EXPLORING THE LINK BETWEEN STUDENT LEARNING STYLES & GRADES IN AN INTRODUCTORY THERMAL-FLUIDS COURSE: A Three-Year Study of Associations

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Introduction

The research reported in this study describes associations related to teaching and learning in the undergraduate engineering education environment where, traditionally, certain types of learners and instructors have dominated the teaching-learning landscape, leaving learners with non-dominant learning styles at a disadvantage. This exploratory study conducted over several years examined the complex relationship of student learning style, as measured through the Kolb Learning Style Instrument, and student academic achievement, as measured through course grades. *Thermal and Fluids Engineering I*, a traditional, analysis-based, multidisciplinary course, was selected as a vehicle for the study. Six different instructors and over 400 students participated over the course of three years. The results demonstrate the extent to which diverse learning styles can impact learning and student engagement in the learning process.

Background

The call for reform in engineering education has clearly focused on developing inquiry-based learning coupled with innovative teaching to attract, develop and retain a diverse body of undergraduate engineering students (Splitt, 2003). Yet, while there is widespread use of terms like "interactive learning" and "student-centered-learning," there appears to be little dialogue surrounding student learning characteristics and their influence on successful learning in engineering education. The principle objective of this study was to explore how students engage learning in an undergraduate engineering course and, subsequently, to examine what association various student learning styles may have on student grades. Evidence suggests that identifying the way in which learners process the task of learning can provide crucial information about factors that can influence learning success (Bransford, et al 1999; Felder, 1996). Supplementing traditional teaching to address diverse learning styles has demonstrated a positive effect on student learning. This research suggests how the science of understanding learning can be employed to improve student outcomes by acknowledging differences in learner characteristics and altering classroom teaching to address specific learning styles.

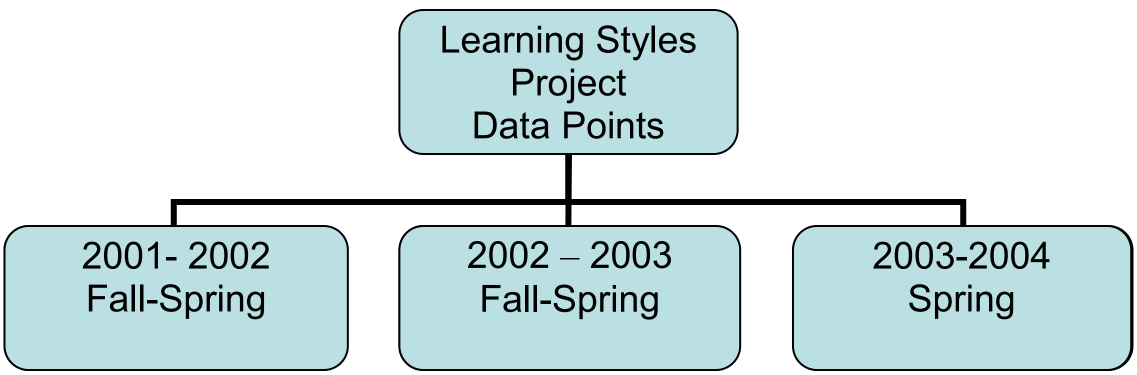
Over the past several years, professors from the School of Engineering at Rensselaer Polytechnic Institute have been working with the University's Center for Innovation in Undergraduate Education (CIUE), an internationally recognized incubator of curricular reform in higher education, to better understand and support learner characteristics. While there is widespread use of terms like "student-centered-learning" in recent years, there appears to be little consensus in the current dialogue about which student characteristics influence which successful learning outcomes, and how. Yet, the sheer weight of evidence acknowledging that learners bring a multitude of approaches to learning compels the educator to be responsive to learner needs. According to Felder & Silverman (1988), receiving an education that is mismatched to their learning style can hinder an engineering student's performance in the classroom as well as their attitude toward engineering as a field of study and career. Armed with the information that a certain percentage of students learn in a manner often ill-served by the traditional engineering classroom and curriculum, this study carefully examined evidence of a link between student learning characteristics and student academic success in engineering education.

