Mapping Conventional Teaching Methods and Learning Styles in Engineering Dynamics

Dr. Meera NK Singh P.Eng, University of Calgary

Meera Singh has over 20 years of academic and industrial experience in the area of applied mechanics. She obtained her PhD. from the University of Waterloo, Canada, specializing in fatigue life prediction methods. Following her PhD studies, she joined the Department of Mechanical Engineering at the University of Manitoba, Canada, where she was a faculty member for 13 years. During that time, she conducted research primarily in the area of the fatigue behaviour of composite materials, was active in teaching courses in applied mechanics, and served as the Chair for the WISE outreach committee. Meera joined the Department of Mechanical and Manufacturing Engineering at the University of Calgary in 2015.

Dr. Leszek Sudak P.Eng., University of Calgary

The University of Calgary where he has been a faculty member since 2001. Since 2008 he has been the Associate Head for Mechanical Engineering. Leszek has earned a BSc (Specialization) in Mathematics, a BSc (Distinction) in Mining Engineering and PhD in Mechanical Engineering all from the University of Alberta. He completed a Post-Doctoral term at Queen's University. His research interests lie in the general area of continuum mechanics and numerical modeling with applications ranging from Biomedical Engineering to Materials Engineering. I have supervised a total of 10 MSc and PhD students throughout my career. My publication record consists of over 45 peer –reviewed journal publications in leading international journals with over 950 citations and an h-index of 15. I have made significant contributions in the area of composite mechanics research. Les has served on numerous University, National and International committees. He has served on the Schulich School of Engineering Undergraduate Scholarship Committee, member of the Schulich School of Engineering Undergraduate Committee, Schulich School of Engineering Post Graduate Committee and many others. He also served as a committee member on the Natural Sciences and Engineering Research Council of Canada (NSERC) for a Strategic Network Grant. He has been a member of several International Research Organizing Committees and currently is the Treasurer for the Canadian Congress of Applied Mechanics. Throughout his time at the University of Calgary Les has taught many undergraduate and graduate courses in Mechanical Engineering as well as general engineering classes such as ENGG 349 and ENGG 317. He has consistently maintained a high Student Approval Rating and has been awarded numerous Undergraduate Teaching Excellence Awards. These include: the University of Calgary Student Union Teaching Excellence Award (2014), the University of Calgary Engineering Students Society Excellence in Teaching Award (2014), the University of Calgary Department of Mechanical and Manufacturing Engineering Teaching Excellence Award (2012), the University of Calgary Engineering Students Society Excellence in Teaching Award (2011), the University of Calgary Engineering Students Society Excellence in Teaching Award (2006) and the University of Calgary Student Union Teaching Excellence Award (2005). In addition, Les has been actively involved as supervisor, mentor and examiner for many graduate students. In particular Les has been a member of 17 different supervisory committees. Les has served as an external examiner to the University for 3 final PhD defense examinations as well as participated as examiner for over 100 different graduate student examinations (such as MSc Oral defense, PhD candidacy and final oral defense as well as MEng comprehensive examinations).

Dr. Philip Egberts P.Eng., University of Calgary

Philip Egberts obtained his Ph.D. from the McGill University in Montreal, Canada specializing in Experimental Condensed Matter Physics, while completing most of his research at the INM-Leibniz Institute for New Materials in Saarbrücken, Germany. Following his PhD studies, he joined the Carpick Research Group in the Mechanical Engineering and Applied Mechanics department at the University of Pennsylvania as a Natural Sciences and Engineering Research Council (NSERC) of Canada Postdoctoral Fellow (PDF). He has been an Assistant Professor at the University of Calgary in the Department of Mechanical and Manufacturing Engineering since September 2013, where his current focus is on the investigation of atomic and nanoscale investigation of friction with the goal of making physical and predictive models of friction. More recently, he has been expanding topics to include engineering tribology, to improve surface engineering for automotive applications and examine lubrication mechanisms for drilling in the oil and gas industry. In July 2015, he was appointed as Associate Head Graduate Studies in Mechanical and Manufacturing Engineering.

Mapping Conventional Teaching Methods and Learning Styles in Engineering Dynamics

Meera Singh, Leszek Sudak, and Philip Egberts
meera.singh@ucalgary.ca; lsudak@ucalgary; philip.egberts@ucalgary
Department of Mechanical and Manufacturing Engineering
University of Calgary
40 Research Place NW, Calgary AB T2L 1Y6

March 20, 2016

Abstract

Engineering dynamics is considered to be one of the most challenging courses at the University of Calgary. For the past 10 years, the failure rate has hovered around 15-20%. This rate has serious implications on student retention for the approximately 400 students each year that require engineering dynamics as prerequisite for several other core courses. An initial failure of Engineering dynamics results in a minimum of a half a year extension to a student's degree program. Furthermore, a second failure of this course requires the student to withdraw from the Engineering school.

The course is offered in multiple sections, taught by several instructors using uniform teaching and assessment methods. Teaching evaluations vary across sections from very poor to those that result in teaching awards, but these results cannot be correlated with the differences in student success rate. The school assures uniformity in teaching and evaluation methods across sections. Specifically, lectures and tutorials involve theory derivations, and example problem solutions. Assignments and exams are geared toward students solving textbook type problems. Although this type of course delivery method is tried and true, and addresses most common learning styles, the student success rate for the course as a whole suggests a need for reflection.

The objective of this paper is to improve student outcomes by examining the demographics and learning styles of a the Engineering Dynamics class of fall 2015. The students were surveyed to determine their learning styles using the Felder-Soloman index of learning styles (ILS) survey. The analysis shows that there are program-specific systemic barriers hindering student success. Furthermore, the learning style survey results indicate that student learning could improved by adopting a more balanced approach to teaching. Associated learning tools, specific to the dynamics curriculum, designed to address the learning outliers are suggested.

1 Introduction

The Schulich School of Engineering (SSE) at the University of Calgary consists of five departments (Chemical, Civil, Electrical, Geomatics, and Mechanical Engineering) and offers specialized majors programs such as Oil and Gas. All students in the SSE take common engineering courses in the first year of their studies. At the end of the first year, students compete for a spot in their choice of program associated with a department or major. As there are limited spaces in each program, students are then offered admittance into a program based on their first year grades. This means that students may not be admitted to the program ranked as their first choice. Normally Chemical and Mechanical Engineering are the most sought after programs, driven by Calgary's industry (primarily oil and gas). The variance in popularity for the various programs, coupled with differences in program enrolment caps, leads to significant differences in the minimum entrance grades between the various programs. From highest to lowest entrance grades, the undergraduate programs students would choose normally follow the order: Chemical, Mechanical, Oil & Gas, Civil, Electrical and Geomatics.

