Student Learning Index and Student Performance in Engineering Statics

Virginia R. Charter, PhD, PE
Oklahoma State University

Abstract

Within higher education, there is an expectation from the various stakeholders that learning will occur. How learning occurs can differ from student to student. Felder and Silverman [1] knew this when creating the Index of Learning Styles. Students must receive and process information in order to learn, but how they do so may impact their performance in class. This study examines how much the Index of Learning Styles can explain their grade achievement in an engineering statics class. Surveying and analyzing 40 students ILS scores and grade achievement in an engineering statics class, a sequential multiple regression analysis was performed to determine if their learning style could explain their grade achievement in the class. This study suggests that how students prefer to receive information, either sensing or intuitive, explains their performance in the class the most.

Keywords: Index of Learning Styles, student learning, grade achievement, faculty teaching, faculty paper

Introduction

Higher education plays a key role in the transfer of knowledge, particularly to the students within the higher education system. Astin [1] states, "… higher education's fundamental purpose is to educate people, to equip them with appropriate knowledge, skills, and other personal qualities, that enable them to perform critical functions in the society and be responsible citizens" [1, p. 37]. This creates a great responsibility to those faculty members imparting knowledge to the students. Furthermore, higher education is pressured by employers to meet these standards via their graduates; this has become an important aspect of accreditation in programs such as architecture, engineering, or engineering technology.

Felder and Silverman urged engineering educators to dedicate their research efforts to understand learning of engineering students because "mismatches exist between common learning styles of engineering students and traditional teaching styles of engineering professors" [2, p. 674]. Felder and Silverman describe learning in higher education is typically a two-step process. The first step is receiving information, which occurs both externally and internally. The second step is processing the received information. The learning styles developed were drawn from Jung's theory of psychological types as well as the learning style model from David Kolb. Having an understanding of these learning styles would assist faculty and instructors in properly developing the pedagogy for the classroom [2]. The purpose of this research is to determine how much a student's grade in an engineering statics class could be explained by their Index of Learning Style scores.

The Evolution of Student Learning and Learning Outcomes

From the beginning of higher education to today, much has changed in the understanding of how students learn and how to evaluate learning. Experiential learning is a key component that has developed as a part of student learning over time. John Dewey is known as one of the great early educational philosophers. Dewey lived during a time where the educational approach was focused on delivering knowledge and not on the student. Dewey felt that teachers needed to take into account the student experience and needs [3]. John Dewey based his criteria of experience on two main ideas: continuity and interaction. Dewey said the "principle of continuity of experience means that every experience both takes up something from those which have gone before and modifies in some way the quality of those which come after" [4, p. 27]. Interaction within the educational context is taking into account both the objective and internal conditions of a given experience [4].

Kolb developed an experiential learning model from the theory that John Dewey promoted. Kolb defines experiential learning as "the process whereby knowledge is created through the transformation of experience" [5, p. 38]. Given his definition of experiential learning, Kolb's learning model consists of a four-stage cycle: concrete experience, reflective observation, abstract conceptualization, and active experimentation. Each of these stages is considered a learning mode. An individual moves through each of these stages throughout the learning process. The cycle then repeats itself continuously [5].

Learning through experience has long since been a key component in higher education, particularly engineering education [6]. In the early 1900s, U.S. higher education engineering disciplines were a combination of a formal mathematical and scientific system in addition to an apprenticeship system. However, in the 1920s, there was a shift towards a more theoretical foundation, but practical application was still taught by faculty that had significant industry experience. During the World War II era, another shift occurred towards the hiring of strong research faculty which resulted in little to no emphasis on practical application and a heavy emphasis on math and sciences theory [7].

In 1976, Harrisberger and Others, as a part of the American Society of Engineering Educators expressed that a experiential learning program should support the following: "problem solving skills, interpersonal awareness, creative expression, communication skills, technical skills, self-confidence building, computation skills, engineering fundamentals, organizational skills, leadership skills, planning skills, professional ethics, engineering judgment" [6, p. 7]. In the late 1980s, the clash between higher education engineering or engineering technology programs and employers emerged. Feedback from employers included the need for engineers with "strong technical capability… skills in communication and persuasion, an ability to lead and work effectively as apart of a team, an understanding of the nontechnical forces that profoundly affect engineering decisions, and a commitment to lifelong learning" [7, p. 168].

