Andragogical Learning Characteristics in Second-year and Fourth-year Mechanical Engineering Students

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Abstract

According to the ABET, the goal of an undergraduate mechanical engineering program is to prepare students to work professionally in the fields of thermal and mechanical systems. As a part of the accreditation process, ABET requires programs to demonstrate how their students are able to acquire knowledge as life-long learners. Employers are interested in new graduates with the ability to think critically and work independently, which aligns well with adult learner characteristics often referred to as andragogy. Previous work on an examination of stakeholder documents and the purpose statements of undergraduate institutions also portrays a desire to create graduates with an andragogical mindset, despite the relative absence of the use of the term andragogy in engineering education literature. Pembridge developed a pilot instrument to measure andragogical constructs utilizing different instruments directly measuring the theoretical frameworks supporting assumptions of adult learning, while also comparing responses from first-year and fourth-year engineering students.[1] He found significant differences between the two year groups of engineering students, with fourth-year students having improved ability at self-directed learning and a stronger sense of adulthood. It is unknown how these results apply to a cadet population, where increased structure and additional military training may influence learning characteristics.

The purpose of this research is to investigate the learning characteristics of United States Military Academy students enrolled in the mechanical engineering major. We surveyed students in a second year design course and a fourth year capstone design course to better understand the progression from a pedagogical to an andragogical learning orientation. Survey data was collected from n = 58 (out of 85 total enrolled) second-year and n = 62 (out of 99 total enrolled) fourth-year

mechanical engineering students. The survey used was a slightly modified version from[1], which drew upon previous instruments aligned with assumptions of andragogy. This survey provides insight in Self-Directed Learning Dimensions Scale (SDLAS), Inventory of the Dimensions of Emerging Adulthood (IDEA), Epistemological Beliefs Assessment for Engineering (EBAE), Engineering Expectancy and Value Scale (EV), and Engineering Design Self-Efficacy. The results of this study contrast the andragogical orientations of second- and fourth-year students at the United States Military Academy. The results of this work allow engineering educators to better understand the current learning states of their students by expanding the contexts within which andragogical learning assumptions are applied. As a result, faculty may be more informed in curriculum decisions to fit the preponderant learning orientation. This work also allows engineering educators to identify strategies to better align undergraduate engineering students with the adult learning characteristics required in professional practice.

Introduction

According to ABET, the goal of an undergraduate mechanical engineering program is to prepare students to work professionally in the fields of thermal and mechanical systems.[2] As a part of the accreditation process, ABET requires programs to demonstrate how their students are able to acquire knowledge as life-long learners. Employers are interested in new graduates with the ability to think critically and work independently, which aligns well with adult learner characteristics often referred to as andragogy. Previous work on an examination of stakeholder documents and the purpose statements of undergraduate institutions also portray a desire to create graduates with an andragogical mindset.[3] Although an isolated study suggests that undergraduate engineering students do transition from youth to adult learning over their undergraduate experiences, little is known, however, regarding the degree to which undergraduate engineering students from a military background transition from being youth to adult learners over the course of their undergraduate education.[1] Consequently, faculty wishing to engage students in learner centered, andragogical learning environments may be uninformed regarding how these environments fit the developmental level of the students.

Background

Malcolm Knowles' work[4] has been salient in contrasting a youth (pedagogical)[5] from an adult (andragogical)[4],[6] orientation to teaching students. These two orientations primarily contrast themselves by the degree to which the learner is dependent on the teacher. Pedagogical learning practices are often teacher-centered, and the teacher makes the decision on how to navigate the body of knowledge for the students. Andragogical learning practices are more learner-centered, allowing the learner to navigate the body of knowledge with the teacher as a facilitator or coach. These contrasting orientations toward learning may manifest themselves in the way faculty structure the learning environment. Pembridge and Paretti indicate that faculty with a pedagogical view of their students may implements a more teacher-centered approach to the learning environment than their colleagues with an andragogical orientation.[7]

Merriam summarizes the assumptions of andragogy into five overall categories.[8] They are:

1. Concept of the Learner: The learner is independent and can direct their own learning.
2. Role of Learner Experiences: The learner has real-world experiences that they can incorporate into their learning.