Each program has a discipline specific curriculum and associated courses. Courses that cover material that is required across the various programs are normally taught in the "common core". Engineering Dynamics (ENGG 349) is one such common core course, required in second year in all of the five main programs except for Electrical Engineering, has a typical yearly enrolment of 350-400 students.

Although based on elementary calculus and a single law of motion, Engineering Dynamics is considered to be one of the most challenging second-year courses. The course failure rate over the past 10 years has been around 15-20%. A student's failure in this course has serious implications on their overall success within the SSE. First, failure has implications on scheduling. If a student is required to repeat the course and it is a required prerequisite for their program, their studies must be extended at least half a year. Second, a failure reduces a student's overall grade point average (GPA) and this may affect their ability to continue on in the program or qualify for financial aid. Finally, if a student fails the course more than once, the student may be required to withdrawal from the SSE.

The global objective of this work is to improve student outcomes in Engineering Dynamics. In order to meet this objective, an in depth analysis was conducted on the Dynamics class of 2015 to identify and respond to all significant factors that contribute to poor student outcomes. The results of this analysis are presented in this paper. Section 2 focuses on the key demographics of the students enrolled in the course and their correlation with student outcomes. In doing so, an attempt is made to identify systemic factors that may be altered to promote an improvement in these outcomes. Section 3 focuses on how the delivery of the course itself can respond to better address the learning styles of the students taking the course. We present a description of the Index of Learning Styles (ILS) survey[1] associated with the Felder-Silverman Learning Style Model (FSLM)[2] in Section 3. Based on the results of the survey conducted in ENGG 349 of Fall 2015, a learning style profile of the class and instructors is then constructed and correlations are made with the key demographics and student success. Finally, this data is used to address the mismatch between the conventional dynamics teaching and evaluation methods used by the faculty, and the learning styles of the students in the classroom. Based on the results of the study, Section 4

Table 1: University of Calgary Grade Point Average – Letter Grade Conversion Chart.

Letter Grade	A+, A	A-	B+	B	B-	C+	C	C-	D+	D	F
GPA	4.0	3.7	3.3	3.0	2.7	2.3	2.0	1.7	1.3	1.0	0

Table 2: Grade Distribution in the 2015 Dynamics Class.

Program	Number of Students	Percent Female	Average GPA Female	Average GPA Male	Overall GPA
Chemical	90	33%	2.80	3.22	3.08
Civil	72	43%	1.67	2.49	2.27
Mechanical	142	28%	2.42	2.70	2.62
Oil and Gas	24	26%	1.90	1.95	1.94
Geomatics	13	73%	1.19	1.70	1.93
Other	9	60%	Not Available	Not Available	1.99
School Wide	352	34%	2.29	2.88	2.57

presents recommendations to improve the overall student outcomes in Engineering Dynamics.

2 Analysis of the Profile and Grades of Students Enrolled in Engineering Dynamics in Fall, 2015

In 2015, 371 students were enrolled in Engineering Dynamics. Of these students, 352 students (34% Female) have received a grade. The remaining 19 students, who have deferred their final exam, are not accounted for in this study. The success of the students in Dynamics was taken solely as a function of their GPA in the course. It should be noted that the University of Calgary works on a 4 point GPA scale, with the corresponding letter grades provided in Table 1.

Table 2 presents the final grades in Dynamics, broken down by the student's program, and then further by gender. The high numbers in Mechanical Engineering reflect the overall size, relative to Chemical Engineering (second largest), and Civil Engineering. As can be seen from the bottom of Table 2, the average school wide GPA was 2.57. The average GPA in the programs follows the same order as the aforementioned minimum entrance requirements by program. This result is to be expected, as those who did the best in first year would be expected to continue to achieve high results in their second year. On the other hand, the material in Dynamics is more aligned with the interests and strengths of Mechanical and Civil Engineers than with Chemical Engineers. This alignment may indicate that students are not necessarily enrolled in the program that is best aligned with their strengths and interests because of the program enrolment caps.

With a dedication to diversity, the SSE has historically has a wide variety of outreach endeavours aimed at increasing the participation of females within the school. Partly as a result of such efforts, the percentage of females enrolled in ENGG 349 was 34%, well above the national

Table 3: Quantification of the number of students that must repeat the 2015 Dynamics Class.

Program	Number of of Students	Percent F's	Percent D's	Percent F's & D's	No. of Students Required to Repeat the Course
Chemical	90	2.2%	1.1%	3.3%	2
Civil	72	12.5%	15.3%	27.8%	20
Mechanical	142	9.2%	5.6%	14.8%	21
Oil and Gas	24	20.8%	8.3%	29.1%	5
Geomatics	13	23.1%	7.7%	30.8%	3
Other	9	22.2%	33.2%	55.5%	2
Faculty Wide	352	8.9%	6.6%	15.5%	53

average of females in engineering undergraduate programs across Canada, which is around 20%[3]. On the basis of the three largest programs, the average GPA of the females follows the same trend as the males. Female students in Chemical Engineering achieve the highest GPA's, followed by Mechanical, and finally Civil Engineering. Interestingly, Civil has the highest percentage (43%) of female enrolment of the three programs. Table 2 indicates that school wide, male students are outperforming female students. This gap implies that there is room for further measures to be taken to promote female retention within SSE. The variance in the GPA between male and female students in Dynamics is analyzed further in the context of learning styles in Section 3.

The percentage of D's and F's is tabulated separately in Table 3. In particular, Mechanical and Civil Engineering programs require a minimum grade of C- (1.7 GPA) in order for their students to use ENGG 349 as a prerequisite for subsequent courses. In all other programs ENGG 349 is not a prerequisite for any other courses, necessitating a lower passing grade of a D (1.0 GPA) for it to be counted towards their degree. If failure of this course is calculated for the individual program requirements, a minimum of 53 of the 352 students (15%) of this class will be required to repeat this course. Of the major programs, this repeat rate is most significant in Civil and Mechanical Engineering, where 27.8% and 14.8% of their students will be required to repeat this course, respectively. Again, this should be juxtaposed to Chemical Engineering, where only 2.2% will need to repeat the course to meet their degree requirements. This significant repeat rate in Civil and Mechanical Engineering has an important effect on their program length since in the following term, these students are normally scheduled to take a fluid mechanics course, which requires ENGG 349 as a prerequisite. Currently, to keep students on schedule with their programs, the SSE offers ENGG 349 in the spring and the fluid mechanics course in the summer. Over the past 5 years, the failure rate in this spring course has been on average 7.7%, which indicates people are failing for the second time.

