Work in Progress: Instructional Strategies to Promote Cognitive Belonging and Engagement in Engineering Courses

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Abstract

This work-in-progress paper explores instructional strategies that may promote cognitive belonging and engagement in engineering courses. Belonging uncertainty contributes to significantly lower than average STEM graduation rates for historically underrepresented students. Lang (2021) posited that if we promote a sense of cognitive belonging in the classroom, i.e., helping students feel like they belong in the courses they are taking, then we can remove a significant barrier to students' learning. One approach he recommends is designing courses with high amounts of structure, which according to Hogan and Sathy (2022) directly contribute to creating an inclusive classroom. To add more structure to an upper-level architectural engineering course, regular and deliberate opportunities for practice both in and outside of the classroom will be added. For example, dedicating about 50% of each class for active engagement and weekly pre-class assignments, respectively. In addition, the following aspects were incorporated to promote a more inclusive environment: a syllabus with student-centered language, development of a classroom participation agreement, and collaborative, in-class learning activities. This paper provides more detail on these strategies and the proposed means of assessment. Instructors may consider incorporating these types of changes into their courses to support their students' sense of belonging and engagement in their courses.

1. Introduction

Historically underrepresented minority students and low-income students are proportionally less likely to graduate with STEM degrees as compared to typically overrepresented students [1] – [3]. These groups of students will be collectively referred to as "from minoritized groups in STEM, or MGS [students]" [4]. A possible key contributor to this gap in graduation rates between MGS and majority students is belonging uncertainty [5] – [8], feelings that an individual doesn't belong at their institution, within their major, and/or within their courses. Belonging uncertainty can last throughout students' undergraduate STEM degrees [9] – [10], through post-graduation into graduate school [9] and the workforce [11]. Thus, a sense of belonging is important for student success across all class levels and for persistence in STEM.

In a mixed method study, Zumbrunn et al. [12] showed that supportive classroom perceptions could be used to predict students' perceptions of belonging within a course and these belonging perceptions can be used to predict factors of student success, specifically motivation, engagement, and achievement. Many studies with children and adolescents have provided evidence that supportive classroom environments lead to student academic success, e.g., Furrer and Skinner [13]. We propose that a supportive classroom can be achieved using high-structure and inclusive teaching strategies, as detailed in Hogan and Sathy [14], and that these strategies may promote cognitive belonging, a term coined by Lang [15], and behavioral and social engagement [16]. Hogan and Sathy in separate publications, [17] and [18] respectively, demonstrated that adding high structure provided disproportionately more benefit for MGS students. These types of teaching strategies were applied in an upper-level engineering course,

which will provide more perspective on the final stage of the professional formation of engineers in an undergraduate degree program. Students at this point in their college career have a stronger sense of themselves in their discipline as compared to first- and second-year students, but the latter group tends to be the focus of most work. The findings will be transferable to other faculty teaching upper-level engineering courses interested in trying these methods to promote cognitive belonging.

2. Theoretical frameworks

Two theoretical frameworks are relevant to the proposed work: 1) Vygotsky's social constructivist theory supports the idea that a highly structured and collaborative environment is conducive to learning [19], and 2) Kahu and Nelson's engagement framework suggests that student belonging promotes engagement [20].

Vygotsky's theory of cognitive development is classified by Schunk [21] as a primary example of social constructivist theory. Relevant to this work are the aspects of Vygotsky's theory related to social interaction and proposed zone of proximal development (ZPD), which both contribute to an individual's construction of knowledge. The instructional strategies implemented (see next section) will encourage peer-to-peer learning (social interaction) with scaffolding (ZPD).

Kahu and Nelson [20] developed a conceptual framework of student engagement, which proposes how structural influences, psychosocial influences, the educational interface, and immediate and long-term student outcomes interact. One component of this framework links a sense of belonging with engagement. They propose that the psychosocial influences of the student-institution relationships, which include student-instructor ("teaching") and student-student relationships, are related to the educational interface. This interface connects the four psychosocial constructs of self-efficacy, emotions, belonging, and well-being, to engagement. The specific aspects of engagement to be studied related to belonging are social and behavioral as defined by Bowden et al. [16].

