Student Achievement Goals in the Signals and Systems Course

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***Abstract*—This Research-to-Practice Work-in-Progress paper focuses on exploring student achievement goals. Achievement goals play an important role in student learning, as they affect multiple learning outcomes, including achievement, effort, and persistence. These effects, however, tend to differ depending on how goals are conceptualized and in which context they are applied. In this study, we used a person-centered approach to analyze how students can be categorized in terms of their goals in the context of an Introduction to Signals and Systems course. To conceptualize student goals, we expanded existing frameworks to include approach/avoidance, mastery/performance, and task/ self/other dimensions. Through cluster analysis, we identified two types of students: (1) students all of whose goals are strong and (2) students whose task- and self-related, but not other-related, goals are strong. Further, we conducted a follow-up analysis to examine potential differences between the two clusters in achievement, effort, and persistence. Results showed that students in Cluster 2 scored higher on some achievement measures than students in Cluster 1. However, no differences were found on other achievement measures, as well as in effort or persistence. Future research may consider exploring potential reasons for these results and replicating our study to confirm the cluster structure.**

Keywords—achievement goals, signals and systems, electrical engineering, effort, persistence.

I. Introduction

Achievement goals that students may have for a particular course have been of interest to educational researchers for a long time. This interest is not surprising considering the influence that goals have on student achievement, persistence, effort, and other learning outcomes [1]–[8]. Despite that, goals have not been extensively explored in electrical engineering courses. In this study, we aim to describe students in an introductory signals and systems course in terms of their goals for the course. We also aim to determine whether students with different goals differ in achievement, effort, and persistence.

II. Literature Review

A. Conceptualization of Achievement Goals

Conceptually, achievement goals are "cognitive–dynamic aims that focus on competence" [8]. Over the years, they have been conceptualized across a number of dimensions. One dimension distinguishes between mastery and performance goals [8]. The former focuses on learning (i.e., mastery of the material); the latter focuses on performing (i.e., getting good grades). Another dimension is a standard used to evaluate competence: an absolute standard (or task-based), an intrapersonal standard (or self-based), and a normative standard (or other-based) [8], [9]. Mastery goals correspond to the absolute and intrapersonal standards; performance goals correspond to the normative standard. The third widely recognized dimension is valence. Competence may be focused on a positive possibility of approaching success (approach goals) or on a negative possibility of avoiding failure (avoidance goals).

Combining dimensions, a number of frameworks for achievement goals have been proposed. One framework distinguishes between mastery, performance-approach, and performance-avoidance goals [1]. This framework was later expanded into a 2x2 framework which splits mastery goals into mastery-approach and mastery-avoidance goals, in addition to performance-approach and performance-avoidance goals [8], [10]. The 2x2 framework was further re-conceptualized into a 3x2 framework to distinguish between absolute and intrapersonal standards within mastery goals [9]. It includes approach and avoidance task-based, self-based, and other-based goals. However, the items developed within this framework focus solely on exam performance, which puts into question if task-based and self-based goals are truly the types of mastery goals. In our view, task-based and self-based goals as well as other-based goals can be both mastery or performance goals, depending on whether the goal is on learning or performance. To include the focus on learning, we combined the 2x2 and 3x2 frameworks, developing a 2x2x3 framework. Our framework includes twelve dimensions, each representing a combination of approach/avoidance, mastery/performance, and task/self/other dimensions.

B. Role of Achievement Goals in Achievement, Effort, and Persistence

The influence of achievement goals on student achievement has been extensively studied. Mastery goals were shown to have either a positive [3], [5], or no relationship [1], [6] with achievement. When split into approach and avoidance dimensions, mastery-approach goals were positively related to achievement, and mastery-avoidance goals were not related to achievement [8]. Performance-approach goals, in turn, had a

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positive [1], [5], [6], [8], or no [3] effect on achievement. Finally, performance-avoidance goals had a negative [1], [3], [5], [8], or no [6] effect on achievement. In the 3x2 framework, task-approach goals, task-avoidance, self-approach, and self-avoidance goals did not appear to predict achievement, while other-approach and other-avoidance goals had a positive and negative impact on achievement accordingly [9]. For effort and persistence, mastery and performance-approach goals appeared to be positive predictors, while performance-avoidance goals were not a significant predictor [1].