The need to address cognitive learning styles grew out of recognition that distinct and enduring differences in student performance were consistently found in required engineering courses—some students thrived while others, despite additional assistance, made little improvement or even declined. Because of the unique dependency in engineering education on cumulative knowledge, a student who acquires less or learns inadequately is at an increasing disadvantage throughout their college career. While academic ability is a major factor in student success, the literature on learning suggests that students' individual learning style preferences may account for some differences in learning outcomes (Kolb 1984; Felder & Silverman 1988). Through a funded project initiative to study student success through the lens of learning styles, a unique opportunity presented to gather data to corroborate differences in learning styles that, in turn, support student success. Ultimately, this research project aimed to be responsive to those learners whose learning style mismatched the traditional curricula and instructional mode.

Method

The research was longitudinal in nature, taking place over the semesters between Fall 2001 and Spring 2004 (See Figure 1). The study involved hundreds of students in the School of Engineering at Rensselaer Polytechnic Institute who were enrolled in *Thermal and Fluids Engineering I* (*TFI*). Each semester students were asked to voluntarily participate in the research project by completing a Learning Styles Inventory instrument at the beginning of the semester to identify their learning preference. Throughout the project, students' class academic standing was monitored and linked to their learning style preference. Analyses included documenting distributions, investigating correlations, and evaluating significance through t-tests and ETA in statistical analyses that included analysis of variance as well as basic regression analysis to determine the proportion of explanation afforded learning styles in student success. By utilizing several semesters, this study brings both the strength of a longitudinal study in drawing more definitive associations as well as provides for a substantial number of participants (students and instructors) at each phase of the project and overall.

Figure 1: Project Data Points



Sample Population

Thermal and Fluids Engineering I is typically offered to 250-300 students from all engineering disciplines per academic year. It is distributed across 3-4 sections per semester, and taught by more than one faculty member. Beginning with Fall 2001 TFI classes, baseline data was gathered on student learning characteristics and performance. The predominant instrument employed throughout the project was the Kolb Learning Style Inventory (LSI, Kolb 1976) although initially, the Cognitive Styles Analysis (CSA) was also utilized[1].

TFI provides students with their first exposure to engineering thermodynamics, fluid mechanics, and heat transfer, with each topic being given roughly equal emphasis. The three topics are taught in an integrated manner, using common notation and a single textbook. The overarching themes are first-law applications and the use of control-volume methods. Thermodynamic topics include fundamental properties, ideal gas relations, heat, work, and the first law. The fluids

[1] The Kolb LSI was efficient and easy to administer: the CSA was deemed unsuitable because its administration was cumbersome and time-consuming.

portion covers fluid statics, the Bernouilli equation, and internal flow. In heat transfer, topics include conduction, convection, radiation, and thermal resistances.

TFI is taught in a studio format, with students having access to mobile computing resources. Class time is divided between short lectures and in-class activities. During the activities, students work alone or in small groups to solve analysis-based problems, similar to typical end of chapter problems in disciplinary textbooks. Each student owns a laptop computer and uses EES, an equation solver with built-in thermodynamic property functions, to complete class exercises.

The grades for the course are based on examinations, homework exercises, and in-class activities. The homework exercises and class activities each contribute 10-15% toward the final course grade, with the balance derived from exams. In all three evaluation modes – homework, exams, and class exercises – students are asked to solve the same type of problem – the traditional short, closed-ended, analysis-based question.

The students registered in the course throughout the project mirrored the general campus in terms of gender, ethnicity and academic ability as measured through university database SAT scores (see Table I). Instructors teaching the course had comparable backgrounds and expertise in the subject area. Course curriculum was designed by engineering school core coordinators assuring that course content, texts and requirements were consistent across instructors and semesters. All classes included similar levels of classroom-based and homework assignments as well as had similar policies and grading schemes.

Table 1
Basic Student Characteristics:

2001-2004	**Overall University Population***	**Sample Population**
Gender	22-24%	21%
Ethnicity	9-10%**	10%
SAT combined	1220-1420	1285

Number of Students: approx 500 students Fall01-Spring04
Of which just over 400 participated in all phases of study
*The university student population includes all schools, not just engineering from where the sample population was drawn
** Ethnicity/Minority status denotes African American, Hispanic, Native American and does not include Asian minorities

Instrument

The first step in understanding how students learn was the robust assessment of learning styles. A learning style can be described as "the way in which learners perceive, process, store and recall attempts at learning" (James & Gardner, 1995) or "an individual's preferred approach to organizing and presenting information" (Riding and Rayner 1998). Research demonstrates that individuals learn in different ways and behave differently in varied learning situations (Sarasin,1999; Sims & Sims 1995). Yet, the dimensions captured in any particular learning style instrument vary according to what aspect of the learner is assumed to influence the learning process: from personality (Briggs & Myers, 1977) to environmental and senses factors (PEPS by

Dunn & Dunn 1984; Gregorc Style Delineator by Gregorc, 1982); to information processing (LSI by Kolb, 1984; 1979; Felder-Silverman, 1988; Cognitive Style Analysis by Riding & Cheema, 1991; LSQ by Honey & Mumford, 1992; Herman Witkin's Field Independence-Dependence Model, 1978/79).