Due to the volume of students, the course was offered in three different lecture sections (Section A, Section B, and Section C) in the same term, by three different professors (Professor A, Professor B and Professor C, respectively). Students in the same program were enrolled in the same lecture sections, with the intent that example problems could be tailored to discipline specific examples. However, all students were evaluated based on the same material, i.e., they were given the same assignments, midterm, and final exam, and grades were set based on a

Table 4: The Migration Pattern Between Sections, by Program (*Indicates the class majority).

Program	Section A		Section B		Section C		Percent Surveyed
	Number Enrolled	Number Surveyed	Number Enrolled	Number Surveyed	Number Enrolled	Number Surveyed	
Chemical	1	2	87*	57*	3	3	67.4%
Civil	0	0	0	4	72*	39*	58.9%
Mechanical	142*	16*	0	34	1	23	49%
Oil and Gas	0	0	24	11	0	0	35.4%
Geomatics	0	0	3	4	10	7	73.3%
Other	0	0	6	0	3	1	50.0

collective scale.

It should be noted that Section A and Section B were offered in different rooms, but at the same time of the day three days a week, whereas Section C was offered in a neighbouring room to Section A, and it began right as Section A ended. For the most part, there was no timetabling conflicts and students could migrate freely between the lecture sections. It should be noted that Professor B is extremely popular among the students and has won several teaching awards for their efforts in teaching this course over the past 10 years. At the beginning of the semester students flocked to Professor B's lecture section. To prevent a visit from the fire marshal, Professor B's classroom was changed to one that would accommodate a larger number of students. Unfortunately, this new classroom was on the other side of the campus, remote from the main engineering buildings, and this move may have acted as a deterrent to students attending lectures.

Table 4 gives an indication of the student migration pattern by program between lecture sections. The total number of students enrolled reflects those originally enrolled in each section, and who additionally have received a final grade in the course. The number of students surveyed represents the students that were present on the last day of class and chose to take the learning style survey during the class. Although the last lecture is normally a popular lecture since the final exam is discussed, it is estimated that over 90% of those in attendance on the day of the survey chose to complete it. It is duly noted that this data is not an exact representation of the average student attendance. For the most part, it can be concluded that the students in all programs, except for Mechanical Engineering, remained in the lecture section that they were enrolled in. The discrepancy between students enrolled and attending in those programs in Lecture Sections B and C is a reflection primarily of the attendance rate the day of the survey. The majority of the Mechanical Engineering students enrolled in Section A, chose to attend either Lecture Section B, or C, or not to attend class the day of the survey.

Table 5 shows the average GPA of the students enrolled in ENGG 349. On the surface the major indicator of the relative success of the execution of the lectures is the GPA of the enrolled students. If this is, and it often is, taken without context, it would indicate that Lecture Section B was executed the most successfully, followed by Lecture Section A, and then C. However, the table indicates that this outcome is also a reflection of the programs that the students are enrolled

Table 5: Grade Distribution By Lecture Section for students who received a grade.

Lecture Section	Total Enrolled	Enrolled GPA	Surveyed GPA	Percent Surveyed
A	143	2.63	2.83	13.3%
B	120	2.76	2.97	90.8%
C	89	2.23	2.48	83.1%
Overall	352	2.57	2.78	57%

in, with Section B's majority comprising of the most successful Chemical Engineering students, Section A's of Mechanical students, and Section C's of Civil Engineering students.

In each lecture section, the enrolled GPA additionally does not reflect the significant migration of students between the lecture sections. However, it is difficult to make conjectures about the relative success of the execution of each lecture based on the surveyed GPA. Nonetheless, given the relative success of the Mechanical Engineering students, one would expect that their influx into Section B would negatively impact the surveyed GPA in that section, whereas their influx into Section C should have positively impacted the surveyed GPA. However, this impact was not seen in either Sections B nor C, implying that the relative styles of the lectures may have marginally influencing grades.

The students that conducted the survey had on average a GPA that was 0.2 higher than the overall section average in all three of the lecture sections. If this data is looked at from the point of view of attendance rate, it can be concluded that those who attended lectures attained GPA's that were higher on average than those that did not. This implies that a significant effect that the more popular lecturer has had on the students' success is the ability to motivate the students to attend lectures.

3 Evaluation of Student Learning Styles

In this section, we examine the learning styles of the students and professors within the Engineering Dynamics Fall 2015 class, as defined by the FSLM. The model itself and the associated survey delivered to the students is detailed in Section 3.1. Section 3.2 presents the results and analysis of the examination with the global intent of highlighting how teaching methods can be altered to be more conducive to the students' learning styles within the class.

3.1 The Felder-Silverman Learning Style Model (FSLM)

Apart from the FSLM, numerous learning style models have been proposed in the literature, including Kolb[4,5], Dunn and Dunn[6], and Meyers-Briggs[7]. All models classify students according to scales that are defined based on the way learners receive and process information. The FSLM incorporates some elements of the Myers-Briggs model and the Kolb's model. The main reasoning for its selection is that the FSLM focuses on aspects of learning that are significant in engineering education. As a benefit to this study, not only have there been extensive studies, such as Refs.[8,9] that have aimed at validating the survey, there is also a great deal of published data[9,10] that we can draw upon for comparison.

The FSLM consists of four dimensions: *Active*/Reflective; *Sensing*/Intuitive; *Visual*/Verbal; and *Sequential*/Global. For the purpose of this study, only highlights of the four dimensions, detailed in Ref.[2], will be described here. The first dimension distinguishes between active and reflective learning styles. Active learners tend to learn by working actively or trying things out, and enjoy working in groups. On the other hand, reflective learners learn best by thinking through and reflecting on the material. They prefer working alone or with one close friend.

The second dimension of the FSLM differentiates between sensing and intuitive learning. Sensing involves receiving information through senses. Accordingly, sensors have a tendency to respond well to facts, data, and experimentation, and solve problems by standard methods. They tend to be patient with detail buy are not comfortable with symbols, such as words. Intuition involves receiving information though the unconscious, or more specifically through speculation, imagination, and hunches. In contrast to sensing learners, intuitive learners prefer principals and theories and are good at grasping concepts rather than memorizing facts. Intuitive learners have the advantage in timed exams since they are more comfortable with symbols, such as words, and can process them more easily than sensors. However, their lack of attention to detail may lead them to careless mistakes.

The third dimension of the FSLM contrasts visual and auditory learners. Visual learners receive information best in mediums such as pictures, diagrams, and symbols. Additionally, visual learners retain the information best when they observe it, and may forget if they just hear it. Auditory learners receive and retain information best that they hear. Accordingly, they learn well through discussions and verbal explanations.