The inconsistency in the effects of goals on achievement may be attributed to the differences in contexts, in which the studies were conducted. Specifically, the studies differed in the level (K-12 [3], [6] or college [1], [5], [8], [9]) and in the subject area (psychology [1], [8], [9], mathematics [3], [6], and chemistry [5]). Due to the seeming importance of context and lack of research on goals in college-level electrical engineering courses, in this study, we focused particularly on the Introduction to Signals and Systems course.

C. Describing Students in Terms of Their Course Goals

Beyond variable-centered analyses, researcher have also employed person-centered analyses to study achievement goals. Specifically, the person-centered approach to analysis has been applied in multiple studies to identify groups (or clusters) of students, characterized by the levels of their goals. One study, conducted in secondary mathematics classes in Singapore, used the conceptualization of goals as mastery, performance-approach, and performance-avoidance goals [3]. The authors found four distinct clusters: "Diffuse" (moderate on multiple achievement goals), "Moderate Mastery" (moderate mastery/low performance approach and avoidance goals), "Success Oriented" (moderate mastery/high performance approach and avoidance goals), and "Approach" (high mastery and performance approach/low performance avoidance goals) [3]. Other studies conducted a person-centered analysis on the goals conceptualized within the 2x2 framework [4], [11], also finding four clusters. The study [4], done in secondary physical education classes in Singapore, similarly to [3], identified a cluster with all achievement goals being moderate (the cluster was labeled as ''moderate achievement goals''). The other three clusters were as follows: "low achievement goals" (all achievement goals being low), "high achievement goals" (all goals being high but mastery-avoidance goals being slightly lower than others), and "mastery achievement goals" (high mastery-approach and mastery-avoidance goals, but moderate performance-approach and performance-avoidance goals). The study [11], conducted in college mathematics classes in Spain, found a somewhat different cluster structure: "low achievement goals, specifically on mastery goals," "low achievement goals, but moderately high mastery approach," "high achievement goals, but low performance approach," and "high achievement goals, specifically on performance approach." These results help to describe the types of students in terms of their achievement goals in a particular context and how these types differ. A useful follow-up analysis typically involves comparing identified clusters on variables of educational interest. For example, the study [4] reported that students in the "high achievement goals" exerted more effort than students in the "mastery achievement goals" cluster, than students in the "moderate achievement goals" cluster, than students in the "low achievement goals" cluster.

In this study, we also employed a person-centered analysis approach to categorize students in the Introduction to Signals and Systems course in terms of their goals. Additionally, we conducted a follow-up analysis to compare the identified clusters on their course achievement, effort, and persistence in the course. We are adding to the body of knowledge about student goals by using the expanded framework of goals conceptualization (approach/avoidance, mastery/performance, and task/self/other dimensions) and applying it to a specific context of the Introduction to Signals and Systems course.

III. Context

The study was conducted in the Introduction to Signals and Systems course, an introductory (200-level) discrete-time signals and systems course. It covers continuous- and discrete-time sinusoids, general discrete-time signals, discrete-time systems, spectral representations of sinusoidal signals, the discrete-time Fourier transform, and sampling. The course is the first signals and systems course in the curriculum and is required for students majoring in electrical or computer engineering.

In the term in which this study was conducted, the class meetings were held in a traditional lecture hall. Each class period began with a reading and review quiz designed to assess the students' understanding of material covered in the previous class period and of the reading assigned for that day. The remainder of the class period included both lecture segments and collaborative problem solving. iClickers were used to collect quiz answers as well as answers (or partial answers) to in-class problems. During group problem solving, students were free to work with any of their peers and were encouraged to ask the instructor or an undergraduate learning assistant for help. The instructor for the course was a tenured faculty member in electrical and computer engineering who had taught higher level signals and systems course a number of times but was teaching this course for the first time.