From the wide array of instruments developed over the past decades, the Kolb Learning Style Inventory (LSI) was chosen as a particularly reliable, valid and efficient instrument. It was also prioritized because of its affinity to learning theory growing out of Kurt Lewin's Experiential Learning Theory (1951) which itself was based on work by Dewey and Piaget that connected experience and environment to the learning equation. According to Kolb, learners prefer a particular method for assimilating information, a method he called a learning style (Kolb 1984).

The Kolb Learning Style Instrument consists of 12 questions in which a student self-reports their perceived preferred style of learning[2]. The LSI categorizes learning styles with regard to an individual's preference for concrete experience (diverger), reflective observation (assimilator), abstract conceptualization (accommodator) or active experimentation (converger). David Kolb (1984) described learning as a process in which knowledge is created through experience. Consequently, Kolb defines learners according to how they grasp and transform information. In essence, different learners approach the learning experience with different types of expectations of the learning situation. For example, divergers ask Why?, assimilators What?, accommodators What if? and convergers How?

The four learning styles may be summarized as follows (see Figure 2):

Divergers are concerned with why information is relevant. They prefer concrete experience (feeling) and reflective observation (watching) for perceiving and processing data. Divergers are imaginative and creative and often prefer to work with people. They are likely to want to keep questions open rather than make decisions.

Assimilators are concerned with "what is there to know?" They prefer abstract conceptualization (thinking) and reflective observation (watching) for perceiving and processing data. Assimilators enjoy creating models and using inductive reasoning. They are likely to prefer theories to interacting with people. They may not be comfortable with randomly exploring a system and they like to get the 'right' answer to the problem.

Accommodators are concerned with the question, "what would happen if?" They prefer concrete experience (feeling) and active experimentation (doing) for perceiving and processing data. Accommodators are typically action-oriented and open to new experiences. They tend to rely on "gut" feelings rather than formal theories. These learners enjoy complexity and are able to see relationships among many aspects of a system.

Convergers (abstract conceptualization/active experimenter) are concerned with how information can be used. They prefer abstract conceptualization (thinking) and active experimentation (doing) for perceiving and processing data. Convergers enjoy problem solving decision making, and practical applications. They are likely to prefer technical task to interacting with people.

[2] Kolb Learning Style Instrument is available from HayGroup.com

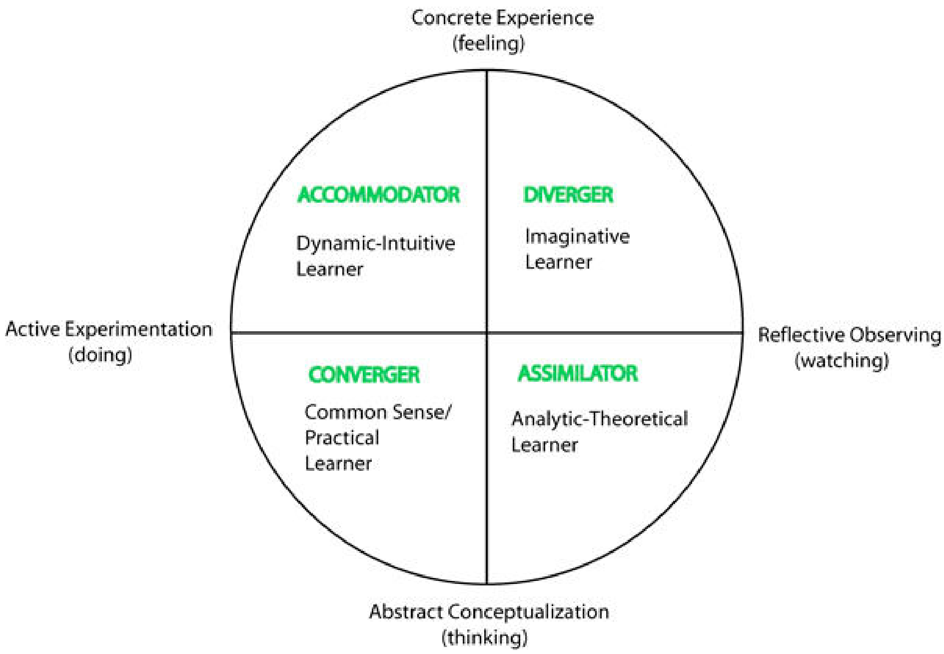


Figure 2 Characteristics of the four Kolb learning styles (Kolb 1984)

