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Analysis of Student Motivation in an Introductory Engineering Technology Gateway Course

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Abstract

Student motivation has a large impact on information retention levels and overall student learning. Previous studies have demonstrated the higher a student's intrinsic motivation, the more successful the student will be in the learning process. At the post-secondary level, student interest is often tied to expected career pathways and outcomes. This work explores student motivation in an engineering technology introductory foundations course. The course is required for all students in the engineering technology department and is recommended for students exploring the engineering technology discipline, creating a unique culture within the classroom. The course includes two lectures, one recitation, and a two-hour hands-on laboratory summing up five hours of class time in a 4-credit course. The course has a total enrollment of over 300 undergraduate students from more than twelve different majors. Students enrolled in the course completed a set of surveys based on the Intrinsic Motivation Inventory (IMI) which is based on Self Determination Theory and is designed to measure perceived interest, intrinsic motivation, and other factors. The structure of this survey was built using subsets of questions (interest/enjoyment, perceived competence, value/usefulness, and relatedness) and quantitative responses based on a 7-point Likert scale. A statistical analysis was conducted to examine the students' motivation, interest in the discipline, perceived competence, and correlated factors. The students were surveyed mid-semester and at the end of the term to determine the impact course activities had on their perceptions. Study results showed all left-skewed data (high scores) with the highest scores in value/usefulness and lowest in relatedness. This indicates students see the value in the course curriculum and its relation to their future careers but the social environment and peer relations in the course should be improved. Skewness quantitative calculations showed high skew for interest/enjoyment, perceived competence, and relatedness and moderate left-skew for value/usefulness subgroup categories. T-test and Mann-Whitney U-test results did not show a significant difference between mid and end of semester survey results indicating student perceptions of the course were already made by mid-semester. Pearson correlation coefficient analysis showed correlations between perceived competence and value/usefulness, interest/enjoyment, and perceived competence and interest/enjoyment and value/usefulness. These findings support current literature demonstrating higher intrinsic motivation scores lead to higher perceived learning.

1. Introduction

The purpose of this work is to study the current conditions and correlations that may exist between the motivation of students in a gateway course and their perceived learning and value from their experiences in an engineering technology freshman gateway course. It is well documented that students' motivation is a key factor in learning [1]. It has also been proven that Self-determination Theory (SDT) represents a broad framework between human motivation and personality. Self Determination Theory focuses on how social and cultural factors facilitate or undermine people's sense of volition and initiative, in addition to their well-being and the quality of their performance [2]. We can use these concepts to gain a better understanding of what factors contribute to student's motivation in a gateway course.

Gateway courses (sometimes referred to as weed out courses) serve a foundational role in the engineering academic program as they introduce several new topics for students and reinforce concepts that they may already know [3]. These courses tend to have extremely high enrollment and are meant to be taken within the first or second year of a student's college career [4]. Unfortunately, these attributes can create a less personal learning environment[4] and can serve as a barrier to student success and persistence in the field [3]. Students who struggle in these courses may become demotivated, lose confidence in their abilities, or question their interest in their intended career path [3]. Additionally, those students who decide to withdraw from the course or fail to complete it within the first two years of their academic program are statistically more likely to not complete their program and withdraw from Science, Technology, Engineering, and Math (STEM)classes [3], [5].

Within SDT, intrinsic motivation has been defined as the drive to engage in an activity for its own sake, without external rewards or pressures [6]. Research shows that a correlation exists between the quality of work and experience of a student and their own personal motivation. Intrinsic motivation is thought to be important for personal growth and well-being, as well as for achieving long-term goals [6]. In gateway courses a students' level of intrinsic motivation can have positive or negative impacts. A lack of intrinsic motivation can be detrimental to students' success both academically and professionally, or if students are motivated correctly, they "can develop an internal desire to learn" which promotes academic and professional success [1].