The fourth dimension of the FSLM contrasts sequential and global learners. Sequential learners follow a linear reasoning process when solving problems. They learn best when material is presented to them in a steady progression of difficulty. In contrast, global learners use a holistic thinking process. Their learning process on a particular subject would be to absorb elements of the subject matter first before they see the connections between the parts and see the whole picture. Since this whole picture is of importance to global learners, they tend to respond well to overviews and broad knowledge.

The ILS survey is a 44 question survey that was developed by Felder and Soloman for identifying an individual's learning styles in accordance with the FSLM. Each question is designed to place the learner's preference within each of the four dimensions. That is, each question is answered by a selection of either a and b, where answer a corresponds to one learning type within each dimension (active, sensing, visual, or sequential), and answer b corresponds to the contrasting preference (reflective, intuitive, verbal, or global). Depending on the relative number of a's versus b's that a learner answers for the questions relating to given dimension, the learner can be described as one with a strong, moderate, or mild preference for one learning style over the other.

Table 6: Summary of Class Learning Style Preferences.

Sampled Population	Active	Sensing	Visual	Sequential	Number of Respondents
All Sections	51.2%	79.2%	78.7%	71.5%	201
Chemical	42.6%	75.4%	72.1%	70.5%	62
Civil	62.2%	88.9%	80%	73.3%	43
Mechanical	53.7%	75.7%	86.5%	67.6%	73
Civil [11]	69%	86%	76%	54%	110
Mechanical [11]	53%	67%	84%	45%	94
Oil & Gas	54%	90.9%	63.6%	72.7%	11
Geomatics	48.5%	81.8%	63.6%	100 %	11
Male	55%	79%	82%	72%	125
Female	45%	78%	72%	70%	76

3.2 Results and Analysis from the ILS Survey Data for the 2015 Engineering Dynamics Class

Voluntary participation in the ILS survey was requested after having been announced a week in advance of surveying the students using the online course management system. The survey took place on the last day of lectures, and it is estimated that over 90% (total of 216 students) of those students in attendance chose to participate. Following the completion of the final exam, and after the grades were set, the ILS data was analyzed to determine the distribution of learning style for each student in the course.

The data analysis was designed to answer the following questions:

1. What is the distribution of student learning styles in the class?
2. Do the learning styles of the students vary by program?
3. How does the learning style of the students match with the course instructors?
4. Does gender have an influence on the learning style?
5. How are learning styles correlated with the student performance, as measured by their individual grade achieved in the class?
6. Do the students required to repeat the class have consistencies in their learning styles?

Table 6 summarizes the learning style data for ENGG 349 analyzed according to program and gender. The percentage of the total respondents that preferred the stated learning style within each of the four dimensions is presented for each of the sampled populations. In Table 6, the learning style preferences of the respondents in all lecture sections is first presented. Overall, the students were more active (51.2%) than reflective, they were more sensors (79.2%) than intuitors, they were more visual (78.1%) than verbal, and more sequential (71.5%) than global. The learning style that was preferred within each dimension is in agreement with numerous studies that have been conducted in engineering classrooms. A summary of some of these studies is given in Ref. [9].

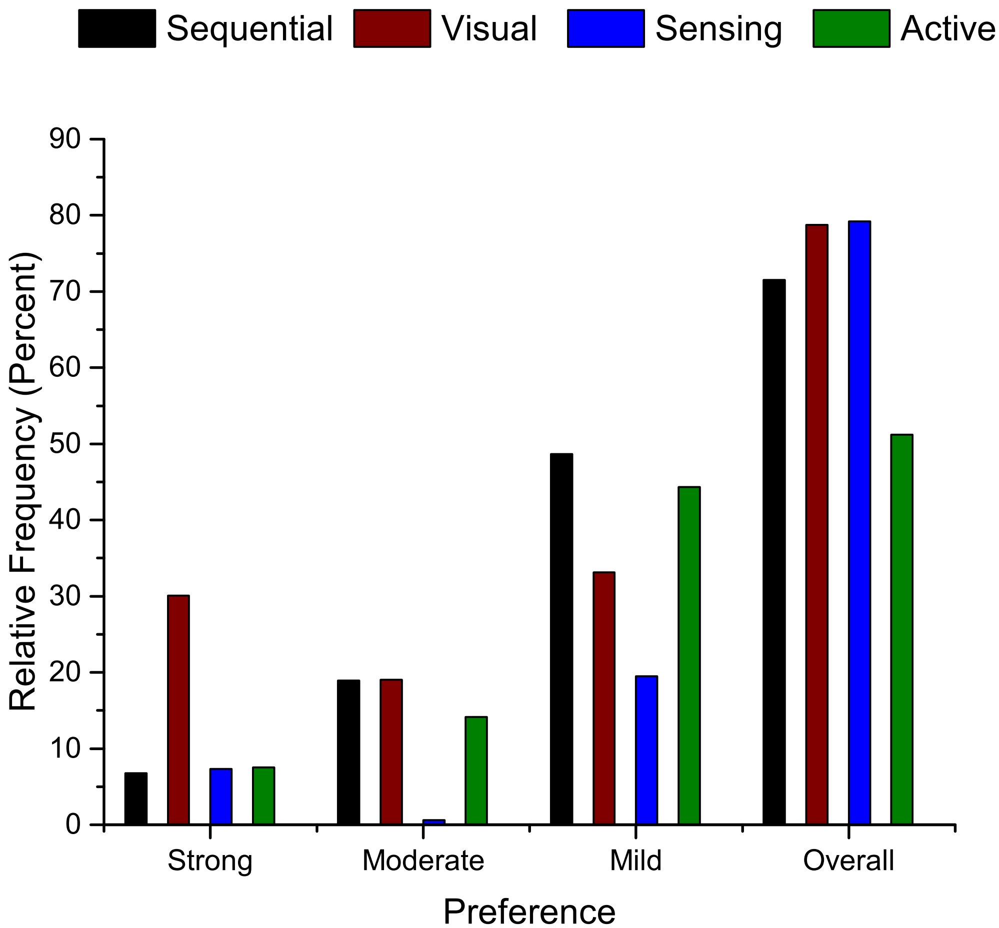

Figure 1: Distribution of the learning styles of the students who took the survey in ENGG349 in Fall 2016, consisting of 216 respondents.

Figure 1 gives an indication of the level of preference for each of the styles for all sections. For example, of the total number of respondents that preferred a sequential learning style, 7% of those had a strong preference, 18% a moderate preference, and 48% a mild preference over the global learning style. Figure 1, also consistent with studies in Ref.[9], shows that a large percentage of the respondents had only a mild preference of one style over another within each dimension. It is noted in Ref.[9], that care must be taken in categorizing the students with only mild preferences since they would be expected to shift between preferences rather than consistently exhibit behaviour associated with a single learning style. These students with mild preferences may be more balanced and respond well to a larger array of instructional methods.

