deliberate discussion with each other and through reflection. We have tried to describe in each section why and how we deployed specific practices and how we improved or changed those over time to make them more efficient, effective, and beneficial for students.

The teaching practices suggested in Part 1 and 2 have the potential to allow for an improved learning environment for students in higher education. By using these strategies to build on the four domains of growth mindset, self-efficacy, metacognition, and belongingness, instructors have the power to improve access, inclusiveness, fairness, and equity. Their implementation will increase both student retention and the quality of education. When the teaching practices are used in tandem, synergistic effects can be expected.

Future research needs to identify which teaching practices are most impactful, for which populations, and why. The current literature identifies various teaching practices and their impacts, but a meta-analysis and comparison across studies is difficult. Some barriers to such an analysis include complications from variances in the class types, instructors, student populations, and knowledge of best teaching practices.

Additionally, various unknown factors could be present in each case, limiting the effectiveness of a meta-analysis.

Even after extensive training through professional development and familiarity with best practices from the liter¬ature, the implementation of active learning pedagogies can be improved [232], [233]. Change in beliefs does not guarantee change in practice. Just as we suggest incorporating belongingness teaching practices into classroom interactions with students, we suggest the same for faculty development around adoption of the teaching practices described in this review. Having the support of a community of practice, such as a faculty learning community, makes pedagogical change more likely. As such, Freeman et al. and Gormally et al. recommend that institutions fostering reform should host regular meetings with instructors. Instructors are asked to discuss and make decisions about implementation of their courses for potential critical review. T¬his practice of fostering belongingness in faculty may be key to facilitating the long-needed switch from advocating for evidence-based teaching practices to implementing evidence-based teaching practices [61], [234].

Our main suggestion, regardless of which teaching practice is used, is to use reflective teaching. John Dewey, an early key theorist of reflective approaches to professional development, defines reflection as "active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends" [235]. He then characterizes reflective thinking as follows: "Reflective thinking, in distinction from other operations to which we apply the name of thought, involves (1) a state of doubt, hesitation, perplexity, mental difficulty, in which thinking originates, and (2) an act of searching, hunting, inquiring, to find material that will resolve the doubt, settle and dispose of the perplexity." Other authors have added to Dewey's thoughts regarding the linkage of reflection with practical experiences, interaction with others, and intuitive action [236], [237]. We view reflection as a cyclical process, beginning with understanding the happenings in the classroom, followed by actively working to improve previous iterations of courses through a critical analysis of successes and failures. In addition, teachers exchanging their experiences through networks help to build a professional community and develop a professional language in teaching and learning. Zeichner and Liston point out that "Reflective action is also a process that involves more than logical and rational problem-solving processes. Reflection involves intuition, emotion, and passion and is not something that can be neatly packaged as a set of techniques for teachers to use" [238]. Reflective teaching has both cognitive and affective components and is characterized by a cyclical process of action and reflection [239]. With such a practice, instructors can expect to improve teaching practices and become high-quality instructors in higher education.

Declarations:
Availability of data and material
Not Applicable

Competing interests
None

Funding
Why Women Persist: Evaluating the Impact of Classroom-Based Interventions, Engineering Information Foundation, Grant # EIF17.10

Authors' contributions

Hempel drafted the manuscript, managed the paper, identified, implemented, and refined the teaching practices described in the document, co-taught with other instructors to gain better insight into the practices, and helped elaborate on and apply the affective factors.

Kiehlbaugh identified, implemented, and refined the teaching practices; co-developed the multi-dimensional affective model for framing the teaching practices; and edited and substantively revised the manuscript.

Blowers conceived the work; identified, implemented, and refined the teaching practices; co-developed the multi-dimensional affective model for framing the teaching practices; participated in drafting the manuscript; and aided in the review process.

Acknowledgements
Special thanks to Justine Schluntz and Kerri Hickenbottom for contributing their own insights regarding these teaching practices and for co-teaching with us. Our discussions about the various practices while co-teaching led to many changes and improvements to our own teaching practices.

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Appendix B

Scalable and Practical Teaching Practices Faculty Can Deploy to Increase Retention: A Faculty Cookbook for Increasing Student Success: Part 2

Abstract

With the increasing need to improve teaching practices in higher education, various researchers have explored methods that instructors can use to promote student success and retention. Here, we synthesize, for the first time, teaching practices that address four key affective domains that influence student success in the classroom. With the implementation of teaching practices focused on building a growth mindset, improving students' self-efficacy, promoting metacognition, and fostering a sense of belongingness, instructors can provide an academic environment suited to student academic growth and retention. As Part 2 of a two-part series, this paper describes our implementation of the various teaching practices described in Part 1. All the practices were designed to be low-cost and scalable so that nearly any instructor in higher education could adopt them. The practices can be flexibly adopted or modified to fit most classroom settings. As with any change in one's practice, we suggest initially adopting the teaching practices described in this work that seem best suited to one's particular teaching situation. After becoming comfortable with a few new practices, we suggest layering on other teaching practices to further develop comfort and expertise with the process of improving one's teaching practice over time. Being reflective regarding one's teaching activities allows for long-term personal growth as an instructor.

Introduction

Improving STEM Education

High-profile organizations in the US are increasingly calling for improved undergraduate education in science, technology, engineering, and mathematics (STEM) (1–3). Various aspects of courses need to be improved, and solutions ranging from improved classroom management practices to direct interventions that address weaknesses in classroom teaching practices have been proposed. Various reports and publications have described barriers to, and promises for, fostering STEM reform (4), facilitating change in undergraduate STEM education (5), implementing STEM education policies (6), retaining students earning degrees (7), and prioritizing STEM literacy for all students (8). One report in particular, "Linking Evidence and Promising Practices in Science, Technology, Engineering, and Mathematics (STEM) Undergraduate Education" by Fairweather, served as a status report on the state of STEM education in the US for the National Research Council Board of Science Education and is an excellent introduction to the topic (9). In general, most improvements in STEM courses involve transitioning from traditional lecturing to evidence-based teaching practices and cooperative learning. Students are also introduced to evidence-based learning methods. As research in these areas increases, the insights gained from discipline-based educational research will allow higher education to become a more effective and efficient system for educating students (1).

Part 2

The first part of this two-part series provides an in-depth review of the literature on four affective domains that we have selected for in-depth consideration, describes their interrelatedness, and includes brief notes on implementation for faculty. It details 34 teaching practices that can be implemented in the classroom and how they connect to the four affective domains (10). A review of the research supporting each evidence-based teaching practice is presented. Part 2 (this work) delves into the application and implementation of the teaching practices, providing insight into how we, along with our colleagues, have implemented these strategies.

Brief Overview of Four Affective Domains

As described in Part 1, the four main affective domains, which can be treated as lenses through which we view our teaching practices, are as follows:

- promoting a growth mindset
- building student self-efficacy
- developing student metacognition skills
- creating a sense of student belongingness

Briefly, having a growth mindset involves knowing that skills evolve over time and with practice, rather than being innate (11). Mindset can be seen in how one reacts to different situations; in the education sense, a student's academic mindset is reflected in how they react to adversity or challenges as they present themselves. If a student receives a low grade, how will they respond to that grade? Having a growth mindset suggests that a student would see the low grade as feedback and as a source of information about how they might improve through effort. Self-efficacy is the belief in one's ability to complete a specific task and achieve a desired result (12). In essence, self-efficacy can be viewed as how much confidence a student has in their ability to solve a specific problem, complete a quiz, effectively present in front of a class, or perform well on an exam. Metacognition is the process of thinking about one's own thinking (13). In practice, a student could use metacognition while studying to improve their study habits. As an example, a student could reflect on how they performed on an exam. They could then reflect on how they studied for the exam – likely, highlighting and rereading the textbook to review content. As they prepare for the next exam, they deploy a different strategy, known as self-explanation, to prepare. After completing the next exam and receiving a higher grade, they could then determine that the shift in study strategy worked for them. Belongingness is generally described as one's sense of fitting into one's environment, group, or community (14). In higher-education classrooms, this environment consists of formal and informal groups of students who communicate and gather to work together, in and out of the classroom.

Instructor Change and Implementation

We want to acknowledge that changing one's teaching practice as an instructor is difficult, in particular when no training on pedagogical best practices has been provided and the use of interventions in the classroom is unfamiliar. As briefly touched on in Part 1, studies of generically implemented professional development have shown that long-term use of the newly introduced teaching practices is limited and that the efforts at implementation that are undertaken are often ineffective (15–17). To facilitate sustained improvement in teaching practices over time, it can be helpful to adopt a long-term mindset about implementing new practices. Once a new intervention has been piloted and found to improve student success and retention, we advocate incorporating the change permanently in one's teaching methodology. This mindset adjustment will allow for the appropriate level of investment and commitment to continued adoption.

Wieman described how his Carl Wieman Science Education Initiative allowed for 69 of 70 faculty to retain and continue to use teaching practices that were new to them during the projects they participated in (18). The two main factors that allowed for this sustained transformation were (1) the use of embedded science education specialists and (2) having a very strong and supportive faculty environment around instruction, something that is not present in many universities and departments across the United States. Borredgo and Henderson suggest four main categories of effective change strategies: disseminating curriculum and pedagogy, developing reflective teachers, enacting policy, and developing a shared vision (5). When faculty consider their teaching environment in the context of adopting new practices, having the explicit support of other faculty and the department can be helpful in the long-term retention of new teaching practices.

One way to approach implementing new teaching strategies involves using a reflective approach to instruction: understanding what type of instructor one is in order to understand one's strengths and weaknesses (19). By beginning with self-reflection, instructors can more readily identify teaching practices that align with their core identities as instructors. Additionally, if a faculty member is aware of a general weakness in their instructional practices—for example, perhaps an instructor is uncomfortable or apprehensive about adopting unfamiliar technology—then they can take action to either learn the technology or delegate the technology aspects of the course to the learning team. Through reflection, the design and management of the classroom environment can be shaped to suit the instructor and still meet the needs of the students.

To avoid becoming overwhelmed, we recommend introducing one or two new practices at a time rather than deploying all of them simultaneously for the first time. As described in each of the applications below, we did not start out as experienced experts in these practices. We arrived at our current form of implementation over a three- to four-year period, during which time we became more comfortable with iterating and experimenting as we built on early successes and failures. Each teaching practice that we deployed gave us another opportunity to improve our own teaching skills. This incremental approach allows faculty to begin small and build comfort with the teaching practices that they choose. If faculty embrace the four affective domains themselves in regard to their teaching—working to develop a growth mindset, improving their own self-efficacy, establishing a sense of belongingness with others committed to improving their teaching, and using metacognitive strategies to be self-reflective—they will find that they too can learn and implement new strategies in the classroom and build the necessary skills for effective teaching.

We highlight now, and will point out again later, that some of our early implementations were not functional or designed well and thus did not work as we intended. Sometimes, there were unexpected positive benefits we did not predict. In all cases, our reflections on what we planned and what occurred led to more robust implementations with greater levels of intentionality. Most teaching practices took time and several iterations for us to become comfortable deploying them and to understand how a given practice affected student success and retention. Even now, our own implementation of the teaching practices continues to evolve each semester as we respond to the unique needs and classroom culture of each new class.

We strongly recommend becoming self-reflective about specific changes made to one's teaching practices. Instructors should focus on what is working for them and what is not working and why. Wieman suggests that when research-based instructional strategies are used and faculty are cognizant of the impact the teaching practice is having on students, the teaching practice tends to be used again in the future (18). This reflective process does not have to be done alone. We suggest that instructors enlist students to provide feedback about their experiences with the implementation of a given teaching practice, which can clarify how that particular practice contributes to student success in the classroom. When planned ahead of time and done in a structured manner, the work of implementing a given teaching practice and collecting data about its efficacy could lead to publication of the results in the fields of discipline-based educational research and the scholarship of teaching and learning (20). Other practices that can support the reflection process include (1) having peers observe in the classroom (21) and (2) co-teaching with other faculty interested in improving their own teaching practices, a practice that allows for immediate third-party feedback over an entire semester when both instructors are present in the classroom for each class session (22). The sustained use of self-reflection can lead to increased long-term use of these teaching practices.

Teaching Practices that Can Influence Student Retention through Growth Mindset, Self-Efficacy, Metacognition, and Belongingness.

Table 1, taken from Part 1 (10), lists the different teaching practices discussed in both papers. The practices are categorized according to which of the four affective domains they address. For the theoretical background supporting each practice, please see Part 1 of this two-part paper series. The following sections briefly introduce the teaching practices, followed by descriptions of how we implemented the practices in our own higher education setting. Our institution is a newly designated Hispanic-Serving Institution that is also a land- and space-grant university, a Research 1 university, and a member of the Association of American Universities (AAU). The total enrollment is approximately 45,000 undergraduate and graduate students.

Table 1: Teaching Practices that Can Influence Student Retention through Growth Mindset, Self-Efficacy, Metacognition, and Belongingness

In the Classroom				
Teaching Practice	**Growth Mindset**	**Self-Efficacy**	**Metacognition**	**Belongingness**
Active Learning	√	√	√	√
Formative Assessment	√	√	√	√
Using a Student Response System	√	√	√	√
Intentional Use of Language to Improve the Classroom Climate	√	√	√	√
Teaching Learning Strategies to Students	√	√	√	√
Modeling Behavior	√	√	√	√
Pre-lecture Quizzes		√	√	√
Use of Learning Assistants		√	√	√
Use of Real-World Problems		√	√	√
Music in the Classroom		√	√	√
Student Teams		√	√	√
Student Teams: Underrepresented Minorities and Women		√		√
Incrementally Solving Problems in Class			√	√
Cold Calling on Students		√		√
Learning Student Names		√		√
Job Openings and Internships		√		√
Lecture Capture			√	√
Class Structure				

Syllabus Practices	√	√	√	√
Soliciting and Using Feedback from Students Mid-Semester	√	√	√	√
Modifying Classroom Layouts		√	√	√
Grading on a Straight Scale	√		√	√
Regular-Interval Homework	√		√	
Group Homework and Exams			√	√
Requiring Attendance			√	√
Cumulative Exams and Quizzes		√	√	
Sharing Rubrics		√	√	
Posting Proficient and Distinguished Student Work	√	√		
Rapid Feedback on Exams and Homework		√	√	
Estimating Time Taken on Assignments			√	
Listing Class Objectives			√	
Outside of Class Events				
Student-Faculty Interactions	√	√	√	√
Informal Events for Students	√	√	√	√
Promotion of an Inclusive Cohort			√	√
Encouraging Office Hour Attendance			√	√

Classroom Practices

Overview of Our Implementation of the Teaching Practices

We frame the remainder of the paper by describing our own trajectories with these teaching practices to show how each teaching practice was initially implemented, how it was improved, and what our next steps will be. This demonstrates how the reflective, iterative process described above allowed us to continuously evolve our practices in ways that further enhance students' experiences with the four domains every semester. Each section describing a teaching practice contains a brief overview and selected references, followed by a description of our implementation of the teaching practice. Our observations about the efficacy of the teaching practices are anecdotal. While we do not yet have rigorous research data showing the effects of these teaching practices on student success in our own classrooms, they are all grounded in existing literature, and many of them are supported by published classroom data demonstrating their efficacy. We are currently collecting data for different student populations in our classrooms to better understand how the teaching practices contribute to student success.

Active Learning

Active learning can be viewed as a range of practices that shift students from passively taking in content presented by the instructor to having students actively engaging with the material during class. In a typical active learning classroom, instructors create opportunities for students to wrestle with the material and delve into the content by completing tasks or having open discussions in a collaborative fashion (23). We use active learning extensively in our courses to take advantage of the documented benefits described in the literature on active learning (10).

In a typical class meeting, we start with a word scramble in which students identify the topic of the day. Students arrive and are instantly engaged with trying to identify the topic. This is a metacognitive activity that engages students in predicting what the topic will be based on what we have been learning.

Next, we typically share a recent news article relevant to the discipline or the topic to be covered. Students then briefly research a follow-up question in response to the article. This activity uses metacognition to bring real-world relevance to the classroom and links course content to significant personal implications, which can help learners transition from being dependent learners to becoming independent learners (24). The next activity that is used to engage students involves sharing an internship opportunity that they may be qualified for (See Job Openings and Internships section below) and asking them to look up the job posting online and provide some information about the opportunity.

The above activities are agnostic to the content and easily deployable in nearly any class. We refer to this set of repeatable activities (word scramble, news article, and internship opportunity) as the class induction period. Starting the class the same way each day provides students the comfort of a familiar pattern during the period when many students are getting settled and interacting with classmates. These activities typically take 3-6 minutes.

After the induction period, students work individually for 3-4 minutes to begin solving a problem. Through the student response system (discussed in Using a Student Response System section), students then report their level of confidence in their ability to solve the problem alone, which provides an opportunity for them to explicitly reflect on their level of self-efficacy. Students are then given 3-4 minutes to work with their team to begin to solve the problem, and then we ask the students to report their level of confidence in their team's ability to solve the problem. This provides the students another opportunity to reflect on their level of self-efficacy and fosters belongingness by having students on the same team communicate and vote. At this point, we either give the teams another 5-10 minutes to work together without structured prompts or we begin moving through a scaffolded series of votes about the procedures and individual steps needed to solve the problem. Some examples are completed in a single lecture, but more complex problems may stretch to five days of engagement to complete.

We keep a high level of student engagement consistently throughout class by asking approximately 20 questions using the student response system in a 50-minute period. Our specific prompts reveal student thinking and allow us to deploy formative assessment (see Formative Assessment section below) while also providing structured assistance to students as they learn new content and problem-solving techniques.

Formative Assessment

There are two main ways to evaluate students in the classroom: through summative assessment and formative assessment. The former focuses on capturing student learning after a section of content is completed and may not be revisited; the later focuses on gaining insight into the progress of student learning as it is occurring (25). Formative assessment strategies that reveal class-level information are relatively easy to use and can be included in every class through the use of student response systems, voting cards, or simple hand raising. In an active learning classroom, instructors can move around the room during activities to interact directly with students and gain insight into their thinking.

