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Student Motivation and Self-efficacy in Entrepreneurial-minded Learning (EML): What These Mean for Diversity and Inclusion in Engineering Classrooms

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Lauren Lowman is a Founding Faculty member and an Assistant Professor in the Engineering Department at Wake Forest University and has served in this role since 2018. In this role, she has developed new interdisciplinary curriculum that bridges engineering fields and reflects the Wake Forest University motto of Pro Humanitate ("For Humanity"). Lauren received a Ph.D. and M.S. in Civil and Environmental Engineering with a focus in Hydrology and Fluid Dynamics from Duke University, and a B.A. in Public Policy Studies from Duke University. Her research investigates how extreme events affect overall ecosystem health, productivity, and sustainability using numerical models, geospatial data analysis, and field experiments. She is also passionate about developing and sharing inclusive teaching practices in STEM fields and received a 2020 Engineering Unleashed Fellowship from the Kern Family Foundation to support this work.

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Dr. Michael Gross is a Founding Faculty and Associate Professor of Engineering at Wake Forest University and is part of the team that is planning, developing, and delivering the brand new Engineering program. The Engineering department is viewed as an opportunity to break down silos across campus and creatively think about reimagining the undergraduate engineering educational experience, integration and collaboration across departments and programs, and how to achieve the motto of Wake Forest University: Pro Humanitate ("For Humanity"). Michael received his B.S. in Chemical Engineering at Bucknell University, and his Masters and PhD in Chemical and Biomolecular Engineering at the University of Pennsylvania. He has broad research interests in materials and composite processing and design, primarily for solid oxide fuel cells, but also for batteries, solar absorbers, and gas adsorption. However, he also has a passion for designing educational experiences that support student intrinsic motivation. Using the Situational Motivation Scale (SIMS), Basic Needs Satisfaction (BNS) survey, and cluster analysis, Gross helps faculty understand the types of motivations their students are experiencing and practical, effective strategies for making positive shifts in student motivation.

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Abstract
This Work-in-Progress paper reports on the development and deployment of active learning classroom experiences designed to support student entrepreneurial mindset (EM), self-efficacy, and motivation. The activities were designed for two core undergraduate engineering courses, Computational Modeling in Engineering and Control Systems and Instrumentation, typically completed in the junior year. The design of the course activities was guided by (1) the "three C's" of the Kern Engineering Entrepreneurial Network (KEEN) framework: Curiosity, Connections, and Creating Value and (2) four inclusive classroom practices: representation, safe spaces for failure, promoting collaboration over competition, and supporting student autonomy.

The Computational Modeling in Engineering activities implemented a Problem Solving Studio (PSS) pedagogy that introduced students to the contributions of scientists, mathematicians and engineers from traditionally underrepresented groups. In the 21st century, an undergraduate student can complete a 4-year degree in STEM without encountering a minority instructor, without reading a textbook written by a minority academic scholar, and without learning a theory proposed by a minority scientist. The PSS activities are intended to provide students with the opportunity to see different aspects of their identities represented in contributions to STEM fields, allowing them to see themselves as creators and innovators. Student motivation as it relates to engaging in these inclusive activities was measured using the Situational Motivation Scale (SIMS).

The Control Systems and Instrumentation activities employed the PSS approach in scaffolding experiences with "Making" activities. The literature suggests that "Making" activities and other hands-on learning opportunities increase student self-efficacy and have positive effects on retention of minority students, particularly into postgraduate studies. Here we focus on assessing the short-term effects of "Making" activities. Assessment included pre- and post-student self-efficacy surveys with three distinct areas of measurement: general self-efficacy, self-efficacy in course outcomes, and self-efficacy in EM-related constructs.

Preliminary data suggests that inclusive PSS activities resulted in positive student motivational responses comprising high levels of identified regulation and external regulation, with moderate levels of intrinsic motivation. Relative to the average motivational response of the entire class, underrepresented student responses were more positive, with high levels of intrinsic motivation, identified regulation, and external regulation. Student self-efficacy in the instrumentation course was shown to increase with daily "Making" activities. Data collected in future iterations of the course will enable a more robust instrument validation across sections and cohorts.

1. Introduction

In the 21st century, an undergraduate student can complete a 4-year degree in STEM without encountering a minority instructor, without reading a textbook written by a minority academic scholar, and without learning a theory credited to a minority scientist. It has been demonstrated in the literature that students identifying with an aspect of the classroom environment improves efficacy, retention, and motivation [1]–[4]. Student motivations influence other learning outcomes, from creativity to critical thinking to self-regulation. Previous work in gender, students of color, LGBTQ+, and other underrepresented groups in STEM education has demonstrated the necessity of institutional, rather than program or department-level change [5]–[8]. This Work-in-Progress manuscript seeks to document curriculum and pedagogical strategies embedded in Entrepreneurial Mindset (EM) frameworks that provide STEM students with a learning experience that reflects the values of diversity and inclusion that institutions of higher education strive to achieve. The novel approach to this work is that it addresses inclusion and diversity at the classroom-level while demonstrating the potential for institutional change by aligning these outcomes with department values and bridging these efforts over the core Junior-level classes in an engineering major.

The future of the Engineering profession requires knowledge, skills, and abilities that extend beyond disciplinary silos. This includes fostering an internationally collaborative approach that is entrepreneurial, socially responsible, and engages the workforce in life-long learning. One approach the authors' department has taken is to cultivate EM through pedagogies that merge technical learning with mindset development. Here, EM is distinct from entrepreneurship, and can be defined as cognitive behaviors (i.e. thinking, attitudes, and behaviors) that are grounded in value creation in any context [9]–[11]. This mindset distinction was particularly important for the authors' department as it also aligned well with efforts to infuse character education in their undergraduate engineering department [12], [13].

In this context, the authors and their department have engaged with the Kern Engineering Education Network (KEEN) to adapt pedagogies that enhance EM to promote inclusion towards improved student self-efficacy and motivation. The KEEN framework postulates the "three C's" of EM: curiosity, connections and creating value [14]. This framework is used extensively within the ASEE community. Beyond sharing pedagogical approaches or specific course outcomes, the framework has linked EM to ABET [15], program assessment [16], faculty development [17], and e-learning [18].

While there are many pedagogical approaches to promote EM, Active Learning Pedagogies (ALP) are extensively cited as an effective approach [9], [10], [18], [19]. ALPs are defined by methods of learning in which the student is experientially involved in the learning process and include practices such as problem-based, discovery-based, inquiry-based, and project-based learning. In addition to supporting EM, empirical evidence reinforces the value of implementing active-learning pedagogies (ALPs) in STEM classrooms – from the positive impacts on student learning and performance to the reduction of achievement gaps in underrepresented groups [20]. ALPs have been linked to improved self-efficacy and the recruitment and retention of underrepresented students in STEM fields, including in graduate research degree pathways [2], [20]–[22].

Current work in ALPs also includes how ALPs affect underrepresented students and those with social minority aspects to their identity, such as sexual orientation, political affiliation, religion, or first-generation status [23], [24]. While there is emerging literature on best practices for integrating EM through ALPs, there is also growing evidence to suggest not all intervention are equal when it comes to inclusion and equitable outcomes. The social aspects of many of these techniques as well as student perceptions have been shown to decrease minority student engagement with the ALPs [25], [26]. This Work-in-Progress paper summarizes the two ALP approaches the authors have taken, informed by KEEN professional development workshops, to infuse EM with best practices for inclusion and equitable student outcomes across the department's two core Junior-level engineering courses.

2. Purpose of the Research

This work hypothesizes that embedding EM curricular activities intentionally grounded in practices aimed at supporting inclusion will improve autonomy for all students and increase overall student motivation and self-efficacy. The focus is on two ALP approaches, Making with Purpose and the Problem Solving Studio. These have been adapted to encourage diverse perspectives by highlighting representation of STEM figures, promoting collaboration over competition, and providing safe spaces for failure. The primary objective of this study is to assess the effectiveness of specific pedagogical approaches in improving student motivation and self-efficacy. Successful implementation of targeted interventions are measured through quantitative metrics based on student self-efficacy and motivation in the classroom and qualitative metrics obtained through surveys.