Figure 2 presents the learning style preferences by program for each of the four dimensions in the FSLM. For the most represented programs in ENGG 349 (Chemical, Civil, and Mechanical), there is a negligible difference in the number of sequential versus global learners. The Mechanical Engineers tended to be slightly more visual than those enrolled in other programs, and a larger percentage of Civil Engineers were sensors than were in other programs. It is interesting to note that the Chemical Engineering students had a larger percentage of reflective

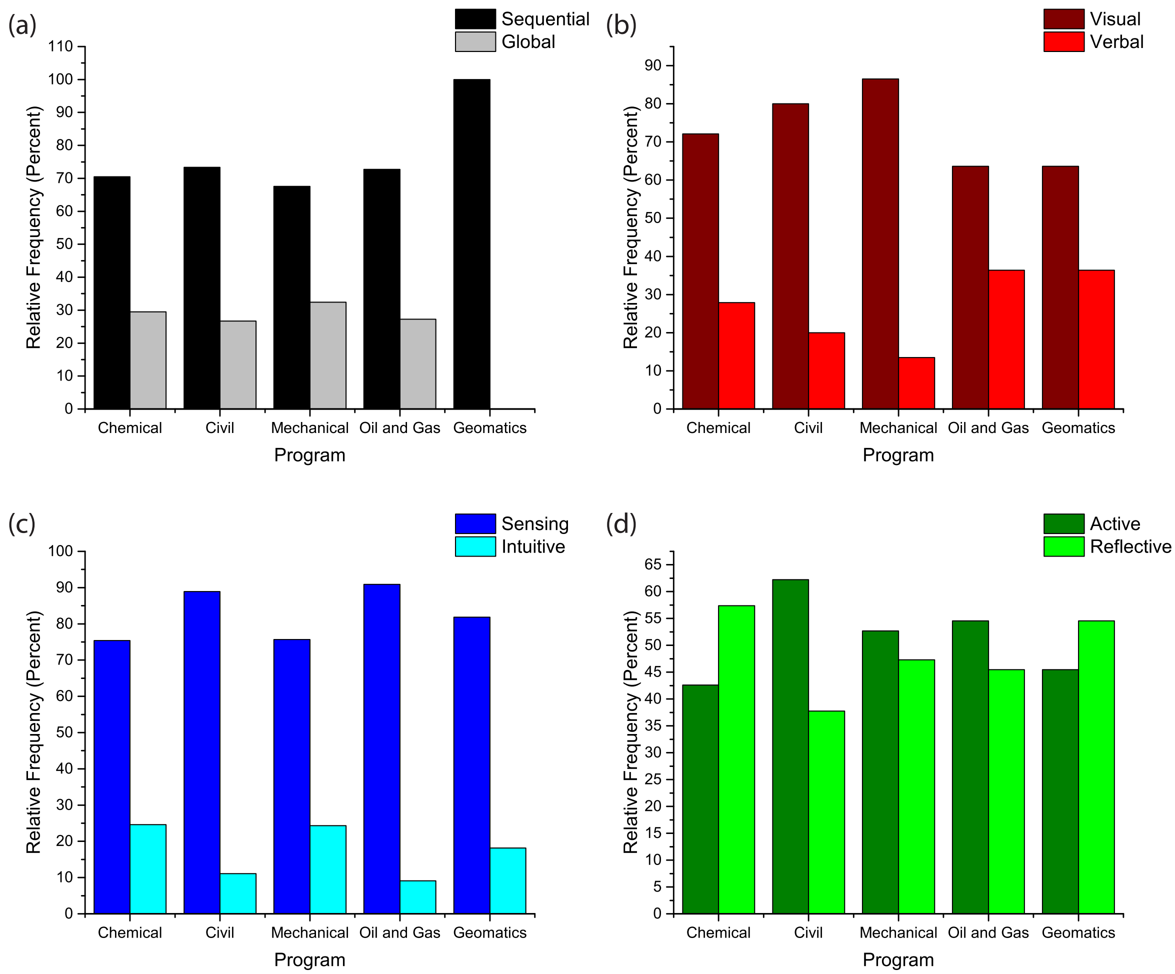

Figure 2: Distribution of the learning styles by program.

learners than active learners, and the reverse was true for the other major programs, particularly Civil Engineering. A summary of the numerical data for each program is presented in Table 6. ILS data from the University of Sao Paulo conducted on their Civil and Mechanical Engineering students[11] is also given in Table 6 for comparison. It is interesting to note that the relative learning style preferences between their Civil and Mechanical Engineering students is the same as between our students in these programs. Specifically, in both studies the Mechanical Engineering groups have a smaller percentage of active learners, sensors, and sequential learners and a larger percentage of visual learners than do the Civil Engineering groups. This consistency may lend support to the conjecture that there is a difference in learning style preferences between the engineering students enrolled in the different programs. This fact is not surprising since studies, such as those summarized in Ref.[9], have shown marked differences in the learning style profiles of the students in different faculties, with engineering students on the whole, sharing relatively similar preferences.

The results of the analysis of learning styles by gender is also summarized in Table 6. The percentage of female students that prefer sensing and sequential learning styles is virtually the