While moving around the classroom as the students work on the assigned tasks, we listen closely to what students are discussing and the ways they ask questions to uncover misconceptions or topics that should be discussed with the entire class or explained in more detail during a subsequent lecture. For larger classes, we use learning assistants (also known as undergraduate preceptors, see Use of Learning Assistants section), who give additional feedback about student learning to the instructor as they interact with groups and individual students. Throughout the semester, we ask students to evaluate their own learning through self-refection. As an example, we occasionally use "one-minute papers" at the end of class to solicit feedback about what topics students are struggling with as they build their understanding. As we use these formative assessments to change our teaching, we demonstrate and promote a growth mindset to the students, build student self-efficacy and belongingness as students see how they and others are performing through low-stakes tasks, and get students to think metacognitively about their responses. For a more complete list of additional formal and informal formative assessment strategies, see the work of Chen and Wittinghill (25). Additionally, Kuiper et al. delve into formative assessment and different teaching strategies implemented by twelve instructors (26).

Using a Student Response System

Student response systems (either electronic or materials based, such as voting cards) provide instructors a way to gather information about student understanding in real time and can be used to perform formative assessment. Student response systems are known by a variety of different names, such as clickers, color cards or voting cards, audience response systems, and polling technology (27). We originally used paper-based voting cards solicit student responses in class (28). In these early iterations, we either had formal prompts built into PowerPoint or would verbally ask a question of the class and then have students hold up a folded paper card that had four brightly and uniquely colored letters on them. After several semesters of using a paper-based solution, we adopted the electronic clickers supported by our university and are now able to capture and display anonymous, real-time student responses for the entire class to see.

The shift from using folded paper cards to an electronic system changed the classroom in positive ways. We noticed that when the students' responses were no longer being filtered by the instructor and were made anonymous to others in the class, students responded more often to the prompts and also asked more follow-up questions. With our student response system, we are able to see in real time how many students have responded to the prompt, making it possible to properly pace the activities. When approximately two-thirds of the class has responded to the prompt, we know we can move on to the post-prompt debrief and discussion.

In addition to these in-class benefits, the system creates a permanent record of all responses, which allows us to conduct item analyses to determine how well both the class as a whole and individual students are understanding individual steps in the problem-solving process. In our most recent iterations, we only assign a participation grade for in-class activities, not a score based on correct answers. This is done to promote a growth mindset. Additionally, we felt that pushing students to focus on always being correct rather than on embracing mistakes as part of the process of learning would make the climate in the classroom too chilly and competitive (29). For more best practices regarding student response systems, see the work of Martyn and Caldwell (30, 31).

Intentional Use of Language to Improve the Classroom Climate
Through the phrasing and wording used in the classroom, we inherently influence all four of the affective domains (32), whether we mean to or not as instructors. One of the authors remembers when they were in their first engineering course and the instructor said, "How sad, most of you won't last two weeks in this major." Initiating the class this way did not set up a positive learning environment. Conversely, intentional language can cause just as much positive impact as those first words caused negative effects. We frame our communication to students around the four domains, always expressing our believe in their abilities and encouraging them to be the best students possible and to adopt a growth mindset. We discovered the importance of language and the impact on students during our first semester co-teaching. We noticed that the language used to frame an activity led to dramatically different reported levels of self-efficacy. When students were told that the activity was very challenging and that they may struggle, their reported self-efficacy at the beginning of the problem-solving session was low. When we framed a similarly challenging activity as well within their ability level, their reported self-efficacy at the same point in the problem-solving process was much higher. More insight into what to do and what to say to improve student motivation and self-efficacy can be found in the work of Margolis and McCabe (33).

Teaching Learning Strategies to Students
By explicitly teaching learning strategies to students, we help them develop metacognitive skills, such as self-explanation, self-regulation, retrieval practice, spaced practice, elaboration, and concept mapping (34). In our classes, the classroom layout is designed to facilitate discussion among students seated at small tables. We intentionally create opportunities for practice with the metacognitive learning strategies described above by creating questions that reveal common student misconceptions. Students are often observed self-correcting as they verbalize their reasoning to their tablemates, which helps students find where they may have gaps in their understanding (35). Tasks we ask students to complete in class incorporate retrieval and spaced practice as we interweave old concepts with new material. We push students to elaborate on why they believe certain answers are correct. Finally, we encourage students to complete a concept map before each exam and to progressively add to the concept map as the semester proceeds; the concept map is often worth a few points on exams to incentivize students to complete one.

Modeling Behavior
We encourage instructors to model the behaviors they are promoting to students for two reasons. First, when students can look to us as role models and see us holding ourselves accountable for improving our teaching practices, they are more likely to be receptive to employing the behaviors they see modeled. Second, we inherently become better instructors by building our own skills and knowledge base. Role models contribute significantly to the growth and development of young adolescents (36).

When instructors adopt a growth mindset, students see a firsthand example of the challenges someone faces when they move outside their comfort zone. Students may then become comfortable with stepping outside their own areas of comfort and challenging themselves. When instructors show how practice builds confidence, students can see how learning is filled with opportunities to find content weaknesses and to invest in addressing those weaknesses. By telling students about our own learning experiences or how we developed our study skills/strategies, we become more relatable and demonstrate that we too struggled when we were students. If students have difficulties on an exam, we do not hesitate to relate our own past exam failures and the resulting resilience and effort it took to make up for the deficit. By sharing our own failures, we foster a sense of belongingness for students through shared experience and contribute to building a positive learning community.

Pre-lecture Quizzes
Pre-lecture quizzes are brief accountability quizzes that can be used to encourage pre-lecture reading and practice with content before class. As we shifted away from presenting content through

lecturing to deploying active learning approaches in the classroom, we were counting on students doing the assigned reading before class. Students would claim to have done the reading but would not have any ability to recall or use the content we had assigned for the reading, since there were no graded elements associated with the reading assigned.

To incentivize students to complete the readings before class, we now use randomized quizzes drawn from a larger bank of questions in our learning management system. We iterated for several years with different implementations—including giving in-class paper-based quizzes each day, using the learning management system but giving everyone the same quiz, and only allowing one quiz attempt—before arriving at our current version of the teaching practice. Students have three attempts to complete the quiz. Each quiz we create contains between three and eight questions, each of which has three to five variants. A teaching assistant or an undergraduate learning assistant can be trained to create these quizzes with high fidelity to free up faculty time to focus on other aspects of teaching. On each attempt, the students are asked to answer a random set of questions drawn from the question banks for the various topics being covered, and their highest score on that quiz is recorded in the gradebook. One of the authors anecdotally overheard a student say, "I made two attempts on the quiz, and then I decided I should just read the section to get it right." The percentage of students who complete the pre-lecture quizzes is consistently 80-90%. The small success experienced when students complete the pre-lecture quiz promotes both self-efficacy and a growth mindset, as discussed in Part 1 (10). Additionally, students tend to work together on the pre-lecture quizzes, further building a sense of community and belongingness. For more information on the benefits of pre-lecture quizzes, see the work of Heiner et al. and Narloch et al. (37, 38).

Use of Learning Assistants

Learning assistants, also referred to as preceptors, are typically undergraduate students whose main job is to guide students through tasks in the classroom (39, 40). Based on the local experience of faculty using active learning techniques in collaborative learning spaces, a preceptor-to-student ratio of 1:20 to 1:25 has been found to be optimal and is the ratio we use in our own classrooms. This is consistent with published ratios used at other institutions (41). After a year of experimenting with using learning assistants, in our second year of implementation, we chose to intentionally recruit a diverse set of students. Women, minorities, and other students with unique backgrounds, such as those with a diagnosed learning disability, were recruited to bring a broadly representative group of successful students into the classroom. Functionally speaking, the learning assistants are intended to help guide student inquiry in the classroom, not to give students answers to the in-class problems. We also deployed short weekly training sessions for the learning assistants to help them engage with students inside and outside the class using best practices. The highly motivated undergraduate students we recruit as preceptors understand the teaching model and are able to assist in our instruction in a wide variety of ways. The preceptors have turned out to be a major beneficial component to the student-centered classroom, aiding in various instructional tasks that otherwise would have taken much time away from us as instructors. For example, in one class, preceptors prepared and sent out a mid-semester survey to students, set up an extra review session, and conducted a thorough review of content prior to an exam.

Use of Real-World Problems

Incorporating real-world problems into classroom instruction, rather than using boilerplate textbook problems, allows for more student engagement and connection with the content (42). We have found that using problems drawn from everyday life that students might have personal experience with makes the content more engaging than using random, unrelated problems covering the same content. Personalizing content by drawing from students own experiences allows them to make connections between what they already know and the content they are learning. Making real-world connections a regular part of the instructional model is challenging in most disciplines (43). In our classes, examples from everyday life are used in an engineering context, a variant of problem-based learning. From calculating water removed from rapeseed in an industrial process to create the canola oil they use to cook their meals, to using the instructor's under-construction pool as an example for modeling fluid dynamics, to determining the amount of time it would take to de-gas an oxygen tank while scuba diving, many examples that connect to the students' own experiences can be applied in the classroom.

Music in the Classroom

Allowing students to access music during specific periods in the classroom, such as during high-stress exams, can reduce stress and anxiety (44), and we have anecdotally observed this in our classroom environment. Our original motivation to allow music in the classroom during exams came directly from a student request. As a result of that initial request, we now allow students to listen to their own music during exams, which has led to a significant reduction in perceived student anxiety. This experience led us to identify other ways in which we could use music in the classroom. We play music quietly before class, which creates a more social environment in which students are more comfortable interacting. This environment also increases the energy level of the class, and that energy then gets channeled into engaged learning experiences during the class session. Although no formal studies have yet documented this effect, we have anecdotally observed that having background music playing before class leads students to socialize more with their group than when there is no music playing in the background, which could support the development of a sense of belongingness.

Student Teams

In our classes, which meet in collaborative learning classrooms (45) with tables that seat four, three- to four-member student teams are formally assigned multiple times throughout the semester. This allows for the implementation of both individual and group work. We formally assign teams and change the teams after each midterm exam to allow students to get to know as many of their peers as possible during the semester. An informal survey given in Fall 2017 asked how many other sophomores each student felt he or she knew in the class and would be happy to work with outside of class. On average, students reported knowing approximately 35 other students. For comparison, one author remembers knowing two people at the end of this course when they were an undergraduate student, and one of those two was their roommate. Another author remembers knowing fewer than five students during their own experience in this course. The practice of creating formal teams multiple times throughout the semester has a strong impact on helping students build a network of peers and sense of belongingness (46, 47).

Student Teams: Underrepresented Minorities and Women

A strong sense of belongingness develops when a cohort of students work together and develop into a cohesive team. The feeling of fitting in is fostered when students—underrepresented minorities in particular—sense the social structure welcoming and accepting them. Rosser showed that ignoring race and gender could be detrimental to group work (48). For a resource on understanding the dynamics of groups, see the book by Bolton and Bolton (49). For evidence-based team formation and assessment tools, we suggest the CATME: SMARTER Teamwork tool, developed from an NSF-funded project dedicated to helping instructors form teams and assess team dynamics (50). In our courses, we create the first round of teams at the beginning of the semester based primarily on their academic record, then secondarily on minority classification. University analytics or an early quiz given in class could be used to rank students based on academics. The highest- and lowest-performing students are distributed among the teams. The remaining students are then distributed evenly. Once students are placed into initial teams, a quick check of demographics is done, and students are shifted between groups so that, if possible, women and other underrepresented groups are not outnumbered. Roughly three to five times each semester, generally after an exam, the teams are shuffled to continually expose students to more of their peers and build a culture of belongingness.

Incrementally Solving Problems in Class

Breaking down a problem and showing the individual steps taken to arrive at a solution is a mainstay of most engineering lectures. This model of instruction can easily be adapted for active learning environments. Because less experienced students tend to need more scaffolding when learning new material (51), we break a given problem down into many discrete steps and decisions. A problem that would typically be covered in one day during an instructor-centered lecture may take three to five class periods to work through using a scaffolded, active model that has the students work through the problem themselves, with our guidance. For this reason, we tend to promote depth of understanding rather than breadth of coverage. While we now work through a given problem more slowly, student response system submissions indicate that 80% or more of the students are working with us at a pace that they can handle cognitively. When we encounter a step that many students do not understand how to do, as evidenced by their initial response to a question, we take the time to stop and give a mini-lecture and then re-poll the question to make sure that students understand the concept before moving on to other part of the problem.

For very complex problems that take many days to solve in class, we create a post-lecture quiz in the learner management software that guides students through the entire problem again but with randomized ranges of variable numbers. Anecdotally, a number of students who might have struggled to stay in engineering have emailed us and indicated that, while the quiz was challenging, it helped them assimilate the whole problem. Experiences like this increase self-efficacy and give students practice with a meta-cognitive process that helps them identify what they know, what they do not know, and where to focus their energy. On post-lecture quizzes, students are given an unlimited number of attempts so that they can iteratively work toward full comprehension and understand the entire problem-solving process.

Cold Calling on Students

Cold calling on students entails the planned or spontaneous selection of a student or group to answer questions presented in class. More often than not, this is a spontaneous event, used as a means to check student engagement with material (52). We use a flashcard app for phones and devices that displays our student names and pictures in random order. To give students time to prepare an answer to the question we are asking, we use the flashcard app at the beginning of the problem-solving period to randomly identify several students who will be called on and then notify them that they will be asked to provide an answer at the end of the allotted time. This gives them time to prepare an answer and to work with their team if they are uncertain.

We want to be clear that when we cold-call on students, we are always positive and growth-mindset oriented in our response to whatever they offer up as their solution, answer, or idea, even if it is "I could not come up with anything." We paraphrase their response and guide them toward the answer by asking simple, guiding questions.

Learning Student Names

Learning student names has been shown to improve the classroom climate and to promote a sense of belongingness (53). Our university system provides a list of official pdf-based pictures of students in our classes. We convert that list into a flashcard app on our smart devices. We describe another use of this app in the section above on randomly calling on students in class. The primary purpose of the app is to help us learn student names. The app is more effective than our prior paper-based methods of memorizing names because we always have it available in a portable form for spaced practice. To make it easy for our colleagues to take advantage of this resource, our university teaching and learning center has developed a website-based version that they are now piloting.

Job Openings and Internships

A valuable part of the educational experience in many STEM disciplines, certainly in engineering, involves participating in an internship or co-op experience prior to graduation (54). After identifying a lack of student awareness about how to identify and apply for internships, research opportunities, and job openings, we decided to share postings for these opportunities consistently in nearly every class session to rectify this problem. Originally, we were simply sharing different openings for career advancement. However, as we progressed in our own development as instructors and applied active learning techniques to this activity, we started having students look up the job postings themselves and answer questions about them. This not only helps students become aware of opportunities available to them but also builds the skill of independently identifying various career opportunities.

Lecture Capture

Lecture capture involves using technology to record content delivered in the classroom (or for an online class) so that it can be viewed repeatedly after the event has occurred. In our classrooms, we use lecture-capturing software to record every lecture. These recordings are made available to students the same day. Some instructors fear that providing recorded lectures may reduce classroom attendance. Because a portion of our students' grades is based on attendance, we avoid this issue of poor attendance that may result from having access to recorded lectures (55). We have found through our own experience that the benefits of allowing students to re-watch a lecture vastly outweighs the potential for a student to skip class and the risk of occasionally having technical issues with the recording software. Our campus IT staff has been instrumental in helping us address those occasional technical issues and build confidence with the lecture capture software (47). Additionally, recording lectures is an inclusive practice designed to increase students' sense of belongingness. If students must miss class for some reason or are not able to attend due to external issues such as childcare conflicts, providing access to a class recording shows the students that the instructor cares about them and their education.

Class Structure and Syllabus Decisions:

Introduction

Even before they enter the classroom, the decisions that faculty make set the tone for the classroom environment and are potentially more important than what happens in the classroom. These decisions include determining how points are allocated among different student activities and deliverables, what grading scale is chosen, and the level of detail communicated to students. This section describes how different structure and syllabus decisions influence the four affective domains.

Syllabus Practices

As instructors, we have found that there is always work to be done to improve the course to better align it with the principles of universal design for learning and to promote the four affective domains (56, 57). This includes regular updates to our syllabus language. The four affective domains are embedded in the language used throughout our syllabi. Specifically, belongingness is promoted by explicitly talking about group dynamics, promoting interactions between students in a collaborative space, and using inclusive language (such as "we," "us," and "our class"). We also include a synopsis of our teaching philosophy, further building the sense of community and openness in the classroom. Growth mindset is promoted through the language used, such as "I want you all to develop…" and "If you don't succeed at first, keep trying!" A section in the syllabus provides supplementary materials and links to resources about building study skills and a habit of self-reflection, encouraging metacognition. Self-efficacy is promoted through the language we use. For example, we state in our syllabus, "Everyone has the right and ability to be successful in this course."

Soliciting and Using Feedback from Students Mid-Semester

In our classrooms, we use mid-semester questionnaires and "minute papers" at the end of the class to provide mechanisms for students to give us feedback on our instruction (58, 59). We use the feedback we receive from students to alter different aspects of the course to facilitate student learning. Providing multiple opportunities for students to provide feedback before the university-mandated end-of-semester review makes it possible to be agile with the course. Because each cohort of students tends to have a slightly different character, we can modify the course each semester to best suit that individual cohort's needs.