Student Learning and Faculty Teaching

According to Ruutmann and Kipper, engineering educators should be helping students develop their learning skills. Teaching is intended to facilitate learning and not the other way around [8]. However, as previously pointed out by Felder and Silverman [2], there is a mismatch in student learning and teaching styles. There needs to be an understanding of the various learning styles in order to apply the appropriate teaching style. The Felder and Silverman model of learning styles and Kolb's learning styles will be presented below.

The Felder and Silverman model learning styles include active or reflective, sensing or intuitive, visual or verbal, and sequential or global. All learners fall into one of the two styles in each category. For instance, a student could be an active, sensing, visual, sequential learner. The Index of Learning Styles (ILS) provides a scale for each one of these 4 categories, where depending upon the students' responses, the ILS will indicate how much a student may be active learner or a verbal learner. Figure 1.1 shows how the ILS scales work to provide a numerical value as to how much a student learning style trends towards one side or the other of the spectrum of learning styles. Within the ILS, the responses are added to output the final value on the scale. For example, a student could score a 9 on the active scale, meaning they heavily rely on active learning.

INTUITIVE	11	9	7	5	3	1	1	3	5	7	9	11	SENSING
VERBAL	11	9	7	5	3	1	1	3	5	7	9	11	VISUAL
REFLECTIVE	11	9	7	5	3	1	1	3	5	7	9	11	ACTIVE
SEQUENTIAL	11	9	7	5	3	1	1	3	5	7	9	11	GLOBAL

Figure 1.1 Index of Learning Style Results Scale

In order to understand how a student learns and how the ILS was developed, each of the categories needs to be considered individually. Students will show preference on the type of information received and will be considered either sensing or intuitive. Sensing students perceive information better through external sights or sounds. Intuitive students perceive information better internally via insights. Students will also naturally divide between being either visual or verbal, which is how they receive external information. Visual learners prefer pictures or diagrams while verbal learners prefer audible language. These two categories of perception and input reflect the first step in the learning process of receiving information. [2]

The second step of the Felder and Silverman learning process is how the student processes and understands the information they received. First, a student must process the information, and will do so either actively or reflectively. Active learners prefer physical activity or discussion while reflective learners prefer self-analysis. Second, a student will work towards understanding the information, either sequentially or globally. Sequential learning happens in steps, whereas global learning is a holistic approach. [2]

It should be noted that there was previously an additional category placing students into either inductive or deductive means of organization of information. However, Felder later removed this category as it was found that students would say they prefer the deductive approach, while in reality, inductive presentation enables students to progress through the reception and processing of information. Felder and Silverman [2] addressed this originally as follows:

> Induction is the natural human learning style…. Most of what we learn on our own (as opposed to in class) originates in a real situation or problem that needs to be addressed and solved, not in a general principle; deduction may be part of the solution process but it is never the entire process" [2, p. 677]

The active or reflective category is derived directly from Kolb's Learning Theory of experiential learning [2]. Kolb's four-stage cycle of concrete experience, reflective observation, abstract conceptualization, and active experimentation is then interconnected with an individual's learning style through the Learning Style Inventory test. Kolb's Learning Style Inventory then provides four basic learning styles: convergent, divergent, assimilation, and accommodation. Each of the learning styles is associated with two of the stages or learning modes in the cycle. Convergent is associated heavily with abstract conceptualization and active experimentation, divergent stresses concrete experience and reflective observation, assimilation relies upon abstract conceptualization and reflective observation, and accommodative emphasizes concrete experience and active experimentation [5].

Felder and Brent explain what type of instructor works best with the four learning styles by Kolb: convergent, divergent, assimilation, and accommodation. Teaching to a convergent learner, the instructor should act as a coach. Teaching to a divergent learner, the instructor should act as a motivator. Teaching to an assimilation learner, the instructor should act as the expert. Teaching to an accommodation learner, the instructor should ask open-ended questions and utilize problem-based learning. [9]

For engineering disciplines, the typical teaching pedagogy only fulfills the needs of the assimilation learner. Felder and Brent [9], recommend that the most effective teaching style, according to Kolb's model, is to teach around the cycle by motivating new topics, presenting basic information on a given topic, practice within the topic, and provide means of applying the topic.