3. Readiness to Learn: The learner has a need to learn based on the acceleration of social changes. The rapidly increasing pace of technological change in society is accelerating this need.
4. Orientation to Learning: The learner sees an immediate application for the learning they conduct.
5. Motivation: The learner is internally, rather than externally motivated.

Table 1 provides a contrast between the assumptions of the learning across the pedagogy to andragogy continuum.

Table 1: Contrast of pedagogical to andragogical learning assumptions. [4,8,9]

Assumption	Pedagogy	Andragogy
Concept of the Learner	Learner dependent on teacher	Self-Directed Learner
Role of Learner Experiences	Few life experiences	Large number of life experiences
Readiness to Learn	Learning needs dictated by teacher	Learnings needs dictated by social role
Orientation to Learning	Content-centered	Problem-centered
Motivation	Extrinsically motivated	Intrinsically motivated

Maintaining a pedagogical approach to the learning environment throughout undergraduate engineering education may be problematic in preparing students for the rigors of professional practice in a complex world. Melnyk and Novoselich assert that engineering faculty often maintain a pedagogical approach to engineering education despite guiding literature that suggests an andragogical approach may be more appropriate.[3] Students who experience only a pedagogical approach to learning may be ill-equipped to independently navigate the larger engineering body of knowledge because they may see faculty as gatekeepers to learning. As the body of engineering knowledge increases at more rapid pace, students must continue to learn to stay relevant throughout their careers. ABET acknowledges this reality through their student outcome (i) which requires students to recognize the need to and engage in life-long learning.[2] More appropriately, faculty may need to assist students along a transition from pedagogical to andragogical learning throughout the undergraduate experience. Pembridge provides preliminary evidence to support how undergraduate engineering students may transition from pedagogical to andragogical learners over the course of their learning experience.[1] Knowles himself acknowledges that pedagogy and andragogy are not binary learning orientations. Instead, learners may exist along a continuum from youth to adult learning.[6] Recognizing the need for this transition from pedagogical to andragogical learning practices, faculty in the Department of Civil and Mechanical Engineering at West Point have incorporated this transition in their teaching model.[10]

One challenge to facilitating students' transition from pedagogical to andragogical learning is a lack of understanding regarding where students sit along the continuum. Employing learning techniques appropriate for adult learners with students who do not possess the characteristics of adult learners, could be problematic. To date, there is little empirical evidence to support a valid and reliable instrument for measuring the andragogical tendencies of undergraduate engineering students.[1,11,12,13]

Measuring andragogical tendencies in undergraduate engineering students becomes problematic because the students are in such a state of transition. The metrics used to classify adult learners such as life experiences, social roles, and age may be blurred when compared with adults in professional practice.[1,12]

Pembridge addressed this lack of a direct measure of andragogy by measuring constructs that relate to the andragogical learner assumptions using established survey instruments. The constructs include:

1) Self-Directed Learning: A person that takes the initiative, is independent, and persistent in their learning.[1,8] This construct relates directly to the concept of the learner assumption.
2) Expectancy-Value: This theory of motivation combines the expectancy of a student's success in engineering with the value they place on engineering related activities. According to Eccles et al. this value may take multiple forms, including attainment (doing well), intrinsic (enjoyment from engagement in engineering), and utility (usefulness of participating in engineering activity).[14] These constructs relate to the learner's need to know, intrinsic motivation, and her/his readiness to learn.
3) Emerging Adulthood: This construct recognizes people in a state of transition from adolescence to adulthood and is typically associated with ages between 18 and 25.[15] This transition period may include identity exploration, which may invoke a sense of in-betweenness, instability, self-focus, and multiple possibilities.[16,17,18] This identity exploration may lead students to better define their social roles and realize the importance of playing a constructive role in society and learning from their life experiences.
4) Epistemological Beliefs: Epistemology describes the grounds or nature of knowledge.[19] Throughout adolescent educational experiences, students may perceive knowledge with certainty and a sense of right and wrong.[20] These students may perceive knowledge as coming from authorities as sources of 'truth'. This relative certainty may change as students progress toward adulthood, garner life experiences and interactions with their instructors and peers. As their knowledge certainty is challenged repeatedly, students may

experience an epistemological shift away from those with authority and recognize more uncertainty in 'truth'.[21,22] This construct relates to the assumptions as self-directed learners, many life experiences, problem center, and readiness to learn.