The purpose of this Work-in-Progress paper is to present the strategies employed by the authors that intentionally infused EM pedagogy with practices intended to enhance inclusion and equitable student outcomes. While the authors have pursued different assessment instruments in their two courses, the underpinning research question of their collaborative work is: *How do EM pedagogies that are purposefully designed around best diversity and inclusion practices impact student motivation and self-efficacy?* This work presents a summary of the interventions and assessments used, along with a narrative of the authors' progress toward developing this research. Preliminary data is presented; however, given the small sample size of data collected, the data are used to illustrate the appropriateness of the research methods at this stage of the research. Importantly, the authors share key insights into the specific pedagogical approaches, challenges in implementation of the interventions, and assessment strategies moving forward in the project.

3. Context of the Research

The authors have focused this work on two different active learning approaches introduced through professional development workshops offered by KEEN. These were *Making with Purpose* and *The Problem Solving Studio (PSS).* The authors attended the workshops during Summer 2019, while developing the two Junior-level, core engineering courses: Control Systems and Instrumentation and Computational Modeling. These workshops focused on the fundamental concepts of the pedagogical approaches and their links to EM. Through subsequent research, the authors have implemented and assessed the approaches.

The courses have now each run six sections across four semesters, with class sizes of 4 to 21 students per section. The junior cohort, though small, represents a diverse student population with 40% women, 20% students of color, 10% international students, and 10% first generation college students.

Described in this Work-in-Progress paper, the authors have developed instruments and implementation plans to evaluate student self-efficacy and student motivation as they relate to inclusive curricular interventions. These instruments have both been previously used to assess EM [19], [27], are linked to student behavior and outcomes [2], [28]–[30] , and have outcomes of interventions in the context of underrepresented students in Engineering [22], [31]–[33]. Currently, each course examines specific interventions (described subsequently) by using metrics designed to assess self-efficacy and motivation. This approach allowed the authors to focus on specific aspects of the pedagogies and develop instruments appropriate for the different outcomes of interest. The outcome of this study will be a broad understanding of how the third-year curriculum in engineering can support EM development and autonomy across students of different backgrounds and identities. Importantly, this work will elucidate how these practices influence inclusivity within the third-year core curriculum.

Making with Purpose: "Making with Purpose" is about understanding and using the skills, craft, and art of making to foster a mindset in students as well as a skillset. "Making" broadly refers to the practice of using tools and technologies as means of prototyping or creating digital or physical artifacts. Historically, this has referred to technologies including 3D printing, electronics and microprocessors, as well as lower-tech everyday tools such as sewing machines and hand tools [34], [35]. The Maker Movement has inspired the creation of many University Makerspaces and the use of "Making" in the classroom. The use of "Making" in education primarily draws on Constructionist learning theory [36]. "Making," as a mode of learning in a formal classroom, is distinct from informal "Making" (out-of-class or community-based), as it must navigate the tensions between satisfying course learning outcomes/objectives and allowing for discovery-based learning [37], [38]. The challenges that this presents when looking at measures such as self-efficacy or motivation include how the setting and context of "Making" may impact influential factors. For example, if the intervention is not sensitive to students with varying previous "Making" experiences or includes performance-dependent grading, outcomes will be more dependent on the context of the intervention rather than the intervention itself.

PSS: This problem-based pedagogical approach, developed by the Biomedical Engineering Department at Georgia Tech [39], [40], is the pedagogical framework used to integrate hands-on, complex problem-solving into the third year course. Under this framework, instructors facilitate student learning by creating an environment where students explore open-ended problems with variable levels of problem complexity and structure [41]. Problem complexity and structure is tailored to individual student pairings in real-time to ensure that they remain in the Zone of Proximal Development (ZPD), where students are neither discouraged because the material is too challenging nor disinterested because the material is below their current capabilities [40], [42], [43]. Another critical feature of the PSS framework is that students work in pairs. Thus, along with the scaffolding from the instructor to keep students in the ZPD, teamwork ensures that students are working in an interactive learning environment where they are co-constructing new ideas with a teammate [44], [45]. The impact of the PSS approach on student learning was assessed in an introductory biomedical engineering course where students applied principles of mass and energy conservation to complex biological systems. Results from this study showed that there was a significant gain in students' conceptual understanding of the material from the beginning to the end of the course [40].

Control Systems and Instrumentation: The *Making with Purpose* workshop was leveraged to develop assessment strategies and inclusive practices for a third year Control Systems and Instrumentation course. The hands-on/lab everyday approach was an adaptation of the PSS [46]. The course is structured so that students work through theory and hands-on labs each class period with a lab partner. There are also larger projects such as an echocardiogram (ECG) build and a final design project. While this course design stretched beyond the PSS model, the key fundamental aspects of PSS were maintained. First, students work in the same teams of two during the semester to complete labture (lab + lecture) tasks, working at a pod of tables with another team of two. Second, the teams all work in a public, shared labture space that includes equipment, whiteboards, projection screens, and peripheral supplies (such as solder station, equipment station, etc.). Instructors and TAs circulate the room during the working session of the labture, providing students with real-time feedback. This real-time observation allows tailored adjustments of complexity for each team, providing scaffolding appropriate to balance challenge for the individual with what could be completed by the team. Finally, another tenet of the PSS used in this model is the use of continuous student feedback (described subsequently). This course leverages "Making" and other hands-on learning to combine topics traditionally taught across several courses including electrical theory, instrumentation, signal processing, and controls. In this course, KEEN's 3 C's of EM are developed in the design, analysis, and development of Arduino-based sensors and control algorithms across a range of engineering applications. An example of the 3C's mapping to the course activities can found in the Supplemental Information (S2).

Computational Modeling: The *PSS* workshop was also used to develop curricular activities for a third-year undergraduate numerical methods course. The approach was adapted to facilitate: (1) integration of coding and numerical methods into one course while keeping students engaged, and (2) infusion of liberal arts into math-heavy curriculum by facilitating conversations about the historical, ethical and societal aspects of computing. The PSS approach was leveraged to introduce undergraduate engineering students to the contributions of scientists, mathematicians and engineers from traditionally underrepresented groups. In class, students are tasked with exploring an open-ended problem with the goal of learning a fundamental numerical methods concept. The problem is contextualized with a real-world application and used to highlight the achievement of an underrepresented STEM figure that links to the concept. Students then work in groups of two while problem complexity and structure is altered in real-time by the instructor. Mapping lesson plans to KEEN's 3 C's provides a way to humanize the individuals behind some of the greatest innovations for STEM fields (Supplemental Information S1). Thus, the goal is to inspire entrepreneurial mindset and enhance motivation in all student populations by providing opportunities for students to recognize that they have the potential to be leaders, creators, and innovators in engineering. The hypothesis is that the curriculum will improve student motivation in the classroom by providing opportunities for students to connect with key figures in STEM and envision themselves as future leaders in engineering.

4. Theoretical Frameworks

Self-efficacy is a psychological construct that refers to a person's subjective belief in one's ability to perform well in a given area. This paradigm emphasizes that whilst skills and knowledge are important, a student's sense of self-efficacy leads them to use their skills, seek support, and engage with their learning [47]. Bandura's self-efficacy theory, as part of the larger

Social Cognitive Theory (SCT), suggests that self-efficacy is developed by four main factors including mastery experiences, vicarious experiences, social persuasion, and emotional states. Self-efficacy has been shown to influence students choosing STEM subjects in higher education. Importantly, self-efficacy, as described by Bandura and others, has been shown to have significant impacts on student recruitment, retention, and progression, particularly across underrepresented student groups [2], [22], [33], [47], [48]. The four factors influencing self-efficacy have, within the same interventions, proven to vary with students based on minority social identities including race, ethnicity, gender, or disability [25].

Questions to assess Engineering and course outcomes self-efficacy have been adapted from previously validated instruments [2], [19], [49]. Sources that incorporate self-assessment indicators of curiosity, creativity, and connections have been conceptualized for EM self-efficacy [[1], [19], [50], [51]]. For example, this conceptualization examined confidence in EM skills-*"I am confident in my ability to create new and unique solutions"*, EM motivation- *"I am not satisfied until I understand how something works"*, and EM behavior-*"If I want to apply a method used for solving one engineering problem to another problem, the problems must involve very similar situations or constraints."*

Self Determination Theory (SDT) posits that motivation exists along a continuum ranging from internal (autonomous) to external (controlled) motivations [52]. The continuum may be described by four types of motivation: 1) intrinsic motivation, a state of enjoyment and inherent satisfaction; 2) internal regulation, a state where initiative in the learning activity is prompted by identified value; 3) external regulation, a state where initiative in the learning activity is prompted by external rewards and punishments; and 4) amotivation, which occurs when a learner finds no value in the learning activity. Prior work has shown that internalized motivation (intrinsic motivation and internal regulation) can lead to desirable learning outcomes and healthy engagement with learning, while external regulation and amotivation fail to do so [53], [54].