Felder and Silverman [2] were able to build upon Kolb's learning styles by adding the sensing/intuition, visual/verbal, and sequentially/globally categories. This enabled educators to have a holistic approach of a student's learning style. Each of the four categories of student learning described by Felder and Silverman correspond with a teaching style. The category of student perception will rely on the content the teacher relays. The content will be either concrete or abstract. The presentation of the content will be either visual or verbal. Faculty relies heavily upon student participation being either active or passive, which corresponds to the students learning being active or reflective in processing information. Finally, the faculty will have their own perspective on whether material should be presented sequentially or globally.

Similar to what was found by Felder and Brent in the Kolb model, there is a mismatch in learning and teaching style. According to Ruutmann and Kipper, most engineering students fall under the sensing, visual, active, and sequential. However, most engineering educators use teaching methods best received by intuitive, verbal, passive (or reflective), and sequential learners [8].

Methods

Given that knowledge transfer is one of the key functions of higher education, it is important to understand how students learn. Furthermore, how students learn could impact their achievement in a given course. Core engineering courses provide fundamental concepts to students, which students build upon throughout their higher education architecture, engineering, and engineering technology programs. Therefore, it makes it even more critical to understand student learning and their achievement. This study looked at the core engineering course of statics. Engineering statics is the study of methods for quantifying the forces between bodies. The forces are responsible for maintaining balance and causing motion of bodies, or changes in their shape. This particular engineering statics course is required for students in architecture, engineering, and engineering technology programs at a land grant research university. This study aims to answer the following question: How does a students' Index of Learning Style explain a students' performance in an engineering statics course?

In order to answer the above question, the Index of Learning Styles (ILS) was administered to students that had completed a full semester of the engineering statics courses. The students were selected through convenience sampling. The students were enrolled in a class that required the engineering statics course as a pre-requisite course, therefore knowing that the student had already taken the engineering statics course. Upon obtaining the ILS scores from each student, their first grade in the engineering statics course was also obtained. Students who withdrew from the engineering statics were not considered. This particular data collection included 41 students for the ILS scores. However, only 40 first attempt grades were able to be obtained from the same students. Each student's ILS score included a measure on a scale in each category. The score associated a student with the strength of each of the categories. An example of the scale is provided in Figure 1.1 above.

Given the scale nature of the above independent variables that are produced by the ILS, the data was transformed to be on a scale of 1 to 12. This enabled data analysis to be performed with a continuous scale. For each of the category scales, the learning style associated most with teaching methods by Ruutmann and Kipper, were designated at the high end of the scale. Therefore, scores between 7 and 12 score were associated with reflective, intuitive, verbal, and sequential learning styles, while scores between 1 and 6 were associated with active, sensing, visual, and global learning styles.

INTUITIVE	12	11	10	9	8	7	6	5	4	3	2	1	SENSING
VERBAL	12	11	10	9	8	7	6	5	4	3	2	1	VISUAL
REFLECTIVE	12	11	10	9	8	7	6	5	4	3	2	1	ACTIVE
SEQUENTIAL	12	11	10	9	8	7	6	5	4	3	2	1	GLOBAL

Figure 1.2 Index of Learning Style Scale Transformed

A sequential multiple regression analysis was completed in SPSS by inputting intuitive/sensing, verbal/visual, reflective/active, and sequential/global scores to determine how much each variable explained the students' grade achieved in the engineering statics course. The order of input into SPSS was based upon Felder and Silverman's description of the two-step learning process of receiving information and processing information. The learning process starts with the type of information to be received, which results in the intuitive/sensing scale. The next scale of verbal/visual provides how the information is received. The second step to the learning process is how one processes and understands the information. Therefore, the scale of reflective/active describes most how a student processes the information. Finally, the student processes information based on the sequential/global scale.

