Assessment of Inverted Classroom Success Based on Felder's Index of Learning Styles

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Abstract

Inverting the classroom is a pedagogical practice that has recently gained significant popularity. With the increase in its use, it is essential to understand the impacts of the practice and students' experiences in this type of classroom. This pedagogical structure was implemented in a first-year engineering course at The Ohio State University to accomplish two major goals: (1) to provide an inclusive learning environment in order to accommodate the learning styles of all students through the incorporation of online multimedia learning modules to be completed prior to class, and (2) to provide more in-class studio time with activities designed to increase active learning. The 15-week course covers a wide variety of fundamental engineering topics and laboratory exercises but emphasizes problem solving and computer programming in MATLAB and C/C++. The class met for four 125-minute sessions per week in classrooms with studio-style seating arrangements in groups of four with a desktop computer for each seat. In this research project, we asked the evidence-based practice question "Does student achievement increase when learning style as measured by the Felder Index correlates to actual preferred preparatory material style?"

While it has gained recent popularity, the inverted classroom has been used in some form or another for approximately the past 15 years. This has been partially brought about by the availability of various technologies, but also by the realization that moving content out of the classroom provided more face-to-face faculty time for constructivist learning experiences. The theoretical framework for this study is to use Felder's Index of learning styles as a basis to compare to quantitative measurements of time on task for each style of preparatory material (student-reported). For this work, the preferred individual learning style as measured by the Felder Index will be correlated with assignment and exam grades and the student-reported time on task by preparatory material style. Preparatory material types presented to the students include videos, readings and online quizzes which were directed at the lower Bloom's Taxonomy levels of remembering and understanding. In-class activities were targeted at the higher Bloom's Taxonomy levels of application, analysis and evaluation. Assessments were created to test comprehension of the preparatory materials and in-class assignments were created to apply and analyze the content actively during class to reinforce concepts.

Data have been collected for the Autumn 2013 academic term on over 200 first-year honors students. Preliminary analysis show a student population with normal distributions on the active-reflective, sensing-intuitive, and sequential-global Felder Learning Styles scales and an extremely skewed visual-verbal distribution favoring visual learners with less than 5% of the total population self-rated as moderate to strong verbal learners. We report on a comparison of the Felder Learning Styles scales, assignment preparation time, and course performance. These results provide insights into significant predictors of student success based on learning style and curriculum type. The ultimate goal is to provide appropriate preparatory course materials to create a successful learning environment for all learning styles.

Introduction

The Ohio State University recently underwent a curriculum change from quarters to semesters. As part of this curriculum change, the First-Year Engineering Program chose to make some major pedagogical changes to the course structure to accomplish two major goals: (1) to provide an inclusive learning environment in order to accommodate the learning styles of all students by inverting the classroom and incorporating online multimedia learning modules to be completed prior to class, and (2) to provide more in-class lab time with activities designed to increase active learning. [1,2,3]

In this research project, we asked the evidence-based practice question "Does student achievement increase when learning style as measured by the Felder Index of Learning Styles correlates to actual preferred preparatory material style?" The Background section provides previous work and related research including our inverted classroom and the multimedia learning materials used. The methods used to collect data for analysis are presented next followed by results, discussion, conclusions and suggestions for future work.

Background

Inverted Classroom

While it has gained recent popularity, the inverted classroom has been used in some form or another for approximately the past 15 years. [3,4,5,6]This has been partially brought about by the availability of various technologies [7], but also by the realization that moving content out of the classroom provided more face-to-face faculty time for constructivist learning experiences. [4] The traditional didactic classroom where the bulk of the basic skills, facts, and principles are presented in lecture (typically PowerPoint) and problems are assigned to be completed by the student on their own prior to the next class leaves the student to struggle on their own as they attempt to master a new concept. In an inverted classroom, the student is expected to become responsible for learning this rote memorization material in preparatory assignments prior to coming to class to become immersed in experiential, active learning and application of new concepts.[8]

Lage, Platt and Treglia published "Inverting the Classroom: A Gateway to Creating An Inclusive Learning Environment."[3] This seminal work reported the ability to reach multiple learning styles by inverting the classroom. Mason et al. compared an inverted and traditional classroom in an upper-division engineering course and found that more material could be covered in the inverted class and student performance was as good or better than in the traditional class.[9]

Felder-Soloman Index of Learning Styles

The Felder Index of Learning Styles (ILS) is used as a measure of learning styles preference. The Index is a 44 question survey that is designed to identify student learning preferences in the four dimensions of the Felder-Silverman model[10]. This tool was developed by Barbara Soloman and Dr. Richard Felder, both from North Carolina State University.[10] There are 11 questions for each of the four dimensions, each of which has two possible answers representing the opposing preferences within the dimension. Each dimension is scored on a scale from -11 to +11.