Modifying Classroom Layouts
In our time as instructors, we have taught in a variety of different classroom layouts. Unfortunately, some classrooms were designed with fixed layouts where group collaboration is difficult. We implemented group work in these settings, but the experience was less than ideal, especially in situations in which the instructor and learning assistants could not physically approach all of the groups because of the seating arrangements. In other classrooms, desks and chairs could be moved or rearranged to allow easy collaboration, building on belongingness and providing broad group work–related benefits across all four affective domains. Rearranging the classroom generally involved moving desks into blocks of four to create optimally sized student groups. With class sizes of up to 50 students, we have found that having students shift desks around to facilitate collaboration does not take up too much class time. Further, the benefits of rearranging the classroom vastly outweigh the time costs. Ideally, collaborative learning spaces would be built by universities to facilitate engaged, team-based classroom practices (60).

Grading on a Straight Scale
We use a criterion-referenced or straight grading scale in our core classes. This is inherently a more equitable practice, as students are compared against a predetermined standard rather than against other students in the course. This approach supports a growth mindset rather than a grade-driven mindset (61). If students put in the time and effort and perform well on the evaluations, they deserve to be graded as individuals, not in comparison to their peers. We believe this approach can lower the competition between students and foster the collaborative environment that we seek to create for our students. Note that with this approach, exams and assignments can still be rescaled as needed using a flat scale to account for a poorly written or unfairly difficult question.

Regular-Interval Homework
In our courses, homework is due weekly or, if the homework requires a higher than average time commitment, biweekly. We have found that students, although resistant at first to doing homework, mention that they appreciated the assignments later in their academic careers. This applies to upper-division courses in particular. We often see upper-division courses with few if any homework assignments; the course grade is then exclusively determined by the grades earned on the two to four exams given throughout the semester. We do not believe that this approach supports student success across all demographics. Students have many demands placed on their time. Without the structured incentive of graded homework assignments, it is difficult for students to prioritize regular study sessions. What tends to follow are cramming sessions before exams rather than a slow and steady progression of learning, which has been shown to be optimal for long-term knowledge acquisition (62).

Group Homework and Exams
Because there is a strong social component to learning, we assign group homework, and our exams incorporate a group component. A typical homework assignment consists of 50% individual questions and 50% group-based questions. Students work as a team to complete the more challenging group questions, and the group receives a single grade for those questions. Students are free to collaborate on the individual questions, although they must do the work themselves.
For exams, we tend to deliver the group portion of the exam first, followed by an individual portion. The student's performance on the individual portion gets used as a scaling factor for the amount the group portion is worth in their overall exam grade. Practically speaking, when students work in groups on homework or exams, they are able to check and refine their understanding of the content through peer feedback, further influencing the four affective domains. Because repeated practice inherently promotes a growth mindset, group homework allows students to practice engineering problems and correct mistakes on low-stakes assignments. On exams, the group portion allows students to address any lingering

misconceptions they may have, making the exam another learning experience rather than simply an evaluation. Because of the collaborative aspect, we can assign much more difficult problems for the group exams and homework. The peer-review process that occurs during group homework and exams builds self-efficacy and belongingness as the students struggle together to solve the challenging problems. Metacognitive strategies are also reinforced because many of the homework and exam problems build on previously learned material, promoting retrieval practice. Some of our group homework assignments have points assigned for completing a concept map (described earlier in the Teaching Learning Strategies to Students section), further supporting the development of metacognition in students. See Part 1(10) for the literature supporting these claims.

Requiring Attendance
Because we use active learning techniques that require students to be present to participate and benefit from the experience, we require attendance. In terms of grading, attendance and/or online presence (in particular for online courses) is generally worth approximately 10% of the course grade. Having a meaningful portion of the course grade based on attendance allows us to ensure students are present to benefit from the classroom practices we are implementing to promote the four domains that help with student retention. Participating in the classroom activities promotes a growth mindset as they experience and learn from small failures and gives students practice with various metacognitive strategies, as discussed in the Teaching Learning Strategies to Students section. Requiring students to be present also allows for more effective group work. Students who are present and participating in class have access to multiple pathways to increase self-efficacy, through vicarious mastery experiences in particular (10, 63). Lastly, because we deploy various measures to build a sense of belongingness in the classroom, students need to be present to create the inclusive environment.

Cumulative Exams and Quizzes
On our assessment instruments, we intentionally dedicate at least a small portion of the material (approximately 10%) to cumulative questions. Most of the coursework in our engineering discipline builds on itself. As such, 50-70% of the material on quizzes could be considered "cumulative." These cumulative quizzes allow for retrieval practice and for students to retain information better. All exams have cumulative components as well. We believe that exams should be viewed as both summative and formative assessment tools; reviewing the mastery of cumulative content on exams allows instructors to determine how students are integrating previously learned material and concepts into current problems and tasks. Using exams as formative assessment instruments also allows the instructor to make any necessary mid-semester changes to the course or syllabus.

Sharing Rubrics
When we first started using grading rubrics, they were not very specific and would allocate many points to a given multistep solutions. We found that this rubric format did not allow students to metacognitively reflect on what they really knew and did not know in a useful way. We now discretize the solution into individual steps, much like we do in a scaffolded classroom activity, and assign points to each step on the grading rubric. We have generated rubrics with as many as 65 discrete steps for some of our exams. Students now come to office hours or turn in a re-grade request and can specifically comment on or ask a question about a specific step and receive targeted help and feedback. This could improve their self-efficacy because they can judge how well they understand each of the steps and then take corrective action. Students thus can take control of their learning in a more targeted way.

Posting Proficient and Distinguished Student Work
In the classroom, we show student work from tasks completed during class. We usually take a photo or display a group's whiteboard to the class via projector, followed by our own solution to a problem. Outside of the classroom, we no longer post our own solutions to homework but instead post student work as keys. Students whose exemplary work is chosen as the solution key are usually emailed for

consent to anonymously post and congratulated on the quality of their work. This feedback is meant to build self-efficacy by providing verbal and vicarious mastery experiences (64, 65).

Rapid Feedback on Exams and Homework

With the many demands placed on faculty time, it can be difficult to provide rapid and targeted feedback to students on their work to improve student affect (66). By having a teaching team (as described in the Use of Learning Assistants section), feedback and grading can be delegated. Graduate teaching assistants, hired graders, or learning assistants can all help with the workload to grade the homework. Additionally, the use of technology, like ZipGrade or GradeScope, can help instructors with or without teaching teams quickly grade exams and quizzes and provide immediate feedback to students.

Estimating Time Taken on Assignments

Developing this teaching strategy has taken time and required feedback from students. Estimating the time to complete an assignment, in addition to the extent of course structure (67), is an area where we are still iterating. The amount of time students take to complete a given assignment does not appear to be static from semester to semester. Because students tend to have access to previous homework solutions, we tend to change the homework assignments each time our courses are offered. We do our best to predict how long students will take to complete an assignment and can typically provide estimates that are accurate to within 30 minutes for a typical student. The predicted amount of time required is provided in parenthesis as part of the assignment details. We ask for feedback from students on how long the assignments actually took to continue to improve our accuracy.

Listing Class Objectives

We originally listed lesson objectives at the beginning of the class period but found that students were often distracted while getting organized. It also did not benefit students who showed up late to class. When we shared them at the end of class, students would be packing up and already checked out. As a result, in our most recent class iteration, we list general objectives at the start of class and then specific learning objectives as we complete them during class. Because we use PowerPoint as our main visual method of delivering content, we include a formal slide after we deliver content where we state the specific learning objective that has just been completed. This supports Lang (68) and McGuire's (34) suggestion to explicitly list class objectives; we implement the suggestion strategically so students can see the link between content and objectives. Additionally, having the learning objectives listed as the relevant content is presented not only increases metacognition but also helps us align the teaching practices with the learning objectives.

Outside of Class Practices:

Introduction

Out-of-class experiences represent the final category in this two-part paper series describing practices that faculty can use to help increase retention and student engagement. From acknowledging students in public, to setting up informal events, to promoting the development of a cohort of strongly connected students, to encouraging students to attend office hours, there are numerous ways in which instructors can increase their connection with students. Simply acknowledging students on or off campus with a friendly wave or greeting provides social and motivational benefits (69). By focusing on the retention of students from multiple angles – not just classroom-only practices – we have found that students become fully immersed and invested in their education. With the extra effort strategically invested by instructors, we have witnessed improvements in each of the four affective domains. As stated in Part 1 (10), we would like to note that these interactions with students are professional interactions and are ones that would not have the same level of intimacy as one would expect in a personal relationship.

Student-Faculty Interactions

Facilitating out-of-class activities and interactions allows us to provide a holistic experience to our undergraduates, a need reported in the literature (70). The goal of education is, in the words of Martin Luther King, Jr., "to teach one to think intensively and to think critically… intelligence plus character – that is the goal of true education. The complete education gives one not only power of concentration, but worthy objectives upon which to concentrate." Many faculty share this same sentiment about the goal of education. As we see students around campus or in the community, we approach them through this lens. We want to help make our large university feel smaller and more personal for students so that they feel comfortable developing their character as well as learning content.

Informal Events for Students

We have social lunches with students approximately every two weeks and specifically invite different small groups of students to join us. We also do biweekly bike rides from campus to local restaurants and share aspects of the community that students may not be aware. We have found that students are much more relaxed and willing to open up about their challenges and fears in this informal context. We have also observed that sense of belongingness increases when students encounter each other in class soon after one of the rides, since they have shared a common experience.

Promotion of an Inclusive Cohort

To create a more inclusive cohort of students, we further encourage students to engage with each other outside of class. Having various social dynamics is hypothesized to lead to better mental health. As students in higher education often fill their day with hours of studying or working to help makes ends meet, very little time is available for socializing. To help students combine both social and study time, we strongly encourage students to work together and to develop a cohort that will likely persist beyond their college years. As mentioned in Part 1 (10), this encouragement to study in groups led to the spontaneous congregation of a network of our students in one of our campus libraries. Anecdotally, student have reported a strong connection to that library as a place to develop as scholars.

Encouraging Office Hour Attendance

Each faculty member holds regularly scheduled office hours in locations that are convenient for students. We specifically conduct polls to ensure that we are choosing times when most students can attend. We are prepared to not only talk about the class content but also to support students through the challenges they face by sharing experiences we have had that are similar to challenges the students are trying to overcome. One of the authors finds it easier for students to meet in the library for office hours, as most of the students who would participate are already in that location. This faculty member often has interacted with between 10 and 20 students in one hour when meeting in the space where students are studying.

Discussion and Conclusion

We promote all of these teaching practices through the lens of four key affective domains: promoting a growth mindset, building students' self-efficacy, developing students' metacognitive skills, and fostering a sense of belongingness. The teaching practices described can be implemented by nearly any instructor in nearly any classroom to promote growth in these four areas. Encouraging long-term integration and use of the teaching practices supports the development of high-quality educational settings for students. Because changing teaching practices is challenging, especially with something as personal and deeply engrained as one's own teaching style, we suggest adopting new teaching practices one or two at a time, starting with ones that integrate well with the instructor's existing beliefs and practices. In essence, we suggest collecting the "low-hanging fruit" first and reaping the rewards of those changes to build momentum and confidence in one's ability to become more student centered. Every instructor will have a different personality and way of managing the classroom. The various practices can be implemented in a number of different ways. It is up to the individual instructor to be creative and find what works best for them.

The process of implementing new teaching practices and developing as an instructor is lifelong. The variety of teaching practices we listed in this work have taken many years to implement and develop. Each practice continues to evolve over time. Just as we would expect growth in our students, we continuously look for ways to improve and grow as instructors. Our successes with the teaching practices have most likely come from being reflective about our teaching. By continuously working to evolve the strategies, practices that once felt awkward and unfamiliar now feel natural, efficient, and effective. The reflection process was not done alone; students, guest observers, members of our faculty learning community, educational specialists, and others have observed our classes and given us requested feedback, which has allowed us to dramatically improve our teaching. Each discussion we have with other curious faculty allows for greater understanding and introduces different perspectives on the practices. We encourage each of our readers to seek this growth themselves so that the improved quality of our combined efforts provides increasing benefits to our students and the future of higher education.

Declarations:

Availability of data and material

Not Applicable

Competing interests

None

Funding

Why Women Persist: Evaluating the Impact of Classroom-Based Interventions, Engineering Information Foundation, Grant # EIF17.10

Authors' contributions

Hempel drafted the manuscript, managed the paper, identified, implemented, and refined the teaching practices described in the document, co-taught with other instructors to gain better insight into the practices, and helped elaborate on and apply the affective factors.

Kiehlbaugh identified, implemented, and refined the teaching practices; co-developed the multi-dimensional affective model for framing the teaching practices; and edited and substantively revised the manuscript.

Blowers conceived the work; identified, implemented, and refined the teaching practices; co-developed the multi-dimensional affective model for framing the teaching practices; participated in drafting the manuscript; and aided in the review process.

Acknowledgements

Special thanks to Justine Schluntz and Kerri Hickenbottom for contributing their own insights regarding these teaching practices and for co-teaching with us. Our discussions about the various practices while co-teaching led to many changes and improvements to our own teaching practices.

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Appendix C

Affective Drivers that Influence the Implementation of An Instructor's Teaching Practices in a Large Introductory General Chemistry Course

Abstract

With the call for teacher reform in STEM education, there is a dramatic need for best teaching practices to be implemented in higher education classrooms. To improve teaching practices, instructors need adequate content knowledge and support to grow as instructors. Less recognized and addressed are the affective drivers which lead an instructor to improve their teaching practices. This case study followed one instructor through their General Chemistry Course over two semesters to gain an in-depth understanding of the affective drivers affecting their implementation of different teaching practices. Through semi-structured interviews based on notes from classroom observations, the instructor was found to have both internally and externally focused affective drivers. The internal factors, focusing primarily on the instructor's self, included basic emotional needs, motivation towards self-improvement and learning, and self-efficacy regarding instruction and chemistry. The external affective factors included feeling like a supportive faculty, feeling empathy towards students, and having expectations for students' personal successes. Understanding these affective drivers, if they are found to be common to other instructors, could allow a professional development team to target and effectively push for teacher improvement and change in the classroom. The authors suggest that approaching teacher development first through the affective lens will allow for more effective support for change and adoption of teaching practices.

Background and Introduction

Teaching and teacher education have evolved dramatically over the past few decades (1). On an instructor's path from novice instructor towards expert performance, there are various pathways to take and different measures faculty consider. As seen in the literature, professional mastery has traditionally been measured by length of experience, reputation and perceived mastery of knowledge and skill (2). In actuality, active engagement in deliberate practice is realistically one of the strongest pathways leading to mastery (3). With feedback from various sources (such as student evaluations of teaching and peer observation), time for reflection, and opportunities to repeatedly perform and refine behavior, an instructor can develop him or herself to be a highly skilled instructor (4–6).

Separate of the classroom characteristics implemented by the instructor, various outside factors come into play when an instructor decides to either adopt or reject different teaching practices. A general, non-exhaustive list of different factors influencing faculty decisions in and outside the classroom could include(7–13):

- Departmental pressures to fulfill university-wide requirements
- Personal beliefs about teaching methodology
- Technical difficulties and proficiencies with classroom implementation of technologies
- Instructor self-efficacy towards implementation of evidence-based teaching practices
- Restrictive curricula that allow no academic freedom
- Amount of pedagogical teacher training
- Collaboration with other faculty in the department or campus regarding teaching and learning
- Professional development influences
- Student-teacher interactions
- Personal beliefs about material and how it is best learned
- Social dynamics in the classroom between all individuals present (teaching team and students)
- Use and beliefs around formative assessment
- Use and implementation of instructional teams and feedback from members of those teams
- Reflective practices and professional growth regarding teaching and learning
- Desired classroom structure, among many others.

With this many factors to consider regarding teaching, instructors can go through a cyclic process when testing new teaching strategies as described by the innovation-decision model discussed by Andrews and Lemons (14). When new strategies are considered, different aspects of the instructor need to be considered. Rather than focusing solely on content knowledge or knowledge of instructional practices, teacher beliefs and self-efficacy play a major role into the adoption of different practices (15). Veen et al. also suggests that the cognitive-affective process needs to be considered to understand the personal, moral, and social concerns teachers may have when considering reform (16). Note that cognitive and affective neuroscience are still interacting on the relationship between brain regions and the physical manifestation of these processes, and are working to understand how cognition and emotions are integrated in the brain (17). Because these affective drivers have not been extensively explored in teacher practice, this case study will focus on one instructor's various emotional, motivational and attitudinal characteristics regarding changing of teaching practices. With a focus on the affective drivers, rather than just the cognitive factors, teaching thinking and choice of practices can be better understood, and allow greater insight into the teacher development process.

Theoretical Framework

In order to deconstruct the different factors that influence the instructor, this case study will use a postmodern/poststructural perspective (18). This viewpoint will emphasize differences and multiple outlooks of the same phenomenon as lived by an instructor to reveal hidden or latent meanings and to uncover further different affective drivers that influence an instructor. The poststructural method allows researchers to tease apart different assumptions and interpretations an instructor has about the world, allowing for claims to be made about how various factors interplay to determine how affective drivers influence teaching practices (18). Models from Dole and Sinatra (19), and Gregoire (20) emphasize that both a teacher's knowledge and their affective drivers should be considered when observing teaching practices. The use of a case study allows for the current study to delve into the affective influencers, as affective perceptions can be highly personalized (21).

Depending on the perspective taken and area of study, affective drivers, sometimes referred to contextually as affective factors, have various definitions found in the literature. English Language Sciences describe affective factors as entities that relate to the learner's emotional state and attitude toward a certain goal (22). Southerland et al. simply describe them as emotions, motivations and beliefs (21), while Cela-Ranilla and Cervera list them as simply feelings (23). Dornyei and Hurd both refer affect to the emotions, feelings and attitudes that individuals bring to the learning experience and the role these play in motivation (24, 25). More generally, affect is a work that encompasses not only emotional states but also many other experiences that involve pleasure, displeasure, and physiological arousal (eg. motivation, physical pain) and which doesn't assume that our various emotions are discrete and separate entities (26). One largely studied example of an affective driver is a teacher's self-efficacy (27). However, this tells only a part of the story of teachers' approaches to their practices, especially with reform and adoption of different practices (28, 29). Examples of affective drivers that could influence an instructor's use of teaching practices are: being motivated by some combination of anticipating rewards, experiencing fear of censure with not doing well, experiencing innate curiosity about a topic, or feeling the desire for future career success.