SDT further argues that humans will adopt internalized motivation when three basic psychological needs are satisfied: autonomy, competence, and relatedness [52], [55]. Autonomy relates to a learner's sense of choice and control which, importantly, can be established by the instructor in the classroom. Competence describes the learner's sense of self-efficacy and mastery of content academically. Relatedness refers to feelings of being connected to instructors and peers in the classroom and a sense of belonging. These basic needs cultivate learning goals as part of the students' identities [52].

5. Contextualizing Inclusive Practices in EM Pedagogies

Inclusive curriculum signifies curricular practices that promote student success across all students [56]. The salient characteristics of inclusive practices that the authors have focused on in the third year core classes include representation of diverse STEM figures, providing safe spaces for failure, promoting collaboration over competition, and supporting student autonomy. Each of these practices is founded in the literature as ways to support inclusive learning environments (e.g., [57], [58]). While all characteristics are featured in both courses, the authors have concentrated the research focus on specific characteristics in each course. Specific examples of how these practices were implemented in the two courses are described below.

Representation

Prior work has demonstrated that representation within one's STEM sub-discipline impacts sense of belonging [59], [60], which may be used to foster "relatedness" amongst students with peers and the instructor [61]. This sense of belonging can be encouraged through media in addition to in-person interactions [62]. Sense of belonging is an important predictor for underrepresented student persistence in college [63], [64]. Core to the approach to enhance EM in core junior-level courses is to integrate representation of diverse STEM figures in course materials and example problems. This first comes into play by specifically highlighting the contributions of underrepresented persons in STEM. In the Computational Modeling class, the PSS activity on the first day of class involves learning Euler's method through an example adapted from the work of Katherine Johnson, a black female mathematician at NASA (Supplemental Information S1). The PSS involves recreating Johnson's work by solving for the position of John Glenn's Friendship 7 capsule at reentry into Earth's atmosphere. Another example highlights Margaret Hamilton, a pioneering female scientist who coined the term "software engineer." Hamilton is the MIT scientist who wrote the code behind the guidance system for NASA's Apollo mission, which brought US astronauts to the moon. This lesson plan adopts the PSS approach to help students learn how to discretize transcendental functions (e.g., exponentials, logarithms, and trigonometric functions) using Taylor's Theorem and then write computer code to implement the functions within a specified error criterion. Currently, these are the two activities for which student motivation data has been collected. Future activities will highlight Alan Turing, the man who developed code-breaking algorithms for British Intelligence during World War II but was punished by his own country for having relationships with men, and Marjorie Lee Browne, one of the first black women to earn a PhD in mathematics. By introducing underrepresented people in STEM and humanizing them by telling their personal and professional stories, we seek to enhance "relatedness" and thus improve student motivation in the classroom (i.e., help students foster a personal connection to the course material that often does not occur in STEM courses).

Encouraging Collaboration over Competition

Peer learning and collaborative working have been shown to improve student outcomes [65], promote inclusion [66], [67] and have been demonstrated in "Making" and PSS pedagogies [21], [39], [40], [68]. The inspiration drawn from PSS for both courses was to support this collaborative work in addition to providing an environment where instructors were able to tailor the experiences to each student's needs. Another approach to enhance EM in the core, Junior-level courses is the continuous use of teamwork, peer-to-peer learning, and group assessments such as projects. The collaborative working environment was a focus for both courses given the pre-requisite structure the department had adopted. Pre- or co-requisites of the course include Physics 1, Chemistry 1, Multivariable Calculus, Linear Algebra and Differential Equations and the Freshman and Sophomore Engineering courses. Neither course requires Physics II (essentials of electricity, magnetism, and optics) or any pre-requisite programming experience. This meant that the courses had to accommodate students ranging from no programming background or basic electrical theory to students with strong computer science/physics background. The authors chose to leverage this by optimizing opportunities for collaborative work and peer-to-peer learning. Students work with the same partner every day of class to complete the active learning portion of each class period. Tables are situated in pods of 4 so that two partner groups share a "pod". Activities often require each partner pair to compare, discuss and share data with each other. This formalized mode of collaboration often leads to teams of pairs working together to solve the problem, comparing methods, and learning from each other's mistakes. While the collaborative environment encouraged peer learning, the courses also included several purposeful opportunities for peer learning through lesson presentations, peer reviews, and shared project deliverables. Collaborative learning included group submissions for projects and portions of the midterm and final exams.

Safe Spaces for Failure

The ability to grow from failure, also referred to in the literature as "performance-avoidance," has been demonstrated to serve as an important predictor of retention of underrepresented students in STEM [57], [69], [70]. Both courses found value in the PSS model to create safe spaces for failure. The negative connotations of failure often lead students to place emphasis on a single "correct" solution rather than engaging with the problem solving or critical thinking [71]. Providing an environment for students to learn from failure not only helps change the narrative or perceptions of failure, but can lead to better innovation, increased student efficacy, and incremental improvement on the problems in which one correct answer *is* required [71]–[74]. In the Computational Modeling course, students work through problems that can be solved with more than one method during the in-class PSS, and most problems do not have a single correct answer as they depend on assumptions the students make while solving the problem. These sessions offer an environment for students to work collaboratively, with real-time access to feedback and problem contextualization. Though deliverables are assessed from the instrumentation course, these are low-stakes, checklist assignments that are often achieved in groups. Low stakes assignments are also used for students to make incremental improvements. Both courses have implemented a form of initial and final assignments. Students receive feedback on low stakes assignments to improve on the higher stakes assessments. Peer review and timely instructor feedback both support this implementation. The aim of the hands-on learning approach is to encourage students to learn from mistakes and use the daily lessons to prepare them for the larger assignments such as projects and exams.

Autonomy

Student autonomy is an active, constructive process that requires instructor support and scaffolding to support development. Student autonomy is an important predictor of student success and motivation [75], [76]. Further, it has been demonstrated specifically to improve outcomes in underrepresented students [76]–[78]. Both courses take advantage of the PSS and "Making" pedagogies to support student autonomy. In the Computational Modeling course, PSS activities are purposefully designed as open-ended problems. Students must construct or choose an approach that they will use to approach a solution to the problem. Within these activities, there are multiple ways to identify a solution and in some cases there are multiple solutions. Students are encouraged to think creatively, and reminded to ensure that the chosen approach follows logic and the stated assumptions can be justified.

6. Assessment Approach and Instruments

A summary of the assessment approach is provided in Table 1.

Table 1. Summary of assessment approach by core junior-level course		
	Core 3rd year course	
	Control Systems and Instrumentation	***Computational Modeling***
Sample size (n)	29	54
Pedagogical approach	“Making” PSS	PSS
Survey instruments	Self-Efficacy	SIMS BNS
COPUS observations	03/04/2020 10/19/2020 02/10/2021	11/21/2019 03/03/2020 01/28/2021 02/23/2021

Self-efficacy Survey
Through support from a Kern Entrepreneurial Engineering Network (KEEN) fellowship, an instrument to examine self-efficacy in an Engineering instrumentation and controls course is currently under development. Assessment of self-efficacy includes pre- and post-student self-efficacy results focused on aspects linked to entrepreneurial mindset: curiosity, creativity, and making connections. A student self-efficacy survey was developed with three distinct areas of measurement: general engineering self-efficacy, self-efficacy in context to course outcomes, and self-efficacy with regards to entrepreneurial mindset. The survey was administered prior to a “Making” project (at Mid-term) and upon completion of the project (Final). The instrument was 30 questions, scored on a Likert-scale 1-5, and took approximately 20 minutes for students to complete. Importantly, no pre- data was taken at the start of the semester. An assumption in this study was that assessment of self-efficacy may be more accurate with some exposure to the course. Although these are junior students, most have had no prior exposure to the equipment or concepts used in the course. All responses are from junior engineering undergraduate students. 29 total survey responses were collected across two sections the course.

Motivation Assessment Instruments
Situational Motivation Scale (SIMS) – The SIMS provides a consistent means to assess intrinsic and extrinsic motivation founded in SDT [30], [80]–[82]. The SIMS has previously been used to evaluate gendered patterns of motivation relative to pedagogical environments in STEM courses ([28]). In the present manuscript, the SIMS was used to measure student motivational responses to inclusive PSS interventions. The SIMS was administered after every inclusive PSS intervention in the Computational Modeling in Engineering course.