Results

The Kolb Learning Style Instrument used in this project defines learning along the dimension of information processing. It focuses on those aspects of learning styles that directly relate to the student's preference for absorbing and processing information conveyed through the materials and instructor throughout the course. In the initial stages of the project, the percentage of students completing the inventory was less than optimal (see Table 2). This was attributed in the beginning to a lack of communication with students regarding the nature of the project (particularly, communicating the fact that instructors would not have identifying information on individual students) as well as to instructor frustration with the necessary time required to complete the survey which, subsequently, took away from instructional time. In subsequent semesters the participation rate went up considerably with better communication to students and improved communication to faculty regarding the efficacy of the project. By the end of the project, a near full completion rate was realized. From the Fall 2001 through the Spring 2004, nearly 400 students (76%) enrolled in TFI participated in this study by taking the Learning Styles Inventory[3]. This high rate of participation at the end of the project can anecdotally be attributed to both superior communication with instructors as well as with students along with ease and convenience in administering the instrument itself: namely, the LSI became available online offering flexibility-- students could complete the instrument outside of class time.

[3] There is an off-campus version of this course that is traditionally offered to students who are simultaneously enrolled with on-campus students. Because the nature of these on and off-campus student populations differ, only on-campus students enrolled in TFI were asked to participate in this study. The off-campus enrollees were not included in the enrollment numbers.

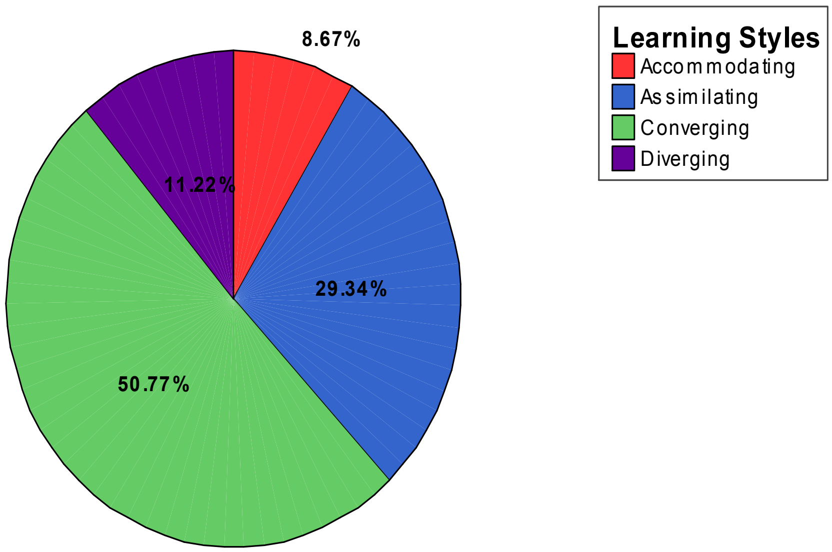
Table 2
Learning Styles Instrument (LSI) Completion Rates

Semester	**LSI Participation Rates**	**Number of Students Enrolled in TFI**	**Number of Students Taking LSI**
Fall 2001*	88%*	33	28
Spring 2002	57%	129	74
Fall 2002	87%	100	87
Spring 2003	73%	102	74
Spring 2004	100%	164	164
Fall01-Sprg04	81%**	528	427

* The first semester, Fall 2001, was considered a pilot so the actual number of students asked to participate was less than the total number of students enrolled in the courses. Overall 87 students were enrolled in three sections of TF1 in Fall 2001, but only one section of 32 students were asked to participate by taking the LSI. **If the students not asked to participate in Fall 01 Pilot are included the participation rate is 73%.