To further explain the classification of the affective subcategories of emotional, moods and motivational states, we can begin to understand what is meant by affective drivers. Emotions, such as anxiety, are complex, multifaceted phenomena that combine feelings (experiential elements), physiology (heart racing, labored breathing), and expression (body language and facial expressions) (30). Some view emotions as distinct prepackaged programs, like apps on one's computer while others argue that emotional experiences are instead complex, interrelated systems of body, brain, and mind. Emotions and emotional regulation are still relatively new fields and are still being clearly defined by research (31). For this paper, we will apply the idea from Gross that emotions generally predispose us to approach rewarding experiences and avoid punishing situations. Emotions are exquisitely sensitive to modulators such as situational context and relevant past experiences (31). Emotions are generally short lived that have a direct object and direct goal, while moods are longer lasting, from hours to days, and may not have an exact contextual factor. Motivational states also have much in common with emotion: they involve goals, invoke approach or avoidance behavior, impact neurochemistry and hormonal responses, and have evolutionary significance (26). Varma, McCandliss and Schwartz point out that education has traditionally treated motivation, emotion, social factors, and learning as discrete, separate concerns in the classroom, whereas neuroscientific findings increasingly suggest that the reward system governs all four of these processes (32). As such, the discussion of the affective drivers will incorporate these different components into the analysis of the instructor's discussion of their classroom. To allow for simplicity of writing, this paper will use "emotions" as synonymous with the closely related terms of "mood" and "drive".

To build a framework of how different affective drivers influence an instructor's thinking, and subsequently influence teaching practice, this paper uses a model that begins with a foundational statement from How People Learn II: "that every individual's learning is profoundly influenced by the particular context in which that person is situated" (33). In this case, our instructor is a learner of various teaching practices and has various characteristics to consider. As suggested by Loftland, Snow, Anderson and Loftland, affective drivers in this research were focused on prior to analysis, and lead to the factors described in this paper (34). The model further draws mainly from the work of Gess-Newsom (35), using the Teacher-Centered Systemic Reform Model (TCSR). This model is mostly comprised of four main areas: teacher thinking, teacher practices, personal factors and contextual factors. Teacher thinking involves teachers' knowledge and beliefs about change, content being taught, students and learning, teaching efficacy, and schooling. Teacher practices are those observable actions taken inside and outside of the classroom that affect a student's education. The personal factors (personal contextual factors in the TCSR model) include the demographic profile of the instructor, nature and extent of teacher's preparation to teach, types and years of teaching experience, and the nature and extent of teacher's continued learning efforts. Additionally, we believe that personal factors can delve deeper into the psyche of the instructor of focus, and could include layers such as those described in the onion model by Korthagen (36). However, these ideas are beyond the scope of this paper. The contextual factors (contextual factors of structure and culture in the TCSR model) varies from a wide scope (bringing in national, state and local contexts) to a school setting, to the department and subject area context, and down to the classroom context. A more detailed description can be found with the work of Woodbury and Gess-Newsome (37). When we apply where affective drivers influence the model, we can create the following simplified model:

Figure 1 - Modified Teacher-Centered Systemic Reform Model of Educational Change

The bolded arrow between teaching thinking and teacher practices and shaded area are where this study focuses on affective drivers. The arrow is highlighted as this will be the focus of the study: the interplay between teaching thinking and teacher practices through the lens of affective drivers. The arrow, in effect, represents the interplay of affective drivers that lead an observer to develop a sense of an emotional rudder that the instructor uses to help guide their decisions (38).

While observing the relationship between teacher thinking and teacher practices, we find that competing factors tend to arise internally and externally within the instructor. For instance, Kosnik et al observed preservice teachers performing self-studies sort through their conflicts and contradictions and examine their prior beliefs and philosophies while teaching. Many of the teachers reported having their deepest feelings and strongest beliefs change in two to three years (39). Dissonance theory, first coined by Festinger (40) and building upon Heider's work (41), assumes that individuals have an innate tendency to align thoughts, attitudes and beliefs. When elements are unbalanced or "dissonant," motivations arise to restore equilibrium and results in a change in behavior. Additionally, under the realm of teacher reform, pedagogical discontentment refers to the gap in the application of affective influences (such as teacher self-efficacy (9)) to understand the change or lack of change of an instructor's practice (42). When looking at the instructor's adopting or discontinued use of different teaching practices, pedagogical discontentment can be applied to the data to help understand the internal debates occurring in an instructor. A more modern model that incorporates literature on both the cognitive and affective side is the cognitive-affective model of conceptual change (20). Although teacher reform is beyond the scope of this paper, the insights from teacher conceptual change allow for tools to help understand the decisions made by an instructor in the classroom.

Purpose of study

With limited literature explaining and detailing the different tensions an instructor would potentially face while transitioning to evidence-based teaching practices, this case-study gives insight for faculty preparing themselves for improving their teaching practices. With so many different aspects and pressures influencing decisions made in and out of the classroom, distilling one instructor's experience can provide lessons for other faculty. In particular, looking at the affective drivers, not simply the cognitive domains, can lead to greater insight into the skill acquisition process (43).

The purpose of this study is to provide greater insight into what affective drivers influence an instructor and how they impact choices and actions. The case study will not only provide insight into the professional and personal pressures that instructors face while transitioning into deploying evidence-based teaching practices, but will provide insight to faculty interested in improving their own teaching. The main questions/hypotheses that this case study will address are:

1. What affective drivers influence teaching decisions and practices?
2. How do these affective drivers influence teacher decisions and practices?

Methods

In this particular single-person case study, one instructor was chosen as the subject for an in-depth study of the different affective drivers involved with selecting and changing teaching practices. The main teaching practice selected for observation includes using tasks in the classroom to improve student learning while deploying a teaching team composed of undergraduate and graduate student assistants. The instructor used a teaching team consisting of four main types of roles: the lead instructor (the faculty member themself), one or more learning researchers, one or more instructional managers, and a team of several learning assistants, depending on the size of the class (reference for IT-P). In addition to implementing an instructional learning team, the instructor implemented formative assessment techniques to gain insight into student learning and by varying their classroom decisions, promote retention and understanding of material, respectively (44–46).

Instructor Profile

The instructor of focus has been teaching for 10 years at their current R1 University. They participated in Faculty Learning Center Workshops for 2 years, an Instructional-Teams Project grant (reference for IT-P), an ACUE program, and numerous workshops both on campus and in national conferences around the United States. In 2017, they was awarded The College of Science Distinguished Early Career in Teaching Award.

Data collection

Data collection pertaining to this paper was conducted from June through December 2018. Every class for both the Summer II and Fall semesters was attended, creating 53 classroom observations. In addition to the observations, 19 semi-structured interviews were conducted, transcribed, and analyzed to gain insight into the instructor's beliefs and factors influencing their teaching and instruction. Pre-semester interviews consisted of planned interview questions. During the semester, interview/discussion questions were guided by the classroom observations, and had an emergent characteristic towards themes seen in the classroom. Post-semester interviews questions contained a mixture of pre-planned questions and open-ended questions to summarize themes and trends that emerged during each semester. Support from the research team ensured that qualitative best practices were followed, such fallacies as observer effect

(Heisenberg effect) were avoided, gave guidelines for reliability, and reducing interviewer subjectivity (47).

Classroom Design

The physical setting in which an instructor teaches can determine how effective different teaching practices are (48, 49). Facilitation of learning in classrooms can have a nearly infinite number forms. To narrow down classroom variations, modern classrooms can fall along a spectrum of being a pure lecture hall to having a fully collaborative learning classroom (see Lee et al for an example (50) of a collaborative learning space). Various measures can help characterize what is happening in a classroom (51), one being the Reformed Teaching Observation Protocol (RTOP) (52, 53). A more recent version, the College Observation Protocol of Undergraduate STEM (COPUS) tool, has been used (54). Further research by Lund et al categorizes classroom according to both COPUS and RTOP as adopted in Figure 1 - Characteristics of Different Lecture Styles (55):

Figure 2 - Characteristics of Different Lecture Styles

Table 1 - COPUS Codes Used in Characteristics of Different Lecture Styles

Code	Description
Lec	Lecture (presenting content, deriving mathematical results, presenting a solution, etc.)
RtW	Real-time writing on board, doc, projector, etc. (often check off along with Lec)
AnQ-S	Listening to an answering student questions with entire class listening
SQ	Student asks question
CQ	Asking a clicker question (mark the entire time the instructor is using a clicker question, not just when first asked)*
FUp	Follow-up/feedback on clicker question or activity to entire class
MG	Moving through class guiding ongoing student work during active learning task
GW	Students working in groups on worksheet activity

Taken from Smith et al. (54) *Note: other forms of formative assessment can be categorized here

COPUS is conducted by monitoring what is happening in the classroom by both the students and instructor every two minutes. Figure 1 above displays what the instructor is doing during class time. If we look at the main characterizing columns of Instructional Style and COPUS Profile, we will notice that lecturing percentage tends to decrease the farther down the table one observes. Additionally, the amount of group work largely influences the characterization of the instruction.

Data using the COPUS tool from Fall 2018 from 10 weekly classroom observations is shown Table 2 of the instructor's teaching in Freshman Chemistry I in a lecture hall oriented classroom design for up to 600:

Table 2 - COPUS Results from Fall 2018

	Lec	AnQ-S	SQ	CQ	Fup	MG	GW	Other
Percent	36%	8%	7%	2%	30%	30%	26%	31%
SD	17%	6%	4%	3%	10%	21%	23%	27%

Note: RtW was not collected. N = 10 classes, taken weekly

The data from Fall 2018 shows that the instructor's class has a mixture of different activities but would be defined as a classroom functioning between a collaborative learning space and extensive peer instruction based on Lund et al's research (55). At different times, but much less frequently, the instructor conducted instruction along the lines of a transitional lecture, where around 80% of the time was spent lecturing or performing a follow up lecture to a student question.

Qualitative Analysis

The research in this work draws upon the guidance of Maxwell (56), Saldana (57), Corbin and Strauss (58), and Bogdan and Kiklen (47) to guide the coding and thematic approach from a grounded theory perspective. The data was binned originally into separate major thematic categories. These broad groupings allowed for easier access to content, and then was used as a data bank to filter different content into the various affective themes found in the results. The filtered down bank of interview data can be found in supplemental materials.

Representation of Results

We report the collected interview data as follows. Quotes longer than three lines from the instructor are represented in block paragraphs. Blocks being with the date when the interview occurred as DD/MM; every interview was performed in 2018. Words in square brackets were added by the researchers to clarify content or context. Anonymity was maintained through putting words in curly brackets to conceal information, such as {co-worker}. This example would represent a co-worker of the interviewer. Words in parentheses represented non-verbal participant responses, such as (laughter) or a (pause). Ellipses (…) were used to indicate a section of data was removed because it is not relevant and to maintain brevity.

Results

To categorize the different emergent affective drivers that have impacts on instructional choices, two main categories emerged: internal affective drivers and external affective drivers. The main difference between the categories is where the focus of the emotional state of the instructor is directed. With internal drivers, “feeling basic emotional needs,” “feeling motivated towards self-improvement and learning,” and “feeling self-efficacy towards instruction and chemistry” were sub-categories that were revealed. These are components that focus inwardly towards the instructor and their teaching practices. Within external factors, “feeling like supportive faculty,” “feeling empathy towards students,” and “having expectations for students’ personal successes” were generated to categorize how the instructor expanded their energies outwards, typically towards students. With these two major classifications, the data reveal a mixture of both internal and external drivers. Figure 3, created from the results obtained, illustrates the different affective drivers influencing the instructor in higher education.

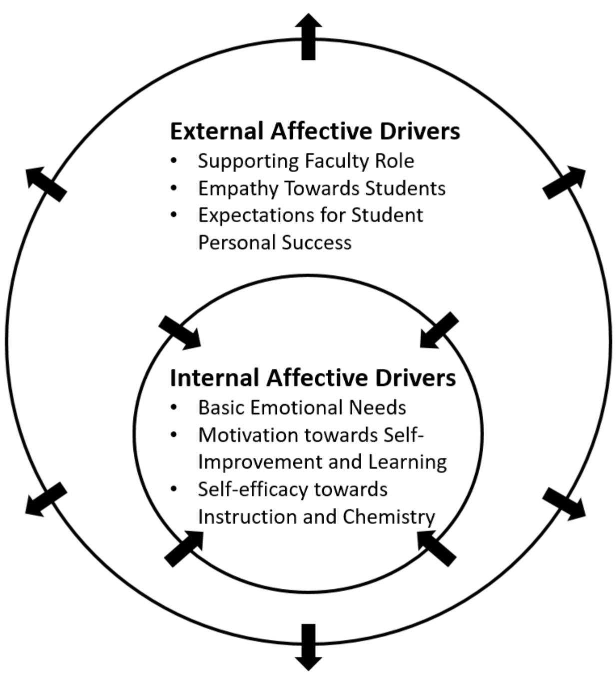

Figure 3 –Main Affective Drivers

Internal Affective Drivers

From the perspective of the instructor, internal affective drivers related to the internal emotional states and needs that they self-reported during the interviews about their students and classroom experiences. These affective drivers were directed at herself, not necessarily to any other entity. Although they may involve other individuals or outside factors, they tended to affect the instructor as the primary focus. We now break this grouping up into the smaller foci.

Feeling Basic Emotional Needs

Of the variety of various emotions that an individual can have, the instructor in the study altered or implemented different teaching practices due to the affective drivers associated with love, joy, care, fear, anxiety, and frustration. The main emotional driver found through all of the interviews was the considerable amount of satisfaction they received from instructing students. They stated:

11/27: Even if I'm having the worst day I will walk out of class happy and in a better mood and be happy and be able to forget it all in class. I can't forget it when I'm lifting and I'm in Aikido. Honestly, teaching is the only place I'm capable of really pushing everything away and just [one] hundred percent focus on my students and their success. And I love that.

This love for instruction seemed to be the upmost driver for the instructor. The motivation to always be pushing students towards success seemed to stem from this basic feeling of love towards teaching and instruction and the interactions with the students. As they generated these emotions in class, the fulfillment appeared to fuel their determination.

The sense of fulfillment and love for instruction is likely a strong driver to why the instructor continuously taught summer classes. Even though they repeatedly mentioned in the interviews of needing a break from the stresses of working in academia. The instructor continued to teach summer courses over the past few summers. They stated, "I love summers, I mean they're crazy, but they're smaller and you really get to know your class … I really get to form personal relationships with the students and so that's why I love summer so much." The instructor reported that summer courses were an easy to alter their teaching practices. The instructor disclosed that the summer was a safe space to implement different teaching practices, as they would be affecting roughly one-hundred students versus six-hundred students during a normal teaching semester during fall or spring semesters.

Perceiving themself as being a role model and receiving the love and respect from students further motivated the instructor to continually push harder in their educational skills. With the direct impact they could have on students simply by displaying their natural work ethic and growth mindset, they appeared to motivate students as well. This in turn made their further develop strong emotional satisfaction. They stated:

07/27: That's what I love about this job. So, the students see that [I love my job]. The students see my passion for it [teaching chemistry], they see that I care, and it makes them care in turn [and try harder in class]. And so then they work harder. And then they have a little bit more enjoyment for a class that they hated. Like my favorite TCE [Teacher-Course Evaluation] comments are "she made me not hate everything about chemistry while I sat in their lecture." And that's probably not what a lot of professors are looking for, but that makes my heart sing.

Furthermore, when students performed well in the classroom, by either answering student response system questions correctly or scoring higher than other classes on an exam, the instructor felt pride. They described that they implemented different tasks and activities for students, as seen in various classroom observations. They believes these in-class and out-of-class activities helped push their students to success. This showed through the instructor having consistently higher-than-average scores on exams compared to the rest of their teaching team. They stated:

08/03: When I see that my students did the best on the final, I definitely puff my feathers a little bit. I would say that is probably -- I like to see an increase in percentage grades, and I like to see my class hanging tough. But if they can kill that final or at least have a good average, I do base a little bit of success on that. I feel like that's a really great thing to have happen.

Not only were the results of the exams a source of pride for the instructor, but walking around the room and listening to students discussions filled their emotional needs. During the group portion of examinations in the summer (where the instructor generated exams) and listening to student discussions fulfilled that need to feel like an adequate instructor:

08/09: [On the group portion of a summer exam] I heard a lot of [students saying] "okay well we've got an OH bond breaking and an OH bond forming," and all of the things that make my heart just warm and like tear up with love and appreciation a little bit."

The use of groups during the summer allowed for great introspection towards the instructor's approach to student thinking, and was reinforced by seeing the positive student-student social interactions. During some open classroom discussions, the instructor was observed and self-reported telling students different study strategies to help them develop as students. These conversations continued to happen in the large-lecture room in the fall, where groups were not implemented due to layout constraints of the physical lecture hall, but still was a practice they wished to continue. With the feedback from students, a sense of joy tended to result when the instructor had positive feedback from their students. They reported:

07/13: And I get a lot of positive feedback from TCEs about doing it [give students tidbits of information or study strategies] and how helpful it is. And that's what basically is what all of these things say. And so I'm - if one student feels like "wow you really let me realize my potential" then I'm happy, even if the rest of them are laughing at me and thinking it's stupid.

This lack of concern about looking foolish in front of students was seen throughout the interviews, as well. The instructor asserted that this indifference towards other's judgement allowed for them to grow in practice. They stated,

07/05: I think that it [feeling judgement from students] brings in an unnecessary stress if you're super concerned about your class liking you. Um, and so that has luckily been something that I was able to get over really quickly, and I know there are other instructors who are so concerned about their popularity, that they will never do anything that pushes their class or whatever because of that reason.

