Student Engagement Profiles in Discrete-time Signals and Systems Courses

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Student engagement has received substantial and growing attention in the education research community [1]. One of the main reasons for the significant interest in student engagement is its power in predicting academic achievement and other learning outcomes, including social and emotional outcomes [2], [3]. A large number of studies have explored relationships between student engagement and a wide range of both predictors and outcomes for various populations. Relatively few studies have investigated student engagement specifically in undergraduate engineering courses. For example, one study examined the influence of co-curricular activities on engineering and computer science students' emotional engagement [4], finding little relationship between the two. Another study investigated how STEM students' sense of belonging impacts their behavioral and emotional engagement [4]. Interestingly, the study was conducted at three levels: university, academic major, and class. Strong links were identified between class-level belonging and positive emotional engagement.

At the course level, of particular importance is student engagement within the classroom environment. Indeed, knowledge about in-class engagement may be more useful for instructors than knowledge about out-of-class engagement (e.g., engagement in homework, extracurricular activities, etc.), as instructors simply have more control over what happens in class. Nevertheless, not many studies have focused on in-class engagement. One example is a study that, using a limited sample of students in a mathematics course, investigated whether different engagement dimensions can predict student achievement in the course [5]. A different study, conducted in a chemical engineering course, dug deeper into in-class engagement and explored it throughout one lecture period [6]. Student engagement here was measured generally, i.e., students simply rated their overall engagement at different time points of one lecture. As a result, the author identified six student engagement types: (1) students who engaged strongly at the beginning of the class period and then slowly disengaged; (2) students who were disengaged at the beginning but peaked in the middle and then gradually disengaged; (3) students who were engaged at the beginning, then fell low but returned to the initial level; (4) students whose engagement was low at the beginning but slowly increased; (5) students who engagement level did not change through the class period; and (6) students who had a mixed engagement types (a combination of two of more types above). This study also explored a potential relationship between engagement types and the knowledge gained in that class period but found none.

Similarly to the study described above, we aimed to develop student engagement profiles in a particular course – discrete-time signals and systems (DTSS) – and to investigate whether student achievement differed among the profiles developed. In contrast to the study described in [6], we differentiated between two dimensions of engagement – behavioral and emotional – and separately explored the levels of engagement in each dimension. We also used a different timeframe; rather than considering a single class period, we asked students to reflect on their engagement across the entire semester. These differences allowed us to develop a comprehensive picture of student engagement profiles, which we hope will be useful for electrical engineering instructors. Specifically, knowledge of students' engagement profiles may help instructors to understand the various ways students engage in a course. This knowledge may also help inform instruction and course management accordingly.

Theoretical framework

A major challenge in conducting research on student engagement is the lack of agreement in the field about how to define student engagement [1]. Researchers whose work focuses on student engagement tend to theorize, conceptualize, and operationalize it in a wide variety of ways. Editors of the *Handbook of Research on Student Engagement* [1] suggested that a commonly accepted understanding of engagement in fact may not be necessary. However, they strongly recommended that researchers describe their conceptualization of engagement and its measurement in each study to avoid the vague use of the concept.

For the purposes of our study, we used the theoretical framework of student engagement suggested by Fredricks, Blumenfeld, and Paris [2], as it is one of the most well-known and comprehensive engagement frameworks in the field. This framework includes three dimensions of student engagement: behavioral, cognitive, and emotional. Behavioral engagement "draws on the idea of participation; it includes involvement in academic and social or extracurricular activities" (p. 60). Cognitive engagement "incorporates thoughtfulness and willingness to exert the effort necessary to comprehend complex ideas and master difficult skills" (p. 60). Emotional engagement refers to students' reactions and feelings toward school, teachers, classmates, etc. In order to operationalize the dimensions of student engagement in our study, we explored the indicators of these dimensions used in other studies.