Table 2 provides a summary of how these four constructs inform the andragogical assumptions.

Table 2: Relating study constructs to andragogical assumptions.[1]

	Motivation		Human Development	
Andragogical Assumption	Self-Directed Learning	Expectancy-Value	Emerging Adulthood	Epistemological Beliefs
Self-Directed Learner	X	-	-	X
Many Life Experiences	-	-	X	X
Need to Know	X	X	-	-
Problem Centered	-	-	-	X
Intrinsic Motivation	X	X	-	-
Readiness to Learn	X	X	-	X

Often, andragogy is used in conjunction with project-based learning (PBL)[3], but little is known regarding whether undergraduate engineering students have developed the adult learning orientation which allows them to fully benefit from these techniques. Students may only view the project as a means to a grade rather than a concrete experience from which to draw upon later in their career. In project-based learning, students solve problems and learn, or often teach themselves, topics in pursuit of accomplishing the project goal.[23] Similar to Knowles' idea of activity-oriented learning, PBL is certainly a departure from the more traditional view of the student as completely dependent on the teaching of the instructor. However, there was little to no discussion in these articles on how PBL fits into any larger view of the student as a more independent, adult learner. A motivating factor in andragogy literature is the nature of knowledge. Knowles points out that as mankind and technology progress, the turnover of social knowledge is accelerating. Whereas in the past, a person could acquire the knowledge they needed for a lifetime at an early age, the advent of the 20th Century made that concept more and more obsolete.[2] It may be necessary to begin teaching college students how to teach themselves new skills. The skills developed in learning the process on one's own will be applicable if they will eventually have to teach themselves varied new techniques and procedures throughout an engineering career.

Purpose

The purpose of this research was to investigate the learning characteristics of United States Military Academy students enrolled in the mechanical engineering major. We set to accomplish this by focusing on two research questions: 1) To what degree do incoming mechanical engineering students meet the assumptions of andragogy? 2) How do indicators of andragogical learning characteristics differ between incoming second-year and fourth-year students?

Methods

In an attempt to quantify andragogical characteristics, this study implemented a composite survey to our second-year and fourth-year mechanical engineering students enrolled in a design course.

Participants

The sample included mechanical engineering students enrolled in two design courses. One course is taken by all second-year students as an introduction to the design process, while the other is a year-long capstone design course taken by all fourth-year students.

Data Collection

The survey instruments utilized in this study were identical to those used in Pembridge et al. 2014, with minimal adjustments made to demographic questions to better align with United States Military Academy terminology. An in-depth background on the questions and survey selection can be found in the original paper, a brief description is outlined in this manuscript for completeness.

The survey had 82 Likert-type items, with selections on agreement with each statement ranging from 1-4 and 0-100. The survey took approximately 20 minutes to complete and was emailed to all students enrolled in the two courses listed above. Measures of the following andragogical measures and outcomes are as follows: Self-Directed Learning Dimensions Aptitude Scale (SLDAS)[24], Engineering Expectancy and Value Scale (EV)[25], Epistemological Beliefs Assessment for Engineering (EBAE)[26], Inventory of the Dimensions of Emerging Adulthood (IDEA)[18], and Engineering Design Self-Efficacy Instrument (EDSE)[27]. Details on the individual measures can be found in the original manuscripts, however EBAE questions were adjusted based on internal correspondence between Carberry and Pembridge. Engineering Design Self-Efficacy Instrument was also administered to each group; while this is not specifically a measure of andragogical learning characteristics it has been used in previous andragogy research as an outcome measure and provides value in understanding a student's beliefs and judgement of current abilities.

Data Analysis

Cronbach's alpha was calculated for each sub-scale of the various survey outcome measures to provide a measure of sub-scale reliability.

Descriptive statistics (group mean and standard deviations) were calculated for each group and used to characterize our cohort to answer our first research question 1) To what degree do incoming mechanical engineering students meet the assumptions of andragogy?