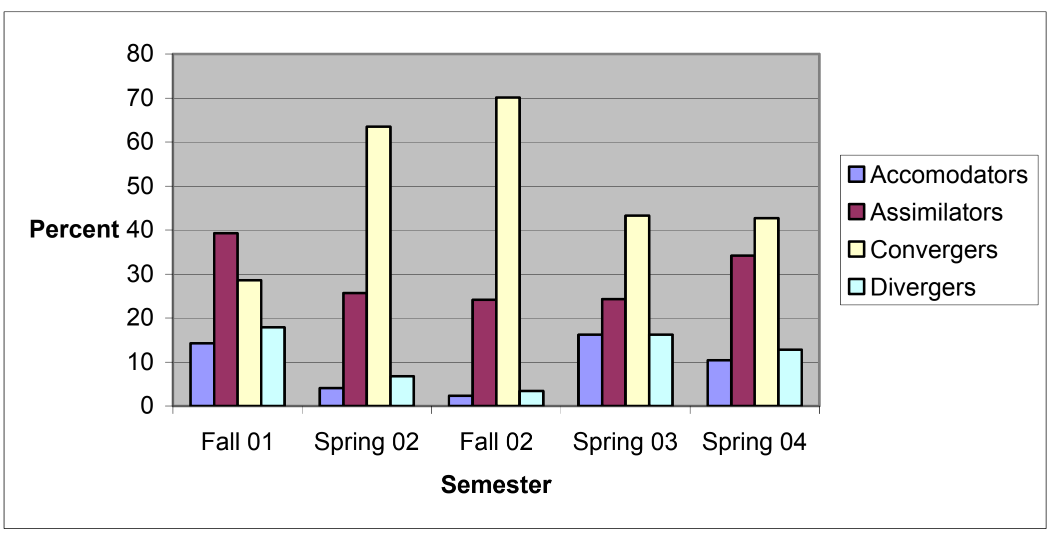
For students taking the LSI, Figure 3 illustrates the distribution of Kolb's four learning styles. As seen, the majority of students (51%) enrolled in this core engineering course fall into the category *converger*. Convergers combine a preference for thinking and doing. The next well-represented quadrant is the Assimilators (29%). Assimilators prefer to learn by watching and thinking. The remaining quadrants, divergers and accommodators, make up about one-fifth of the TFI student population. These non-dominant learning style students prefer feeling and watching (divergers) and doing and feeling (accommodators). Kolb and colleagues provide extensive empirical work that relates learning style to subject disciplines. Divergers tend to be in creative disciplines such as writing or the arts, and accommodators tend to be in professions that require intuitive thinking, such as teaching. Convergers tend to be in applied fields (scientists, lawyers) and assimilators prefer academic pursuits such as pure science or mathematics. Thus it is not surprising that 80% of the students in this course fall into the converger and assimilator categories.

Figure 3
Distribution of Learning Styles Overall



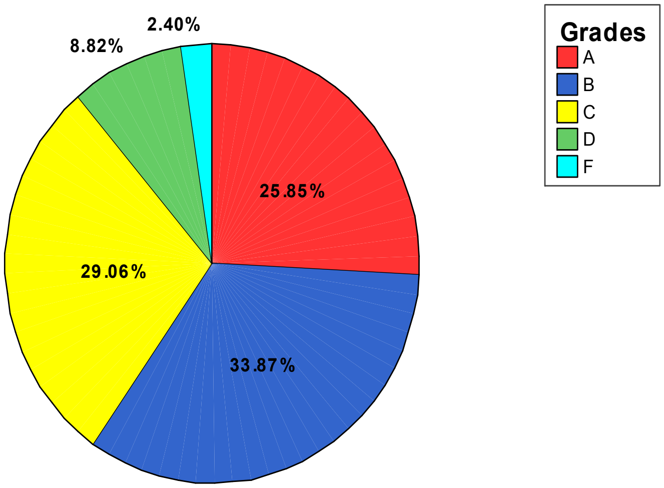
Over the semesters, the distribution of these categories fluctuated with 2002 having the highest number of students falling into the Converger category and the lowest number of Accomodators and Divergers (see Figure 4). Convergers typically are associated with practical professions like engineering and often dominate the learning landscape in engineering education. This dominant distribution of learners in the classroom can have an unfavorable influence on those whose learning style preference differs (Felder & Silverman, 1995).