One of the most commonly used indicators of behavioral engagement is participation, specifically in-class participation, participation in extra-curricular activities, and participation in lab/study groups [3], [4], [7]–[12]. In-class participation may include both academic and non-academic behaviors. The latter may in turn include attendance, absenteeism, or tardiness [3], [8], [9], [13] as well as conduct, behavioral incidents, disruptive behaviors, and following instructions [3], [9], [13]. Indicators of academic in-class participation are often merged with out-of-class ones. Those indicators may include attention [12], [14], on-task/off-task behaviors [8], diligence [14], as well as effort and persistence [4], [12], [15], [16]. Additionally, measures of behavioral engagement also contain such indicators as time spent on in-class learning [17], homework and other learning outside of class [14], and extracurricular activities [13]. Finally, homework completion is also used to indicate behavioral engagement [12].

The most commonly used indicators of cognitive engagement are approaches to learning (e.g., deep vs. surface) [10], [12], [18], [19], as well as self-regulation, effort, and persistence [3], [18], [20]. Some researchers also include value of learning, importance of learning and/or good grades, commitment to learning, identification with school, and relevance of the material as indicators of cognitive engagement [3], [13], [16], [20]. Other indicators found in the literature are attention [20], goal orientation [16], reliance on the teacher [14], problem solving approaches, coping with failure, work styles, work preferences [8], and again time spent on homework and homework completion [13].

Indicators of emotional engagement typically include various emotions and feelings toward learning, class, school, peers, and/or teachers [4], [8], [10], [12], [14], [16], [20]. These emotions can be either positive (e.g., enjoyment, interest, happiness, excitement, curiosity, etc.) or negative (frustration, boredom, anxiety, sadness, nervousness, anger, etc.). Other frequently used indicators

are sense of belonging to class and/or school [11], [15] and value of learning [12]. Less common indicators of emotional engagement are achievement orientation [14], relationships with peers and/or teachers [13], [21], and harmony among racial groups [13].

Research questions

This study focuses on in-class engagement; therefore we selected only those indicators for each engagement dimension that are applicable specifically to classroom-level measurement. In particular, we used student in-class behaviors such as listening, note taking, asking question, answering questions, and participation in group work as indicators of behavioral engagement, and student emotions, interest, and attitudes as indicators of emotional engagement. Cognitive engagement, which we measured via student approaches to learning, was excluded from the present study due to measurement problems (the low internal consistency of its components). In this study, we asked: (1) What student engagement profiles can be developed based on indicators of behavioral and emotional engagement in a DTSS course? (2) Is there a relationship between the identified engagement profiles and student achievement in the course?

Context

The study was conducted in a junior-level DTSS course at a large public university. The course is the third in a sequence of signals and systems courses; it is preceded by an introductory signals course and a continuous-time signals and systems course. Topics covered in the course include system properties, discrete-time (DT) convolution, DT Fourier series, the DT Fourier transform and frequency analysis, the z-transform and pole-zero representation, linear time-invariant filtering, and the discrete Fourier transform.

The study includes data collected during two offerings of the DTSS course. While the instructor and the course content were the same for the two offerings, the structure of classroom instruction changed significantly. In term 1, the course was taught in an active learning with technology (ALT) classroom. The classroom featured tables that seated up to 9 students with a large monitor/screen dedicated to each table. The walls were fully covered in whiteboards to facilitate group work. Each class period began with a multiple-choice reading and review quiz designed to encourage students to go over material from previous class periods and complete the reading assigned for the current class. Students submitted quiz answers using iClickers. Following the quiz, the majority of the class period was devoted to having students work in assigned groups of three on open-ended problems. Some problems also included multiple-choice elements that students answered via iClicker. The instructor and three learning assistants canvassed the room to provide feedback and answer questions.

In term 2, the course was taught in a traditional lecture classroom but still with a significant amount of active learning included. Again, each class period began with a multiple-choice reading and review quiz. More time was devoted to traditional lecture in term 2 than in term 1, but at least half of the class period was devoted to group problem solving. Rather than having assigned groups of three, students were free to choose their work group. While most students collaborated, a few worked alone. Since white boards were not available to display work, groups worked on paper and submitted answers only to certain aspects of the problem (those that lent themselves to

multiple choice format) via iClicker. The in-class problems used in term 2 were often shorter and narrower in scope than those used in term 1 because the lecture-style room did not support giving students feedback as they worked through a longer problem, and hence it was difficult to keep struggling students on track.