Two statistical models were used to test for differences in our survey outcome scales between our second-year and fourth-year engineering students to address our subsequent research question 2) How do indicators of andragogical learning characteristics differ between incoming second-year and fourth-year students. Model 1 was an analysis of variance (ANOVA) to test for differences between class years. Model 2 was an analysis of covariance, which tested for difference by year while accounting for age as a covariant. F-Statistics were calculated for each variable in both statistical models. Significance level was set at alpha < 0.05.

Results and Discussion

The number of survey participants broken down by class year, gender and age are shown in Table 3. There was a relatively high respondent rate with 68.2% of second-year and 62.6% of fourth-year mechanical engineering students responding to the survey. Age was significantly different between groups (P<0.001) and male students were a majority of the sample population. The aggregated survey data for each subscale for second-year and fourth-year students, along with the Cronbach's alpha and F-Statistics for both models, are shown in Table 4.

Table 3: Sample population details.

Demographics	Second-Year	Fourth-Year
Participants	58	62
Total Enrolled in Course	85	99
Percentage Responded	68.2	62.6
Gender (M / F)	49 / 9	57 / 5
Age (Mean ± SD)	19.3 ± 0.7	21.4 ± 0.8

Research Question 1: To what degree do incoming mechanical engineering students meet the assumptions of andragogy?

The first research question was intended to identify to what degree incoming mechanical engineering students meet the assumptions of andragogy. The means and standard deviations for each subscale are shown in Table 4. SLDAS is scored as a sum of 8 questions for the Self-Management subscale and 9 questions for the Motivation and Self-Monitoring subscale, with each question out of 4 possible points (Strongly Disagree - 1; Disagree - 2; Agree - 3; Strongly Agree - 4). Second-year mechanical engineering students were well above the midpoint for all three of these scales (Figure 1), with an average score of almost 82% of the maximum available points. Self-Directed learning overlaps with four of the andragogical assumptions (Table 2)

IDEA questions were also scored similarly to SLDAS, however each subscale was the average of specific questions relating to the scale. As shown in Table 4, the IDEA subscale means ranged from 2.77 to 3.29 for the second-year students. This subscale of emerging adulthood corresponds to the assumption of a large amount of life experiences. While this is a relative quantity, it appears that second-year students believe they are substantially emerging as an adult.

EBAE was calculated as an average value of questions with ratings from Strongly Disagree (0) to Strongly Agree (10). Simplicity of Knowledge, Source of Knowledge, and Justification of

Knowing all had a mean of over 7 out of 10. Certainty of Knowledge was the only scale which measure below half of the possible score, with a mean of 4.67 for the second-year students. However the Certainty of Knowledge subscale also had a vastly lower Cronbach's alpha, which may have influenced the scores.

Engineering Expectancy and Value Scale was found with questions scored from 1 thru 7, with the subscale averages as follows; 5.59 for Expectancy, 6.27 for Intrinsic, 6.41 for Attainment and 5.81 for Extrinsic. In almost all measures of andragogical learning characteristics, our second-year design students scored in the upper half of each subscale. Based on these results and previous work by Pembridge et al[1]. on first-year engineering students, it seems that entry level collegiate students meet the assumptions for andragogy. This opens the door to more research on how one might better align teaching strategies to adult learning characteristics, without as much uncertainty on if younger college students are prepared for such a change. This attempt may better prepare our graduates for future work in the engineering discipline.

Table 4: Descriptive statistics and analysis of variance findings associated with comparison between groups.