Basic Needs Satisfaction (BNS) scale – SDT argues that motivational responses are more positive and internalized when three basic psychological needs are satisfied: competence, relatedness, and autonomy. The BNS is a measure of these three basic psychological needs and the BNS used in the present study was adapted from [32].

The SIMS and BNS survey instruments are provided in Supplemental Information S4. Motivation assessment surveys were deployed to students at the end of class periods where inclusive PSS activities took place. All responses are from junior engineering undergraduate students. 54 total survey responses were collected and 7 total responses were from underrepresented students.

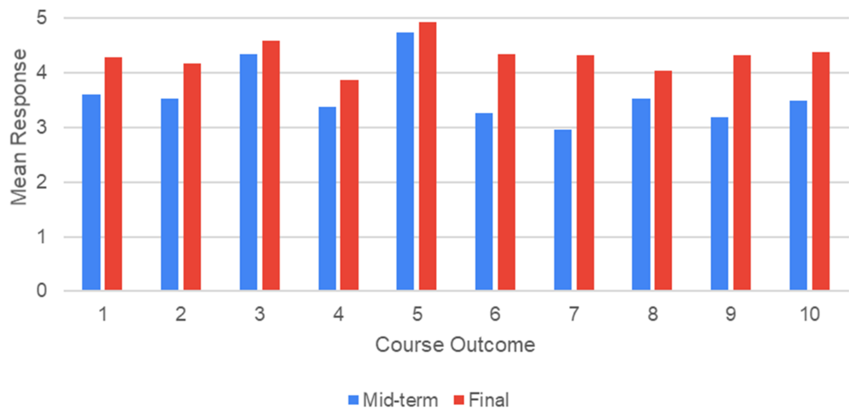
Classroom Observation Protocol for Undergraduate STEM (COPUS)
COPUS [85] observations were completed by a trained member of the teaching support office. COPUS uses an online platform known as GORP (Generalized Observation and Reflection Protocol) for real-time data collection. Through GORP, the observer can select codes for observed classroom activity for both the instructor(s) and students. Observations are coded in 2-minute intervals until the class session is over. If the observer makes a mistake, they can note it during the next interval, and adjust the data accordingly by hand, after class. Data is automatically analyzed in GORP and can be exported to a spreadsheet for further analysis.

The COPUS evaluation process was also part of the development of this Work-in-Progress. We followed the clustering convention put forth by Stains *et al.* [86] in order to better capture the broader types of instructor and student behaviors that we were interested in at this stage in the study -- who's talking, who's working, who's actively engaged in the learning process The goal of observations in both junior-level courses is to quantitatively measure student engagement and instructor behaviors across different topics and instructors (i.e. how did student engagement vary across different topics and instructors?). In future, these observations will be used to specifically examine student behavior during class to determine how well self-efficacy and motivation instruments link to student and instructor behaviors.

7. Preliminary Results and Observations

Self-efficacy
The self-efficacy instrument was only administered in the Control Systems and Instrumentation course. Validity assessment for the self-efficacy instrument includes content, criterion, and construct [49], [87]. Criterion validity used ten experience-based outcome questions in which the hypothesis that more experience will yield higher self-efficacy was tested. This included questions related to course outcomes and "Making" skills such as *"I feel confident in my ability to critically analyze instrumentation systems"* and *"I am confident in my ability to use Making tools in my course projects."* Numerical responses were analyzed in SPSS. A Shapiro-Wilks test for normalcy for pre- and post- data revealed all data to be normally distributed ($p>0.05$) with a t-test indicating significant changes in pre- and post- self-efficacy responses.

The course outcomes questions consisted of five general questions (1-5) related to confidence in performance. Five questions also specifically addresses the course learning outcomes (6-10). Comparisons of means (Figure 1) and number of responses indicated significant increases in efficacy across all outcomes except three. It was expected course outcomes 3, *"I am confident I can learn the basic concepts presented in this course,"* and 5, *"I am confident in my ability to work effectively in a group setting,"* would not see a significant increase since the initial scores were high. Course outcome 4, *"I am confident I can understand the most complex material* *presented in this course,"* was the lowest initial non-course learning outcome in the pre-test and was observed to increase, though not significantly in either the mean or the number of responses.



	Course Outcome Questions
1	*I'm confident I can do an excellent job on the assignments, projects and tests in this course.
2	*I'm certain I can master the skills being taught in this class.
3	*I'm confident I can learn the basic concepts presented in this course.
4	*I'm confident I can understand the most complex material presented in this course.
5	*I'm confident in my ability to work effectively in a group setting.
6	**I feel confident I can apply principles of digital and analog circuits for system analysis and design.
7	**I feel confident I know how and when to apply amplification, filter circuits, and sampling for analog and digital signal processing for a variety of applications
8	**I feel confident in my ability to critically analyze instrumentation systems.
9	**I feel confident in my ability to communicate analysis of systems in a variety of professional contexts.
10	**I feel confident in my ability to test, debug and prototype electrical systems.

Figure 1. Student self-efficacy responses for course learning outcomes. Data was collected pre- and post-completion of the course project. For clarity outcomes were numbered on the graphs with the corresponding question shown underneath. *Indicates questions developed from MSQL [88]–[90] . **Indicates course learning outcomes from the syllabus of the course.

General Engineering self-efficacy (questions provided in Supplemental Information S2) was high in both the pre- and post- surveys with no statistical difference found in pre and post surveys or across sections. This was expected in a junior cohort. Median responses of 4 (agree) were given to questions relating to engineering problem solving, such as *"I am confident in my ability to work on a problem until I find the best solution."* Students also responded with a median response of 4 (agree) in questions related to ways of learning. This included how listening to direct instruction, working with other students and watching demonstrations gives confidence in solving Engineering problems. Notably, there was a statistically significant ($p<0.05$) increase in the mean response to *"I am confident I could explain engineering concepts to another student."* Application of "Making" skills also had an initially high mean and median response with only slight increases in the post-surveys. Of note with regards to how the "Making" activities and project enhanced EM, all EM-related outcomes saw a positive effect between the pre- and post-surveys (Figure 2), though none significantly. The questions, which related to "Making" and

“Making” activities mapped across KEEN’s 3 C’s. Some questions linked to how students relate “Making” to EM while some were linked to how students viewed themselves as entrepreneurial minded makers (EM self-efficacy). The Connections question, which showed a decrease in response, was a reverse-worded question to be used for further instrument validation.

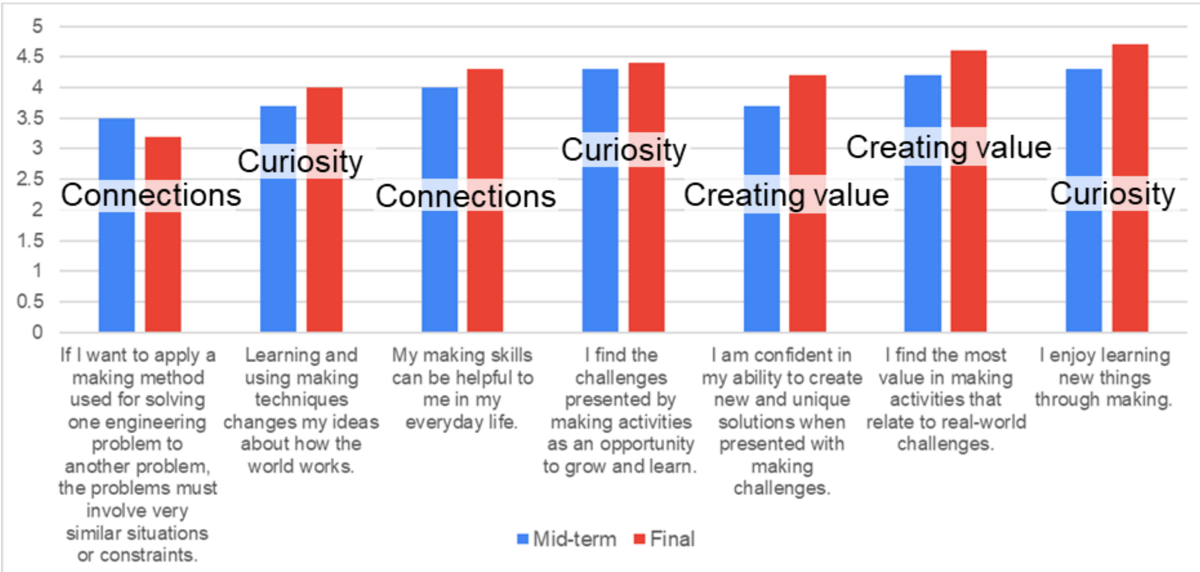


Figure. 2. Student self-efficacy responses for EM-related outcomes. Data was collected pre- and post-completion of the course project.