Additionally, students who perceive themselves positively as capable and competent learners tend to be more motivated and engaged in their studies, which in turn can lead to better academic performance and outcomes. Students who feel confident in their own knowledge and abilities in certain subjects are more likely to continue taking those subjects when they become optional [7]–[9]. Conversely, students who do not feel confident in their abilities can lack the motivation to improve their skills. Nadiah, Arina,and Ikhrom (2019) [10] found that because students had a negative mindset and did not believe in themselves, their performance suffered. A balance must be struck. It is vital that educators and instructors build a positive and encouraging environment for their students but must also be mindful and give appropriate feedback, so students don't fall behind due to elevated ego [11].

Finally, A student's social environment, including relationships with peers and instructors can have a significant impact on their confidence and enjoyment of school as well as their motivation. Kulakow and Raufelder (2020) [12] hypothesized that when students are placed in an environment where they are given the chance to decide what to learn they report higher levels of motivation and enjoyment. Alongside this, Ryan et. al. (1994) [13] found that when students feel more secure and comfortable with their instructors, they show signs of higher motivation. They continued to show that inversely students that formed no emotional connections suffered from lower self-esteem and in turn lower motivation for school. Mirzaei and Forouzandeh (2013) [14] found that a learner's understanding of their surroundings has a direct effect on their motivation and the students that perceived themselves as fitting into the culture performed better.

2. Methods

2.1 Research Design

The gateway course provides a foundational understanding of the various disciplines within engineering and as such does not provide great depth into the engineering cores. The course includes students from twelve different majors within the School of Engineering Technology plus students from various majors across the university who are considering changing majors or declaring (for those who are undecided) an engineering technology major. The twelve core engineering technology majors are subdivided into four-degree programs as seen in Table 1. The course learning outcomes and in turn curriculum reflect this degree program organization (particularly Outcome Three). As such one of the main goals of the program is for students to determine which degree program and major best fits them and as such this is the first course learning outcome. Outcomes One and Three are accomplished through introduction of students to the basic foundational concepts and skills in the four-degree programs and by investigating course plans for the various majors and traditional careers within the disciplines.

The gateway course learning outcomes are presented below:

1. Develop an academic pathway for success in the student's selected major.
2. Select appropriate strategies and technologies to solve technical problems.
3. Apply foundational principles and tools of electrical, industrial, manufacturing, and mechanical engineering technology to address technical problems.
4. Apply computational tools to address technical problems.
5. Work in a team to solve an engineering technology problem.
6. Demonstrate awareness of professional standards, practices, culture, and issues in engineering technology.

The course is organized as a 4-credit hour course with two 50-minute lectures, one 50-minute recitation, and one 1 hour 50-minute lab per week. In lecture, the concepts and corresponding calculations are introduced. Recitation provides time for lab content prep and for working through the weekly homework questions. Recitation instructors generally provide additional examples to help students with more challenging homework problems. Lab topics correlate with the lecture concepts and provide a hands-on learning component to empirically execute the theoretical concepts.

Over the last few years, the course has grown dramatically due to an increase in the size of the college and department and the addition of new majors. The course has also experienced a merger. Previous versions included two separate non-synchronized courses, a three-credit hour lecture/recitation course and a one credit hour lab course. The content has remained primarily the same, but in the new version lecture and lab topics were synchronized. Due to the changes in size, diversification of majors, and integration between lecture and lab, the goal of this work was to provide a baseline assessment of student interest, perceived competence, relatedness, and usefulness of the course.

The content for the first half of the course includes:

- An introduction to engineering notation
- A review of trigonometry and algebra concepts
- Usage of Excel for collecting data of experiments
- An introduction to Matlab and its applications to statistics and quality
- Plotting and graphical representations
- Introduction to electrical elements, Ohm's Law and Joule's Law
- Programming logic

For the second half of the course, the content includes:

- Alternate current, direct current, Kirchhoff's Voltage Law, and Kirchhoff's Current Law
- Energy conversion and motors
- Statics and resultant forces
- Moments, pulleys and trusses
- Mechanical systems