The absolute value of the final score reveals the "strength" of a preference, ranging from "balanced" (score of 1 to 3) to "strong" (score of 9 – 11). The ILS can be broken down into the "processing" dimension on the active/reflective scale, indicating the preferred way learners process information; the "perception" dimension on the sensing/intuitive scale indicating the preferred way learners perceive information; the "input" dimension on the visual/verbal scale indicating the preferred way learners are inputting information; and the "understanding" dimenstion on the sequential/global scale indicating the preferred way learners are adapting information.[11]

A number of studies have previously investigated various dimensions of the ILS with respect to learning engineering principles. One study used a binary logistic regression model and found that gender, sensing and visual learning styles (ILS) were significant predictors of achievement. [12] They recommended accommodating these learning styles to promote academic success. Other studies have found correlations between the sequential/global and sensing/intuitive ILS scales [13,14], and that the active/reflective scale does not correlate with any of the other three scales [10]. A recent study by Hames and Baker looked at the relationship between ILS and cognitive abilities in engineering students. [15] They found that performance in terms of response time and not accuracy was related to the global/sequential, active/referential, and visual/verbal scales in addition to stronger correlations for females between learning styles and processing speeds. They suggested that focusing materials to enhance learning based on these differences could serve to increase female success in the engineering classroom.

The Inverted Classroom

The Ohio State University's First-year engineering program offers two sequences to students, the standard sequence and the honors sequence which both consist of two courses. This paper focuses on the honors sequence, specifically the first course in the sequence, 1281H, which emphasizes problem solving through computer programming.

Course Structure and Classroom Configuration

First-year engineering students enrolled in the Fundamentals of Engineering for Honors (FEH) sequence at The Ohio State University complete a two-semester sequence of classes that cover a wide variety of fundamental engineering topics and laboratory exercises were eligible to participate in the study.

The first course (ENG 1281.01H) emphasizes problem solving and computer programming in MATLAB and C/C++. All courses include a laboratory component designed to expose students to a wide variety of engineering disciplines and topics. The semester-based course met for four 125-minute sessions per week in classrooms with studio-style seating arrangements in groups of four with a desktop computer for each seat.

Course Materials

With the conversion to semesters in the 2012-2013 school year, an inverted classroom structure was implemented. In this pedagogical model, the content remains the same but the instructional day is divided into two parts: preparation and application. Table I shows the components and timing of a typical inverted class day. Students work on remembering and understanding (the

lowest two levels of the Bloom's taxonomy) [16] with readings, guided videos, and quizzes prior to class; this leaves more classroom time available for the higher levels of Bloom's taxonomy, especially application.

Students are given a short lecture to review the preparation work, and then given guided activities or assignments to reinforce their learning. In a class such as this one where a large portion of the application requires specialized equipment, this is an important benefit to students. After class, students complete assignments and prepare for the next class.

For a four credit hour semester course, students were expected to spend approximately 30 to 90 minutes per night on preparatory work. Approximately half of the preparatory videos were created using Camtasia Studio 8 software (TechSmith, Okemos, MI) and Microsoft PowerPoint presentations with voice over. The other half used Camtasia Studio 8 in conjunction with a Bamboo Capture Pen and Touch Tablet (Wacom, Tokyo, Japan) and SmoothDraw 4 (SmoothDraw.com). Video length ranged from approximately 10 minutes up to nearly 21 minutes. Students were given instructions on how to download and use VLC media player, a free cross-platform (Windows, Mac, Linux, Unix, etc.) multimedia player to change the playback speed of videos. Playback time at speeds of 1, 1.5, and 2 times speed were provided to students for each video along with the playback time for specific topics. Reading assignments were designed to take no longer than 30 – 60 minutes.