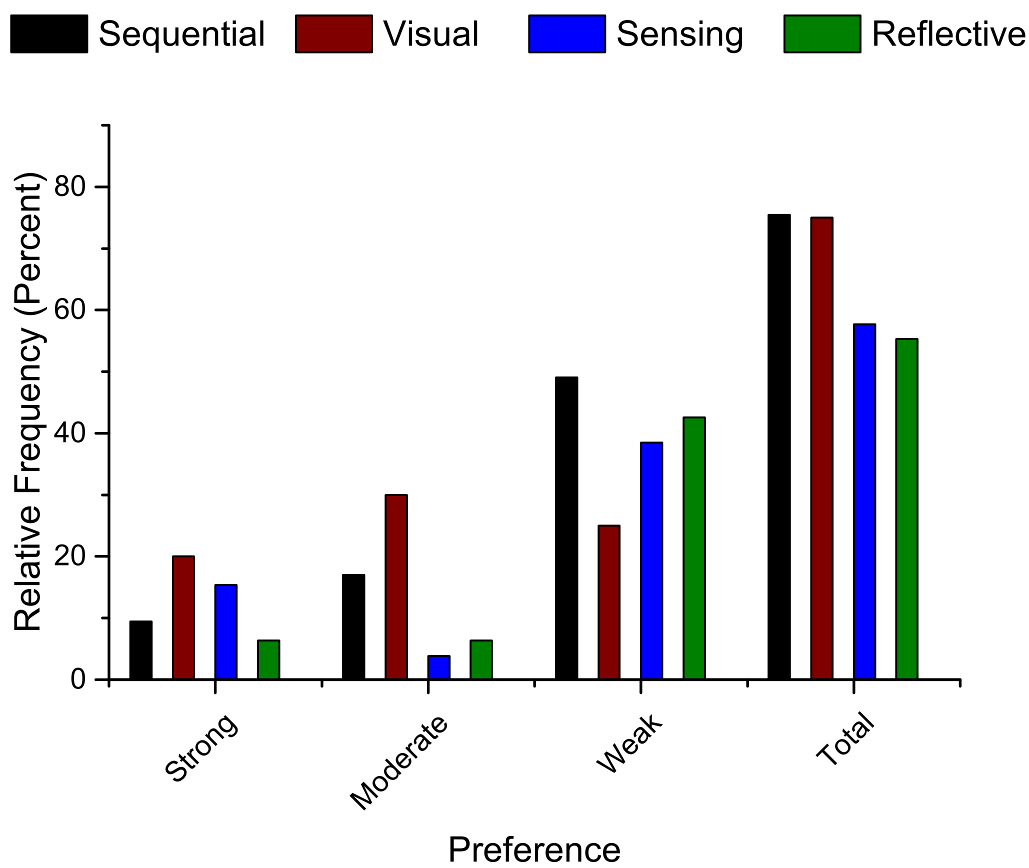

Figure 3: Distribution of the learning styles for female students in ENGG 349.

same as the male students. However, the data suggests that 10% more of the males are active and visual learners than are the females. In a comparative study of engineering students, a very similar trend in the differences in learning styles between male and female participants was observed[12].

Since the males in the class outperformed the females, it was necessary to look further into the learning styles of the females to determine whether or not the preferences of the female students were strong or moderate, rather than mild. If the female students had strong or moderate learning preferences, it may suggest that they may not respond well to teaching methods that are not aligned with their learning style. Figure 3 dissects the learning styles of the female participants. There is a significant number of females that show strong and moderate preferences particularly in the sequential and visual learning style categories. This highlights the need for a teaching style that is adaptive to all learning styles.

When analyzing the learning style preferences by lecture section, no significant difference were found between students enrolled in the sections and those of the entire class. In other words, students were not migrating to lecture sections based on learning style preferences. Table 7 shows

Table 7: Learning Style Preferences of Professors teaching Lecture Section A, B, and C.

Learning Style Dimension	Professor A	Professor B	Professor C
1	*Moderate Active*	Strong Reflective	*Moderate Reflective*
2	*Moderate Intuitive*	*Moderate Intuitive*	*Strong Intuitive*
3	Moderate Visual	*Moderate Verbal*	Strong Verbal
4	*Strong Global*	Strong Sequential	*Moderate Global*

the results of the ILS survey given to the three professors teaching those sections. The italicized results indicate a mismatch between the preference of the majority of the students and the preference of the professor. It is interesting to note that all of the three professors had either moderate or strong preferences for one learning style over another within each dimension. This is in contrast to a large amount of students who seemed only to have mild preferences for one style over the other. This italicized preferences indicate a mismatch between the instructors learning style preference and that of the majority of the students in their respective sections. It is interesting to note that Professor B's (the most popular professor) learning styles more closely matched those of the students enrolled in their class than did Professor A's or C's. However, all three professors exhibit different learning preferences than the class they were teaching indicating major learning/teaching style mismatches within the sections.

The final grades in the course were plotted against learning style for each of the four dimensions of the FSLM in Figure 4. The graphs indicate that, for the most part, there are negligible differences in the final grades of students that preferred one style over another, except in the active/reflective dimension. In this case, all degrees of reflective learners outperformed the active learners. This fact may be a reflection of the high performing Chemical Engineers being predominately reflective learners. Although there were no students surveyed that had a strong preference for intuitive learning, those that had a moderate preference for intuitive learning actually achieved the highest marks overall in the course. This result may be due primarily to the fact that all three of the instructors were intuitive learners. It should be noted that the students that had strong preferences for sequential, verbal, intuitive (moderate) and reflective learning styles achieved the highest marks in the course. These learning styles are consistent with Professor B's learning styles, and it may be possible that these students belonged to Lecture Section B, where the overall grade and attendance was higher.

Figure 5 shows the learning style preferences for the F & D students. Due to the relatively small number of students, it is difficult to make conjectures of the influence of their learning preferences on their outcome. However, their is a large percentage of weak students that have strong and moderate preferences in all four of the learning dimensions. If the teaching methods do not match the learning preferences, these students may experience difficulty in assimilating and retaining the knowledge.