Results

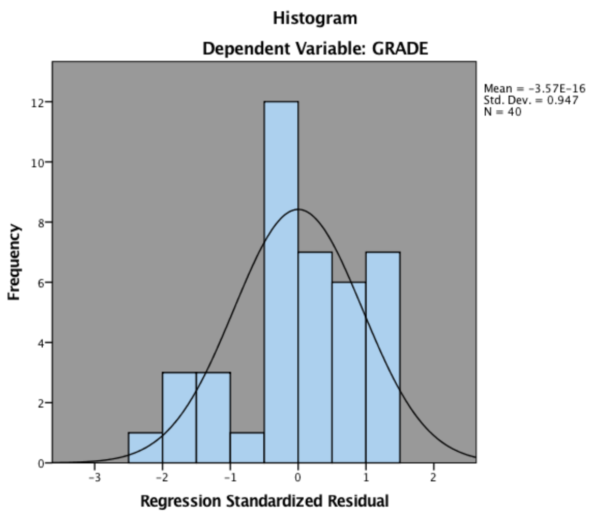
The purpose of this research was to determine how much a student's grade in an engineering statics class could be explained by their Index of Learning Style scores. To accomplish this purpose, students' scores on their ILS were regressed using a sequential multiple regression analysis.

The results of the analysis are shown in Table 1.1. The first variable entered in the regression, intuitive/sensing score, resulted in a statistically significant increase in explained variance ($\Delta R^2 = .112$, $F[1, 38] = 4.801$, $p < .05$). The remaining three variables, entered in the order of verbal/visual ($\Delta R^2 = .010$, $F[1, 37] = .432$, $p > .05$), reflective/active($\Delta R^2 = .008$, $F[1, 36] = .348$, $p > .05$), and sequential/global($\Delta R^2 = .022$, $F[1, 35] = .903$, $p > .05$), were all found to not be significant. These findings suggest that the first step in the learning process of how students prefer to receive information is the most important.

Table 1.1 Total Effects of Intuitive-Sensing, Verbal-Visual, Reflective-Active, Sequential-Global Scales on Final Grade in Engineering Statics

Variable	$b(SE_b)$	β (total effects)	ΔR^2
Intuitive-Sensing Scale	-.127 (.058)*	-.335	.112
Verbal-Visual Scale	-.048 (.073)	-.103	.010
Reflective-Active Scale	.046 (.078)	.093	.008
Sequential-Global Scale	.090 (.094)	.156	.022

When looking further into the regression coefficients and the total effects of each variable, the intuitive/sensing was again found to be significant at the $p = .05$ level. The remaining scales of verbal/visual, reflective/active, and sequential/global were not found to be statistically significant. However, these coefficients do provide an explanation of the type of learner that is best suited for an engineering statics course: sensing, visual, reflective, and sequential.



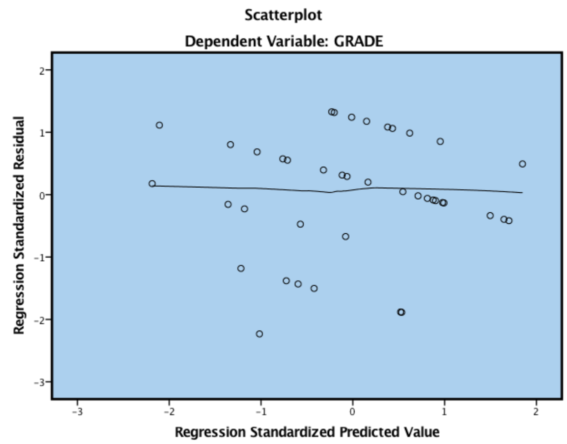


Figure 1.3 Standardized Histogram

Figure 1.4 Standardized Scatterplot

In testing the assumptions of multiple regression on the data set, it was determined that the data meets the assumption of homogeneity and there was homoscedasticity of the residuals as can be seen in Figure 1.4. Furthermore, the residuals met the assumption of linearity as shown by the loess line in Figure 1.4. The data was distributed normally. This is based upon a visual inspection of the histogram in Figure 1.3 and the skewness and kurtosis statistics were less than +/– 2. The Shapiro Wilks statistic was found to be significant. However, this could be explained due to the small data set and an outlier of Case 12, as shown in the box plot of Figure 1.5. The data does not have multicollinearity, based on the tolerance and VIF values of the variables.