Table I. *Typical Inverted Class Day Schedule*

Before Class	**During Class**	**After Class**
• Preparation activity: Reading, video, or problem(s) • Evaluation: online quiz or turned in solution	• Short lecture • Activities • Application assignments or lab	• Finish application assignments, open lab • Prepare for next class

Methods

This study was conducted under Institutional Review Board exempt protocol #2013E0570 in accordance with the Office of Responsible Research Practices.

We have collected data through online surveys and daily preparatory work quizzes given via the online course management tool to students in the first-year engineering program.

Study Population

The study participants were approximately 200 current students in eight sections of the honors first-year engineering program who consented to participate in the study. The honors program is open to first-year engineering students that have been given 'honors' status based on high school achievement and standardized testing. Students who indicated previous programming

experience as part of their high school preparation were directed to enroll in the 'advanced' programming course, which was not included in this study. In the first semester of the program (Autumn), students were introduced to problem solving methods, working in groups, and computer programming in MATLAB and C/C++.

Data Collection

The Felder ILS was administered as a measure of learning styles preference to compare to the self-reported times with each type of preparatory materials and was given on-line as a questionnaire. After completing the ILS, students were asked to respond to the following questions in an open-ended response format: "Were your learning preferences what you expected? If so, how do you study to target your preferences? If not, what was different and how do you think you may study differently to target them?" These responses were coded and reported on. In addition, at the end of the semester, students were asked in their weekly anonymous journal system to comment on their experience in the inverted classroom and whether, in their experience, they preferred the inverted classroom or the traditional lecture. These results were analyzed and summarized.

The survey collected data according to sample questions below. As indicated, many of the data were collected in an on-going manner with each assignment using their daily preparatory quizzes given in the online course management system. The questions included with each daily online preparatory quiz are adjusted to include only the appropriate questions based on the preparatory material for that day. A sample set of the questions are shown below:

Example Daily Online Quiz Questions on Preparatory Material

Fill in the blank:

1. I completed _________ of the preparation assignments for this class day.
(response options of: none, some, half, most, all)
2. How much time did you spend on the reading assignment(s)? (hh:mm)
(response options of: 0:00, 0:15, 0:30, 0:45, 1:00, through to 3:00 in 15 min increments)
3. How much time did you spend taking the preparation quiz? (hh:mm)
(response options of: 0:00, 0:15, 0:30, 0:45, 1:00, through to 3:00 in 15 min increments)
4. How many interruptions did you have during your total preparation time?
(response options of: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, more than 10).

Data from each population were aggregated and the responses were used to run comparisons between groups. Daily assignments were broken down and analyzed by course content (MATLAB or C/C++) and by available preparatory materials for that lesson.

Results

The analysis of the study data are presented as aggregate data based on the Felder ILS preference. A preliminary analysis of performance and time on task is presented for only the Visual-Verbal scale.

Figure 1 presents a summary of the Felder ILS results for the study population. All scales were relatively balanced except the Visual-Verbal scale, which was heavily weighted toward the Visual end of the scale.