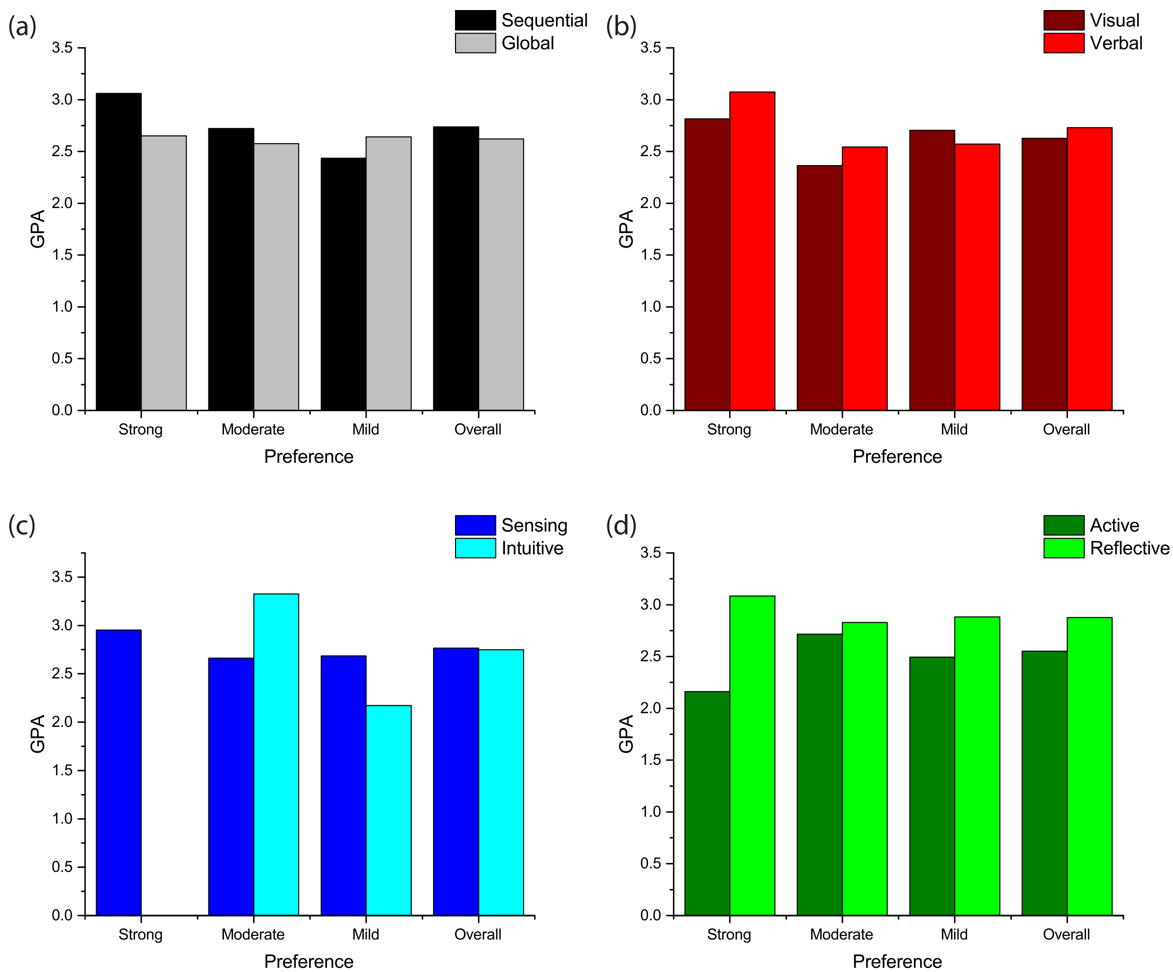

Figure 4: GPA versus learning style preference.

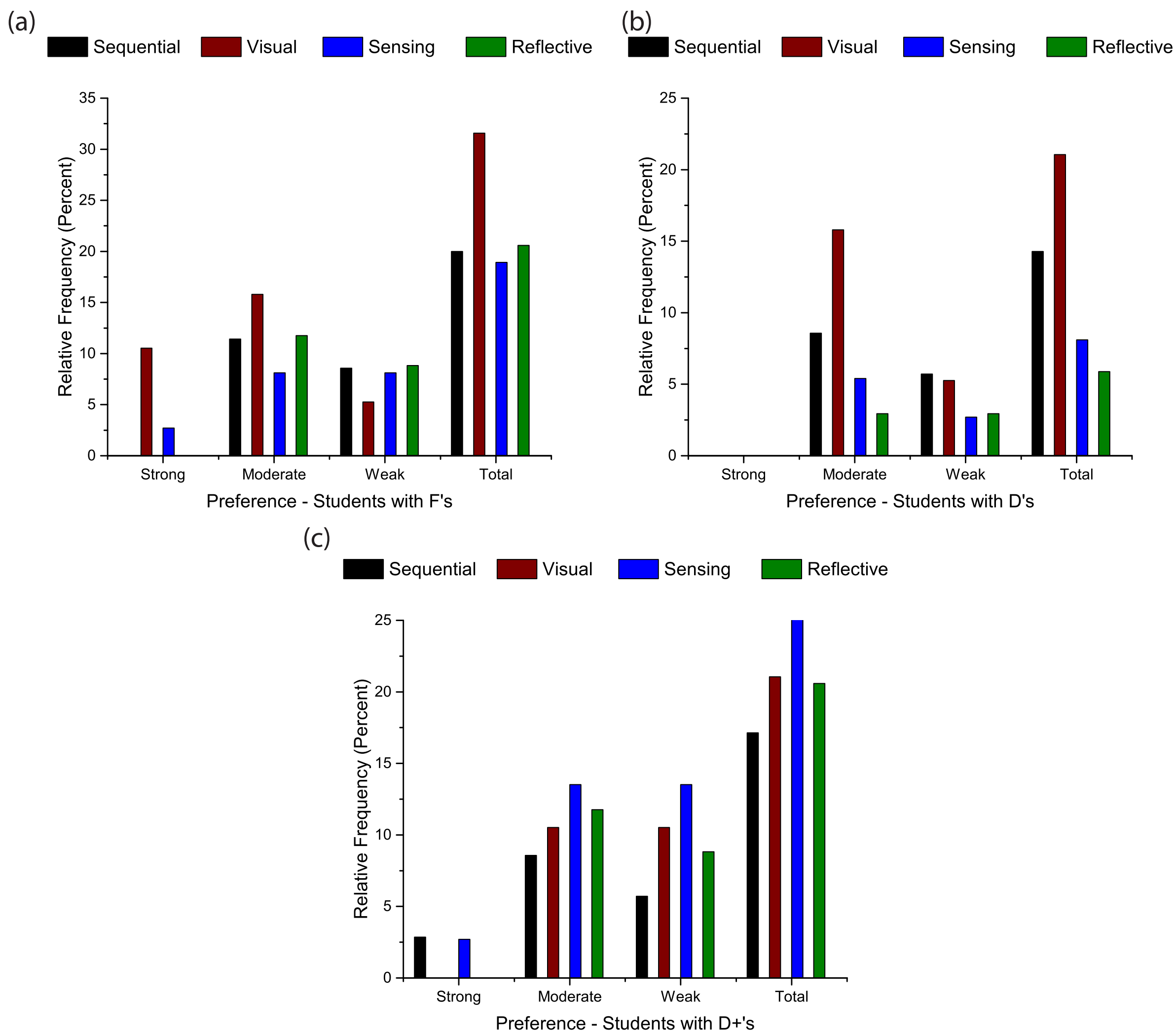

Figure 5: Distribution of the learning styles of the students for students achieving an F, D, or D+.

4 Summary

Section 3 highlighted systemic difficulties that affect student outcomes in Engineering Dynamics. Firstly, the comparison of the grade distributions between the programs has highlighted the fact that caps on student enrolment within each program has resulted in students in programs that may not be aligned with their strengths and interests. That is, Engineering Dynamics is best aligned with the discipline of Mechanical and Civil Engineering, yet the Chemical Engineering students are significantly outperforming all others in this course. Moreover, the relative success of the students between programs follows exactly the same order as the relative minimum entrance requirements between programs.

The analysis also brought forth the necessity for the course administrators to not make decisions regarding the direction of the course based on conjectures that have been made on the relative GPA between the lecture sections. The relative success of each lecture section is most closely a function of the program of the majority of student enrolment. The analysis of the class data brought forth that students that attended lectures outperformed those that did not. Although attendance rate is not absolutely controllable by a professor, some measures can and should be taken by them to encourage students to attend and actively engage in lectures. From an administrative perspective, seemingly small decisions, such as the location of the classroom and the selection of lecture section for the most popular professors, should not be taken lightly, as they effect attendance rates, and therefore student outcomes.