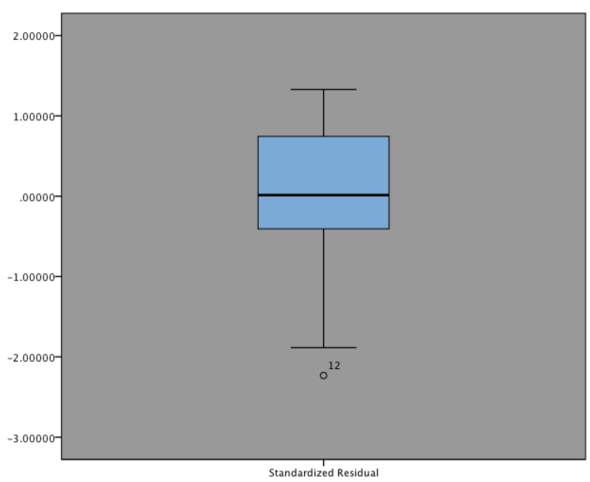


Figure 1.5 Standardized Residual Boxplot

Finally, when reviewing the casewise statistics, it was found that Mahal. Distance value was greater than the critical value for the 5 degrees of freedom Chi squared critical statistic ($x^2 =$ 11.070). The case that caused this violation was case 28; which upon looking at the individual scores, this could have been caused by an extreme verbal/visual score. All other Mahal. Distance values were less than the chi squared critical statistic. The Cook's distance was less than .5 for all the cases. The DF Beta measure reaffirmed a potential issue with Case 12. Case 12 would have the greatest change in the regression equation if it was not included in the model.

Analysis

Students' scores on their ILS were regressed using a sequential multiple regression analysis. The ILS score of intuitive/sensing was found to be significant in the students' grade achievement in the course. The individual regression coefficients for the total effects also confirmed that the intuitive/sensing scale was the only score found to be significant as well. All remaining ILS scores were not significant.

When looking closer at the regression coefficients, this particular data set found that the student that scored as a sensing, visual, reflective, and sequential learner typically performed better in the class. When reviewing the course content for engineering statics, this type of learner coincides with the methodology and technical content of engineering statics. This differs compared with what Ruutman and Kipper [8] have indicated on the type of teaching methods typically associated with faculty in engineering. The coefficients confirm the mismatch between teaching and learning in the reflective/active scores and how students process the information.

Furthermore, if students that scored on the sensing end of the scale of how they like to receive information, faculty should take that into consideration on how to present information, as these students like to perceive information through external sights and sounds.

Given the limited size of the data set in this research, future research in this area should include replicating this study with similar core engineering science courses as well as comparing ILS scores and grade achievements in the various engineering, architecture, and engineering technology disciplines.

Conclusion

Student learning is an important aspect of higher education. Student learning is what ties many elements of higher education together. Students, faculty, employers, and accreditors all want the same thing – students who learn and develop while in college. "What today's students know and are able to do will shape their lives and determine their future prospects more than at any time in history" [10, p. 2]. Students need to have an understanding of their own learning style such that they can ensure they are giving themselves the best advantage when learning the different content. Similarly, faculty are impacted by student learning in that they need to understand how students learn so that they can modify their teaching style accordingly.

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Virginia R. Charter, PhD, PE

Dr. Virginia Charter is an Associate Professor and Program Coordinator for the Fire Protection and Safety Engineering Technology at Oklahoma State University. She obtained her BS in FPSET from OSU, her MS in Fire Protection Engineering from Worcester Polytechnic Institute, and her PhD in Educational Leadership and Policy Studies – Higher Education. Prior to returning to OSU, she practiced as a consulting and design engineer for nine years in Las Vegas, Nevada. She has worked on many of the infamous Strip properties planning for and evaluation of fire protection, life safety, and risk control systems. Her research is focused on areas that impact fire protection system effectiveness, building and fire codes and standards, and engineering education. She is a licensed professional engineer in Nevada, California, and Oklahoma. She serves as an alternate member of several standard committees, including NFPA 13, NFPA 20, and NFPA 101. She currently sits on the UL Fire Council, is an SFPE Foundation Governor, and Chairs the Higher Education sub-committee to the Society of Fire Protection Engineers Professional Qualifications Committee. She is also a member of the American Society of Engineering Educators.