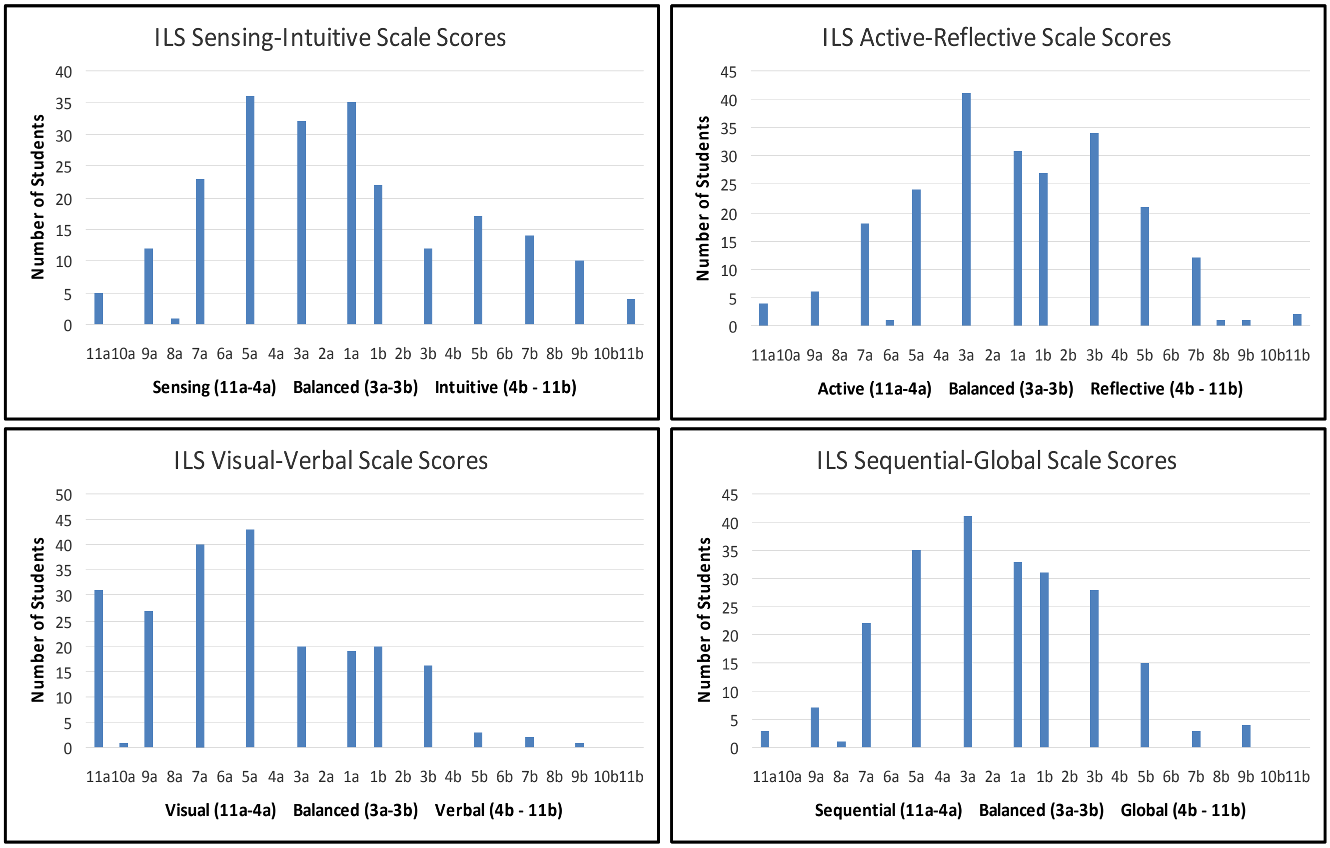

Figure 1. Felder Index of Learning Styles for Study Population

Another way to look at the ILS distribution among this population is to group the students according to their preferences: strong (11 – 4) and balanced (3a – 3b). This summary is shown in Figure 2 with the number and percent of students scoring in that range for that scale above the scale name.