Having the feeling of joy/love/happiness was a powerful driving force for the instructor that was the focus of this study in their instruction. However, there were negative emotions felt by the instructor when attempting new practices. There were fears, insecurities, anxieties, and other negative emotions felt throughout their entire teaching career that became evident during interviews. Transitioning between a traditional lecture style, in particular when lecturing was all the instructor knew, was a scary time. They reported:

08/03: And so my biggest fear was losing student contact moving to a big lecture hall and the ability to wander through and talk to the students and do these in class activities and engage with them. It allows me to have that contact that I value and is my love for this. I get to see - I mean I like teaching because -- explaining something 900 times, and man, when I see that light bulb go off. I mean you've seen it. We all love that. That's why we're here. And if I don't get that moment to see it, it's hard to stay motivated, you know? So, but in hindsight, thinking back to it, I really would have hated teaching if it just turned into traditional "I'm just going to lecture in front of all of you" … I mean I'm staying here because I love it, not because I'm getting paid mad amounts of money.

Even with the retrospective appreciation of switching to an active style of teaching, the instructor was feeling nervous about timing, and ensuring that student had the appropriate amount of time to adequately complete tasks. They stated, “I talk too much. I really talk too much, but I need to figure out how to stop talking so much because I just, I think that I would have more class engagement.” This would allow student to engage with each other and spend more time constructing knowledge.

A level of uncertainty has followed the instructor through the instructor’s career and their deployment of different teaching practices. They stated, “I always have my entire life [had the perception that the class is going negatively even if evidence points to the contrary] … but it's my basic insecurity of I want them [her students] to enjoy the class.” With the negative feeling arising, and sometimes a sense of freneticism, the instructor will decide for a particular lesson: “I’m never teaching honestly that material that way again; I've already made that executive decision in my mind.”

With their hard work and grit to always be improving the classroom environment, the instructor did occasionally feel aggravated when students seems to not push as hard as they do. They reported: “There’s a lot of students that come up and are like, ‘You work harder than most of your class.’ And that's where a lot of my frustration comes from.” They then continued to say, “I don’t feel like I should care more than they do, and I don’t feel like I should work harder than they are necessarily. Um, but I do like the fact that there are students that recognize that.”

With the different basic emotional needs being fulfilled (or not), the instructor has a strong driver to improve their teaching practices. Studying their love for teaching, in particular the satisfaction they feel with helping students improve in the classroom, and their negative emotional drivers, the instructor described many ways these emotional drivers affected their instruction.

Feeling Motivated towards Self-Improvement and Learning

As seen in the previous section on basic emotional drivers, the emotional energy the instructor gained from their needs fueled their drive towards self-improvement and learning. Throughout the interviews, the instructor displayed a very strong drive to improve their teaching practices and worked towards bettering the classroom for students. From that love of chemistry and teaching, they stated:

11/27: And luckily, I found something that I really love. And then as I move through life, I realized, more and more how important it is to really love what you do … what I've discovered is I have a huge passion for Chemistry. Chemistry saved my life in a lot of ways, as this interest in it. And so I feel like I have the ability to mold both of those passions [chemistry and coaching] that I have into my career. And I think it's good because it allows me to level up in both aspects.

The concept of “leveling up” was a minor theme throughout the interviews. Leveling up, to the instructor, meant improving in all areas of their teaching. They wanted to be the best teacher, mentor, role model, professor, coach, and mother as possible. Leveling up entailed achieving a personal goal and another challenge is created. In terms of instruction, the next challenge usually involved using formative assessment techniques to see where student outcomes went poorly and could be improved. During the NSF Funded Instructional-Teams Project, the teaching team used by the instructor, and the professional development during the time helped with the reflection process needed for improvement in the instructor’s teaching practices and in increases in their self-efficacy regarding teaching large STEM classes. The instructor revealed their internal motivation when they stated:

12/11: Everything about the Instructional Team Model has helped me level up because more than anything else -- I always sit and reflect on my classes -- but this was not only my reflection. I think it was more constructive to my teaching and recognition of things. The thing too is that my team is so sweet. There is a lot of "no I just think everything is going so well," and I love that, but I know it can be better…

All in all, it's just made me be more reflective in my teaching that I already was, which is a good thing as long as you are accepting to all of the things that need change.

The Instructional-Teams Project also helped the instructor progress their instruction further by building on their motivation towards self-improvement and learning different teaching strategies. In particular, they mentioned, “I think you just have to be willing to experiment, and have to be okay with failing some days, and accepting of the fact that some days, if you're going to level up, there are going to be days that you walk out going, ‘oh my god, I'm so glad the attendance was low -- or whatever it happens to be.’” They elaborated more about the Instructional-Teams Project and the feedback to help with their teaching practices:

07/05: There's a lot that I learned about how I can be in the classroom, how other people are in the classroom, things that just don't work for me, that are super successful for other people. Things to try. And methodology. Papers to read and what not. But I would say that the Learning [Instructional] Teams Project last semester has been the biggest game changer for me. I really did that selfishly to level myself up more than anything else.

The instructor realized that the evolution of their instruction was not easy. They articulated, “You have to be willing to look bad, or look like the meany (sic), or willing to make mistakes and open about that mistake and own it. You have to be willing to do those things, and if not, it would be a stagnant classroom and not evolve in any way.”
With the help of the professional development, their own experience, and the support of their teaching team, they was able to implement novel teaching strategies in the classroom. This was seen in their use of a lecture capture device, called Panopto:

08/09: I'm just here to support the students. If they're going use them [different educational technologies] and be successful, then I'm all for giving it to them. So I'm at least in the Fall going to experiment with the Panopto videos and really seeing if it helps the students.

By getting out of their comfort zone, the instructor found that the use of lecture-capture had vastly more positive effects than negative effects in the classroom. The instructor originally was worries that students would not attend lecture, and would opt out of classroom time because the recordings would be available. However, the instructor testified that they did not notice a drop in attendance, and also receive positive affirmations about the recordings. The push to try novel teaching practices was further elaborated on as they discussed their belief on helping students succeed in the classroom:

10/11: And then one thing that I really was talking about implementing with you and before was this idea of giving the students some more like tools in their toolbox to be successful in school. And I haven't had the chance in the review sessions to do that, but I did make a video which quite a few people actually watched and I got five stars on it.

From the instructor’s perspective, by creating different items for students to use, they further allowed students to succeed in the classroom. The idea was to constantly improve the instructor’s teaching by adding these teaching materials. This trend followed for them to challenge students appropriately and having a level of rigor in their class. The instructor stated:

07/05: I think it took me a long time to feel comfortable pushing my students, even if it meant them getting angry at me for the time they're sitting in the room. And now, I'm okay with that. Like, it took me a while to feel comfortable - it wasn't that I wasn't necessarily doing it, but I don't think I was doing it my best way possible. But it was not - the forcing them to work, because I was someone who wouldn't have wanted to do that. That sort of thing was very difficult for me in the beginning. And still, it I'm asked to push my students above and beyond a little bit, that can be a bit of a challenge. So, but, it's one way I've embraced and accepted.

Seeing the students improve created a cyclic process of creating encouraging emotions in the instructor, promoting teaching practices that appeared to work, then receiving optimistic feedback from students. With the positive affirmations they received, it would appear that the instructor thrived on the constructive feedback given by students. However, when asked about this, the instructor reported:

08/09: Well I mean hearing them [give positive affirmations] is not the driving force. Recognizing it [positive affirmations are present] is the driving force. I mean if nobody ever said anything to me, I would still see it, and that would be enough for me to keep pushing. Of course I like hearing the nice things, you know? But if nobody ever sent me a nice email, I wouldn't work any less.

Concerning the instructor's motivation towards improvement, their dissatisfaction played a large influence on their drive to evolve. Outside contextual factors pulling their time also had a slightly negative influence, but the "feel" of the class was not fitting in the way they wanted. The instructor stated:

09/27: I haven't been satisfied with how a lot of my lectures went this semester so far. I think there's been one that I liked. It was alright, the rest I'm like- not happy with. A lot of it is because I'm spending most of my time on this online class so I'm just not able to prepare the way I'd like to, normally I run through the lecture several more times in my head before I deliver it. So, I like to feel like a machine up there.

With the affective drivers pushing the instructor towards improving their teaching practice, they saw improvements through their desire for self-improvement and growth in instruction.

Feeling Self-Efficacy towards Instruction and Chemistry

In order to have the courage to implement different teaching practices, the instructor needed to feel like they had the potential to perform new practices well or continue ones they were already using. With their background in chemistry and obtained teaching history, they was able to get out of their comfort zone and try new techniques. For instance, they stated:

08/09: So the active learning aspect of things was brand new to me coming in as an instructor [almost 10 years ago]. And like I said, I read research, and it allowed me to have the parts of teaching that I loved and was scared that I was going to miss, which was student interaction, which was going from a small class [roughly 100 students] to a big class [500-600 students].

The instructor's personal experience helped them believe in their instruction and ability to "level up" as a teacher. The instructor believes that their experience while an undergraduate student, along with the sheer determination to pass their introductory Chemistry course, helped them with their present mindset. The instructor stated:

09/27: I remember failing it [Introductory Chemistry] the first two times and finally passing it, and then falling in love with it ... I was just taught very topically, for me there was no connection between any of this stuff … I think that's where my love for the chemical thinking curriculum [sources: (59–61)] comes in because it's not topical. It [the Chemical Thinking Curriculum] really promotes this critical-thinking; they [students] have to connect the pieces. Where in traditional Gen Chem you don't.

The instructor elaborated further on how their own struggles learning the content allowed for a very firm grasp on the various chemistry topics. As they progressed through their undergraduate courses, the instructor realized that with hard work, anyone could succeed. They eventually transitioned into graduate school, which further allowed them to build their teaching skills:

08/03: My love for teaching, I developed by being forced to be a TA in graduate school and being like "wow I really actually like this stuff, and I want to stay within that teaching aspect of things." And because I really worked very hard at everything I've done in life. I've been "I'm mediocre at everything, I have to work way harder than my peers, I'm severely dyslexic, I had to go to private tutors during school just to learn to not make 12 21 every time I wrote it down."

With the instructor's struggles, they gained successes as an instructor. As the instructor pursued teaching and instruction, they absorbed different sources of input: from peer-to-peer discussions, to attending faculty-learning communities, seminars, and self-instruction. The instructor's transition to deploying active learning happened after reading literature on the subject from various sources:

08/09: I mean I bought into the active learning things [after reading Small Teaching by James Lang] - I drank the Kool-Aid and whatever, but that book and the cognitive psychology behind learning was a real mind opener for me. And it made me be more willing to try new things in the classroom, I think. So just the integration of that and the discovery of that book was hugely beneficial to me as an instructor.

With these experiences, the instructor created a strong belief in using tasks in the classroom and the power of engaging students with material to help them learn the content. With the confidence in incorporating aspects of active learning, they had full confidence that their teaching style was working well. They reported on their instruction:

08/03: The more engaged the students are in the material and asked to work on the material in class, the better they are going to absorb the material and do. I know we've talked about flipped classrooms and that I don't feel that this level -- of flipped classroom - is a good idea. Yea, I just don't think they are advanced enough with how to handle an education to do that. But, I do think that forcing them to work on activities and talk to each other more, is better.

And as mentioned earlier in the paper , the students in the instructor's classes were out-performing the other instructors' students on their common exams. Of the various factors relating to student success, the instructor's internal drive towards general improvement was a strong indicator of continually reflecting and evolving the instruction used in the classroom.

External Affective Drivers

When diving into the emotional motivators of the instructor, external affective drivers relate to the emotional state and needs that emphasize the students and teaching team. The emotional states worked towards influencing someone or something outside of the instructor, primarily the students. When considering these external factors, rather than having a primary focus on herself for these states, the instructor diverted their energies towards external entities.

Feeling like a Supportive Faculty

The instructor had a strong sense of their identity tied into their instructorship and their sense of being a parent. The instructor elaborated many times through the interviews on how their family will always come first. Juxtaposed to their family obligations was their overwhelming desire to be a successful instructor and to feel like a supportive faculty member to students. The instructor had a clear-cut belief on what a general chemistry instructor should be in the classroom:

10/25: The role in the Gen Chem class for the instructor is to give them the tools that they need to survive, whatever that is -- critical thinking and to get through school and that sort of thing -- but also to spark some level of excitement and engagement and curiosity, so that they want to keep going… But I think the role of the Gen Chem classroom is to just get them excited about being educated and excited about the challenge, you know, and giving them the tools that they need to survive and all those sorts of things. I think that's a huge role in the gen chem classroom for the instructor or any freshman level required curriculum class.

The constant reflection and deliberate use of teaching practices allowed the instructor to isolate the different practices that they believes were working the best. For instance, they believed themselves to be more of a coach in and out of the classroom:

11/27: And again, whatever it is that I do that seems to be successful, I just keep doing it and it keeps working … I don't think a lot of other instructors play that coach role, and I play that coach role. I think that those who read my emails are like -- it would give me that extra like "okay. I don't want to do it, but I just need to do it. But I can do this," and I think that also plays a role in trying to keep the morale up, and trying to keep everybody pushing and stay with me. Constantly saying, “I know that this is hard right now, but we can do this,” I think, saying stuff like that is really beneficial towards the motivation of the class. And I think that plays a big role.

This belief pushed the instructor to continuously find ways to engage students with the chemical material. For example, the instructor chose to implement occasional demonstrations or virtual laboratory in class. They often told stories to the students to keep the engagement high. However, they continuously had an internal debate about the use of lecture.

07/13: So there are two things in this. The first is this is something that I very much struggle with. I default to lecturing very easily. And I try very hard not to. However, it is still one of my biggest challenges in the classroom by far. I just default to lecture. Because I too am tired, so I think -- there definitely have been times in the class where I'm like "it's time to stop talking" and give them something to do, you know? So that's part of it - that's just a struggle that I'm still continuously trying to get ahold on.

But the struggle the instructor was discussing indicates their affective states are externally focused and student-centered, even though the balance between lecture and task were the primary focus. From the perspective of the instructor, this was not necessarily a bad thing – they believed that having that balance was what allowed for a class with high student engagement and understanding of the material.

07/13: I've also found that I've had a lot of success by balancing lecture and activities. I've found that if I give the students what they want - which is lecturing - then they become more engaged when I want them to be engaged in the "let's thinks" [tasks in the classroom] … If I lecture too long, they're not going to work on the activities because they know I'm going to tell them what's going on. If I don't give enough of a lecture, or what they feel is enough, then they won't even start because they feel like they don't have enough information to go forward.

This balance between giving the students what they want (lecture) and pushing them appropriately (task) seems to give the instructor a robust practice of guiding the student to learn content. When asked to elaborate more on the process, the instructor reported:

07/13: So I've found that especially with different parts of the material that they struggle with a little bit more, if I talk for 3-5 more minutes, I have 20% more of my students actually engaged in the activity afterwards. And that is enough for me to put in a little bit more lecture time, even if I kind of in my head am like "this goes against what I really want to do." But this give and take has really worked well with me and the students. So I've found a lot of success with the lecture-active learning type of balance.

With the extra perceived engagement by students in learning the content, the lecture-active learning cycle continued to always provide what felt like an adequate about of preparatory lecture to get students to participate on tasks. The instructor continued to elaborate on their view of what was occurring in students' minds:

10/11: So sometimes I want to talk a little bit longer because I know that, then they'll feel satisfied like, "okay she's giving me what I need. I'll give them what they want. I'll do this problem," or they feel like "okay, now I have a little bit more confidence moving into this." And so then I get a little bit more participation and engagement in the classroom and whatever I can do to get more engagement, I am going to try. And I have just discovered for myself, I get way more engagement in those activities if I give them more lecture than is probably desired. So that's one reason why, and that my [teaching] philosophy, again, is like if I can get them to be engaged, even if it means talking a little bit more, I'm talking a little bit more because then I get the engagement.

But the balance between lecture and task was hard to maintain. The instructor reported that they reverted to lecturing too much rather than shift to tasks or open discussions. The affective driver to feel like a supportive faculty member towards students tended to push them towards giving students what they thought was best for them, even though the instructor understood that students did not always know what was best for themselves:

08/09: And the thing that makes it [moderating the use of lecture] so hard is the students love it. And so it's like, like I said, I'm there to support the students even if they don't recognize what I'm doing is support. It's hard when they start -- when I start seeing more engagement or more listening or more whatever because I am lecturing versus when I am giving them the opportunity to do off task stuff. That's just -- it's always been a big fight for me. And it's like I said I don't think it's the correct atmosphere for a fully flipped classroom.

For students that have only known lecture through their collegiate lives, the use of lecture may be a strong tool in the higher education tool box. By providing something familiar and "easy" to the students, the stresses and anxiety that may arise can be reduced. The instructor has been reported to be a gifted lecturer from her TCE's, and for them to utilize their lecturing skills to build a classroom was beneficial to them.

09/27: I get a lot of students who come back as a senior and then are like, "Wow I really didn't realize how much you gave me towards my ability to prepare and be successful in other classes." To me, four years later, to have somebody come back with that recognition that these are the tools that "you really got me to see," I consider that to be successful.

Since the instructor has been teaching for almost a decade, they have seen the students come back full circle and thank them for their hard work as an instructor. Having students appreciate the challenge they provided to them, in particular to grow not only as students, but as people, allowed for the instructor to feel like a supportive faculty member. The office hours, creating supplemental activities and support documents for students, opening extra review sessions and office hours all contributed to students' successes, and in turn giving the instructor the sense of satisfaction for being a compassionate faculty member.