3. Instructional strategies implemented

Lang [15] posited that if we promote a sense of cognitive belonging in the classroom, we can remove a significant barrier to students' learning, i.e., students asking themselves, "Do I belong here?" To increase this sense of belonging Lang recommends incorporating several instructional strategies into courses, including providing high structure in the classroom as detailed in Hogan and Sathy [14]. Tanner [22] provides 21 instructional strategies to promote student engagement, several of which serve to increase structure and create an inclusive classroom environment. Selected strategies of this nature were incorporated into an upper-level, architectural engineering (AE) course, AE 458, Advanced Architectural Acoustics and Noise Control, at The Pennsylvania State University. The course had an enrollment of 25 students and is required for AE students in the mechanical systems option and is an elective for AE students in the other three options.

3.1 Instructional strategies to create an inclusive classroom environment

Three strategies were implemented to create a more inclusive classroom environment as shown in Table 1. The first strategy was to develop a revised syllabus with language that is student centered, conveys a supportive and welcoming environment, includes text that students belong in the course, and is more personalized with first-person statements [14, Ch.3]. The second strategy was to collectively develop a class participation agreement with the students during a class period early in the term [23]. Lastly, to encourage participation from all students and peer-to-peer learning, collaborative learning activities were added in the form of small group work with guided activities and example problems to most lectures. (This last strategy overlaps with increasing the time for active participation during the lecture as listed in the previous section.)

Table 1. Strategies to create an inclusive classroom environment.

Item	Description
Inclusive Syllabus	1. Student-centered language and tone, e.g., "Research shows that using your devices during class can be disruptive to your learning." vs. "Use of your devices is not allowed during class."
	2. Statement of belonging, e.g., "You have worked hard to be here; you belong here!" [14] "You belong here regardless of your background, religion, high school experience, …"
	3. Supportive tone, e.g., "I've developed the notes to be fill-in-the-blank style to promote engagement during the lectures." vs. "Fill-in-the-blank notes will be used in this course."
Class Participation Agreement	Divide students into small groups and ask them to create a list of desirable behaviors for a positive learning environment; discuss as a class to reach a consensus on the final list.
Collaborative Learning Activities	Students work in small groups on guided activities and/or example problems for parts of the lecture to promote peer-to-peer learning.

3.2 Instructional strategies to add structure to promote a sense of cognitive belonging

To add structure to the course, students were provided with regular opportunities for deliberate practice with the course content as recommended in [14]: a) pre-class, low-stakes assignments that consist of a short reading assignment, viewing of a YouTube video, listening to auditory demonstrations, or a combination accompanied by a series of short questions; b) the class periods were modified to increase in-class time for active participation to at least 50% of the lecture; c) approximately weekly homework assignments; and d) exam preparation assignments will be required. More details about each of these strategies can be found in Table 2.

Table 2. Strategies to add structure to the course.

Item	Description
Regular, deliberate practice	1. Weekly pre-class assignments to help prepare students for some of the content in the upcoming lectures, which contain about 5 questions based on assigned reading excerpts, videos, and/or audio demonstrations.
	2. Weekly homework assignments to provide regular practice and interaction with course content.
Opportunities for Engagement during Lectures (~50% of lecture period)	1. Q&A with online tool, e.g., TopHat, to gauge content comprehension and encourage active participation with content; encourages participation from students who prefer not to speak up in class; allows for more think time.
	2. Collaborative learning activities with clear, written instructions. Individuals can only process so much information at one time, so very helpful to both say and display instructions. The activities were structured with a mix of prompts for students to attempt parts on their own and then share their findings with the group. Groups were instructed to come to a consensus and a designated reporter would to share the group's findings.
	3. Fill-in-the-blank notes to emphasize key points and allow for practice working through examples.
	4. Reflection at the end of the class on how course content connects to something they've experienced in their daily life, and/or a previous concept they've learned in any course [15].

4. Assessment instruments

To evaluate if the identified teaching strategies influence social and behavioral engagement, two assessment instruments were used. An in-class observation protocol and student questionnaire were developed based on Naibert and Barbera's engagement survey [24], which is a slightly modified version of Wang et al.'s survey [25]. This survey has approximately 7-10 items for each of the four types of engagement, cognitive, emotional, behavioral, and social, and these items are consistent with the engagement definitions provided by Bowden et al. [16]. Four items for the engagement types of interest, behavioral and social, were selected for use in this study.

For the in-class observation protocol, each item was scored from 0 to 4 to indicate the approximate percentage of students engaged in the manner represented by each item. The scoring system was adapted from an item in [26]. The in-class observations were made by a professor and graduate student in the field of engineering education research during two class periods during the fourth week of the semester.