This preliminary data suggests that the course had some positive impact on self-efficacy across the three domains surveyed. Initial data points to the course design having a positive impact on EM-related outcomes. Further data will be collected on student self-efficacy of these domains in Spring 2021 and in future semesters. The goal is to provide a more complete dataset and to perform further instrument validity assessment and factor analysis to compare across sections and student groups. Additional related test questions will be developed to conduct content analysis. Content analysis of the self-efficacy instrument will include Cronbach’s α to test inter-item reliability among the three survey domains (course, Engineering, and Making). Construct validity will examine how these categorizations of EM self-efficacy outcomes relate to each other, as well as how this quantitative data compares to activities observed through COPUS observations [85] and qualitative responses in focus groups. The instrument will also begin to collect demographic information to determine if equitable outcomes across student groups are observed.

Motivational Profiles
Motivation instruments were only administered in the Computational Modeling in Engineering course. The motivational profiles provide a way to visualize the modes of student motivation. Ideally, amotivation and external regulation would be low, while identified regulation and intrinsic motivation would be high [31], [32]. This means that students are engaged out of their own interests and perceive value rather than out of external pressure. The preliminary results represent a small sample size (n=54) collected over two class periods in spring 2021 during which the inclusive PSS activities were implemented. We find differences in the motivational profiles between men and women (not shown) and between the entire class and underrepresented

students (Figure 3). Specifically, underrepresented students showed a "High Autonomous-High External" type motivational profile where they experience high identified regulation and balanced intrinsic motivation and external regulation. In contrast, the mean responses across the entire class demonstrates that students experienced a "High Identified-High External" motivational profile, indicating lower intrinsic motivation, and balanced identified and external regulation [Add 2021 Motivation Paper here]. Each plot also shows the self-determination index (SDI) for the two student populations, which is a value representing students' overall levels of motivations ranging from –18 (amotivation) to +18 (intrinsic motivation). The SDI is higher for the underrepresented students than for the entire class, and both are positive. These results would suggest that our inclusive pedagogy supports autonomous motivations for 3rd year undergraduates. Further data will be collected on motivational profiles in spring 2021 and in future semesters to in order to provide a more complete picture, along with statistical analysis, on how inclusive pedagogy affects student motivation.

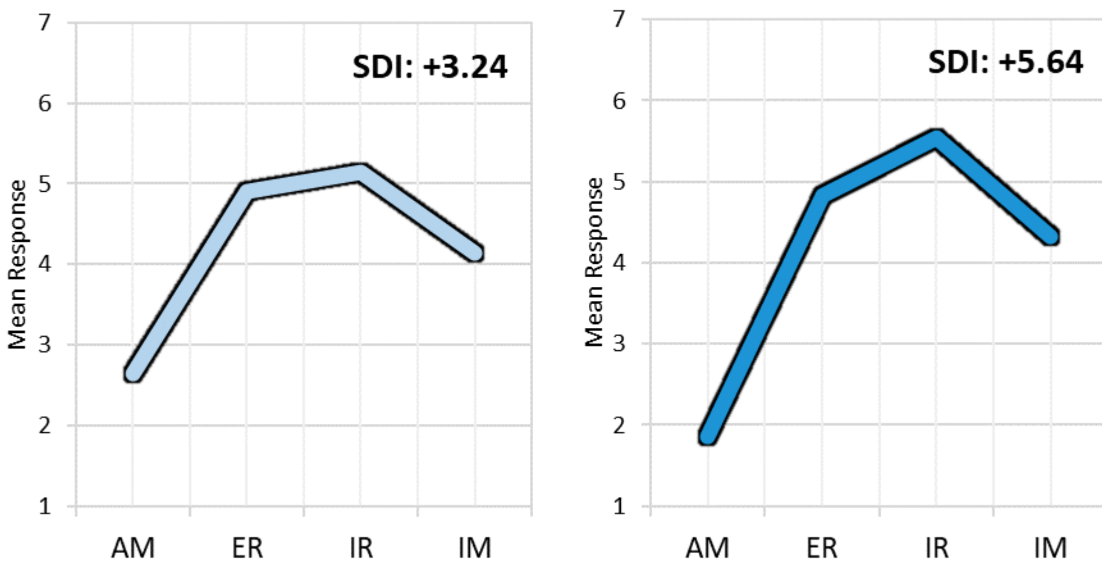


Figure. 3. Motivational profiles showing student mean responses linking to amotivation (AM), external regulation (ER), internal regulation (IR), and intrinsic motivation (IM). Left: overall class average. Cluster Type 3. Right: underrepresented students. Cluster Type 2.

Basic Needs and Satisfaction

Students' basic psychological needs satisfaction along the dimensions of relatedness, competence, and autonomy are shown in Figure 4. These responses were collected from the same class periods as the SIMS data displayed in Figure 3. We find the mean responses for relatedness, competency, and autonomy to be lower for underrepresented students. This suggests that underrepresented students experience lower basic psychological needs satisfaction. Interestingly, this initial result that psychological basic needs dodoes not align with the more positive motivational responses of underrepresented students. [29], [91]. One possible explanation for the misalignment is that five of the nine reverse-scored items in the BNS have been shown to have a misfit via factor loadings analysis. Another potential shortcoming of the BNS is that it better aligns with course-level or contextual-level needs satisfaction, while the SIMS provides a situational, or activity-level, measure of motivation. For example, BNS items include "most days I feel a sense of accomplishment in this class" and "people are generally friendly to me in this class." We are currently working to collect additional SIMS and BNS data to conduct a statistical analysis on the correlations between the motivation subscales and basic needs. We are also exploring the use of more situationally oriented scales such as the Activity Feelings State instrument [92], [93].

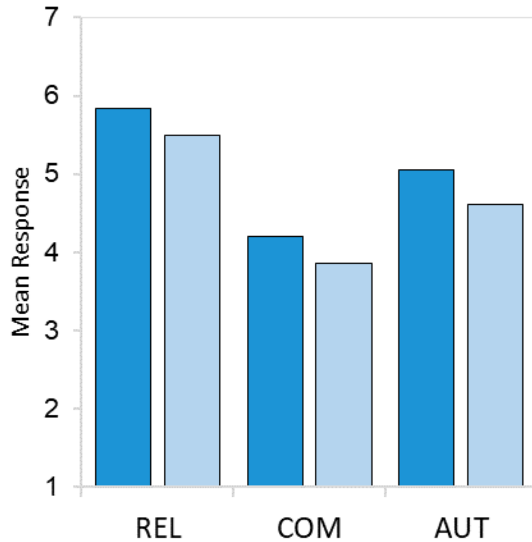


Figure 4. Student basic needs responses across the dimensions of relatedness (REL), competency (COM) and autonomy (AUT). Dark Blue: overall class average. Light Blue: Underrepresented students.

COPUS

Control Systems and Instrumentation: Observations of student and instructor behaviors were completed on three separate dates, corresponding to a typical class day (2/10/2021), a project working day (10/19/2020), and review session (3/4/2020). From Figure 5 a typical class day saw the instructor presenting 33% and guiding 60% of the time. Students were receiving 36% and working 55% of the time. During the project work day, students worked 62% with 19% of their time spent receiving or talking. During this time, it was noted the Instructor spent 76% of the time guiding. The collaborative learning of the course can be demonstrated through observing the student and instructor activities during a typical review session. Students spend 56% of the time talking, while only 41% receiving (coinciding with the instructors 41% presenting). The goal of review session is to have students explain concepts to each other with guidance from the instructor. After a brief overview of topics the review session was facilitated by a student posing a question to the class, followed by each pod discussing and formulating their group response. The groups would then discuss amongst each other with the instructor giving guidance. Importantly, the hands on, collaborative nature of the course can be tracked through these observations. Future work will link these observations of instructor and student behaviors to the self-efficacy pre- and post- surveys to evaluate the effect the classroom setting and learning environment as a factor in self-efficacy.