Table 1. School of Engineering Technology Degree Programs and Majors

	Degree Programs			
	Electrical Engineering Technology	**Industrial Engineering Technology**	**Manufacturing Engineering Technology**	**Mechanical Engineering Technology**
Majors	Audio Engineering Technology	Industrial Engineering Technology	Automation and Systems Integration Engineering Technology	Mechanical Engineering Technology
	Computer Engineering Technology	Supply Chain and Sales Engineering Technology	Digital Enterprise Systems	
	Electrical Engineering Technology		Mechatronics Engineering Technology	
	Energy Engineering Technology		Robotics Engineering Technology	
			Smart Manufacturing Industrial Informatics	

2.2 Data collection

Data was collected from students enrolled in a freshmen introductory course during the Fall 2022 semester at two time periods – mid-semester (Survey One) and end of semester (Survey Two) to provide an understanding of students' perceptions related to the course. This work does not compare student perceptions before the course began. It determines if student perceptions changed from mid to end of semester. The survey information is anonymous and does not track specific students through the progression of the course. Data is aggregated for statistical analysis. Students who did not complete the survey were removed from the pool (43 total incomplete data sets across both surveys). 310 data sets from Survey One and 307 data sets from Survey Two were evaluated. Surveys were deployed as class attendance quiz points for participation only and data was stored securely in an alternate location from grades and the learning management system. Students uploaded an image of the completion screen only for participation, so their individual responses were kept anonymous. The survey tool utilized was Qualtrics XM™.

2.3. Instrument

Student motivation was measured using the IMI (Intrinsic Motivation Inventory) survey from the [15] Center of Self-Determination Theory. The IMI is used to assess students' experience in a variety of environments including classroom settings and workshops. It is defined as a validated multidimensional measurement device that has been used to measure the level of intrinsic motivation and self-regulation. The structure of the survey consists of different groups of questions including: interest/enjoyment, perceived competence, value/usefulness, and relatedness. Each of the questions are ranked using a 7-point Likert method and are detailed in Appendix 1. [15]

2.4. Study Limitations

The study limitations include a limit on initial data. The study assesses general course perceptions and as such surveys were ran mid and end of semester. Initial survey data at the beginning of semester was not gathered. Therefore, this is not a pre/post analysis. Survey results were recorded as attendance points for the class, but not all students completed the assignment. Results are limited to those who chose to participate only. The survey assesses student perceived responses and does not use formalized grade assessments. Survey responses are anonymous and therefore data aggregate analysis was performed. Assessments do not follow individual students through their course progression.

2.5 Data Analysis

Data was analyzed using the Statistical Package for Social Sciences (SPSS) software, where the results obtained in each subgroup of questions were averaged. The groups included the following:

Intrinsic Motivation Subgroups averaged:

- Interest/enjoyment
- Perceived competence
- Value/usefulness
- Relatedness

The data sets for each survey were assessed for normality, skew, and kurtosis. Data sets were compared to determine if there was a significant change from mid-semester to end-of-semester responses. The question subsets were assessed for correlation to detect relationships between topics. The following statistical methods were used in the quantitative analysis.

- Assessment of skew using Skewness value [16].
- Kurtosis to determine if the samples are heavy-tailed or light-tailed compared to a normal distribution [17-18].
- T-Test- A student independent un-paired, two-tailed t-test with a level of 5% was ran for the subgroups Interest/Enjoyment, Perceived Competence, and Relatedness. The t-test assessed if there was a difference between Survey One and Survey Two results [20].
- Mann-Whitney U-test - This test was used for unpaired highly skewed samples. The test provides a non-parametric analysis to detect a difference between data sets. In this case, Survey One and Survey Two [21]. This was used for the Value/Usefulness subgroup.
- Pearson's Correlation Coefficient was used to detect relationships and the strength of those relationships between the subgroups used in this study [22].

3. Results and discussion

Using the Descriptive Statistics Tool in SPSS, the basic descriptive statistics such as mean, standard deviation, skewness, and kurtosis were obtained. Each of these are shown below for each of the surveys: Survey One and Survey Two. These results show the data sets are left-skewed (higher average values). Based on the skewness calculations, the subgroups Interest/Enjoyment Perceived Competence, and Relatedness are slightly skewed with large sample sizes in both groups. Value/usefulness is left-skewed and is highly skewed even with large sample sizes.