IV. Methods

A. Participants

Data for this study were collected from the students in the Introduction to Signals and Systems course at a large public university in the U.S. Out of 64 students enrolled in the class, 40 agreed to participate in the study. The students were predominantly sophomores (n=13) or juniors (n=17). Most students majored either in Electrical or Computer Engineering. In terms of gender, the majority of students were male (n=34). Students also represented various races and ethnicities: 16 students were White, 10 students were Asian, six were Hispanic, two were African-American, three students reported their race as mixed or other, and one student preferred not to identify his/her race. Lastly, students' ages ranged from 18 to 36, with a mean of 22.24 (SD = 3.89) and a median of 21.

B. Procedure

Data for this study were collected at two time points. At the beginning of the semester, students completed two tests: one assessed students' initial conceptual understanding of the material and the other assessed their initial knowledge of complex numbers. Also at the beginning of the semester, students completed a survey that measured their goals for the course. At the end of the semester, students took the two tests again and filled out a survey with questions about their learning in the course as well as with demographic questions. Students' course grades were obtained from the instructor after the semester was over. We describe each measure below.

C. Measures

1) Achievement Goals

To measure achievement goals within our framework, we used a combination of instruments. To measure the six performance dimensions, we used the instrument of [9]. To measure mastery-task approach and avoidance dimensions, we adapted the mastery subscales of [3]. For the rest of the dimensions, we developed the items ourselves, by analogy with [3], [8], and [9]. Each dimension was indicated by three items (with the exception of the avoidance-mastery-task dimension, which was indicated by two items, due to a typo in the excluded third item). Response options ranged from 1 ("Not true of me") to 7 ("Extremely true of me"). Composite scores, used in the analysis, were created for each dimension via averaging the items. Sample items for each dimension as well as each dimension's reliability are presented in Table I.

TABLE I. GOAL DIMENSIONS, SAMPLE ITEMS, AND RELIABILITY

Goal Dimension	Sample Item: My goals for this class are…	Cronbach's alpha
Approach-Mastery-Task	To understand the course content as thoroughly as possible.	0.617
Approach-Mastery-Self	To understand the course content in this class better than I understood the course content in my previous classes.	0.828
Approach-Mastery-Other	To understand the course content better than other students in this class.	0.924
Approach-Performance-Task	To get a lot of questions right on the exams in this class.	0.559
Approach-Performance-Self	To perform better on the exams in this class than I have done in the past on these types of exams.	0.748
Approach-Performance-Other	To outperform other students on the exams in this class.	0.884
Avoidance-Mastery-Task	To avoid an incomplete understanding of the course content.	0.380
Avoidance-Mastery-Self	To avoid having a weaker understanding of the course content in this class than I have had in my previous classes.	0.388
Avoidance-Mastery-Other	To avoid having a weaker understanding of the course content than other students in this class.	0.873
Avoidance-Performance-Task	To avoid incorrect answers on the exams in this class.	0.705
Avoidance-Performance-Self	To avoid doing worse on the exams in this class than I normally do on these types of exams.	0.796
Avoidance-Performance-Other	To avoid doing worse than other students on the exams in this class.	0.836

2) Achievement Measures

We used four measures of achievement: a measure of conceptual understanding of the material, a measure of the knowledge of complex numbers, perceived learning, and a final course grade. The use of multiple measures increases the reliability of the results as no single measure is perfect (each measure has its strengths and weaknesses); it also allows for a deeper investigation of the goals' impact on achievement.