The outside-class and assessment elements of the course had the same structure across the two offerings. In both term 1 and term 2, homework was assigned approximately weekly and was due in class the following week. Two midterm exams and one final exam were given, and students completed two Matlab projects in groups of three.

Participants

The course was taught by the same instructor in both terms considered in this study. The instructor was a full-time faculty member at the university with over 10 years of teaching experience. S/he had taught the DTSS course discussed here several times prior to the two terms in question. Student participants in the study were predominantly male, junior or senior students, majoring in electrical engineering. The majority of students were also domestic and in-state. However, they varied greatly in GPA. The students were also diverse in race/ethnicity with over half being either White or Asian. The average age was 24.11 (SD=6.85) with a minimum of 20 and maximum of 71; the median was 22. More information about student demographics is presented in Table 1.

Measures

A survey about behavioral and emotional engagement was administered to the students in each of the two terms, using the same procedure in each term. Students were asked to complete a survey in the paper-and-pencil form during one of the class periods toward the end of the term. The instructor left the room for the time of survey administration.

All engagement items were measured on a 6-point Agree-Disagree Likert Scale, where 1 was “Strongly Disagree,” and 6 was “Strongly Agree.” Reversed items were recoded prior to the analysis. We conducted an exploratory factor analysis (EFA) with the principal axis factoring (PAF) as an extraction method and Direct Oblimin as a rotation method to establish the internal structure of each scale. Specifically, employing EFA allowed us to determine the dimensionality of the constructs, i.e., which dimensions (or factors) the constructs have and which items indicate which dimensions. We used PAF as an extraction method, as it utilized only the common variance among items, thus allowing to establish the underlying structure. Finally, the Direct Oblimin rotation was chosen as a commonly used oblique rotation method, i.e., a method that does not preserve 90° between factors during rotation. Thus, this method allows factors to be correlated, which we hypothesized to be the case in our study. Indeed, dimensions of one construct will be expected to correlate to some extent, as they indicate the same construct.

Table 1. Student demographic information

Characteristic	Number of students	
	Frequency	%
Student Classification (N=80):		
- Junior	40	50.0%
- Senior	38	47.5%
- Other	2	2.5%
Major (N=70):		
- Electrical Engineering	66	94.3%
- Computer Engineering	4	5.7%
GPA (N=76):		
- 3.51 or better	18	23.7%
- 3.01 up to 3.50	29	38.2%
- 2.51 up to 3.00	25	32.9%
- 2.01 up to 2.50	4	5.3%
Residence (N=79):		
- Domestic, in-state	66	83.5%
- Domestic, out-of-state	1	1.3%
- International	12	15.2%
Gender (N=81):		
- Male	69	85.2%
- Female	12	14.8%
Race/Ethnicity (N=78):		
- African-American	5	6.4%
- Asian	25	32.1%
- White	28	35.9%
- Hispanic	8	7.7%
- Other/Mixed Race	12	15.4%

The scale for behavioral engagement was developed by the authors and initially consisted of 25 items. During the EFA, seven items were deleted because they either did not load well on any factors or cross-loaded. The results revealed that the final behavioral scale included five factors with associated eigenvalues greater than one; the five-factor solution also produced factors that were meaningful and interpretable. The factors were the following: listening (3 items; Cronbach's alpha = 0.561), note taking (3 items; Cronbach's alpha = 0.916), asking questions (4 items; Cronbach's alpha = 0.881), answering questions (4 items; Cronbach's alpha = 0.856), and group work participation (4 items; Cronbach's alpha = 0.788). The loadings (the pattern matrix) are presented in Table 2. All factors except the listening factor had high reliability and item loadings. The listening factor had acceptable characteristics, and we decided to keep it due to its importance in measuring behavioral engagement. The values for each factor were calculated as arithmetic means of their items. Low to moderate correlations among factors (see Table 3) provided further support for multidimensionality of behavioral engagement