Survey Instrument	Cronbach's alpha	Second-Year		Fourth-Year		Model 1: F-Statistic		Model 2: F-Statistic (Age Covariate)			
		Mean	SD	Mean	SD	Year	p-value	Year	p-value	Age	p-value
SLDAS											
Self-Management	0.777	25.22	3.08	24.71	3.22	0.8	0.373	0.02	0.898	0.67	0.416
Motivation	0.779	30.64	2.82	30.24	3.13	0.53	0.469	0.05	0.816	0.06	0.808
Self-Monitoring	0.827	29.31	2.95	29.50	3.55	0.1	0.751	0.14	0.71	0.48	0.488
IDEA											
Identify Exploration	0.643	3.20	0.33	3.12	0.41	1.52	0.219	0.49	0.483	0	0.975
EXP / Possibilities	0.785	3.29	0.43	3.12	0.54	3.87	0.052	1.56	0.214	0.01	0.912
Negativity / Instability	0.797	2.81	0.57	2.85	0.47	0.14	0.713	0.24	0.626	0.11	0.737
Other-Focused	0.535	2.77	0.41	2.60	0.53	3.77	0.055	0.53	0.467	0.27	0.605
Self-Focused	0.784	3.07	0.40	2.85	0.57	5.79	**0.018***	0.4	0.529	0.98	0.325
Feeling "In-Between"	0.596	3.09	0.45	2.92	0.59	2.89	0.091	0.89	0.346	6.01	**0.016***
EBAE											
Certainty of Knowledge	0.074	4.67	1.13	4.89	1.47	0.79	0.375	0.14	0.713	0.04	0.844
Simplicity of Knowledge	0.374	7.94	1.34	7.33	1.36	6.17	**0.014***	2.2	0.141	0	0.984
Source of Knowledge	0.625	7.78	1.29	7.42	1.30	2.22	0.139	0.4	0.528	0.08	0.778
Justification for Knowing	0.379	7.23	1.16	6.98	1.23	1.24	0.267	3.26	0.074	2.01	0.159
Expectancy-Value											
Expectancy	0.862	5.59	0.90	5.19	1.09	4.74	**0.031***	0.94	0.335	0.16	0.693
Intrinsic	0.750	6.27	0.85	5.54	1.34	12.31	**0.001***	5.73	**0.018***	0.16	0.691
Attainment	0.742	6.41	0.59	5.39	1.27	31.4	**<0.001***	8.4	**0.004***	0.26	0.61
Extrinsic	0.770	5.81	1.07	4.87	1.54	14.83	**<0.001***	3.36	**0.069***	0.3	0.583
Self-Efficacy											
	0.942	65.92	18.87	76.10	11.92	12.66	**0.001***	9.05	**0.003***	1.24	0.268

Significant differences (p<0.05) denoted with bold*. Self-Directed Learning Dimensions Scale (SLDAS); Inventory of the Dimensions of Emerging Adulthood (IDEA); Epistemological Beliefs Assessment for Engineering (EBAE); Experimentation (EXP); Standard Deviation (SD).

Research Question 2: How do indicators of andragogical learning characteristics differ between incoming second-year and fourth-year students?

The second research question was to investigate how indicators of andragogical learning characteristics differ between incoming second-year and fourth-year students. F-statistics for both statistical models are shown in Table 4. Mean and standard deviations are also both shown in a figure for each survey scale below.

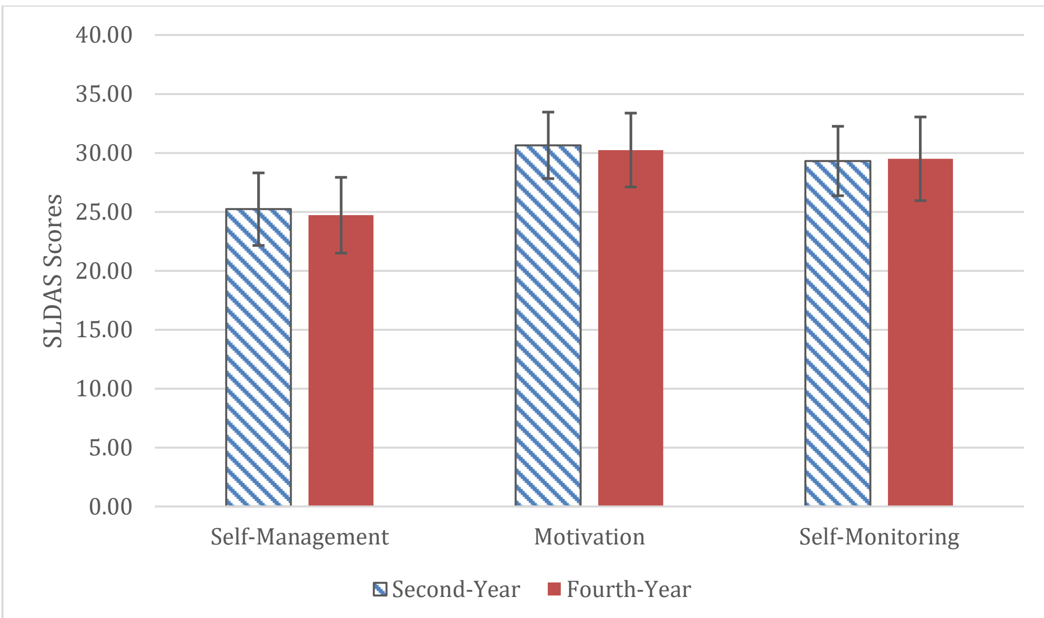

Figure 1: Self-Directed Learning Aptitude Scale (SLDAS) comparison of student responses.