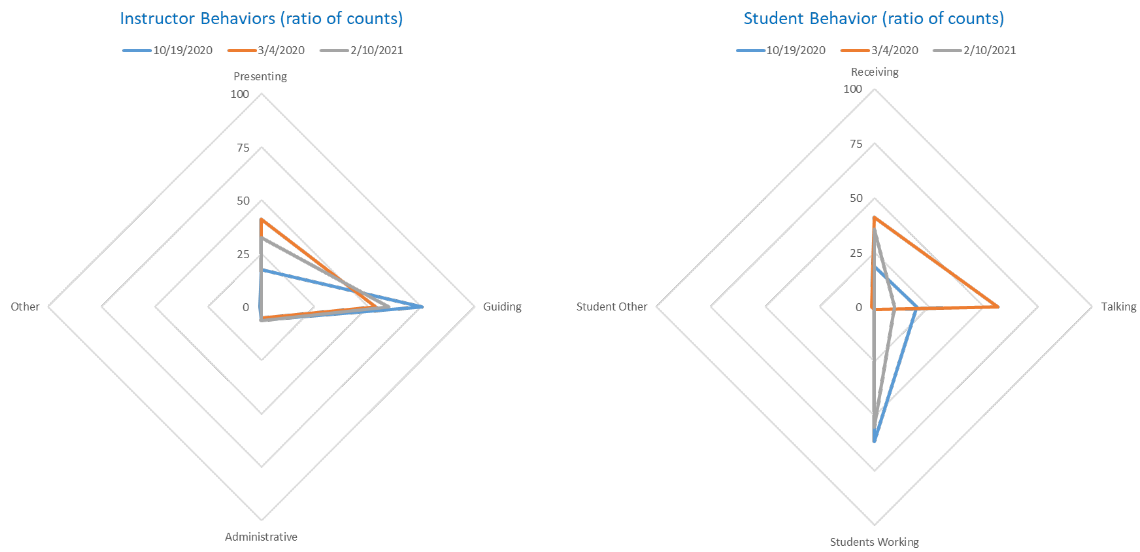


Figure 5. COPUS observations from the Control Systems and Instrumentation class demonstrating the percentage of time during a course period that the instructor and students were engaged in particular behaviors. Course periods reflect typical class lab day (2/10/2021), project work day (10/19/2020) and a review day (3/4/2020). Left: COPUS observations of instructor behaviors. Right: COPUS observations of student behaviors.

Computational Modeling: Observations of student and instructor behaviors provide additional context on how students were engaged during the class period in which the inclusive PSS was implemented (Figure 6). The two dates in Spring 2021 (1/28 and 2/23) correspond with the SIMS and BNS data shown in Figure 3 and 4. Prior observations were made in Fall 2019 during an inclusive PSS activity and in spring 2020 during a traditional lecture. These observations were included for comparison. During the traditional lecture class (3/3/2020), the instructor was primarily presenting and to a smaller extent guiding students, while the students were spending more than 50% of the class period receiving the lecture (Figure 6). In contrast, on two of the inclusive PSS class periods (11/21/2019 and 1/28/2021) the instructor guided for more than 75% of the time while students were working or talking for more than 50% of the time. It is clear that how the instructor implements the inclusive PSS activity plays a large role in how the students engage in the class. On 2/23/2021, the instructor dedicated equal amounts of time to presenting and guiding students, which led to students spending more time receiving rather than working on the problem. Future work will link the COPUS observations of instructor and student behaviors to the motivational profiles and BNS to evaluate the relationship between in-class behaviors and student motivation.

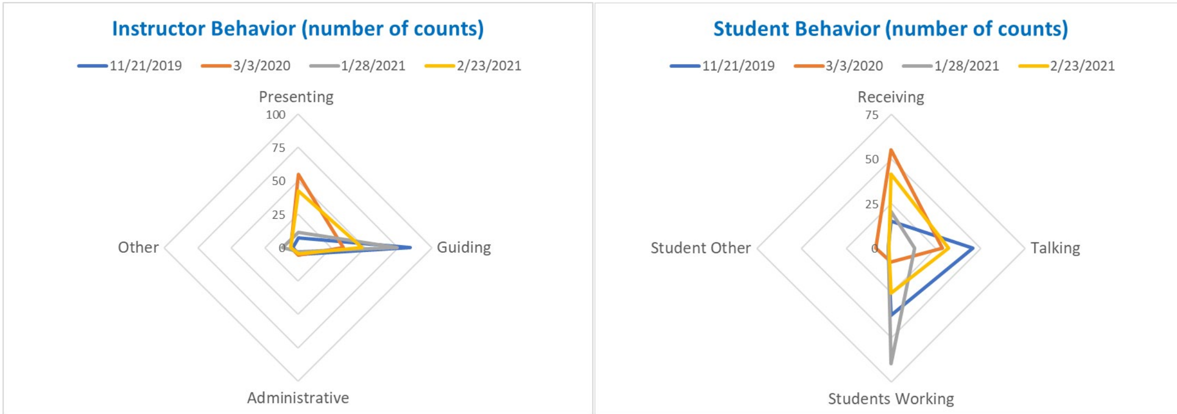


Figure 6. COPUS observations from the Computational Modeling class demonstrating the percentage of time during a course period that the instructor and students were engaged in particular behaviors. Course periods reflect traditional lecture (3/3/2020) and inclusive PSS activities (11/21/2019, 1/28/2021, and 2/23/2021). Left: COPUS observations of instructor behaviors. Right: COPUS observations of student behaviors.

It should be noted, COPUS observations are limited by the fact that a trained individual must label an in-class interaction/behavior in real-time. Multiple behaviors can occur at the same time and some may be missed. This can create some issues with missed labeling or mislabeling during active learning class activities. Additionally, data are collected in 2-minute intervals, which can cause some temporal discrepancies in the record.

Student Feedback

Course evaluations asked students to reflect on the following questions:

1.) What did you do to help your learning in this course?
2.) What helped your learning in this course?
3.) Our Department Values are integrity, empowerment, inclusion, growth, compassion and joy. To what extent did this course embody these values? What suggestions for improvement do you have?
4.) What did this professor do well in supporting your learning?
5.) What suggestions do you have to improve the learning in this course?

Student feedback was examined for specific comments related to the four characteristics of inclusive practices in focus for this study. Overall course comments were categorized either by positive or negative reflections, then sub-categorized by key words presented in column one of Table 2. The chosen quotes for the paper were those that included phrases from the key word analysis and were complete, thorough thoughts. Importantly, the authors did not observe any negative comments related to the key words. Negative comments that were observed, however, were unrelated to the key words of interest in this study. A summary of student feedback from course evaluation forms is presented to demonstrate how students perceived the components of the inclusive curriculum interventions (Table 2). In analyzing student feedback, comments related to the intentional inclusive practices implemented in each course were observed. Future work includes a thematic analysis of qualitative data from mid-term as well as final course evaluations.

Table 2. Student Feedback on Inclusive Practices in the Junior Core Curriculum	
Representation	Control Systems and Instrumentation *"I thought that this class fostered a very inclusive learning environment. I was able to grow and develop my problem solving skills, and I was able to develop my team skills."*
	Computational Modeling *"I thought the class in general really promote these values with the work we did on a variety of problems. I also felt like it was a very inclusive class where we valued everyone perspective, which allowed us all to grow."*
Collaboration over Competition	Control Systems and Instrumentation *"I appreciated the collaborative environment that was fostered throughout the course. I work well when working through problems with others and the lab partner focus helped this."* *"I relied on my peers and especially my lab partner to help aide my understanding of the material of the course."*
	Computational Modeling *"The peer review assignments were very helpful for the problem solving labs because it gave me the opportunity to look at my partner's work and get feedback on my own. It allowed me to see a different perspective on how to approach the problem. "* *"I think this class helped me become closer with some of my peers even though we could not work on things together in person. We all would work together if there was something challenging us or if something was uncelar (sp.)"*
Safe Spaces for Failure	Control Systems and Instrumentation *"Opportunities were presented for you to learn more about the topic. You gained more knowledge obviously, but you also learned by being in a group or having a partner. Finally figuring out a concept after being confused feels great."*
	Computational Modeling *"Also, the different types of things we did helped my learning, like problem sets, labs, and in class group work. Not having sample codes for some assignments also really helped my learning, because I was able to think and work through the problems myself and better learn it than when were originally provided with the code."*