Table 2. Pattern matrix for behavioral engagement

Item	Factor				
	Listening	Asking Question	Answering Questions	Note Taking	Group Work Participation
I give my instructor my full attention during class.	**0.460**	0.320	-0.011	0.256	0.109
Usually I do something irrelevant to the class when my instructor is lecturing. (r)	**0.528**	-0.161	0.141	0.061	-0.033
I don't listen attentively to the instructor during class. (r)	**0.581**	0.090	-0.191	0.109	0.273
I ask my instructor to explain the material again if I didn't understand it.	0.070	**0.858**	-0.059	-0.090	0.007
I ask my instructor to repeat what he/she said if I missed it.	-0.074	**0.601**	0.271	0.143	0.027
I ask follow-up questions until I fully understand my instructor.	-0.127	**0.736**	0.192	0.136	0.041
I ask questions when I don't understand something in the material my instructor is explaining.	-0.094	**0.761**	0.264	0.007	0.059
I volunteer when I know the correct answer.	-0.028	0.275	**0.649**	-0.047	0.162
I don't volunteer in class even when I know the correct answer. (r)	0.060	0.107	**0.824**	-0.143	0.107
I prefer not to speak in front of the whole class. (r)	0.258	0.104	**0.634**	-0.146	-0.018
I usually don't answer my instructor's questions out loud, but I answer them in my head.	-0.189	0.100	**0.583**	0.102	0.065
I take notes regularly.	0.033	0.026	-0.005	**0.975**	-0.037
Generally, I don't take notes. (r)	0.026	-0.144	0.003	**0.854**	0.039
I take notes most of the class time.	0.073	0.196	-0.166	**0.873**	-0.079
I always participate in group activities when my instructor asks us to.	0.151	-0.160	0.242	0.140	**0.512**
I substantially contribute to the work of my group.	-0.007	0.000	0.045	-0.086	**0.819**
I participate in group discussions.	-0.209	0.048	0.158	0.085	**0.777**
I am fully involved in the work my group does.	0.125	0.087	-0.169	-0.083	**0.619**

Note. (r) indicates reversed items.

Table 3. Correlations between the behavioral engagement factors (N=82)

#	Factor	1	2	3	4	5
1	Asking Questions	-				
2	Note Taking	0.065	-			
3	Group Work Participation	0.372**	0.003	-		
4	Answering Questions	0.520**	-0.006	0.367**	-	
5	Listening	0.040	0.365**	0.297**	0.093	-

Note. ** $p < 0.01$

The emotional engagement scale included items about students' emotions in class, interest, and attitudes toward group work. The items for emotions and attitudes toward group work were developed by the authors; an initial scale consisted of 13 items. For the interest subscale (4 items), we used an existing measure of interest from the Approaches and Study Skills Inventory for Students (ASSIST) [22], which can be accessed online [23]. During the EFA, two items were deleted because they either did not load well on any factors or cross-loaded. The results revealed that the final emotional engagement scale included three factors, all meaningful and interpretable, with eigenvalues greater than one. The factors were the following: interest (4 items; Cronbach's alpha = 0.832), emotions (5 items; Cronbach's alpha = 0.817), and attitudes toward group work (6 items; Cronbach's alpha = 0.879). The loadings (the pattern matrix) are presented in Table 4. All factors had high reliability and item loadings. As in the analysis of behavioral engagement, the values for each factor were calculated as arithmetic means of their items. Low to moderate correlations among factors (see Table 5) again provided further support for multidimensionality of emotional engagement.

As a measure of student achievement, we used students' final course grades. The grades were on the scale from 0 to 100. Final course grades included the following components: homework assignments, reading and review quizzes, in-class group problems (graded primarily for completion), Matlab projects, the two mid-term exams, and the final exam. The percentage of each component toward the final course grade is shown in Table 6. The in-class activities (quizzes and in-class problems) were given slightly higher weight in term 1 than in term 2. This difference reflects the fact that before-class preparation was particularly important in the ALT classroom and that more time was spent solving open-ended in-class problems.