The draft student questionnaire regarding behavioral and social engagement included the same four items for each engagement type that were included in the observation protocol, with the language modified to be in survey format. For the rating questions, a 6-point Likert scale was used from Strongly Disagree to Strongly Agree. The survey was administered at the end of the second observed lecture and again in a period towards the end of the term.

±o investigate possible impacts of the instructional strategies on cognitive belonging in the course, a set of three items from Walton and Cohen [5] on belonging uncertainty were adapted,

i.e., “I belong in this course” and “When I struggle/succeed in this class, I feel that I really don’t/do belong in this class”, and included an opened-ended question. The same 6-point Likert scale as the engagement survey was used. This questionnaire was administered to students near the end of the term. In a single session, students were asked to complete this set of questions twice from the perspective of at the start of the class, a retrospective pre-survey, and at the current time in the class, a post survey. This survey administration approach was used since prior work has shown that once participants have been exposed to an experimental intervention, their evaluation of baseline, or their starting point for the scale, can shift, which is known as response-shift bias [27] – [28]. By having participants complete a post survey and then a retrospective pre-survey in one session, it can increase the validity of the data by reducing the effects of this bias.

5. Timeline

The timing of the implementation of the course strategies and the assessment data collections over the course of the 15-week semester are shown in Fig. 1.

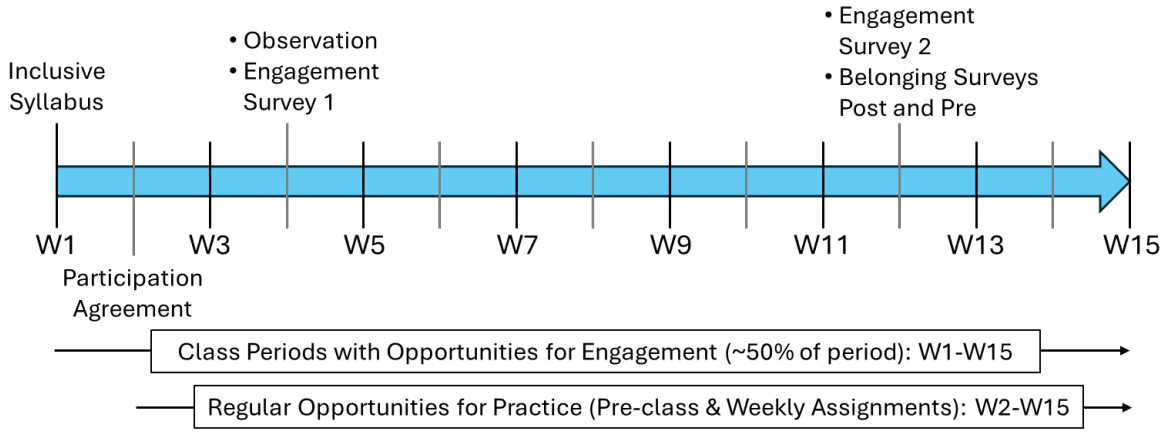

Figure 1. Timeline for instructional strategies and assessments over the 15-week term.

6. Next steps

A mixed-methods approach will be used to analyze the data. The results from the in-class observations and surveys will be used to inform the development of an interview protocol to explore some of the initial findings in more detail. The interview will also be used to obtain students’ feedback about the effectiveness of the specific strategies implemented into the course. Purposeful sampling will be used to recruit approximately 5-7 students for interviews in the weeks following the end of the course. These findings will be used to inform changes to the next annual offering of the course and a similar assessment method will be used.

7. Implications for faculty development

The work of this study will benefit other faculty as it shows how to incorporate strategies to promote a sense of belonging in students. Interactive workshops could be developed to give faculty the opportunity to reflect on their courses in terms of both inclusion and structure. For the former, faculty could be provided with examples of student-centered language from syllabi, inclusive statements for syllabi, and practices for creating classroom participation agreements. To

add structure to courses, evidence-based best practices on the number, types, and frequency of opportunities for students to learn material could be discussed. In addition, pedagogical approaches for lectures that provide a structured environment for learning could be explored, e.g., statement of learning objects for each lecture, including written instructions, etc. These techniques should also be modeled during the workshop.

Acknowledgements

This work was supported by NSF Award 2407013.

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