Table 2. Descriptive statistics for Survey one.

Descriptive Statistics								
	N	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
					Statistic	Std. Error	Statistic	Std. Error
Interest/ Enjoyment	310	5.347	1.100	1.210	-0.623	0.138	0.076	0.276
Perceived Competence	310	5.311	1.058	1.120	-0.745	0.138	0.495	0.276
Value/ Usefulness	310	5.885	1.011	1.022	-1.468	0.138	3.668	0.276
Relatedness	310	4.960	0.835	0.697	-0.187	0.138	-0.008	0.276

Table 3. Descriptive statistics for Survey Two.

Descriptive Statistics								
	N	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
					Statistic	Std. Error	Statistic	Std. Error
Interest/ Enjoyment	307	5.289	1.136	1.290	-0.771	0.139	0.894	0.277
Perceived Competence	307	5.377	1.050	1.102	-0.683	0.139	0.989	0.277
Value/ Usefulness	307	5.796	1.089	1.187	-1.495	0.139	3.473	0.277
Relatedness	307	5.014	0.907	0.822	0.031	0.139	-0.380	0.277

3.1. Means Comparison

Figure 1 shown below plots the Survey 1 and Survey 2 average results for each Intrinsic Motivation Inventory subgroup. These results average the student responses from all questions in that subgroup. The questions themselves are included in Appendix I. As shown in Figure 1, students rated value and usefulness highly. There is less than a 0.1 difference between Survey One, value of 5.89 and Survey Two value of 5.80. Next, students perceived competence in course material was high. There is a mean increase from Survey One to Survey Two. Survey One had a value of 5.31 and Survey Two had a value of 5.38. Students also rated interest/enjoyment high with approximately a 5.35 on Survey One and a 5.29 on Survey Two. The lowest rating was Relatedness. Students rated Relatedness as 4.96 in Survey One and 5.01 in Survey Two. The course has only three lab-based team activities. This could result in a lack of socialization in the class and lack of trust between peers.

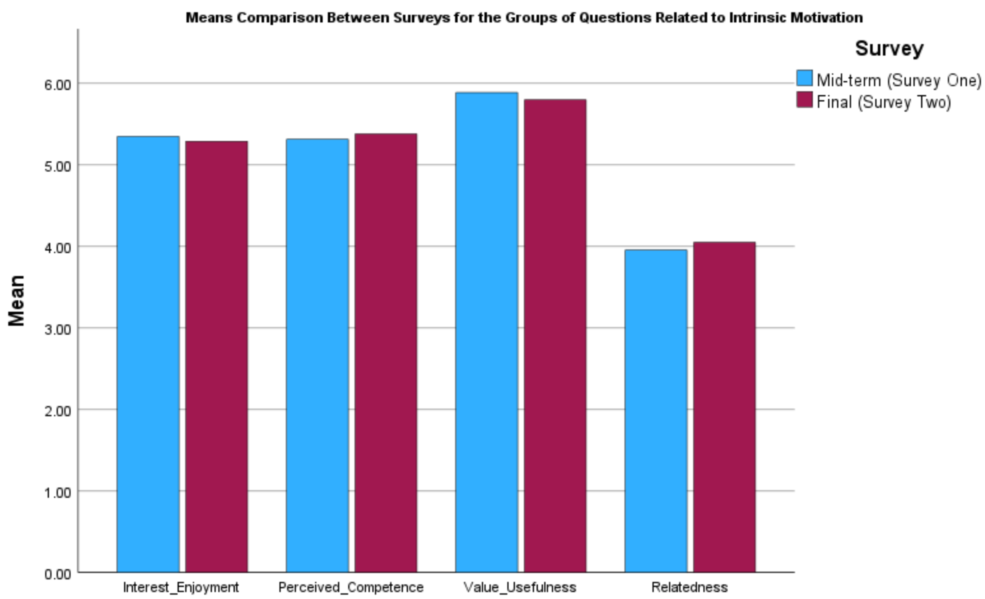

Fig 1. Means comparison between surveys for the groups of questions related to Intrinsic Motivation.

