NSF RIEF: Applying Inclusive Teaching Strategies to Promote Belonging and Engagement in an Upper-level Engineering Course, Year 1

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Introduction and Research Objective

To create classroom learning environments that will be effective for as many students as possible, Tanner (2017) recommends several teaching strategies to create a highly structured classroom environment [1]. In general, these strategies promote feelings of inclusion and participation by all students, many of which are categorized as active learning strategies [1], [2]. In turn, a highly structured classroom environment can lead to higher levels of student achievement [3].

The research objective of this RIEF project is to explore how a highly structured classroom environment may support a sense of belonging as demonstrated through changes in behavioral and social engagement in the classroom. An upper-level architectural engineering course, AE458 Advanced Architectural Acoustics and Noise Control at The Pennsylvania State University with 25 students, is being used as a pilot for this study. This mixed-methods study includes surveys, in-class observations, and interviews to assess possible changes in belonging and engagement. This project will contain two rounds of data collection. The first round and a preliminary analysis of that data set is described in this paper.

Theoretical Framing

The theoretical basis for this work comes from Vygotsky's theory of cognitive development [4], and Zumbrunn et al.'s (2014) model [5] and Kahu and Nelson's (2018) framework [6] which both support the connection between belonging, engagement, and success.

Vygotsky's theory of cognitive development is a social constructivist theory [4]. This theory is in alignment with the research objective that a highly structured environment, which includes significant peer engagement, is an effective approach to support student learning. Key relevant elements of this theory are the zone of proximal development (ZPD), which includes a high degree of scaffolding, and social interaction with the instructor and peers.

To study belonging and engagement in the context of a highly structured class, we drew on the following frameworks when designing methods. Based on quantitative data, Zumbrunn et al. (2014) developed a model that showed students' perceptions of a supportive classroom environment, which the purposeful interventions in this study are intended to create, can predict belonging [5]. They also identified that students' perceptions of belonging can predict motivation, engagement, and achievement in that course, consistent with other literature, e.g., [7], [8]. Kahu and Nelson's framework (2018) proposes that four psychosocial constructs, including belonging, are the key mechanisms that explain students' educational experiences and how that experience is related to student engagement, success, and retention [6].

Of the outcomes related to belonging cited in [6]-[8], this study focuses on engagement, specifically behavioral engagement and social engagement as defined by Bowden et al. (2021) as

two of the four pillars of student engagement, with the remaining two being affective and cognitive [9]. Behavioral engagement can be observed for example in terms of students' level of participation during class periods, while social engagement can be observed for example in terms of sharing ideas with and helping peers. It is hypothesized that the instructional strategies being used in this study may increase both forms of engagement.

Methods

Three new instructional strategies were incorporated into the upper-level architectural engineering course: (1) Weekly, brief assignments to prepare students for some of the topics in the week's lecture, (2) Increased incorporation of think/pair/share with online question response system (TopHat), and (3) Reduction of the time spent during class periods lecturing to incorporate more small group discussions with worksheets with groups of 3-4 students. These strategies are in addition to other existing course elements that add structure to the course, such as fill-in-the-blank notes that students complete during lectures to encourage active listening.

To assess student belonging and engagement with these new instructional strategies, three different strands of data were collected: surveys, observations, and interviews. First, students (n = 20) were surveyed in week 12 of the 15-week term to obtain self-ratings of behavioral engagement (four items) and social engagement (three items) in the class period they were surveyed, adapted from Naibert and Barbera's (2022) validated survey [10]. Also included in this survey were three items related to students' sense of belonging uncertainty in the course, adapted from Walton and Cohen's sense of social fit in the department scale [11]. Students rated each item using a 6-point, bipolar agreement Likert scale (1 = Strongly Disagree, 6 = Strongly Agree). Open-ended questions were included to prompt for elaboration on student ratings of engagement and belonging items. A preliminary data analysis was conducted using descriptive statistics and linear regressions.