There were no significant differences found between second-year and fourth-year mechanical engineering students in the Self-Directed Learning Dimensions (Figure 1). Both groups had relatively high scores in each of the subscales, however there was no difference between the two and age was not a significant covariate.

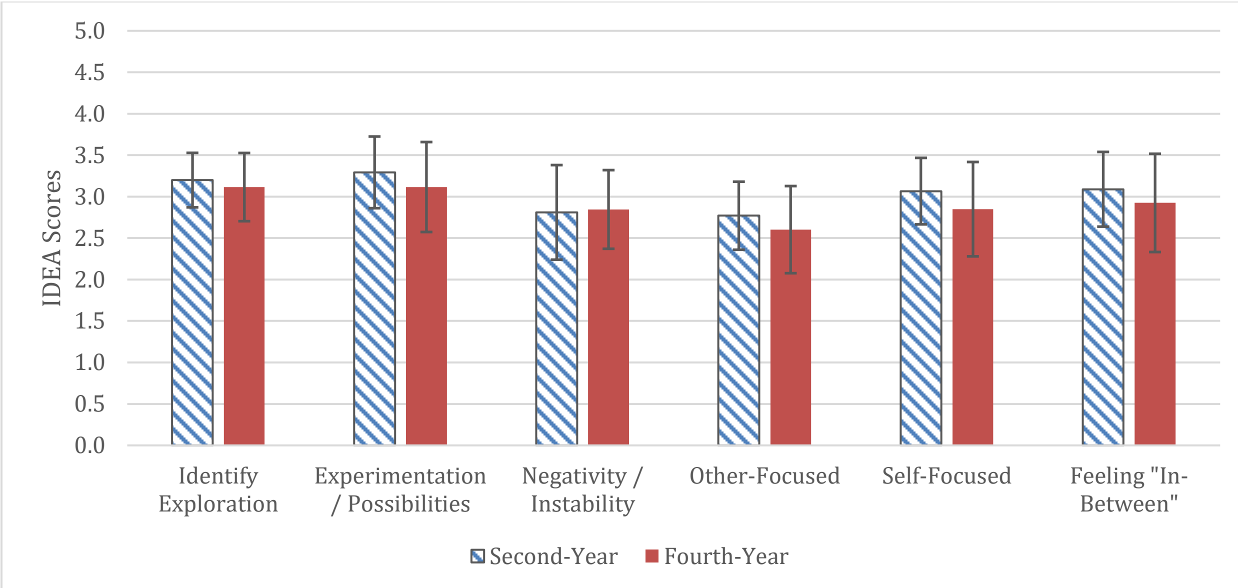

Figure 2: Inventory of the Dimensions of Emerging Adulthood (IDEA) scale comparison of student responses.

For the IDEA scale, we found that our second-year students were significantly more self-focused than our fourth year students ($p<0.05$) utilizing statistical Model 1. However when age was added as a covariate in Model 2, there was no longer a significant difference between groups (Table 4).