Next, mid and end of semester survey results were compared to see if there was a significant difference between results from these groups. Based on the quantitative calculations of skewness, the means of the groups Interest/Enjoyment, Perceived Competence, and Relatedness between the two surveys were compared using an unpaired t-test, as they have a large sample size and their distributions are slightly skewed [1], [2]. Given that the group Value/Usefulness is highly skewed, the non-parametric Mann Whitney test was used to compare the difference in means between the samples for this group. [3]

- **T-test for slightly skewed groups**

The t-test was run in SPSS for the three groups (Interest/Enjoyment, Perceived Competence, and Relatedness). For this test, the pair of samples for each group of questions is assumed to be independent and to have equal variances. Each of the t-tests have the following hypothesis:

H0: $\mu 1 - \mu 2 = 0$

Ha: $\mu 1 - \mu 2 \neq 0$

The hypothesis H0 is rejected if the p-value is smaller than the level of significance α=0.05. The results obtained are shown below in Table 4 for independent samples T-tests. For the three groups, the p-values are higher than α=0.05. This concludes that there is insufficient evidence to infer that there is any difference between the means in Survey One and Survey Two.

Table 4. T-Test Results

Independent Samples Test							
	t-test for Equality of Means						
	t	df	Significance (Two-Sided p value)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Interest/ Enjoyment	0.645	615	0.519	0.058	0.090	-0.119	0.235
Perceived Competence	-0.778	615	0.437	-0.066	0.085	-0.233	0.101
Relatedness	-1.818	615	0.070	-0.094	0.051	-0.195	0.008

- **Mann-Whitney test for the value/usefulness group**

As seen in descriptive statistics tables of value/usefulness in both Surveys, this group is highly skewed and the comparison of means between surveys should be carried out using non-parametric methods. Particularly, the Mann-Whitney U-test is often used for comparing difference between means in unpaired samples [3].

The hypotheses for this are as follows:

H_0: the two populations are equal.
Ha: the two populations are not equal.

The null hypothesis H0 would be rejected if the p-value is smaller than the significance level. α=0.05 The results from this test can be seen in Table 5. The p-value is higher than the level of significance of α=0.05 so there is insufficient evidence to infer that there is any difference between the means in Survey One and Survey Two.

Table 5. Mann-Whitney test of independent samples for value/usefulness.

Hypothesis Test Summary			
Null Hypothesis	Test	Significance (p-value)*	Decision
The distribution of value/usefulness is the same across Survey One and Survey Two	Independent-Samples Mann-Whitney U Test	0.388	Retain the null hypothesis.
*The significance level is 0.05.			

3.2. Correlation Analysis

In order to study the relationship between variables, the Pearson correlation coefficient was computed by pairs for all four question subgroups. Table 6 depicts the results obtained from the correlation analysis conducted in SPSS.

Table 6. Pearson correlation coefficients.

Correlations					
		Interest/ Enjoyment	Perceived Competence	Value/Usefulness	Relatedness
Interest/ Enjoyment	Pearson Correlation	1	0.611**	0.723**	0.008
	Sig. (2-tailed)		0.000	0.000	0.849
	N	617	617	617	617
Perceived Competence	Pearson Correlation	0.611**	1	0.527**	0.108**
	Sig. (2-tailed)	0.000		0.000	0.007
	N	617	617	617	617
Value/ Usefulness	Pearson Correlation	0.723**	0.527**	1	0.147**
	Sig. (2-tailed)	0.000	0.000		0.000
	N	617	617	617	617
Relatedness	Pearson Correlation	0.008	0.108**	0.147**	1
	Sig. (2-tailed)	0.849	0.007	0.000	
	N	617	617	617	617
**. Correlation is significant at the 0.01 level (2-tailed).					