Feeling Empathy towards Students

Because of their past experiences as a student who struggled learning the content, the instructor displayed a considerable amount of empathy towards students, in particular those that also struggled with material. The instructor had difficulty communicating with other students when they were a student, and this introverted nature followed their throughout their education. The instructor often found themselves working on school material alone, or if in the occasional group, still tending to work on their own. This influenced the instructor's need to call on students and drive for answer in class:

07/05: I was definitely 'do not call on me; please let me be in my little bubble. You can't see me. I'm just going to do my best.' I'm definitely someone where if I came in and it was a collaborative learning space, I would have been so terrified and miserable, and like "this is the worst thing ever" but I think as the semester would have proceeded, I would have gotten into it if I had that type of experience, and so I am really sympathetic to the loners and the ones who don't want to [participate].

This empathetic response to shy or withdrawn students can be a source of conflict for the instructor: between pushing students out of their comfort zones for personal growth and allowing them to feel comfortable in the classroom. Form the view of the instructor, being comfortable talking in front of the 600-student class is beneficial to not only the contributor, but also the rest of the class as the perspective gave different insights to the masses. However, the anxiety this could cause students to speak in front of hundreds of their peers was apparent. More often than not, the instructor decided to have the compassionate response towards students drawing from their perspective as a student:

08/03: I'm not going to be that unforgiving teacher, and I'm not going to be that teacher who is like "this is the only class you take, and your whole life should be chemistry and this class because it's mine." I really try to be a lot more understanding of all of that. Because I've seen both sides of it - from the student perspective.

The instructor believes that the compassionate response is the best response for increasing student motivation in and outside the classroom. They reported on their past experience: "And I am far more driven and willing to work hard and suffer through a class that I hate or whatever if the teacher seems to care." By showing empathy in the classroom, the instructor believes that benevolence will be more of a motivator than a hindrance to students' education.

When asked to further elaborate on how the instructor would have behaved in a collaborative learning classroom, the instructor expressed:

11/08: I would have been one of the very first to push back. It's really funny to say as somebody who teaches a class of 600 ... I have no problem with it anymore. I took a drama class as a senior, and because I was so paranoid to talk to people if there were more than two people around me, I would not open my mouth. I would not ask a question in class. I would not answer a question in class. I would turn the mic away … my guess is just thinking about myself halfway through the semester I probably would have started interacting with students and really, really started appreciating the active learning aspect in the classroom.

This realization of slowly coming to terms with being an instructor who uses an interactive classroom led the instructor to have a fluctuating view of how they attempted to engage students to work with each other. On one hand, the instructor knew that students will reject talking into a microphone in front of 600 students. On the other hand, they understood that, with a sympathetic approach, students could appreciate the learning process and begin to interact more and more in their own comfort zones. As far as the instructor was concerned, they stated:

11/08: That's why I'm very forgiving to students who are like, "I don't want to speak into the mic." That's okay. I've been in other classes where teachers are like "I don't care what you say." And I definitely am sympathetic to those students and as well as the loners.

The instructor was not solely focused on the students who struggled with the social interactions in the classroom. They also had a wider perspective on the class, with a special focus on the students with extra needs. As a result of these different personality types of students, the instructor arrived at the following teaching philosophy:

08/03: My philosophy of teaching is that there are a lot of different brains in my classroom and they all learn differently. So my goal is to introduce the material is an many different ways as I can so every student can latch on to hopefully one of those different explanations, or thought processes, or whatever it happens to be. So, I try to teach to -- I try to be understanding to the fact that a) they're not just in my class and b) most of them are not going to be chem majors and c) they all learn very differently and it's my job to figure out how to reach all of them.

With this wide-perspective view of different learners in the classroom, the instructor believed that they could provide the best instruction to the majority of students. They described themselves fluctuating in the balance between pushing students to interact and allowing them to be comfortable throughout future classes, in an attempt to best understand how the classroom climate could be best addressed for optimal learning.

Having Expectations for Students' Personal Successes

With the various affective drivers which pushed the instructor to make particular teaching decisions, a major component was caring about the students' personal successes. The instructor mentioned on various occasions that they believed a good education promoted intelligence and character, a didactic emphasized by Martin Luther King, Jr. (62). In terms of caring for their success:

10/25: I still want them [students] to care at least half as much as I care about their success. Because it matters. You know, it matters towards their confidence in themselves when they look back on this. And it matters for their success in building a life for themselves that they're proud of and happy in.

But success for students varies. There is no tangible way to concretely describe "success" for a group of individuals, as each unique person could be pursuing something different. For the instructor, the perception of success revolved around their role as an instructor, and what they believed was necessary for a student to live a fulfilling life:

09/27: I get students to come to the dark side or change majors to chemistry (laugh) at least a couple times a semester- I consider that to be a success. I've had students walk out with a D or a C but say they have a different understanding on how to study and what it means to be successful and what progress is, and I consider that to be successful. You know, all those things are success. I also feel a sense of pride when my class scores the highest average on the final exam. That I feel is successful.

With the various goals of how the instructor believed students could be successful, the need to help students with both content and character development paved the way towards how they taught in the classroom. With each independent teaching decision in the classroom, choices around teaching practices were generally made with a specific purpose in mind. For instance, the instructor constantly saw that students were ill-prepared for college. They mentioned:

08/03: I mean I think that the biggest take home message is that I've heard and what I recognize most in my students is that they're just not prepared for college. They don't have the background for it. Which means I would like to give them an opportunity to be successful in college … To me the main point of this class is teaching critical thinking skills. Teaching these students how to build a complex argument from the ground up. Because no matter what discipline they go in, that's the expectations of someone coming out of [the university] with an undergraduate degree.

How did this belief propagate in the classroom? By having different levels of error framing (63) and promoting what would be classified as a growth mindset. The instructor pushed students to be okay with mistakes, to share their work even if it was not correct or flawless. The instructor believed that having the peer-to-peer experiences of working together to understand problems is the best way to learn. They explained:

08/09: Your best teacher is your last mistake. If I can expose that misconception through student work anonymously, and let everybody see like "you're not alone in this" and that's okay, and let's correct it before you get out of here and carry on with the wrong understanding. So to me, that's one of the best. Just because -- I'm lucky at times because I do have students who are like "yea I was wrong and here's my thinking." But in front of 600 students it's rare.

With that building of error framing and allowing students to safely fail in the classroom, the instructor believes that they are also building confidence. The students could learn their limitations and expand upon them when they actually knew what they understood. This engagement correlated with success in the instructor's mind:

07/13: And that [building student self-efficacy] only happens through mistakes and individual time with the material. So I'm constantly trying help students figure out how they can be the most successful, which is very different for everybody. But, usually it comes from some sort of integrations of group and individual effort. And not being afraid of making mistakes.

The instructor recalled a time a student thought they were successful as an instructor:

11/27: So one thing that a student said to me, a long time ago, was that they felt that I was just able to keep the attention of the class more so than other teachers. And that played probably one of the largest roles on the success of the class. And I do think that plays a large role: my ability to keep the attention of the class and keep at least those who are interested, engaged and stuff like that … And I think the more engaged the students are, the better that they're going to do… A priority is to have those kids be confident and successful.

This desire to have the students become successful created an internal conflict in the instructor. They enjoyed the occasional aside to keep the class entertaining for not only herself, but for the teaching team and the students. They enjoyed telling the occasional story that may or may not have been related to the topics at hand. However:

11/27: If digressing and adding a few jokes in there that makes me have more fun and maybe they have more fun creates a less successful environment, I'm not going to do it. I'm failing at my job. And that's, that's not fair to my class, just because I want to be a little bit more lax because that's how I feel I want to be. You know, and then I don't cover half of the material that they're tested on? Really, I can't do that.

Classroom observations supported the idea that the instructor really tried to control digressions from content that was important. Digressions in the summer, where the class was very fast paced and felt rushed to the instructor the majority of the time, rarely occurred. The occasional digression or story played out a handful of times in the fall semester when the students were slightly ahead on material comparted to the rest of the general chemistry instructors. The instructor explained: "And so depending on where we are in the lecture and the material and how good I feel about the timing and how good I feel about the position that the classes is in to be successful in the exam is going to dictate my ability to digress a little bit more, joke around a little bit more."

The main focal point for the instructor's focus through the semesters was on student success. With the focus on "intelligence plus character (62)," the instructor honestly put forth effort towards that goal. As eluded to earlier, they fundamentally believed that their role was not to simply teach chemistry:

08/03: That [knowing how to study and think critically] yes, will make them more successful in their career choice, but I mean I think it just makes you a better person if you know how to not blindly accept what everybody tells you and to be able to come up with your own thought process, you know? And I've said it before, like, intelligence plus character is the goal of a true education. I think the ability to critically think and trust their gut and trust their thought process and be able to come up with their own conclusions to whatever it happens to be, whether as a career or in life is hugely important.

With the affective driver of having expectations for students' personal successes, the instructor was able to tailor their teaching practices to reflect their views to try to facilitate student success. With the goal of giving a more holistic education, and understanding that a class of 600 students has a variety of different opinions of what "success" is, the instructor expended much of their energy to help students move towards feeling accomplished and successful in the introductory chemistry courses.

Discussion and Conclusion

As a case study, this paper focused on one instructor's teaching practices used in a large, introductory general chemistry course. The affective drivers that pushed them to make different decisions in the classroom were explored to observe what and how these drivers affected their teaching practices. The original research questions that were asked were:

1. What affective drivers influence teaching decisions and practices?
2. How do these affective drivers influence teacher decisions and practices?

Various affective drivers can influence an instructor's teaching practices and decisions. The main affective drivers that emerged in this study were categorized in two main ways: as internal affective factors, and external affective factors. The internal factors, focusing primarily on the instructor's self, included basic emotional needs, motivation towards self-improvement and learning, and self-efficacy towards instruction and chemistry. The external affective factors included feeling like a supportive faculty role, feeling empathy towards students and having expectations for students' personal successes. These drivers affected the instructor's teaching decisions through a variety of means. The main highlights of the reasons on why these drivers affected their teaching were:

1. The instructor had a large internal driver to feel loved and respected from students, and pushed herself to obtain those feelings
2. The instructor had a natural inclination to "level up" in all aspects of their life, including teaching and instruction. Their discontent with certain lectures pushed them to further improve the content.
3. The instructor needed to have a sufficient level of self-efficacy towards instruction and chemistry to attempt new or novel teaching practices. They also continued practices that worked and, from their perspective, were largely successful for students.
4. The instructor wanted to feel like a supporting faculty member to students. This was seen through the implementation of different practices, such as balancing task versus lecture, creating supplementary materials, and pursuing different intellectual areas for growth.
5. The instructor felt a substantial amount of empathy towards students as relatable from their own experiences as a student. As such, they largely balanced the way they push students to engage in the classroom while staying within their comfort zone.
6. The instructor had the fundamental belief that intelligence and character are the foundation of an academic education. They pushed non-content related topics onto students to build their ability to succeed in the future as scholars.

The application of understanding the affective drivers for instructors leads to considering the realm of professional development. By understanding what drives an instructor – knowing how they are motivated – one can create scenarios that would help the instructor of interest improve in their teaching and instruction. For instance, literature on teacher reform often describes discontent as a main driver for change (35). Southerland et al. describe pedagogical discontentment as "a teachers' dissatisfaction with what they know about teaching and its role in conceptual change about teaching practices" (21). As we observed the instructor's teaching practices and their affective drivers towards new teaching practices, the use of new technologies arose because of this dissatisfaction. When the instructor was not satisfied with a particular lecture, they modified the happenings in the classroom to better fit what they wanted.

With many different affective drivers, it is important to note that the instructor was a gifted lecturer as determined by her Teacher-Course Evaluations comments and anecdotally from students, so having more lecture could be beneficial for the instructor of study, but not other instructors. This case study is not generalizable to all instructors; however, a few of the key points from this study could be influential in the practices and thinking of other instructors. Akilli and Genc suggested that for professional development, selecting affective drivers on learning strategies and classroom activities seemed to be highly effective to teacher change (64). By performing a similar mini-diagnostic on instructors and determining their affective drivers, a profession development specialist could understand how to motivate instructors for long-term change. Just as the instructor in this study was a student of instructional practices, other faculty can be viewed as learners of higher education. Practices such as metacognition would be immensely beneficial to the development of educators as they too can take advantage of modern learning science (65). Since metacognition has been shown to increase student learning and retention of knowledge (66), the same reflective process will help with the adoption of different teaching practices.

Not only could the affective drives found in a diagnostic help established faculty and staff improve their teaching, but upcoming instructors (such as graduate teaching assistants) could be of great benefit to this approach as well. Understanding the drivers of newer and less experienced teaching professionals could largely benefit the target approach of professional development. Fajet et al. found that upcoming teachers conceive of teaching primarily as a task involving affective, interpersonal relationships rather than a profession requiring a skilled and knowledgeable practitioner (67). Teacher reform could focus on where the upcoming teachers could develop to become better, well-rounded individuals.

More often than not, most professional development workshops and series are normalized to allow for an ease of implementation (68). By identifying both the cognitive and affective components of an instructor, professional development allows for greater and more in-depth development to occur as the instructional transformation can be more personalized. By understanding the affective drivers, professional development can be targeted, more efficient, and beneficial for all parties involved. However, these programs are limited to those who are interested and have the incentive to participate (27).

To conclude, affective drivers for instructors are important and arguable an equal source of change within instructors. The knowledge of how to change is fundamental for instructors, but the motivation to do so needs to be present. The instructor of interest found that changing their ingrained teaching practices was reasonable when understanding the benefits of the modified teaching practices. The affective drivers of feeling basic emotional needs, feeling motivated towards self-improvement and learning, feeling self-efficacy towards instruction and chemistry, feeling like supportive faculty, feeling empathy towards students, and having expectations for students' personal successes were all largely influential to the instructor.

Conflict of Interest Statement

The authors report no conflict of interest for this paper.

Acknowledgments

The authors would like to thank the NSF Grant for the funding of this research.

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Appendix D

Student Evaluation of Teaching in an Engineering Class and Comparison of Results Based on Instructor Gender

Abstract

A core chemical engineering course was co-taught by a male and female instructor to approximately 90 students for two semesters via an active learning environment in a collaborative learning space. The experiment removed many confounding factors regarding student evaluations in prior studies, allowing for a clearer investigation of students' views of instructors based on gender. Preliminary evidence from this study shows gender bias against female instructors, and may be applicable to other male-dominated STEM disciplines.

Introduction

Student evaluations of teaching (SETs), sometimes referred to as teacher–course evaluations (TCEs), play a fundamental role in higher education. No one in the university setting spends more time with an instructor than the enrolled students, making regular and systematic feedback from students a powerful source of information for gaining insights into instruction quality(2). SETs are becoming increasingly important for faculty promotion decisions, student course selection, and auditing purposes(37). Student feedback can provide actionable knowledge to deans, department heads, faculty, instructional developers, teaching assistants, and students. Given well-constructed questions, students can provide valid, reliable, and useful data concerning the classroom experience. Instructors can obtain information from SETs to improve their own practices, and students can decide whether to take a course with a particular instructor. Certain classroom practices also can be appraised indirectly from SETs through year-to-year or instructor-to-instructor analysis of teaching. With the use of SETs, instructors are able to improve their teaching practices, ultimately allowing students to have the greatest opportunity for learning(17).

There are limitations and resistance to the exclusive use of SETs for making promotion and tenure decisions. In particular, the methodology used to construct SETs is important. The evaluations need to contain robust questions and be able to provide clear, unbiased results. Of the many possible biases present in SETs(17, 38–41), this paper focuses on gender bias. Although the literature does not show clear agreement on the issue, many prior papers have discussed how instructor gender may affect SETs(17). Much of the prior research has involved laboratory studies, which attempt to control aspects of courses or instructors that may influence student results. In these types of studies, students may read descriptions of professors and then complete SETs(17). Students may be asked to look at photographs and then rate instructors or may be given syllabi and be supplied with gender cues and then evaluate the hypothetical teaching ability of the instructors based on the limited information(42). In contrast, observational studies are "real life" in that they collect data from enrolled students in live classes(43), often across sections or semesters to pool enough data to provide meaningful analyses(44–46). These types of studies have become more common in recent years as automated university data collection, electronic archival of the ratings, and statistical methods for handling large data sets have become available. One such study was published by Fenn, who determined that the gender and race of the instructor are significant, with female and non-white instructors being downgraded by students within Economics and Business(39). Having a greater understanding of SETs and the student biases that are present in those assessments will allow those using SETs to mitigate how student biases may influence promotion and tenure decisions and other reward structures. As the culture of higher education is moving toward recognizing and rewarding quality teaching at research universities, it is paramount to recognize the biases inherent in one of the main forms of evaluation(47).

Because SETs are often the only method of instructor evaluation used at higher education institutions, recognizing biases that exist will allow departments to appropriately assess instructors (48). However, there does not seem to be a consensus on student biases, and the literature varies among fields.

For instance, Nadler et al. showed that psychology students showed an increased gender bias against female faculty, whereas law students showed a decreased gender bias(49). The lack of identifiable trends in the literature on SETs exists for several reasons. Most of the experiments did not occur in a field setting or only involved one lecture or presentation by an instructor(50), making it difficult to know whether the results would hold true in regular classrooms during a full semester(51). Basow and Silberg suggested that it would be useful to look at classroom behaviors to see how those behaviors affected teaching effectiveness(40). Spooren et al. reviewed the SET literature in 2013 and noted that many biasing factors could impact instructor evaluations, including the course discipline or sexual orientation of the instructor(52), and that gender could play additional roles. Additionally, when a field of study is largely segregated between men and women, various sources suggest that there is a gender minority bias when students evaluate instructors of the majority gender(53). Anderson and Smith pointed out that one would have to control for the exact content of the course, including lectures, requirements, and time of day to systematically determine whether there are gender biases(54). To address the limitations of prior studies, we set up an educational experiment in which aspects of the classroom experience for students were as uniform as we could other than the experience level, age, and gender of the faculty members.