The second form of data collection was an in-class observation of behavioral and social engagement that took place over two periods in weeks 4 and 5, respectively. The observations were made by a faculty member and graduate student at Clemson University in the Engineering and Science Education Department. The protocol design was inspired by the Mathematics Classroom Observation Protocol for Practices ($MCOP^2$) [12], and the observers were asked to score different aspects of student behavioral and social engagement. The results of the observations across the two observers were compared for consistency and used to visualize the percentage of students displaying one or both forms of engagement over the course of the lecture period.

Lastly, five students were interviewed about their experiences in the classroom shortly after the end of the semester. These five students were selected from those class students who volunteered to be contacted. Purposeful sampling was used to invite students with a range of demographics and year in the degree program. The interview protocol consisted of questions about the instructional strategies used in the course and the students' sense of belonging in the course. The 30-45 minute interviews were conducted by an external researcher from Clemson

University and recorded using an online meeting platform. Generated transcripts were verified and corrected as needed. The transcripts were qualitatively coded in MAXQDA 2024™ software, primarily using *a priori* codes drawn from the theoretical models mentioned previously and the interview questions, and two emergent codes. Two researchers coded the five transcripts. Initially, each researcher coded the same two transcripts before meeting to reach consensus on the coding definitions. Subsequently, they each independently coded the remaining three transcripts and refined two more definitions. A high level of intercoder agreement was achieved across all five transcripts ($\kappa \geq 90\%$). A preliminary thematic analysis was conducted to explore emergent themes regarding instructional strategies and engagement.

Preliminary Findings

Survey Data

The descriptive statistics for each construct were obtained and are summarized in Table 1 ($n = 20$ students). The results show the students were relatively well engaged with mean ratings of approximately 4.7 (Slightly Agree – Agree) on a 6-point scale for both types of engagement and had low levels of belonging uncertainty with a mean of about 2.8 (Slightly Disagree – Disagree). The internal consistency reliability was accessed using Cronbach's alpha [13] for each item set used to measure each construct. The behavioral and social engagement items were found to be consistently measuring their underlying constructs with alpha values of 0.91 and 0.92, respectively. The fit is not as good for the three belonging uncertainty items with alpha equal to 0.71. However, all measurements are above the acceptable threshold of 0.70 [13]. Regression analyses were conducted for each of the engagement types with belonging uncertainty – see Table 1. Using a conservative threshold of $p < 0.01$ due to the small sample size and to protect against false positive results, these results do not indicate that there is an influence of either engagement type on belonging uncertainty. A limitation of this analysis is the relatively small sample size. The responses to the open-ended questions provided some additional context for the ratings given, however it was determined that the format of the questions didn't yield rich data that warranted a formal qualitative analysis.

Table 1. Survey data descriptive statistics and regression analysis results. Each item was rated using a 6-point, bipolar agreement Likert scale (1 = Strongly Disagree, 6 = Strongly Agree).

Construct	Descriptive Statistics		Regression Analysis w/ Bel. Unc.		
	Mean	Std. Dev.	R^2	p	Bel. Uncertainty =
Behavioral Eng. (4 items)	4.69	0.96	0.187	0.0322	0.536 + 0.490(Beh_Eng)
Social Eng. (3 items)	4.69	0.92	-0.0509	0.781	3.20 – 0.0857(Soc_Eng)
Belonging Unc. (3 items)	2.78	1.02	N/A		

In-Class Observation Data

No clear conclusions may be drawn from the in-class observation data as the structure of the observation protocol was a poor fit with the structure of the lecture period. The protocol was designed to record observations in seven periods of 10 minutes over each lecture period. However, this division did not align well with the timing of the different instructional approaches

used throughout the lecture. For example, a 10-minute period could include both lecture notes and small group discussion, with different implications for engagement scores. The protocol was also too quantitative in nature, which didn't allow for sufficient time to take meaningful notes or adequately capture social engagement during shorter small group discussions. In Year 2 data collection, the protocol will be revised to be structured and events-based [14] as opposed to time-based to allow for richer descriptions of student engagement during the activities. This protocol will be similar to the student observation codes in the Classroom Observation Protocol for Undergraduate STEM (COPUS) by Smith et al. (2013) [15].