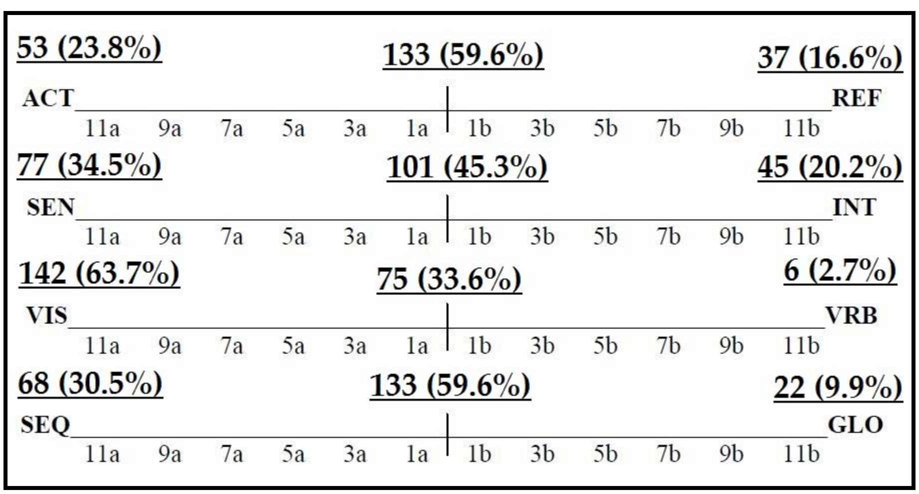

Figure 2. Summary of student population on ILS scales

Table II. Summary of MATLAB Reading only Assignments

MATLAB Reading Only (3 assignments)						
Felder Learning Style	Avg Read Time (hr.)	Avg Prep Grade (10 max)	Avg Assign Grade (20 max)	Avg MT 1 (100 max)	Avg Final (100 max)	Number of Students
Strong Visual	0.42	9.27	19.00	82.02	86.44	54
Mod Visual	0.45	9.32	19.18	83.30	86.58	73
Balanced	0.46	9.24	19.43	83.14	87.61	68
Mod Verbal	0.45	9.13	19.10	74.63	80.70	5
Strong Verbal	0.42	9.33	18.17			1

Table III. Summary of MATLAB Reading & Video Assignments

MATLAB Reading & Video (8 assignments)								
Felder Learning Style	Avg Read Time (hr.)	Avg Video Time (hr.)	Avg Total Time (hr.)	Avg Prep Grade (10 max)	Avg Assign Grade (20 max)	Avg MT 1 (100 max)	Avg Final (100 max)	Number of Students
Strong Visual	0.30	0.29	0.59	9.31	19.28	82.02	86.44	51
Mod Visual	0.34	0.30	0.64	9.26	19.21	83.30	86.58	67
Balanced	0.33	0.29	0.62	9.23	19.30	83.14	87.61	67
Mod Verbal	0.33	0.24	0.56	9.16	19.06	74.63	80.70	5
Strong Verbal	0.22	0.22	0.44	8.38	19.25			1

Table IV. Summary of C/C++ Reading Only Assignments

C/C++ Reading Only (9 assignments)						
Felder Learning Style	Avg Read Time (hr.)	Avg Prep Grade (10 max)	Avg Assign Grade (20 max)	Avg MT 2 (100 max)	Avg Final (100 max)	Number of Students
Strong Visual	0.35	9.41	19.01	78.88	86.44	47
Mod Visual	0.36	9.31	18.62	78.40	86.58	63
Balanced	0.32	9.40	19.15	79.32	87.61	60
Mod Verbal	0.40	9.42	18.88	72.57	80.70	5
Strong Verbal	0.22	8.29	19.56			1

Table V. Summary of C/C++ Reading & Video Assignments

C/C++ Reading & Video (6 assignments)								
Felder Learning Style	Avg Read Time (hr.)	Avg Video Time (hr.)	Avg Total Time (hr.)	Avg Prep Grade (10 max)	Avg Assign Grade (20 max)	Avg MT 2 (100 max)	Avg Final (100 max)	Number of Students
Strong Visual	0.30	0.32	0.62	9.02	18.80	78.88	86.44	50
Mod Visual	0.29	0.27	0.56	8.93	18.68	78.40	86.58	69
Balanced	0.30	0.25	0.55	8.87	19.28	79.32	87.61	64
Mod Verbal	0.44	0.20	0.64	8.94	19.46	72.57	80.70	5
Strong Verbal	0.21	0.25	0.42	9.33	19.93			1

Data were included only for students *who completed all assignments and submitted responses for the daily online course management tool quiz regarding time spent on preparatory materials for each type of preparatory assignment*. Therefore, the number of students varies between Tables II through V. Even though the number of students varies, the average scores for midterm 1 (MT 1), midterm 2 (MT 2) and the final exam *are the same across Tables II through V for each ILS group* of students. These data are repeated in each appropriate table for comparison purposes only. Table II shows average results for MATLAB assignments which only had reading material provided in the preparatory work. The data collected includes the average student-reported time (in hours) spent reading, the average preparatory quiz grade, the average daily assignment grade and the average midterm (MT 1, which focused on MATLAB) and final exam scores along with the number of students in each group based on ILS score. This student population only had one student in the "strong verbal" category, therefore the midterm and final scores were not included. Table III shows similar data for MATLAB assignments with both reading and video presented in the preparatory materials. Tables IV and V show similar data for the C/C++ assignments with MT 2 scores which focused on C/C++.