The goal of this study was to provide insight into how gender biases may influence SET scores within a highly controlled environment. A co-teaching model was used in which each faculty member instructed with the same teaching model and taught for the same number of lectures throughout the semester. The model closely follows one that Bullard and Felder suggested in the context of a chemical engineering curriculum (55). By controlling multiple aspects of the course, we created a significantly more controlled environment than studies in the past. Based on past research and knowing that chemical engineering is a largely male-dominated field (56), our hypotheses were that the following would occur in a core sophomore chemical engineering course:

1. The female instructor would be evaluated by students as a less effective instructor through Likert scale rankings of instruction.
2. The female instructor would receive more negative open-ended comments than the male instructor.

This study explores students' views of male and female instructors in chemical engineering.

Methods

Anderson and Smith pointed out that one would have to systematically control for the exact content of the course, including lectures, requirements, and time of day, to determine whether there are gender biases(54). We argue that we not only controlled these variables but that we also controlled the students, the classroom configuration, the difficulty level of the material, and the teaching style with high fidelity.

Instructor Profiles

The male instructor had taught at the university for 16 years when the experiment started, is a tenured full professor, and is a University Distinguished Professor, which is the highest teaching award given by the institution for excellence in undergraduate instruction. In the years leading up to the experiment, this instructor had used a predominantly active-based approach with partially-flipped hybrid classes in which students do pre-lecture activities (e.g., watching a brief recorded lecture, reading the textbook, and/or completing a reading quiz) prior to attending class. This instructor has used some form of active-based teaching for 15 years (57, 58).

The female instructor had taught at the university for 5 years when the experiment started, was a career-track lecturer, and won a university-wide teaching award in the second year of this experiment. Her teaching experience before teaching the experimental course included two 1-unit laboratory courses and a 2-unit freshman engineering course in which she deployed formative assessment technologies such as clickers and other web-based tools to enhance instruction(59). She was just starting to explore active teaching techniques prior to the first experiment. Both instructors had received PhDs in chemical engineering, so their fundamental knowledge was similar. Neither instructor had previously taught the material in the course; this was a new classroom experience for both instructors. They worked together to collaboratively build an active course.

Classroom Design

The class chosen for this research was a sophomore-level core chemical engineering course with a starting enrollment of approximately 90 students. In terms of gender, the students were 25-30% female. The class is a 4-credit class that met three times per week for a 50-minute lecture and again for another 50 minutes in small breakout sessions with a teaching assistant or an undergraduate learning coach (also known as a preceptor) to solve homework problems that are due the following week.

In the spring of 2016, both instructors involved with the class were teaching the course for the first time and did not have materials from a prior instructor. The instructors developed the course content as the semester unfolded. Course materials included classroom pre-quizzes that were due before 36 of the 45 class meetings; the pre-quiz scores represented 10% of the total grade in the course. Attendance in class was required and made up another 10% of the total grade. The male instructor created all of the exams and the rubrics for those exams, while both instructors created homework assignments, lecture materials, and pre-lecture quizzes throughout the semester. The students did not know which instructor had created specific content or assignments for the class. On any given day, one faculty member would have created the pre-lecture quiz while the other created the lecture content. One of the professors would then deliver the content in class, while the other was present and functioned as a preceptor, answering questions from students and helping students solve the active engagement problems. The professor not lecturing would take notes of potential improvements to the lecture. Because of the consistent peer observation, feedback and collaboration on content creation, there was a rapid convergence in teaching style and presentational mode, eliminating limitations of some prior work(60) in which teaching mode was an interfering variable(61). Spooren et al. discussed how the number of control variables included in studies, how variables were measured, and the research techniques could interact with the sample characteristics to lead to confounding results in SETs(52). We believe that the rapid convergence of teaching styles, as measured by the COPUS tool, described later, eliminated many of the potentially confounding variables.

The spring 2016 course was broken into six discussion sections, and the 2017 course was broken into seven sections, with between nine and twenty-four students in each section. Each section met separately for one hour per week for discussion and small-group problem solving outside of the main three hour-long lectures held per week. In 2016, the discussion sections were facilitated by a teaching assistant, and in 2017, by undergraduate student preceptors. Neither instructor was involved in that portion of the class other than selecting materials that the teaching assistant or preceptors would use to aid in student learning.

In the second year of co-teaching, the instructors would often switch and deliver the materials/slides created by the other instructor in the first year. The largest variance on the classroom experience was the lecture creation process in year one when the two instructors had different foci. The female instructor was more detail oriented in some aspects of the delivery while the male instructor was bigger-picture oriented when content was created. In year two, by presenting each other’s slides with little or no modification, the differences in instructor experience and preference in content presentation were removed. Both instructors adapted simultaneously to the new co-teaching model. The instructors developed ground rules where both instructors were comfortable taking control of the class to lead a short section if they felt the other instructor was missing details or was failing to notice a student misconception when students were struggling with content. This relinquishing of control by one instructor to the other was equally common for both the male and female instructor. Both brought different skills to the classroom. The male instructor had never used the clicker/voting technologies that the female instructor had been using and capitalized on the instructional affordances that the technology brought in year one. The female instructor had been using active methods in the small seminar setting, but, unlike the male instructor, had never taught a 100+ person class that met three times a week. Personal reflections and observations determined that both instructors were convergent in teaching style.

Statistical Analysis

The institution where this work was conducted is a large Research I institution and is a member of the Association of American Universities. SETs (termed TCEs locally) are conducted automatically in the last four weeks of the semester in an online format. To maintain student confidentiality, the TCEs at the study's R1 institution do not report the individualized demographics of the students, and there is no way to track responses back to students, even through de-identification. To encourage students to complete the assessment, a small number of bonus points (representing ~1% of the grade in the course) were offered if the class response rate was above 90%. In the years included in the study, the response rates were high, with >95% percent responses each year. Of the 14 Likert questions prompted on the SET, the following five questions were analyzed for this study:

1. "What is your overall rating of this instructor's teaching effectiveness?" with a value of 5 being "almost always effective", 4 "usually effective", 3 "sometimes effective", 2 "rarely effective" and 1 "almost never effective"
2. "What is your overall rating of this team's teaching effectiveness?" with a value of 5 being "almost always effective", 4 "usually effective", 3 "sometimes effective", 2 "rarely effective" and 1 "almost never effective"
3. "What is your overall rating of this instructor compared with other instructors you have had?" with a value of 5 being "one of the most effective", 4 "more effective than usual", 3 "about as effective as usual", 2 "less effective than usual" and 1 "one of the least effective"
4. "What is your overall rating of this team's teaching effectiveness compared with other teaching teams?" with a value of 5 being "almost always effective", 4 "usually effective", 3 "sometimes effective", 2 "rarely effective" and 1 "almost never effective"
5. "I was treated with respect in this course" with a value of 5 being "strongly agree", 4 "agree", 3 "uncertain", 2 "disagree" and 1 "strongly disagree"

In addition to the TCEs from 2016 and 2017, data were collected on the previous instructors' ratings for the course for comparison to the study instructors. Because the scope of the paper does not extend into historical performance evaluation and there were significant differences in response rate and variance in the years prior to the study, no statistical t-tests were performed on the historical data. The two categories collected for historical comparison were the "overall rating of the instructor's effectiveness" and the "comparison to other instructors" found in Table 1.

A standard Student's t-test with equal variance was used to compare Likert data. Zimmerman concluded that optimum protection from Type I errors is assured by using the Welch test whenever sample sizes are unequal (62). Because the sample sizes were identical within years and very close between years, the Welch test was unnecessary, as no corrections for heteroscedasticity were necessary(62, 63). Because the samples show no significant differences in variance, neither the unequal variance t-test nor the Mann–Whitney U test was used(64). For five-point Likert items, de Winter and Dodou (65) found that t-tests and Mann–Whitney–Wilcoxon (MWW) tests had no Type 1 errors above 3% in a randomized population, suggesting that t-tests and MWW tests have similar power. Norman also concluded that parametric statistics can be used with Likert data, "with small sample sizes, with unequal variances, and with non-normal distributions, with no fear of coming to the wrong conclusion"(66). We provide various parameters to avoid misconceptions, such as assuming that ordinal Likert data yields perfect interval responses between numbers. A normal alpha value of 0.05 was used; because the dependent variables were broken down into various categories, the Bonferroni alpha value of 0.01 was also used(67, 68).

The following open-ended questions from the SETs were analyzed:

1. "What did you especially like about the way this instructor taught the course?"
2. "What suggestions would you make to improve the way this instructor taught the course?"
3. "What did you especially like about this course?"

4. “What suggestions would you make to improve this course?”
5. “Please write any additional comments you may have below.”

The open-ended student responses were coded by following a qualitative coding analysis. Each student response was given a unique number to allow for a blind analysis. To prevent instructor identification and researcher bias, a third-party research assistant assigned single-blind identification numbers to each response and de-gendered the instructor of each response . Duplicates and nonsense answers were removed by the third party. If there were duplicate answers, they generally were the same response to a question for both instructors in the same year. Once this correction was done, roughly 10% of the remaining sample was initially analyzed to create a codebook for the responses for a semi-grounded approach(69). The initial screening and generation of codes were based off Basow’s work(70). Seven different categories were generated, with positive and negative coding in each category. Those categories were Scholarship (including positive phrases such as “knowledgeable about the material,” “great learning strategies,” and “insightful answers” and negative phrases such as “you do have a PhD,” “offer better help,” and “too many mistakes”), Organization and Clarity (positive phrases such as “thorough on materials,” “prepared,” and “impressive time management” and negative phrases such as “disorganized,” “not legible,” and “needs more preparation”), Quality of Personality (positive phrases such as “short and to the point,” “patient,” and “respectable” and negative phrases such as “too apologetic,” “annoying,” and “condescending”), Instructor-Group (positive phrases such as “walked us through each step,” “good at encouraging class,” and “[positive] class involvement” and negative phrases such as “it [interaction] forced us to rush,” “more guidance…to team,” and “[need] help with delegating in a group”), Instructor-Individual (positive phrases such as “successful in making me learn,” “helped me see,” and “genuinely care about the students” and negative phrases such as “[I was] left a bit confused” and “answers…confusing”), Dynamism/Enthusiasm (positive phrases such as “effort,” “enthusiastic,” and “cares a lot” and no negative phrases found), and Overall General Comments (either positive or negative). In addition, if any comments specifically pointed out shortcomings between the instructors, those comments were placed in a special category and analyzed.

Two other third-party analysts returned results after coding the entire set of student comments that remained after duplicates were removed, and performed an inter-rater reliability (IRR) test to confirm appropriate analyses(71). Of the five open-ended questions, only questions 1 and 2 had similar numbers of unique responses. Questions 3 and 4 had many duplicate responses, signifying that students copied and pasted responses for both instructors into these questions. Question 5 had only a few duplicates and was considered in the coding analysis. As such, the IRR test was performed on Q1, 2, and 5 by randomly sampling 20 comments from each section and having both the researcher and two student analysts code them. The coding choices were compared, and the percentages for each category were reported. Figure 1 below illustrates the filtering of open-ended responses.

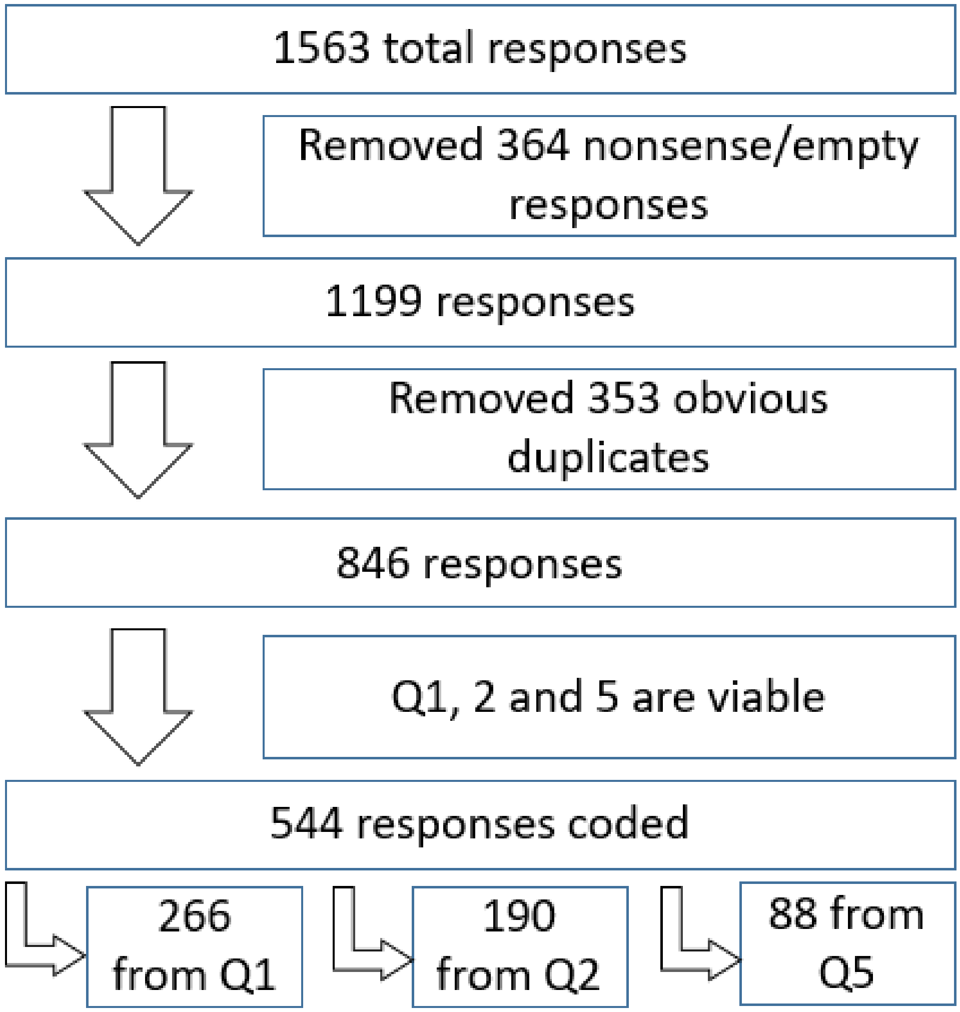

Figure 1 – Breakdown of Individual Response Filtering Process for both Years

Both 2016 and 2017 responses were analyzed independently and then grouped together for analysis. The responses for each instructor were also compared between 2016 and 2017 to determine whether the pattern of comments for either instructor had changed from year to year.

The Classroom Observation Protocol for Undergraduate STEM (COPUS) was used to characterize the teaching practices of the instructors.(72) There were two different observation days for each faculty member to capture typical classroom days. The COPUS tool was used to record what the students and instructors were doing every two minutes during the 50-minute session. The data are presented in the Results section. The task character (usually incorporated into COPUS) was beyond the scope of this project, and so data were not collected in this area. The observation was conducted by a third party trained in COPUS.

Results

The following historical data shown in Table 1 from previous all-male instructors of the course were collected to provide a reference point between the instructors in the study and the previous instructors of the course. Note that the class size has grown over time, and all student responses were on a scale of 1 to 5 for all years:

Table 1 – Comparison of Likert data for past instructors and the study instructors

	Likert Topic:	Instructor Effectiveness		Compared with Other Instructors	
Year	Instructor*	Average	n	Average	n
2017	MI	4.67	90	4.58	90
2017	FI	4.44	90	4.58	90
2016	MI	4.23	86	4.13	86
2016	FI	4.08	86	3.67	86
2015	PMI-1	3.32	68	2.90	68
2014	PMI-1	3.00	53	2.40	53
2013	PMI-1	3.73	55	3.31	54
2012	PMI-1	3.34	50	3.06	50
2011	PMI-2	3.14	63	2.68	63
2010	PMI-2	3.62	53	3.30	53
2009	PMI-2	2.93	40	2.45	40

*MI = current male instructor, FI = current female instructor, PMI-# = past male instructor, different from the current MI

The following results were obtained from the Likert data using Student's t-test. Table 2 presents the average scores for each of the Likert categories, given in mean ± standard deviation. Table 3 displays the calculated p-values from Student's t-test.

Table 2 – Means from categories, with 5.0 being the maximum possible score

	Instructor*	2016 (n=86)^	2017 (n=90)^	Combined (n=176)^
Overall Effectiveness	MI	4.23 ± 0.08	4.67 ± 0.06	4.45 ± 0.05
	FI	4.08 ± 0.08	4.44 ± 0.07	4.27 ± 0.06
Team Effectiveness	MI	3.86 ± 0.09	4.63 ± 0.06	4.26 ± 0.06
	FI	3.86 ± 0.09	4.63 ± 0.06	4.26 ± 0.06
Comparison to other instructors	MI	4.13 ± 0.09	4.58 ± 0.06	4.36 ± 0.06
	FI	3.67 ± 0.09	4.58 ± 0.06	4.14 ± 0.06
Comparison of Team	MI	3.71 ± 0.10	4.59 ± 0.06	4.16 ± 0.07
	FI	3.82 ± 0.10	4.59 ± 0.06	4.19 ± 0.07
Respect	MI	4.63 ± 0.06	4.86 ± 0.04	4.74 ± 0.04
	FI	4.63 ± 0.06	4.86 ± 0.04	4.74 ± 0.04

^Means are given in the format: mean ± standard deviation; *MI = male instructor, FI = female instructor

Table 3 – Significance of Likert Scores via P-values resulting from Student's t-tests

Question†	Overall Effectiveness	Team Effectiveness	Comparison to other instructors	Comparison of Team	Respect
2016 MI to 2016 FI	0.096	0.500	<0.001*,^	0.219	0.500
2017 MI to 2017 FI	0.008*,^	0.500	0.500	0.500	0.500
2016 MI to 2017 MI	<0.001*,^	<0.001*,^	<0.001*,^	<0.001*,^	0.001*,^
2016 FI to 2016 FI	0.001*,^	<0.001*,^	<0.001*,^	<0.001*,^	0.001*,^
Combined 2016 and 2017 MI to FI	0.007*,^	0.500	0.005	0.362	0.500

* α=0.05; ^Bonferroni adjusted α=0.01; †MI = male instructor, FI = female instructor

Tables 4 and 5 contain the summary reports from the coding analysis. The categories, as noted in the Methods section, were Scholarship, Organization and Clarity, Quality of Personality, Instructor-Group, Instructor-Individual, Dynamism/Enthusiasm and General Comment. Of the five questions, only Questions 1 and 2 had a sufficient number of viable responses for comparison of the male and female instructor comments. Many duplicate responses were given for Questions 3 through 5, where students copied the same response verbatim for the male and female instructors. As a result, questions 3 and 4 were not considered in the coding scheme; for question 5, only the 2016 data were coded because 2017 had a complete set of duplicates between instructors. Table 4 shows the total counts and proportions (in percentages) of positive and negative comments for the instructors.