Interview Data

The interview transcripts were analyzed using five main *a priori* codes. The details for the engagement and belonging codes can be found in Table 2. The unit of analysis was a student.

Table 2. Codes and sub-codes for qualitative analysis of interviews.

Code	Sub-Code	Definition
Behavioral Engagement	Interaction with the instructor	Asking the instructor questions and responding to instructor questions, including small group report outs.
	Perseverance during challenging task	Continued to work on example problem/worksheet question when difficult.
	Staying focused and on task	Focused (paying attention) and putting effort into learning the material during the class period by doing what is expected during that part of the lecture, e.g., writing notes, listening, etc.
	Felt prepared to achieve	Students felt prepared to achieve during the lectures and/or for assessment items / mastery of the material as a part of engaging in the activities.
Social Engagement	Understand peers' ideas	During group discussions (worksheet activities), talking to group mates and trying to understand what they're saying.
	Share ideas with peers	During group discussions (worksheet activities), sharing own ideas/answers with group mates.
	Offer or ask for help from peers	During group discussions (worksheet activities), ask group mates for help or offer group mates help if they seem unsure.
	Cooperation with small groups	Worked with group mates to complete the worksheet.
Belonging	Supportive classroom environment	Students feel comfortable to participate in classroom activities and discussions.
	Unsupportive classroom environment	Students felt uncomfortable or hesitant to participate in classroom activities and discussions.
	Motivation to learn the material	Students intrinsically want to learn the material; includes at a high-level (e.g., motivation to pursue this degree).
	Getting to know peers in the class	Students feel they have the opportunity to get to know their group mates and classmates.

From initial analyses, some preliminary themes began to emerge from the data:

1. A supportive and comfortable classroom environment (belonging sub-code) was frequently mentioned in the context of interactions with the instructor (behavioral engagement sub-code) and social engagement (main code).
2. None of the students reported another students' behavior as a contributing factor to an unsupportive or uncomfortable classroom. Instead, the reasons cited for an unsupportive and uncomfortable classroom environment were when students had a shy group member or when class absences resulted in groups of only two students.
3. Behavioral engagement was primarily described as students feeling prepared to succeed in the course, with interactions with the instructor also frequently mentioned.
4. The small group discussions were the most frequently mentioned course element with peer familiarity (social engagement) contributing significantly to a comfortable classroom environment, which increased throughout the term. The students really appreciated the opportunity to get to know their peers.
5. Students found it helpful to share ideas with their peers to check their understanding of course concepts.

These and other preliminary trends will be shared in greater depth at the poster session.

Conclusions and Future Work

As a result of the course structure changes, the students felt prepared to succeed in the course and overall found the classroom environment to be supportive and comfortable because of positive interactions with the instructor and their peers. The students felt the instructor created a safe learning environment and enjoyed having the opportunity to get to know their peers and learn from them. The implications of these findings may be relevant to engineering faculty development in terms of using specific instructional strategies to create a comfortable learning environment. For example, instructors may be encouraged to increase opportunities for students to work and discuss ideas together to increase peer familiarity, as it appears to contribute to a stronger sense of belonging. This finding is somewhat in line with Strayhorn's (2008) finding (2008) that students who interact with diverse peers have a greater sense of belonging [16].

Next steps are planned for the second year of the project, which will include a second round of data collection as well as instrument revision. The survey will be revised to include more valid items for social engagement and belonging from previous research. The observation protocol will be completely redesigned to elicit more detailed comments and be compatible with the flow of the class period and the different instructional strategies used throughout the observed lectures in an events-based approach. The thematic analysis of the interview data will be completed, and the findings will be used to modify the interview protocol to explore some topics more in depth in the second round of data collection in Year 2.

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