Autonomy	Control Systems and Instrumentation *"My partner and I usually tried to work through the problem for a good while before asking though, which often times resulted in us figuring it out which I think was pretty valuable."* *"Lab time was always incredibly joyful and the attitude in the room was always positive. We were empowered to learn to master the material and class time and office hours were always super inclusive."*
	Computational Modeling *"The assignments that were done in this class were very intentional and aided my learning of complex concepts. I felt a great sense of accomplishment when turning in either a problem solving lab or a problem set."* *"I think this course really embodied growth. I remember when we started learning Matlab in the intro classes and were very confused, but now we all understand a lot of Matlab and how to code many different types of problems. I also thought it really embodied inclusion, because I feel I became a lot closer with both my peers and professors"*

8. Discussion and conclusions

The goal of this Work-in-Progress manuscript was to investigate how purposeful design of EM pedagogies may also promote inclusive practices in courses. This was developed across the core, junior-level curriculum in a general engineering undergraduate program. Preliminary student self-efficacy data in the instrumentation course was shown to increase as a result of PSS-inspired daily Making activities. Self-efficacy was shown to increase more in the technical skills compared to the more conceptual areas, which agrees with previous studies [22], [37]. This work leveraged several different instruments towards investigating self-efficacy in several dimensions [19], [45], [49]. Data collected in future iterations of the course will enable a more robust instrument validation across sections and cohorts and allow us to investigate other pedagogical approaches beyond the Making activities. Crucial to this work, we will also investigate self-efficacy at the individual level to examine underrepresented student outcomes distinct from cohort data as these have historically been shown to differ across interventions [3], [22], [25].

Preliminary data from motivational instruments suggests that inclusive PSS activities improved motivation amongst underrepresented students. Positive SDI values across all student groups postulates that inclusive PSS activities led to high motivation not only for underrepresented students but for all students. This preliminary result is in line with prior work that has shown that underrepresented students respond positively when they can curry a sense of belonging in academic spaces [59], [62], [64], [94]. One area of further exploration is the mismatch between SIMS and basic needs observed in the underrepresented student group. Future work will also examine more thoroughly the link between course behaviors, documented by the COPUS instrument, to student self-reported motivation from the SIMS and BNS instruments.

In both courses, COPUS observations were used to confirm the active learning approaches in terms of student and instructor behaviors during the class activities. This was examined to ensure a level of consistency across instructors and sections with regards to the interventions. These observations also demonstrated the importance of the consistency in course design and the instructor's role in affecting motivational and self-efficacy outcomes. This was further observed in course evaluation comments. Course evaluation comments also demonstrated that student perception was sensitive to the intentional design of the courses with regards to implementing inclusive EM approaches.

This preliminary research gives some promising insights into how EM pedagogies can be intentionally designed to support inclusion. To further the work documented in this Work-in-Progress paper, key considerations and goals for future study include:

- Implementation of EM should be purposeful if the goal is also to facilitate an inclusive learning environment. Clear goals and definitions of what an inclusive classroom is has provided the authors a valuable framework from which to test interventions.
- Included in the intentionality of the course and intervention design should be instructor training on the pedagogical approaches (i.e. in this study, PSS).
- Future work to investigate the nexus between motivation and self-efficacy across the junior cohort can provide a richer picture of what EM development across a cohort could mean for inclusion and retention of underrepresented students.
- Given the amount of evaluation and ALP used in the core curriculum, future work will also consider ALP and survey fatigue across the two studies.
- The impact of this work will also include longitudinal consideration of the junior cohort into their Senior Capstone experience. This work will examine whether students translate gains from the EM pedagogies in their junior year into their Capstone design experience.

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Supplemental Information

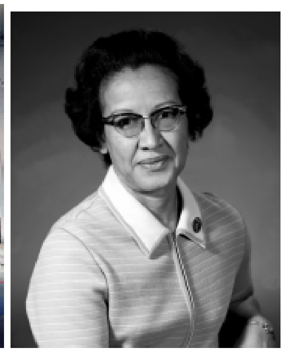
S1. PSS Activity Details

Student Handout:

Katherine Johnson / "Hidden Figures"

EGR 312
Problem Solving Studio

August 27, 2019



"Tell me where you want the man to land, and I'll tell you where to send him up"
- *Katherine Johnson*

1 Background

The 2016 film *Hidden Figures* depicts the significant contributions of Katherine Johnson, a American mathematician and NASA scientist, in developing and pioneering the mathematical work that made human space flight and reentry possible. A pivotal scene in the film depicts Johnson working through the estimation of the point of reentry for astronaut John Glenn's capsule *Friendship 7*. In 1962, Glenn was the American to orbit the Earth and his feat was impossible without the diligent work of Katherine Johnson. Johnson also had a pivotal role in calculating the trajectories for the Apollo mission that brought American astronauts to the moon.

2 The Set-up

In the technical note written by Johnson, she describes how to determine the position of a capsule orbiting the Earth. This capsule is the refrigerator-sized space craft that John

Glenn piloted in a series of orbits around the Earth. The problem faced in the series of equations described below is how to determine the location of the capsule at burnout (i.e., when the engines turnoff) in order to have the capsule arrive at a predetermined location on Earth. You will be solving the same problem that Johnson solved in 1959, and recreated famously in the *Hidden Figures* movie.

The problem was this: NACA (pre-NASA) scientists and engineers knew the latitude and longitude from which they were launching Glenn's capsule and the location in the Atlantic ocean where they intended to retrieve the capsule. They also knew that Glenn was to orbit the Earth three times. The unknowns were: 1) at what location above the Earth (i.e. azimuthal angle) should Glenn turn off the engine for his descent back into Earth, ψ_1, 2) what was the difference in longitude between the initial burnout position and the selected point on Earth through which the scientists wanted the capsule to pass $\Delta\lambda_{1-2e}$, and 3) how much time would pass between passing through the selected point on Earth and burnout, $t(\theta_{2e}) - t(\theta_1)$. In order to solve for these parameters, Johnson used the following system of equations:

$$\lambda_{2e} = \lambda_2 + n\omega_E T \tag{1}$$

$$\Delta\lambda_{1-2e} = \lambda_{2e} - \lambda_1 + \omega_E \left[t\left(\theta_{2e}\right) - t\left(\theta_1\right)\right] \tag{2}$$

$$\cos\left(\theta_{2e} - \theta_1\right) = \sin\phi_2 \sin\phi_1 + \cos\phi_2 \cos\phi_1 \cos\Delta\lambda_{1-2e} \tag{3}$$

$$\left[t\left(\theta_{2e}\right) - t\left(\theta_1\right)\right] \approx \frac{T}{360}\left(\lambda_{2e} - \lambda_1\right) \tag{4}$$

$$E(\theta) = 2\tan^{-1}\left(\sqrt{\frac{1-e}{1+e}}\ \tan\frac{\theta}{2}\right) \tag{5}$$

$$t(\theta) = \frac{T}{2\pi}\left(E(\theta) - e\sin E(\theta)\right) \tag{6}$$

$$\sin\psi_1 = \frac{\sin\Delta_{1-2e}\cos\phi_2}{sin\left(\theta_{2e} - \theta_1\right)} \tag{7}$$

Instructor Template:

PSS Session Development Template

PAGE 1: PROBLEM DESIGN

Learning Goal(s)	Targeted Misconceptions
• Apply a numerical method (Euler's method) for the first time to solve a physically-relevant problem • Internalize the historical context of the development of numerical methods	• Solving complex problems is hard and out of the students' ability • Numerical methods require a computer

Entrepreneurial Mindset Alignment

- **Curiosity**
  Evidence: Apply a new problem solving technique
- **Connections**
  Evidence: Connect to physics, math, aeronautics, and the history/evolution of using "computers" for problem solving
- **Creating Value**
  Evidence: Uncover what made human space exploration possible/Brilliant breakthroughs do not always come from new ideas

Problem Context: Katherine Johnson (as shown in the movie *Hidden Figures*) figured out how to calculate the reentry of a capsule into Earth's atmosphere after orbiting the planet

Problem Situation / Background / Case	Problem Question
Solve for the trajectory of John Glenn's capsule on reentry to the Earth. Explore the state of computers in the 1950s and the idea of human computers.	How did Katherine Johnson find the burnout position (i.e. when Glenn cut's the capsule's engine) so that he will land at a specific latitude and longitude in the ocean?