For the most part, although the professors teaching the course do not necessarily have coincident learning styles, their teaching methods are similar due to the nature of the course and give preferential treatment to certain learning styles over other. In all sections, the chalk board was used to deliver lectures that, for the most part, started with a theoretical development followed by a presentation of an example problem. This logically ordered progression of the material is well suited to sequential as opposed to global learners. However within this dimension, the effect of the learning style of the professor can influence the delivery method. That is, instructors with a global learning style may deliver the sequential developments in the fashion of a global learner. Due to the shear volume of material, there is little time in the lectures for the students to actively engage with the material. By their nature, lectures strongly favour auditory learners over visual learners and the medium of knowledge transfer, the chalkboard, is not the best choice available to produce diagrams that visual learners can easily assimilate. Similarly, lectures favour intuitive learners versus sensors, as the sensors have a relatively difficult time with the symbols or words that they must assimilate. The timed exams, that are often incomplete when returned, again favour intuitive learners. Moreover, all professors teaching the course were intuitive learners and as such, their method of delivery leaned towards principals and theories rather than experimentation.

The lack of time for student engagement in lectures did not do service to the active learners within the classroom. Moreover, the theoretical developments in the lectures may have been more suitable for the reflective learners than their more experimental active counterparts. Students are assigned problems that are vastly different to reflect a wide array of practical applications. It is the ability of the students to properly model the physical phenomenon in each question that encourages them to think like engineers. In other words, reflective thinking is absolutely mandatory in this course, and the success of reflective over active learners supports this.

Table 8: Class learning preferences compared to delivery style bias.

Learning Style Dimension	Active/ Reflective	Sensing/ Intuitive	Visual/ Verbal	Sequential/ Global
Class Learning Preference	Active (51.2%)	Sensing (79.2%)	Visual (78.7%)	Sequential (71.5%)
Bias in Teaching Methods	Reflective	Intuitive	Verbal	Sequential

Apart from lectures, there are weekly tutorials in ENGG 349. In these tutorials, graduate teaching assistants present example problems that are similar to the assignments. They use the chalkboard to present the problems in a sequential fashion, very similar to the lectures. As a result of this formula, the tutorials, like the lectures, are more conduce to students that are sequential, auditory, intuitive, and reflective.

The mismatch between the class learning preferences and the delivery style bias is shown in Table 8. This table highlights the fact that the structure of the course itself is not conducive to the majority of the class that are sensors and visual. Furthermore, although the course is structured to give bias to sequential learners, two of the three professors showed moderate and strong tendencies towards a global learning style. Their presentation of the theory may have followed their more global style tendencies. The relative popularity of Professor B may have been in part due to their sequential learning style. The findings of this study cannot answer these questions.

In order to better address the learning styles of the entire class, it is recommended that a more balanced approach to the lectures and tutorials be considered[13]. The adoption of a balanced approach would at least pay tribute to students with strong and moderate preferences within the four dimensions that may currently be opposite of the bias in instructional methods presented in Table 8. In turn, this may better address the learning styles of both genders within the classroom, and of those at the bottom of the class that are required to repeat the course. Inductive teaching methods that are more student centred can easily be adopted within the classroom, if the instructor is aware of them and wishes to do so. Inquiry-based learning and problem-based learning approaches would be particularly useful tools to aid the instructor in implementing these teaching methods. In the upcoming year, the format of the lectures will be altered accordingly and tutorials will become student centered workshops where students will fully participate in physical demonstrations and problem solving.

In conclusion, the analysis has demonstrated that there are a number of architectural barriers to student success in ENGG 349. These barriers result from factors controlled by both the administrative and teaching staff. The learning styles of the students in ENGG 349 are diverse, yet typical of most engineering students across the world. This fact suggests that instructors must close the gap between their teaching methods and their students' learning styles. A more balanced approach to teaching will likely increase student success and result in a reduced failure rate of the students.

References

[1] R M Felder and B A Soloman. Index of learning styles questionnaire, 2001. URL https://www.engr.ncsu.edu/learningstyles/ilsweb.html.

[2] RM Felder and LK Silverman. Learning and teaching styles in engineering education. *Engineering education*, 78(June):674–681, 1988. doi: 10.1109/FIE.2008.4720326. URL http://www.academia.edu/download/31039406/LS-1988.pdf.

[3] Natural Sciences and Engineering Research Council of Canada. *Women in Science and Engineering*, volume 2010. 2010.

[4] Alice Y Kolb and David A Kolb. The kolb learning style inventory — version 3 . 1 2005 technical specifi cations. *LSI Technical Manual*, pages 1–72, 2005. doi: 10.1016/S0260-6917(95)80103-0.

[5] D Kolb. *Experiential learning: Experience as the source of learning and development*. Prentice-Hall, 1984.

[6] Rita Stafford Dunn and Kenneth J Dunn. *Teaching students through their individual learning styles*. Prentice-Hall, 1978.

[7] I B Myers. *The Myers-Briggs Type indicator*. Consulting Psychologists Press, 1962.

[8] Malgorzata S Zywno. A contribution to validation of score meaning for felder- soloman ' s index of learning styles. In *Engineering Education*, pages 1–16. American Society for Engineering Education, 2003. URL http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.167.7813{&}amp;rep=rep1{&}amp;

[9] Richard M Felder and Joni Spurlin. Applications, reliability and validity of the index of learning styles. *International Journal of Engineering Education*, 21(1):103 – 112, 2005. doi: 0949/-149X/91. URL http://www.ijee.ie.ezproxy.lib.monash.edu.au/articles/Vol21-1/IJEE1553.pdf.

[10] Mohd Salman Abu Mansor and Aziah Ismail. Learning styles and perception of engineering students towards online learning. *Procedia - Social and Behavioral Sciences*, 69(Iceepsy):669–674, 2012. doi: 10.1016/j.sbspro.2012.11.459. URL http://www.sciencedirect.com/science/article/pii/S1877042812054456.

[11] A Kolmos and J E Holgaard. Learning styles of science and engineering students in problem and project based education. *Proc. of the 36th Annual SEFI Conference*, page 2–5, 2008. URL http://www.sefi.be/wp-content/abstracts/1243.pdf.

[12] P A Rosati. Gender differences in the learning preferences of engineering students. In *Proceedings of the 1997 American Society for Engineering Education Annual Conference & Exposition*, pages 2.212.1 – 2.212.7. American Society for Engineering Education, 1996.

[13] Michael J Prince and Richard M Felder. Inductive teaching and learning methods: Definitions, comparisons, and research bases. *Journal of Engineering Education*, 95(2):123–138, 2006. doi: 10.1002/j.2168-9830.2006.tb00884.x.