Results

The descriptive statistics for the eight identified factors (listening, asking questions, answering questions, note taking, group work participation, interest, emotions, and attitudes toward group work) and achievement are presented in Table 7. A series of independent t-tests revealed statistically significant mean differences between the term 1 (ALT room) and term 2 (lecture classroom) offerings only on Interest ($t(80)=2.13$, $p=0.036$; Cohen's $d = 0.47$) and Group Work Participation ($t(80)=2.25$, $p=0.027$; Cohen's $d = 0.49$). In other words, students in the term 1 offering had higher levels of interest and group work participation than did students in the term 2 offering (with a medium effect size for the differences).

Table 4. Pattern matrix for emotional engagement

Item	Factor		
	Interest	Emotions	Attitudes toward Group Work
Regularly I find myself thinking about ideas from lectures when I'm doing other things.	**0.644**	-0.147	-0.127
I sometimes get 'hooked' on academic topics and feel I would like to keep on studying them.	**0.743**	-0.021	0.003
I find that studying academic topics can be quite exciting at times.	**0.830**	0.131	0.130
Some of the ideas I come across in the course I find really gripping.	**0.696**	0.010	0.066
The topics covered in the course fascinate me.	0.389	**-0.611**	-0.038
This class causes me to feel bored. (r)	0.126	**-0.674**	0.150
Being in this class is enjoyable.	0.224	**-0.579**	0.171
I don't like the topics we cover in class. (r)	-0.036	**-0.814**	-0.079
The class experience makes me feel frustrated. (r)	-0.132	**-0.574**	0.097
I dislike participating in group activities. (r)	0.084	0.039	**0.802**
I like to solve problems in groups.	0.047	0.040	**0.768**
I am tense and nervous while participating in group activities. (r)	-0.015	-0.125	**0.504**
I enjoy group discussions.	-0.032	-0.137	**0.794**
I am comfortable while participating in group activities.	-0.042	-0.051	**0.692**
I like to get involved in group activities.	-0.002	0.108	**0.964**

Table 5. Correlations between the emotional engagement factors (N=82)

#	Factor	1	2	3
1	Attitude toward Group Work	-		
2	Interest	0.155	-	
3	Emotions	0.342**	0.464**	-

Table 6. Final course grade composition

Component	Term 1	Term 2
Readiness Assessment Quizzes	5%	4%
In-Class Problems	7%	5%
Homework Assignments	7%	9%
MATLAB Projects	16%	17%
Midterm Exams	40%	40%
Final Exam	25%	25%

Table 7. Descriptive statistics for engagement factors

Variable	Whole Sample (N=82)		Term 1 (N=40)		Term 2 (N=42)	
	Mean	SD	Mean	SD	Mean	SD
Attitudes toward Group Work	4.49	0.97	4.58	0.96	4.41	0.99
Interest	4.09	0.95	4.31*	0.88	3.87*	0.98
Emotions	4.16	0.97	4.31	1.03	4.02	0.91
Asking Questions	3.82	1.21	3.76	1.14	3.87	1.30
Note Taking	5.16	1.22	5.11	1.23	5.21	1.23
Group Work Participation	5.01	0.77	5.20*	0.63	4.83*	0.85
Answering Questions	3.00	1.24	3.03	1.22	2.98	1.27
Listening	4.73	0.94	4.76	0.91	4.71	0.97
Achievement	83.88	7.63	82.90	7.96	84.81	7.27

Note. * Mean differences significant at $p < 0.05$.