Problem Difficulty "Adjustment Levers" (structure, complexity) (see Jonassen paper) Structure: - Provide context for the problem – what the parameters and variables mean in the system of equations - Provide diagrams of the capsule orbit and trajectory - Show clip from the movie *Hidden Figures* when Johnson figures out how to solve the problem - Tell the students how many iterations to solve for Complexity: - Provide system of equations that must be solved - Provide both eastward and westward launch positions - Ask the students to code their solution method in MATLAB and plot results - Ask the students to include the correction factor for the oblateness effects (i.e. Earth not a perfect sphere)

PAGE 2: PROBLEM AS GIVEN TO STUDENTS

How will the problem be introduced to the students?

- ❑ Paragraph – Hand out summarizing the problem and providing the system of equations
- ❑ Video – Show "Euler's Method" clip from *Hidden Figures* movie
- ❑ Pictures
- ❑ Journal Article??
- ❑ News Story?
- ❑ Other – Falling sphere viscometer experiment

Problem Statement

Given Assumptions	Given Constraints	Given Ranges
$\omega_E[t(\theta_{2e}) - t(\theta_1)] \approx \frac{T}{360}(\lambda_{2e} - \lambda_1)$	• Solve by hand	• Need to solve

S2. Making PSS Workflow and Example Activity Mapping.

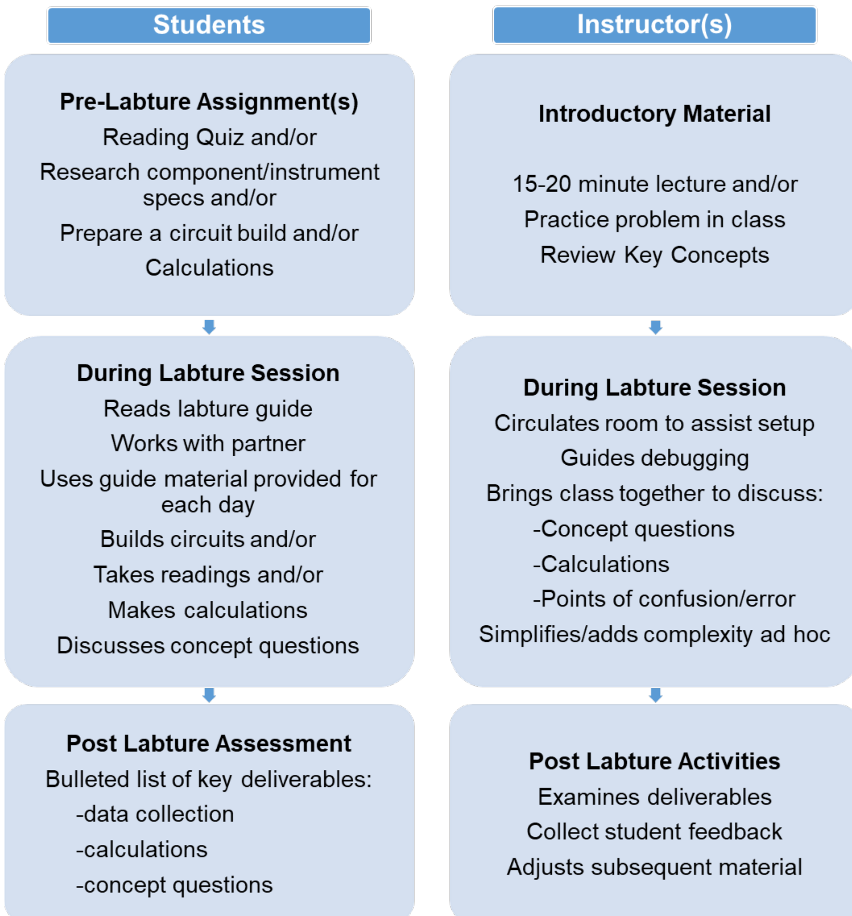


Figure S1: The typical workflow of the PSS inspired lab/lecture (labture) for instrumentation following the students and instructor behavior. Class periods are 1 hr and 50 min. Students complete some pre-labture reading/work prior to each class. Instructors open class with brief lecture overview and any clarifications for the hands-on portion. At least 1 hour is dedicated to the hands-on portion of the lectures. Some extend beyond one class period to support multiple learning objectives or extensive data collection. Post labture includes student submission of key deliverables and instructor collection of student reflections or reviews.

S3. Self-Efficacy Survey Instrument

Course Outcomes

1. *I'm confident I can do an excellent job on the assignments, projects and tests in this course.
2. *I'm certain I can master the skills being taught in this class.
3. *I'm confident I can learn the basic concepts presented in this course.
4. *I'm confident I can understand the most complex material presented in this course.
5. *I'm confident in my ability to work effectively in a group setting.
6. **I feel confident I can apply principles of digital and analog circuits for system analysis and design.
7. **I feel confident I know how and when to apply amplification, filter circuits, and sampling for analog and digital signal processing for a variety of applications.
8. **I feel confident in my ability to critically analyze instrumentation systems.
9. **I feel confident in my ability to communicate analysis of systems in a variety of professional contexts.
10. **I feel confident in my ability to test, debug and prototype electrical systems.

General Self-Efficacy

1. When given an engineering design problem, I am confident that I will be able to solve it.
2. I am confident in my ability to work on a problem until I find the best solution.
3. If I get stuck on a problem on my first try, I usually try to figure out a different way that works.
4. The taught components of the course give me confidence in my ability to solve engineering-related problems.
5. Working with other students gives me more confidence to solve engineering-related problems.
6. After I study a topic and feel that I understand it, I have difficulty solving problems on the same topic.
7. If I get stuck on a problem, there is no chance I'll figure it out on my own.
8. I am confident I could explain the course concepts to another student.

3C's

1. I am not satisfied until I understand why something works the way it does.
2. If I want to apply a method used for solving one engineering problem to another problem, the problems must involve very similar situations or constraints.
3. Learning engineering changes my ideas about how the world works.
4. My engineering skills can be helpful to me in my everyday life.
5. I enjoy making activities (i.e. building and creating).
6. I find making activities frustrating.
7. I find the challenges presented by making activities as an opportunity to grow and learn.
8. Design constraints are an enjoyable challenge in making activities.
9. I am confident in my ability to create new and unique solutions when presented with challenges.
10. I find the most value in making activities that relate to real-world challenges.

S4. Student Motivation Surveys

Situational Motivation Scale (SIMS)

Directions: Read each item carefully. Using the scale below, please circle the number that best describes the reason why you are currently engaged in this activity. Answer each item according to the following scale: 1: corresponds not at all; 2: corresponds a very little; 3: corresponds a little; 4: corresponds moderately; 5: corresponds enough; 6: corresponds a lot; 7: corresponds exactly.

Why are you currently engaged in this activity?
Because I think that this activity is interesting
Because I am doing it for my own good
Because I am supposed to do it
There may be good reasons to do this activity, but personally I don't see any
Because I think that this activity is pleasant
Because I think that this activity is good for me
Because it is something that I have to do
I do this activity but I am not sure if it is worth it
Because this activity is fun
By personal decision
Because I don't have any choice
I don't know; I don't see what this activity brings me
Because I feel good when doing this activity
Because I believe that this activity is important for me
Because I feel that I have to do it
I do this activity, but I am not sure it is a good thing to pursue it

Basic Needs Satisfaction (BNS)

Please rate the following items based on your behavior in this class. Answer each item according to the following scale: 1: corresponds not at all; 2: corresponds a very little; 3: corresponds a little; 4: corresponds moderately; 5: corresponds enough; 6: corresponds a lot; 7: corresponds exactly.

I really like this people in this class
I do not feel very competent in this class
People tell me I am good at what I do in this class
I feel like I am free to decide how to do things in this class
I get along with people in this class
I pretty much keep to myself when I am in this class
People care about me in this class
I am free to express my ideas and opinions in this class
I feel pressured in this class
I consider people in this class to be my friends

I have been able to learn interesting new skills in this class
People are generally friendly to me in this class
Most days I feel a sense of accomplishment in this class
I frequently have to do what I am told in this class
In this class, I do not get much of a chance to show how capable I am
I feel like I can pretty much be myself in this class
There are not many people in this class that I am close to
There is not much opportunity for me to decide for myself how to do things in this class
The people in this class do not seem to like me much
I often do not feel very capable in this class
People I interact with in this class tend to take my feelings into consideration