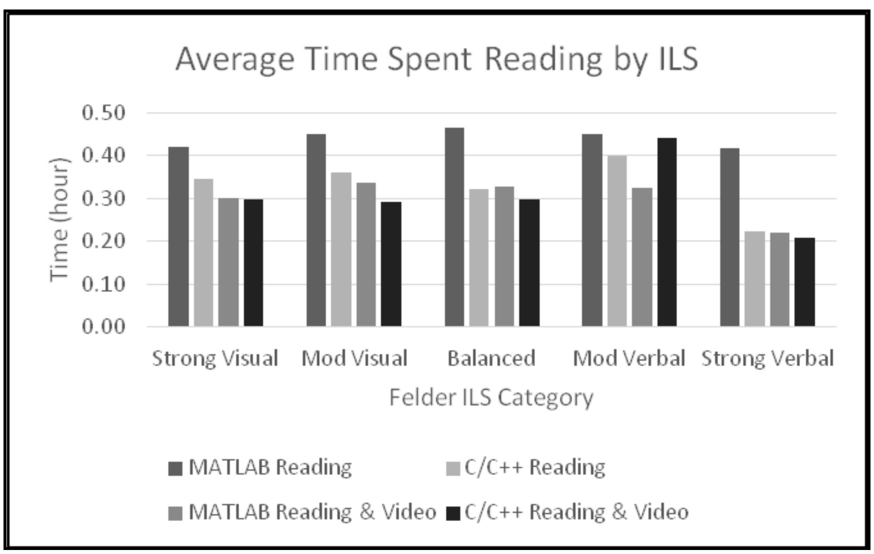

Figure 3. Comparison of Average Time Spent Reading by ILS Category

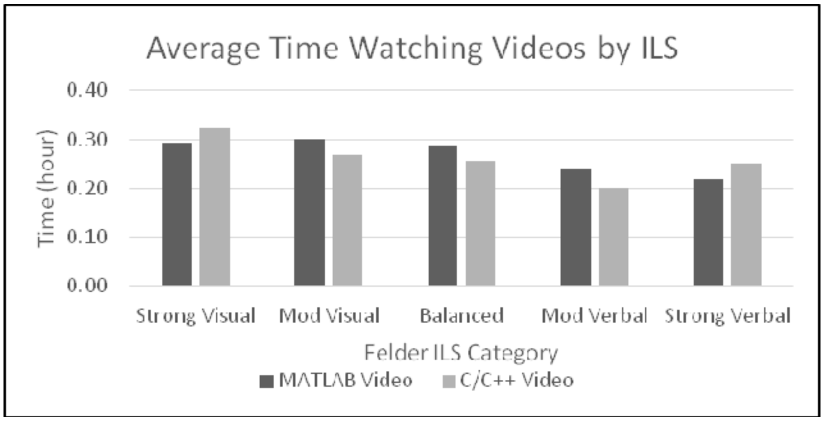

Figure 4. Comparison of Average Time Spent Watching Preparatory Videos by ILS Category

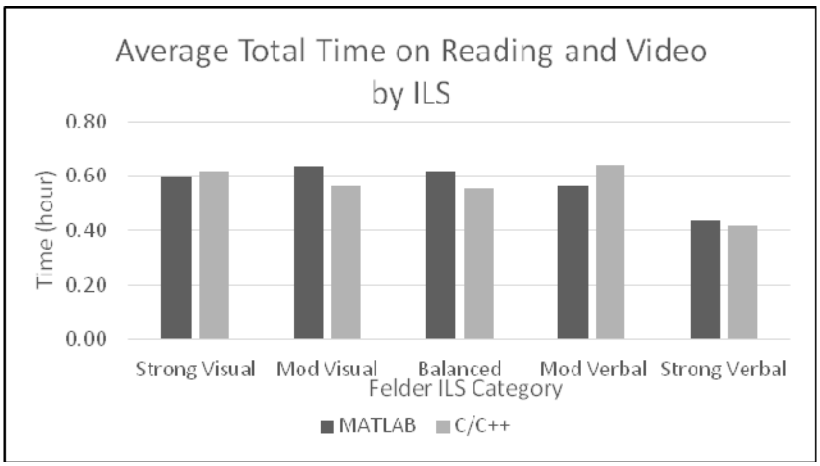

Figure 5. Comparison of Total Time on Preparatory Activities by ILS Category

Figures 3 through 5 are comparisons of the average time spent on the provided preparatory assignment by ILS category, type of preparatory material (reading, video, or both), and type of assignment (MATLAB or C/C++).