Research Question #1. To determine student engagement profiles, we conducted a cluster analysis based on the eight factors. The hierarchical cluster analysis suggested a four-cluster solution, which was further confirmed by the k-means cluster analysis. The results are presented in Table 8. We have assigned descriptive names to each profile based on the characteristics displayed. The students in the first profile (N=21) – Passive Learners – took notes intensively but were relatively unengaged based on other factors. Students in the second profile (N=26) – Absorbers – were characterized by their unwillingness to ask or answer questions in class while being actively engaged according to other factors. Students in the third profile (N=10) – Collaborators – were unwilling to take notes and answer questions in class but were engaged otherwise. Lastly, students in the fourth profile (N=25) – Engaged Learners – were highly engaged based on all factors.

Table 8. Descriptive statistics for clusters

Factor	Passive Learner (N=21)		Absorbers (N=26)		Collaborators (N=10)		Engaged Learner (N=25)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Attitudes toward Group Work	3.86	0.97	4.32	0.87	4.28	0.68	5.29	0.60
Interest	3.12	0.93	4.29	0.59	4.90	0.77	4.36	0.73
Emotions	3.15	0.67	4.30	0.71	4.28	0.83	4.83	0.82
Asking Questions	2.90	1.10	3.60	1.13	4.15	1.04	4.67	0.81
Note Taking	5.19	0.91	5.74	0.39	2.45	0.74	5.61	0.57
Group Work Participation	4.32	0.83	4.97	0.57	5.10	0.65	5.59	0.40
Answering Questions	2.29	0.56	2.20	0.55	3.13	1.22	4.39	0.93
Listening	4.22	0.95	5.21	0.59	4.30	1.29	4.85	0.81

As a follow-up to the cluster analysis, we also examined whether the number of students per cluster differed between the two course offerings. The Chi Square test of association revealed that there is no relationship between clusters and course offerings, $\chi^2(3) = 1.14$, $p = 0.767$. The number of students in each cluster enrolled in each term is presented in Table 9.

Table 9. Clusters by class frequencies

Cluster / Course Offering	Term 1	Term 2	Total
Passive Learner	9	12	21
Engaged Learner	14	11	25
Collaborators	4	6	10
Absorbers	13	13	26
Total	40	42	82

Research Question #2. To test whether the identified clusters differed in achievement, we conducted an ANOVA analysis. It showed no statistically significant differences between the clusters on achievement, $F(3,82)=1.031$, $p=0.384$. Passive Leaners, on average, had a final grade of 84.21 (SD=8.32), Absorbers – 82.27 (SD=6.52), Collaborators – 87.20 (SD=8.88), and Engaged Leaners – 83.94 (SD=7.57).

Discussion

The results of the cluster analysis provide interesting insight into the different ways in which students engage with the content, with the instructor, and with each other during class periods. While it may be convenient to assume that engagement is a unidimensional characteristic and that students are typically engaged or not engaged, the cluster analysis shows that students may be engaged in a variety of different ways. While a significant subset of the students fit the "ideal" engaged learner profile, others may engage primarily with other students (collaborators and absorbers) or primarily through absorption of content (absorbers and passive learners). A unifying element of the three profiles other than engaged learners is their relative unwillingness to answer questions in class. As a topic for future study, this finding raises interesting questions about the impact of such reluctance in an active learning classroom and the effectiveness of efforts to create a classroom environment that supports risk taking.

Lack of association between engagement clusters and achievement is also an interesting finding. Certainly, this finding needs to be further explored using a larger dataset, but these initial results indicate that students are able to master the material to roughly the same degree via very different engagement profiles. An interesting topic for future work is to study if/how students with different engagement profiles respond to different classroom environments. In the study presented here, the relatively similar distributions of students across profiles in the two offerings of the course may indicate that students' in-class engagement is not significantly affected by the classroom environment. A possible hypothesis is that students benefit in some way from classroom activities even if they are not fully engaged. For example, students unwilling to ask/answer questions still learn from the questions and answers provided by their peers. Similarly, a student who is unwilling to actively participate in group work may benefit from observing the discussion that takes place among collaborating peers. Knowledge of students' engagement profiles could serve

as a tool for creating effective groups in collaborative classrooms by, for example, grouping students such that absorbers are distributed across groups.

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