Table 4 – Total counts and proportion of positive and negative comments across all categories

		Total Count		Proportions (%)	
Year	Instructor*	Positive	Negative	Positive	Negative
2016	MI	183	84	69	31
2016	FI	163	75	68	32
2017	MI	209	61	77	23
2017	FI	203	68	75	25
	MI	392	145	73	27
	FI	366	143	72	28

*MI = Male instructor, FI = Female instructor

The following treemaps were created to illustrate the coded data. A breakdown of all categories, along with the original comments, is provided in the supplemental documents. Figures 2 and 3 depict the numbers of coded responses in each category across both years for both instructors combined, for the male instructor, and for the female instructor, respectively.

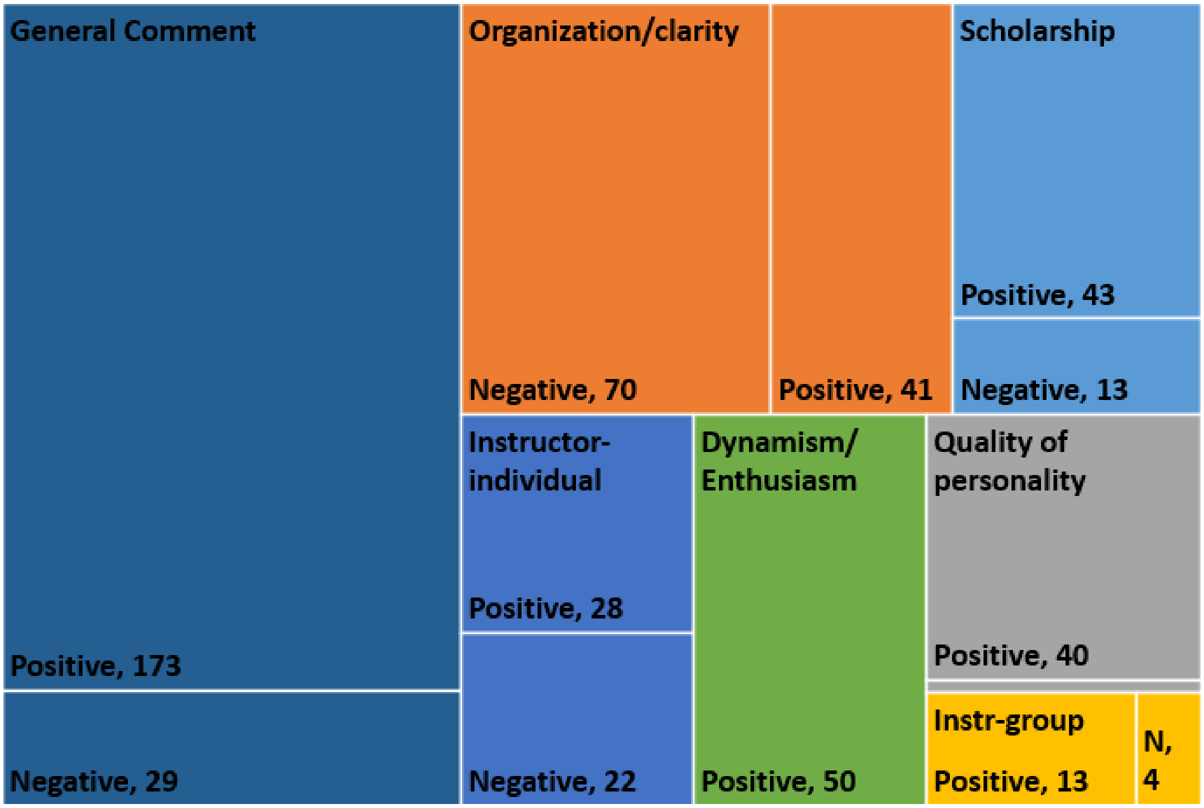

Figure 2 – Treemap for the male instructor across the coded categories

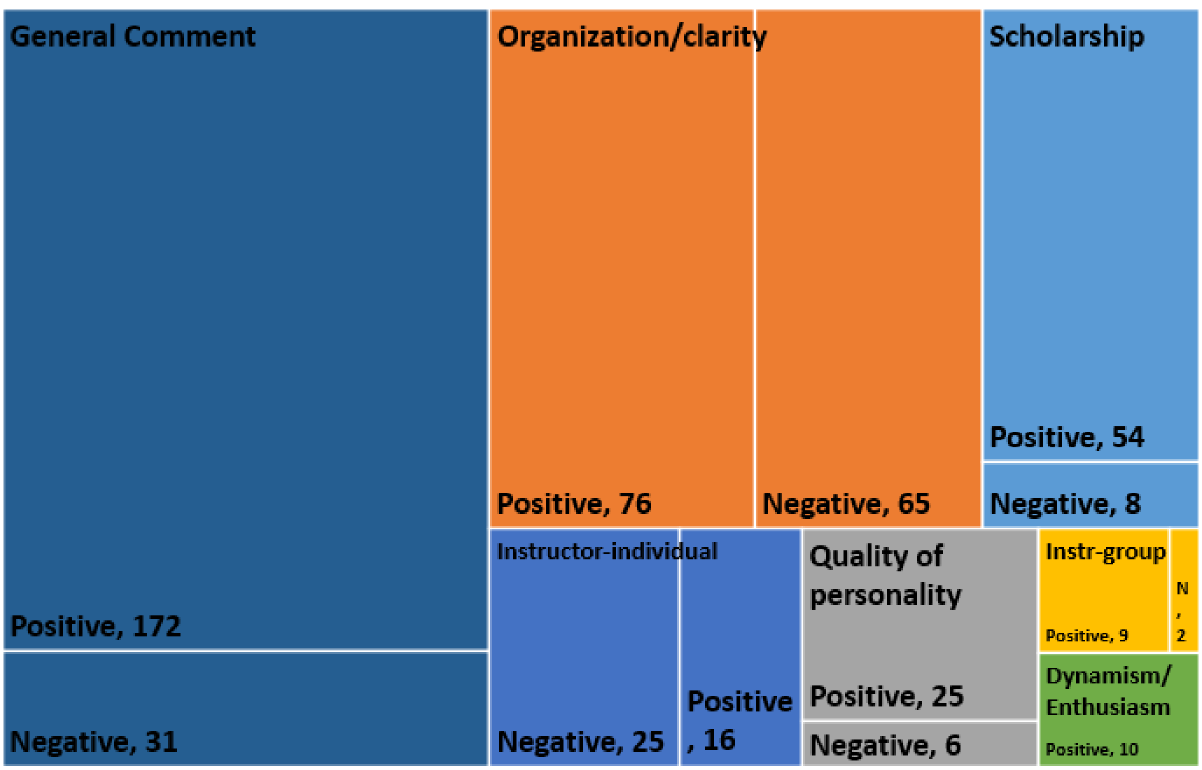

Figure 3 – Treemap for the female instructor across the coded categories

Table 5 lists the percentages from the inter-rater reliability test between the researcher and the third-party verification.

Table 5 – Inter-rater reliability between the researcher and third-party student analysts, in %

Scholarship		Organization and Clarity		Quality of Personality		Instructor-Group	
Researcher-Student 1	Researcher-Student 2	Researcher-Student 1	Researcher-Student 2	Researcher-Student 1	Researcher-Student 2	Researcher-Student 1	Researcher-Student 2
82.5	80	80	77.5	92.5	90	97.5	90
Together:	81.25	Together:	78.75	Together:	91.25	Together:	93.75
Instructor-Individual		**Enthusiasm**		**General**			
Researcher-Student 1	Researcher-Student 2	Researcher-Student 1	Researcher-Student 2	Researcher-Student 1	Researcher-Student 2		
90	75	95	92.5	100	60		
Together:	82.5	Together:	93.75	Together:	80		

The COPUS data that were collected are shown in Figure 4. Four total class periods were used to collect the COPUS data, two for each instructor out of the 45 days of in-class time. A key to the COPUS data is provided below Figure 4; note that not all categories appear on the COPUS diagrams. Categories not present in Figure 4 had no data collected in them, meaning neither students or instructors performed those actions.

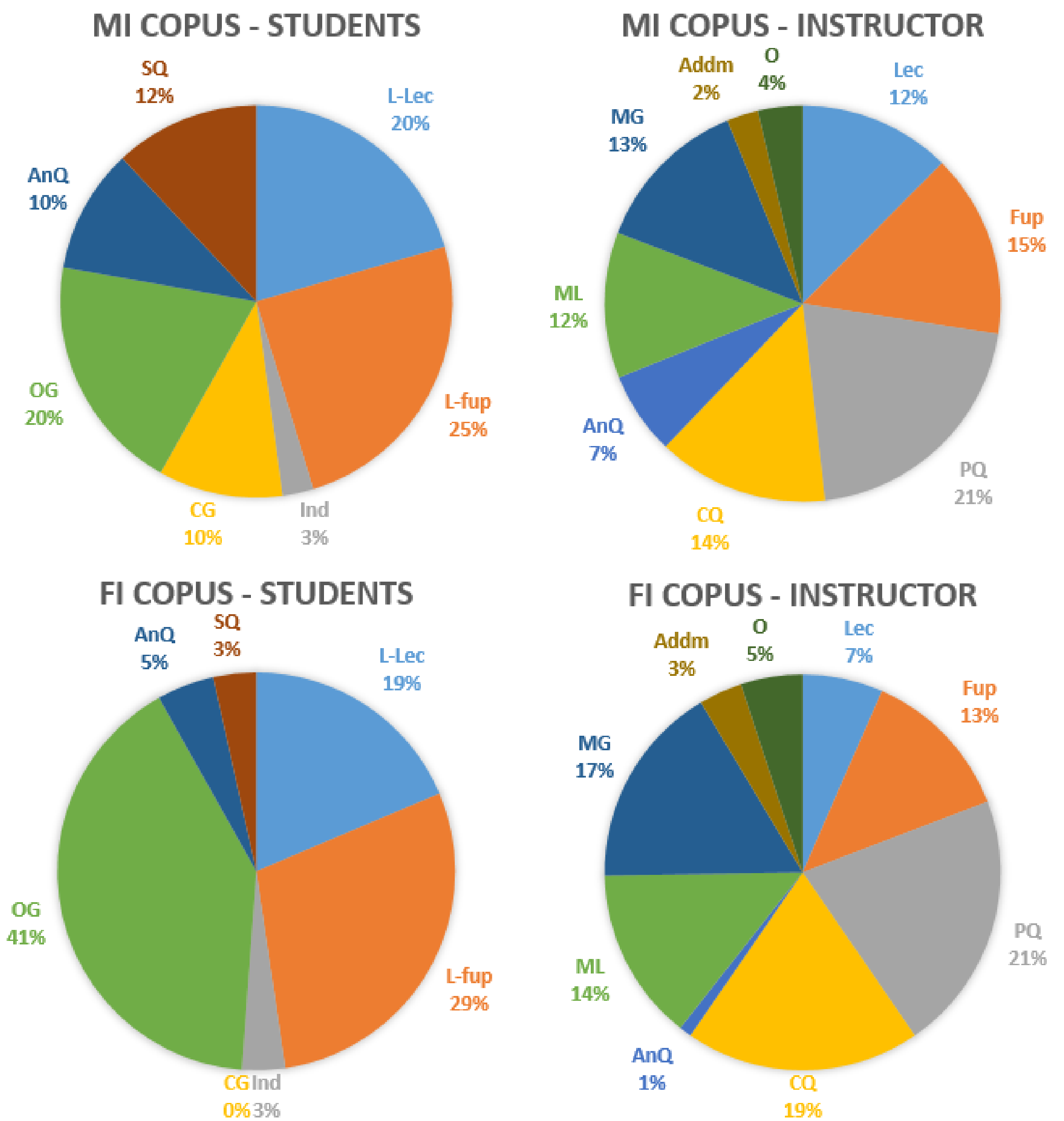

Figure 4 – COPUS results from the male instructor and the female instructor on two separate days*
*MI = Male instructor, FI = Female instructor

Discussion and Conclusion

Based on the Likert scale analysis of the SET scores and the evaluation of the open-ended comments, there seems to be a bias against female instructors in a male-dominant sophomore level chemical engineering course. When using SETs as a means of measurement, the instructors statistically differed in scores on overall effectiveness, indicating that females are slightly to moderately biased against.

Looking at the Likert comparisons shown in Table 1, in 2016, the male instructor was considered significantly better than other professors compared with the female instructor ($P<0.001$). In other words, the male instructor was seen as better than his peers more so than the female instructor was seen as better than her peers. Most of the students, at that point, had had no other female instructors in other core chemical engineering classes. Although they had not had any instruction from other female staff from the department, students could have interacted with female instructors from other departments, making it difficult to draw many conclusions regarding what genders the students may be comparing the instructor.

The overall effectiveness in 2016 as shown in Table 2 was close to being significantly different, with a P-value of 0.096. The students rated the male and female instructors identically in terms of team effectiveness and respect toward students (P=0.5 and P=0.5). The components that each instructor contributed to the team respective to other academic teams showed that they viewed the male instructor as a better influence – but not significantly (P=0.219). Thus, this difference may be due to random chance. In 2017, the students rated the male instructor as having a significant positive difference in overall effectiveness (P=0.008). Thus, the students viewed the male and female instructors as significantly different; the male instructor was rated higher than the female instructor (4.67 ± 0.06 and 4.44 ± 0.07, respectively). In all other aspects, the two were rated identically, as most students reported the same Likert scores for both instructors (P=0.5) in these other categories. It should be noted that the male instructor had taught each student cohort in a core course the previous semester and so was already familiar to the students before the study course began. This confounding factor could not be designed out. Both instructors were highly rated compared to past instructors, and the measures taken to converge teaching methods attempted to minimize any effects of this. Future research should investigate this further.

When looking at the instructors from year to year, both outperformed themselves from the previous year in all categories (P=0.001 or <0.001 in all categories), showing that they both were able to improve the students' perspectives of their teaching abilities from 2016 to 2017. When the 2016 and 2017 results were combined, there was a statistical difference between the students' view of the teaching effectiveness between the male and female instructors. The Likert analysis shows that for both years combined, the students viewed the teaching effectiveness of the two instructors as statistically different (P=0.007). The students also viewed the male instructor as much more effective compared with other instructors than the female instructor compared with other instructors (P=0.005). The difference in contribution to team effectiveness compared with other teams showed that the male instructor was rated higher, but not significantly (P=0.362). Both instructors were rated higher than the previous instructors historically, but no statistical tests were performed on these historical data. Because of the anonymity of the collected data, we are unable to associate the gender of the student with their ratings of the professors. As such, we can only take bulk parameters for the class as a whole, such as ratio of percent male to percent female, and draw general conclusions from the data.

In terms of the qualitative data, when we looked at both the male and female instructors' open-ended comments, there were similar patterns of positive and negative responses from the students. The proportion of comments that were coded as either positive or negative (or having a mixture of both) came out to be roughly equal for both instructors. An inter-rater reliability (IRR) test was used with two other coders to show that researcher bias was minimized. As seen from Table 6, there was considerable agreement between the researcher and the student analysts. The full coding analysis can be found in the supplemental material. Between the male and female instructors, the male always had a slightly higher proportion of positive to negative comments overall (73% positive to 27% negative vs 72% positive to 28% negative, respectfully). The biggest difference was primarily in the language used by the students. In particular, one student used profanity when creating an open-ended comment about the female instructor. In addition, when a student comment compared the two instructors, the female instructor was reviewed negatively for creating exams that were too difficult or grading more harshly than the male instructor. However, as stated in the Classroom Design section of the paper, the male instructor created the exams and the grading rubrics for evaluating those exams. The COPUS data provided in Figure 4 show the similarity between the two instructors' teaching practices and that the instructors did not differ significantly in teaching strategy, spending nearly the same amount of class time on each type of activity. Note that the COPUS data were collected over 2 class periods for each instructor out of the 45 total classroom events during the first year. The COPUS data gives insight into the teaching styles (and their similarities) but cannot be statistically distinguished as different with a sample size of two. With the collaboration, convergent teaching style, and controls placed on the study, it is difficult to justify that the variance in the SETs was from the difference in teaching instruction and experience between the male and female instructors.

Of our original hypotheses:

1. The female instructor would be evaluated as a less effective instructor through Likert scale rankings of instruction and
2. The female instructor would receive more negative open-ended comments than the male instructor,

only the first hypothesis was supported by the data collected for this study. The combination of the Likert data and the coded open-ended comments support the notion that female instructors experience at least slightly more negative bias than male instructors in male-dominated STEM fields such as chemical engineering. As this project is ongoing, we have replicated our work with another two instructors in two other classes, but we are not yet ready to analyze that data.

Conflict of Interest Statement

The authors report no conflict of interest for this paper.

Acknowledgments

Thanks to Jonathan Cox for performing the COPUS analysis on both the male and female instructors during their class sessions.

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