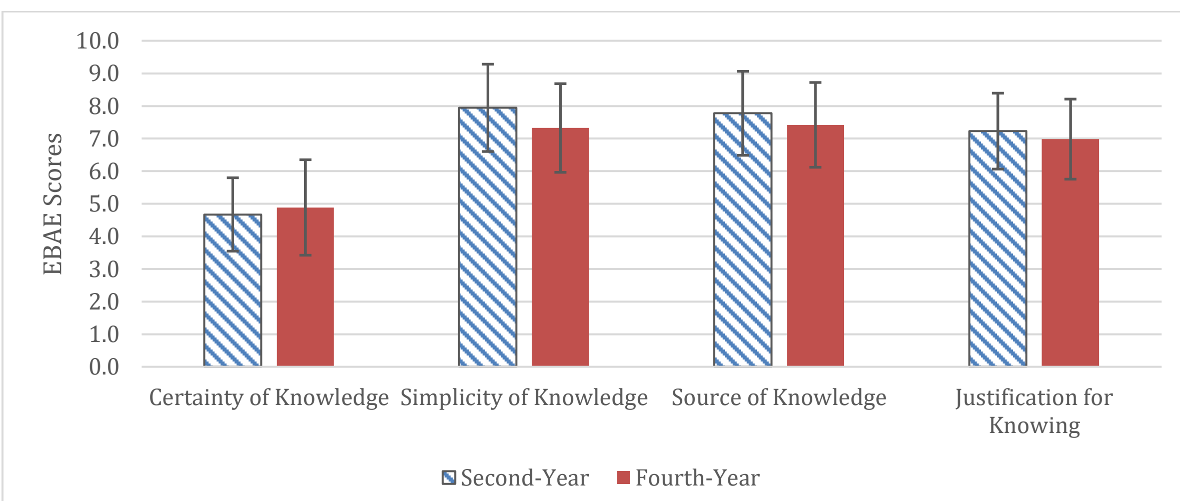

Figure 3: Epistemological Beliefs Assessment for Engineering (EBAE) scale comparison of student responses.

Second-year students had significantly higher EBAE scores on the Simplicity of Knowledge subscale with Model 1 but not Model 2 (Table 4). The other three subscales were not significantly different between groups utilizing either model.

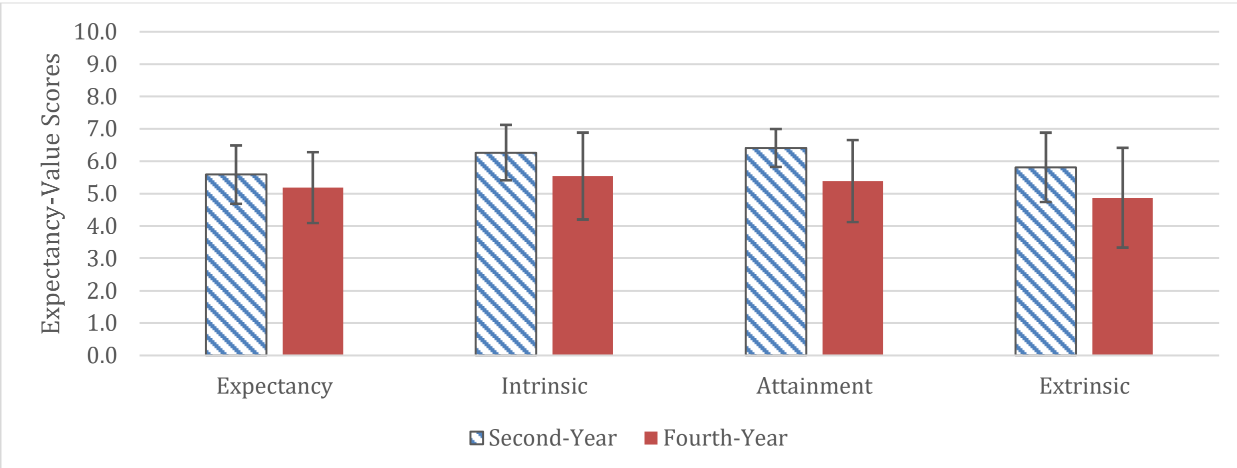

Figure 4: Engineering Expectancy and Value Scale comparison of student responses.