Table VI is a summary of the responses to the questions students were asked to answer after completion of the Felder ILS, specifically, “Were your learning preferences what you expected? If so, how do you study to target your preferences? If not, what was different and how do you think you may study differently to target them?” Responses were coded and tabulated into Table VI. Not all students answered every suggested question, therefore the total number of respondent varies for each question.

Table VI. Summary of Open-Ended Responses

Learning Style Match?		**Target ILS?**		**Make Changes in Future?**	
YES	182	YES	124		
		NO	52		
		N/A	6		
NO	39			YES	30
				NO	9

Results from the end of semester anonymous journal are summarized in Table VII. Out of the 99 student responses received, 68 students (68.7%) preferred the inverted approach, 19 students (19.2%) preferred the standard lecture classroom approach, while 12 students were comfortable with either.

Table VII. Anonymous journal response summary.

Preferred Classroom Style (99 total responses)		
Inverted	Both	Lecture
68 (68.7%)	12 (12.1%)	19 (19.2%)

Discussion & Conclusions

The population in general was extremely skewed on the visual-verbal ILS scale, but nearly balanced on the other three scales. This isn't totally surprising for an engineering population, but it is not what is typically found in all engineering populations. A study of over 500 students in Malaysia, South Africa and Finland showed a nearly balanced population in the visual/verbal learning styles which is not consistent with this engineering population sample from the US. [17] These differences may very well be cultural differences which can be studied further and should be considered when addressing a multi-cultural, diverse student population. Our distributions were much closer to those found in a small population (n = 51) of undergraduate engineering students at Texas Tech. [15]

The students who performed the highest overall across most categories (assignments, MT's, final) were the students who scored within the "balanced" category on the visual-verbal ILS scale. This balanced group was the largest group in all ILS scales except on the visual-verbal scale as shown in both Figures 1 and 2.

The verbal students when compared to the visual students, in general on preparatory materials, spent more time reading and less time watching videos and still performed the poorest across most categories (assignments, MT, final). This would seem to indicate that the preparatory materials provided may not have been the most effective in meeting this group's preferred delivery approach. Previous studies have shown that students perform better when there is a match (or fit) between learning style and learning materials.[10-15,17] To see this disparity in time spent on the various tasks between ILS categories in a more visual way, Figures 3 through 5 are provided. The trend of time spent on reading can be seen in Figure 3, where average time is broken down by ILS group and by type of assignment (MATLAB or C/C++). It is clear there is a trend with the "strong verbal" students spending the least average time on reading, and the "strong visual" and "moderate visual" spending the most time on watching videos in Figure 4. Not surprisingly, all ILS categories spent more time reading for the MATLAB assignments since MATLAB is inherently a more visually-oriented programming language. Surprisingly, Figure 5 shows that the "strong verbal" cohort spent on average 0.20 hours less per assignment, regardless of programming language. This could be a result of so many issues for the strong verbal learners in an engineering classroom ranging from lack of appropriate and effective preparatory materials to a mismatch in instructor delivery approaches that it cries out for further study.

Tables VI and VII show a summary of the results of questions students were asked to respond to after completion of the Felder ILS (Table VI) and after completion of the course (Table VII). In Table VI, of the 182 participants (82%) that thought their ILS scores reflected what they expected, 124 participants (68%) said they already targeted their learning styles when studying. Of those who said their learning styles were not what they expected, 30 participants (77%) of these students said they would make changes in the future to target their ILS learning style. After completion of the course, approximately 70% of the responding students (99 total) said they preferred the inverted style of classroom.