a) Conceptual Understanding: To measure conceptual understanding of the material, we used 17 out of 25 multiple-choice items from the Discrete-Time Signals and Systems Concept Inventory (SSCI) [12]. The selected items covered frequency, discrete-time convolution, linearity and time invariance, fundamentals of the discrete-time Fourier transform and frequency response, and sampling. The removed items were either not relevant to the course content or had negative correlations with the total score on the pretest. The test had moderate reliability for the pretest (Cronbach's alpha = 0.593) and high reliability for the posttest (Cronbach's alpha = 0.741). Composites scores, used in the analysis, were calculated as a sum of all items for each testing.

b) Knowledge of Complex Numbers: Knowledge of complex numbers was assessed via the complex number test. The test consisted of 25 multiple-choice questions that covered evaluation of trigonometric functions; conversion between polar and rectangular representations; Euler's identity; complex conjugates; addition, subtraction, multiplication, and division of complex numbers; powers of complex numbers; plotting in the complex plane; and frequency and phase of sinusoids. The test had high reliability: Cronbach's alpha was 0.789 for the pretest and 0.726 for the posttest. Composites scores, used in the analysis, were calculated as a sum of all questions for each testing.

c) Perceived Learning: We measured actual and potential amount of learning. The actual amount of learning was measured by the item, "How much have you learned in this class?" The potential amount of learning was measured by the item, "How much could you have learned in this class in the ideal circumstances?" For both items, response options ranged from 1 ("Not at all") to 5 ("Very much").

d) Course Grade: The course grade is a weighted average of the main course assignments. The calculation was based on the following schema: 20% for Midterm 1, 20% for Midterm 2, 18% for laboratories, 4% for in-class problems, 5% for quizzes, 8% for homework, and 25% for Final Exam.

3) Effort and Persistence

Measures of effort and persistence were adapted from [1]. Effort was indicated by two items (e.g., "I put a lot of effort into this class."); the scale had high reliability (Cronbach's alpha was 0.826). Persistence was indicated by four items (e.g., "When I become confused about something I'm studying for this class, I go back and try to figure it out."); the scale had high reliability (Cronbach's alpha was 0.721). Response options ranged from 1 ("Strongly disagree") to 5 ("Strongly agree"). Composite scores, used in the analysis, were created for each construct by averaging the items.

V. Results

A. Research Question #1: Goal Clusters

To describe students in terms of their course goals, we performed a hierarchical cluster analysis. The results revealed a two-cluster solution, which was confirmed via a k-means cluster analysis. The first cluster included 30 students, all of whose goals were strong. The second cluster included 10 students who had strong goals with respect to task and self (no or small differences with Cluster 1) but did not appear to prioritize other-based goals (large differences with Cluster 1). The means for each cluster as well as the significance of the differences between the clusters on each goal dimension are presented in Table II.

TABLE II. CLUSTER MEANS BY GOAL DIMENSION

Dimension	Cluster 1	Cluster 2	F (1, 38)
Approach-Mastery-Task	6.22	6.33	0.178
Approach-Mastery-Self	6.22	5.38	5.781*
Approach-Mastery-Other	5.63	3.00	39.176*
Approach-Performance-Task	6.50	6.23	1.384
Approach-Performance-Self	6.36	5.50	9.835*
Approach-Performance-Other	5.62	2.80	46.022*
Avoidance-Mastery-Task	6.28	6.15	0.170
Avoidance-Mastery-Self	6.16	4.72	21.309*
Avoidance-Mastery-Other	6.04	2.87	102.311*
Avoidance-Performance-Task	6.50	6.13	2.669
Avoidance-Performance-Self	6.24	5.47	3.934
Avoidance-Performance-Other	5.95	3.13	53.237*

* indicates $p < 0.05$.

B. Research Question #2: Comparisons of Goal Clusters on Achievement, Effort, and Persistence

To answer the second research question, we explored cluster differences on achievement, effort, and persistence. The descriptive statistics for each measure by cluster as well as for the whole sample are presented in Table III. Sample sizes (N) are specified for each measure, as they vary slightly between measures due to missing data.