Results showed a weak correlation (0-0.3) between the following subgroups:

- Relatedness and value/usefulness (0.147)
- Relatedness and perceived competence (0.108)

From the results obtained above, it was observed that the following pairs of groups presented a moderate correlation (Between 0.3 and 0.7):

- Perceived competence and value/usefulness (0.527)
- Interest/enjoyment and perceived competence (0.611)

The following pairs of groups of questions presented a strong correlation (Greater than 0.7):

- Interest/enjoyment and value/usefulness (0.723)

The strong correlations between interest/enjoyment and value/usefulness and moderate correlations between perceived competence and value/usefulness and interest/enjoyment and perceived competence support the theory of student's interest and motivation increasing their level of learning and in turn students' seeing the value of their work.

4. Conclusions

The results of this work demonstrate that students see value and usefulness in the course related to their future career goals as seen by their ratings of 5.80 – 5.88 out of 7.00 in the value/usefulness category. This value is close to the one obtained in previous work [24] which studied the effect of gamified STEM practices on students' intrinsic motivation where the mean of the value/usefulness category was 6.1 using the IMI. They also rated interest/enjoyment and perceived competence as greater than 5.29 out of 7.00 in all surveys in the course demonstrating that students are gathering confidence in their skills and are interested/enjoy the classroom work and future career path. This is supported by a previous study [25] where motivation in early college engineering was assessed. The results of [25] indicated that the first semester is a critical period for supporting or undermining students' perceptions of the value and relative cost associated with engineering.

On the other hand, they rated relatedness lowest which correlates to the social environment and peer interactions. This could be improved in future course iterations through additional teamwork and smaller group settings. Students are primarily first or second semester students, new to the university and from a variety of majors. They are generally meeting their peers for the first time and doing so in a large class. Formal methods such as additional teaming and peer group homework assignments and discussions should be implemented to formalize and facilitate an improved social environment. Within this work, a significant difference was not noted between mid-semester and end of term results suggesting that student opinions on course material have already formed by mid-semester despite the frequent change in foundational topics discussed in the course. Future iterations of this survey will assess student initial perceptions of the course at the beginning of semester.

Strong or moderate correlations assessed via Pearson's coefficient were found between combinations of the groups of interest/enjoyment, perceived competence, and value/usefulness.

This supports past studies stating that student intrinsic motivation improves student performance [6]. Future iterations of this work will delve deeper into linkages between specific majors and the items assessed in these surveys to evaluate the impact of the course on the twelve majors involved in this study. Also, data from the beginning of the semester will be collected to compare the effect of the course after the first half and second half of the course.

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Appendix I.

Intrinsic Motivation

Interest/Enjoyment

I enjoyed doing the course laboratory activities very much.

The course laboratory activities are fun to do.

I thought the course labs were boring. *

The course labs do not hold my attention at all. *

I would describe the course labs as very interesting.

I thought the course labs are quite enjoyable.

While I was doing the course labs, I was thinking about how much I enjoyed it/them.

Perceived Competence

I think I am pretty good at this course.

I think I do pretty well in the labs, compared to other students.

After working on the labs for a while, I felt pretty competent.

I am satisfied with my performance in the labs.

I was pretty skilled at the lab activities.

The course labs are activities that I couldn't do very well in. *

Value/Usefulness

I believe the course labs could be of some value to me.

I think that doing the course labs is useful for my future career.

I think the course labs are important to do because it can expand my knowledge in the field.

I would be willing to do some of the labs again because they have some value to me.

I think doing the course labs could help me to improve my understanding of course materials.

I believe doing the course labs could be beneficial to me.

I think the course labs are important activities.

Relatedness

I feel really distant from my classmates.*

I really doubt that I would ever be friends with anyone in this course. *

I felt like I could really trust my classmates.

I'd like a chance to interact with my classmates more often.

I'd really prefer not to interact with my classmates from this course in the future.*

I don't feel like I could really trust my classmates in this course. *

It is likely that my classmates and I could become friends if we interacted a lot.

I feel close to my classmates.

* These items are reversed scored by subtracting the recorded value from 7 since they are designed to measure the opposite values