Previously reported results comparing the new inverted classroom performance to the old traditional lecture-style classroom showed no statistical difference between the grades on the course final exam from both classroom styles, suggesting that the new inverted approach did not harm students. [18] In addition, the timing of the material was such that the programming instruction was in the first semester of their college experience rather than the second as it was for the traditional setting. Therefore, the fact that students performed the same under both instructional pedagogies has more meaning when you consider that the students in the inverted class were first-term freshmen still adapting to college courses, life, and maturity. When considering individual performance rather than aggregate data, we found no correlations to time on task with performance. We had previously shown a strong correlation between individual preparation grade and the corresponding daily application grade [18] and strong correlations were also found between the sum of preparation and application grades compared to the quiz grades and the sum of the midterms and final exam indicating that the preparation activities were effective in introducing the material required to successfully complete the application activities. [18]

The results of the student survey indicate similar findings as evidenced by student open-ended feedback. The inverted approach does appear to reach multiple learning styles as evidenced by their feedback. It was also apparent that there is a period of adjustment to the flipped classroom which puts the responsibility for learning on the student, which also better prepares them for their future education. This is similar to what Jeremy Strayer found when comparing the traditional lecture-based course, to an inverted class. He states “Students in the inverted classroom were less satisfied with how the classroom structure oriented them to the learning tasks in the course, but they became more open to cooperative learning and innovative teaching methods.” [19]

Table VIII shows a summary of each of the four specific ILS learning style scales’ preferred learning material along with what is provided in the inverted classroom to support this learning style as proposed by the authors. These provide a basis to understand the student outcomes in the inverted classroom and why nearly 70% of the students at the end of the term preferred the inverted classroom approach. Table VIII has a number of strategies that the inverted approach, as currently implemented, provides to meet that particular learning style. The fact that nearly 70% of the student population that responded to this anonymous journal question seems to indicate that the inverted classroom is a good fit for about 70% of the student population. In addition, we previously reported that students who preferred the inverted classroom approach earned over 15% more extra credit than those that preferred the traditional lecture-based approach and over 10% higher than those that preferred a partially inverted approach. This may result from those students who prefer the inverted approach being more comfortable with learning independently.

Improvements can still be made in classroom preparatory materials to better fit the more verbal learning style student, in in-class activities, and also the individual instructor's in-class delivery of the daily activities to aid the more verbal learner. Females tend to have a more verbal tendency along with an intuitive tendency. [15] This combination of learning styles usually needs more time to process information. Hames and Baker suggested that by focusing learning materials on this ILS group of students which tends to be predominantly females and minorities would increase diversity in the engineering population. [15] This student population favors more in-class discussions which allow time for processing new concepts.

It is possible that the inverted preparation materials may help focus student learning which helps them become more efficient learners as indicated by short preparation times while keeping

Table VIII. Summary of Four ILS Learning Style Scales' Preferred Learning Material

	Active	**Reflective**
ILS Preference	Group; Application	Individual; Repetition
Inverted Approach Provides	Active application; In-class activities	Preparatory Materials

	Sensing	**Intuitive**
ILS Preference	Facts; Solving real world problems	Interpretations; relationships to link facts
Inverted Approach Provides	Preparatory work; Daily application assignments	Daily active assignments; Discussions

	Sequential	**Global**
ILS Preference	Linear, logical steps	Randomly absorb material
Inverted Approach Provides	Preparatory reading; Design process	Freedom of preparatory material; real-world applications

	Visual	**Verbal**
ILS Preference	Pictures, diagrams, demonstrations	Written and spoken explanations
Inverted Approach Provides	Preparatory videos; Daily application assignments	Daily group work; preparatory reading

average performance on preparation assignments and daily application assignments high. This seems to be more a result of the inverted classroom rather than specifically learning styles. Based only on the ILS Visual-Verbal scale, our preparation materials appear to not fully address the needs of moderate to strong verbal students enough. This could relate to female retention since females tend to rate higher on the verbal scale. [15] This issue still needs to be addressed across engineering courses.

In the future, we plan to run a comprehensive regression analysis on all four ILS scales, preparation time, and gender to see what correlates strongest with performance in addition to broadening the study population to all first-year engineering students.

Challenges/Limitations

This research design has multiple limitations. First, the sample population is limited to first-year honors engineering students; therefore the results may not be translatable to a general first-year engineering population. Investigating a broader cross-section of first-year engineering students will be a future emphasis for this study. In addition, the limited number of students who tested in the moderate to strong verbal category made the sample size too small for valid statistical comparisons.

Acknowledgment

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