TABLE III. DESCRIPTIVE STATISTICS

Measure	Cluster 1		Cluster 2		Class Overall	
	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N
Complex number pretest	12.7 (4.50)	30	16.40 (3.50)	10	13.63 (4.53)	40
Complex number posttest	20.83 (3.16)	30	22.50 (2.64)	10	21.25 (3.09)	40
SSCI pretest	6.69 (2.85)	29	5.89 (2.37)	9	6.50 (2.74)	38
SSCI posttest	11.79 (2.87)	29	14.33 (2.83)	9	12.39 (3.03)	38
Actual amount of learning	4.03 (0.63)	29	4.44 (0.53)	9	4.13 (0.62)	38
Potential amount of learning	4.69 (0.47)	29	4.78 (0.44)	9	4.71 (0.50)	38
Course grade	78.94 (11.45)	30	87.92 (8.17)	10	81.18 (11.35)	40
Effort	4.03 (1.00)	29	4.00 (0.71)	10	4.03 (0.92)	39
Persistence	3.94 (0.63)	29	4.00 (0.49)	10	3.96 (0.59)	39

First, we conducted an ANCOVA test to determine if there is a difference between the two clusters in students' conceptual understanding of the material at the end of the semester, controlling for their initial understanding. The results revealed that students in Cluster 2 had higher conceptual understanding than students in Cluster 1, $F(1, 35) = 6.378$, $p = 0.016$. The adjusted means were as follows: 11.75 for Cluster 1 and 14.48 for Cluster 2. Second, we conducted an ANCOVA test to determine if there is a difference between the two clusters in students' knowledge of complex numbers at the end of the semester, controlling for their initial knowledge. The results showed no such difference, $F(1, 37) = 0.078$, $p = 0.781$. The adjusted means were as follows: 21.18 for Cluster 1 and 21.47 for Cluster 2. Next, we conducted an ANCOVA test to determine if there is a difference between the two clusters in the actual amount of learning, controlling for the potential amount of learning. The results indicated no significant difference, $F(1, 35) = 3.030$, $p = 0.091$. The adjusted means were as follows: 4.05 for Cluster 1 and 4.40 for Cluster 2. Finally, we conducted three independent t-tests to determine if there are differences between the two clusters in the course grade, effort, or persistence. The results showed that students in Cluster 2 had higher course grades than students in Cluster 1, $t(38) = -2.282$, $p = 0.028$. However, no significant differences were found between clusters in effort, $t(37) = 0.100$, $p = 0.921$), or persistence, $t(37) = -0.274$, $p = 0.786$.

VI. Discussion

In this study, we identified two clusters of students in terms of the goals they have for an Introduction to Signals and Systems course. While both clusters had similarly strong task- and self-related goals, students in the second cluster prioritized other-related goals substantially less than students in the first cluster. Interesting also are the sizes of clusters. There were three times as many students in the first cluster as in the second. To explore the clusters further, we examined whether they differed in achievement, effort, or persistence. Our analysis showed that students in the second cluster had higher conceptual understanding of the material and course grades than students in the first cluster. However, no differences between the two clusters were found in students' knowledge of complex numbers, perceived learning, effort, or persistence.

The conceptualization of students' achievement goals within approach/avoidance, mastery/performance, and task/self/other dimensions adds new information to the body of knowledge about students' course goals. The study also helps to advance knowledge about students' goals specifically within signals and systems education. Further, the results can inform teaching practice. As not prioritizing other-related goals may lead to greater learning, instructors may consider creating a non-competitive learning environment and making this focus explicit to students. Considering that our results were from a single course offering, a replication of our study with a larger sample size is needed to confirm the cluster structure and cluster effects on learning outcomes. Additionally, future research should further examine the reliability of goals dimensions, as some of them had low reliability. Lastly, due to the general limitations of achievement measures, the study should be also replicated with different achievement measures.

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