The Engineering Expectancy and Value scale showed the most consistent differences between our two student groups (Figure 4). Model 1 showed that second-year students had significantly higher scores in every subscale compared to fourth-year students (Table 4). When age was controlled for in Model 2, the Expectancy subscale was not significantly different between groups, however the other three subscales were still significantly greater for our second-year students. These differences were our most consistent finding when comparing the second-year and fourth-year engineering students. While our early collegiate students appear similar to previous work at other academic institutions, our four-year students appear substantially lower in each category. We hypothesize that this may have some underpinnings in the unique aspects of the United States Military Academy. All graduating students will immediately be commissioned and begin their career as an active-duty officer. Only a subset of these students will be military engineers, while many will focus on other specialties. We believe this may alter their perception on the applicability of engineering to their short term career goals. There are also many motivating factors to obtaining good grades, specifically this factors into their overall ranking and therefore ability to get a preferred military specialty and first duty location. By the beginning of their fourth-year, these overall rankings are fairly set and the selection for military occupational specialty occur in the first semester. So while having a high grade point average and doing above-average academically is very important for students, the fourth-year students likely put substantially less emphasis on grades. These factors may also be important for institutions with a sizeable ROTC student population, as similar career decisions are made based on student overall rank.

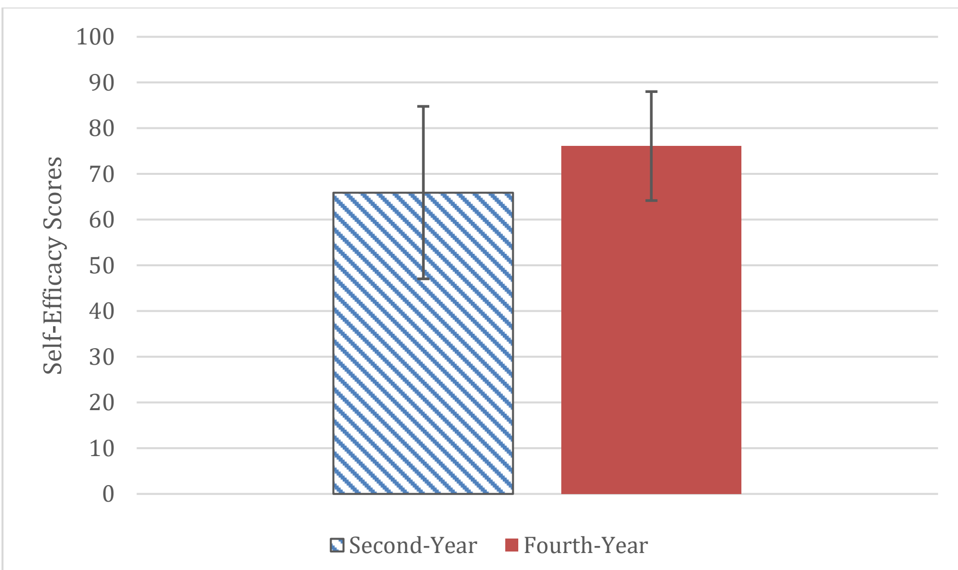

Figure 5: Engineering Design Self-Efficacy Instrument scale comparison of student responses.

Self-Efficacy was the only scale where our fourth-year students had significantly higher scores, which is consistent with previous work.[1] While this is not a survey meant to determine andragogical characteristics, it has previously shown a positive relationship with academic success in engineering courses.[27]

Conclusions

All significant findings for andragogical characteristics found increased values in our second-year students compared to our fourth-year students. Self-efficacy was higher in our fourth-year students, which is promising, however this is not meant to be an indicator of adult learning characteristics. Pembridge et al. also counter-intuitively found many andragogical scales to be significantly higher in first-year students compared to fourth-year students. This may be attributed to more experience with difficult coursework for older students, however this speculation could not be answered by the current study. Unique aspects of the United States Military Academy may also play a role in the results of this study, as individual job assignments are varied across military occupational specialties. Therefore a substantial number of mechanical engineer focused students will not be involved in traditional mechanical engineering disciplines. This study may also provide value for institutions with sizeable ROTC enrollment, where those graduates follow a non-traditional career path.

Future Work

There is still much research necessary on andragogical learning characteristics and teaching techniques before a potential shift in strategy for engineering education. We were surprised to find higher scores of adult characteristics in our second-year students compared to our fourth-year students on certain surveys. To better understand these results, more research is needed to follow students longitudinally throughout their undergraduate engineering education. This would allow us to see, on an individual basis, just how these characteristics change over time. We intend to continue this line of research with our second-year students and follow them until graduation to better understand this aspect of andragogical characteristics. More work is also needed on the assessment mechanisms for andragogy, and developing a survey which accurately quantifies an individual's position along the continuum of each andragogical assumption.

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