Figure 4
Distribution of Learning Styles by Semester



Turning now to the grade distribution, the overall mean grade-point average over the length of the study was 3.7 on a 5-point scale where A is 5, F is 1[4]; standard deviation was 1.02SD; N=499. In other words, on the average, students in TFI generally received a C+ grade. Grade distribution is shown graphically in Figure 5.

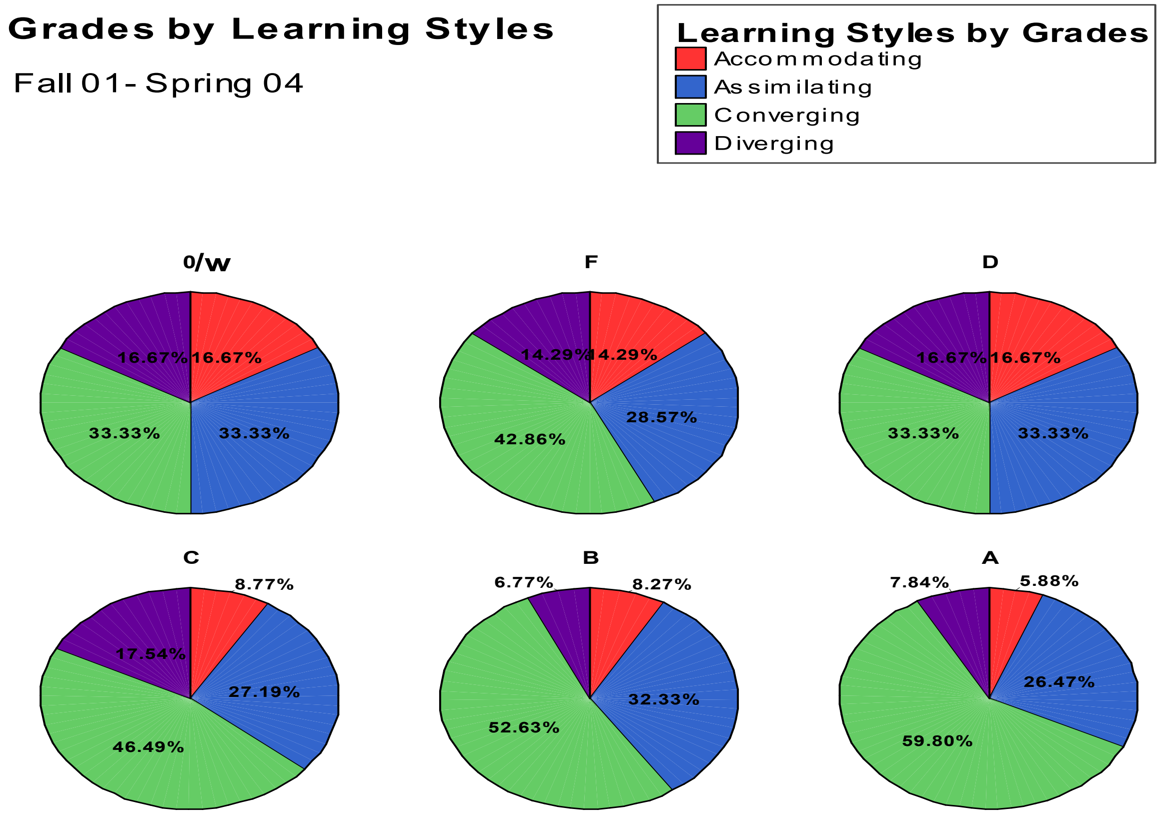
Figure 5
Distribution of Student Grades Overall



Grades did not distribute evenly amongst the four learning styles. Information on learning styles and grades was available for just under 400 students with grade information available for just over 500 students. (a loss of about 23%). As noted above, on average, students in TFI received a C+ grade. As shown in Figure 6, convergers, who constitute 51% of the population, receive proportionally larger percentages of A's and B's than other styles and smaller percentages of C's, D's. and F's. Assimilators, who constitute just under 30% of the population, receive grades in proportion to their population. Accomodators and divergers, who together constitute only 20% of the population, received proportionally fewer A's and B's and more of the lower grades. Nearly 30% of all D's & F's are given to the 20% of the student population from the non-dominant learning styles---accommodators and divergers.. Included is also a look at the types of learners that withdrew from the course. As seen, those from the non-dominant learning styles appear to withdraw from the course at proportionately higher rates than their dominant learning style peers. Looking closely at the association of learning styles to classroom performance overtime, the data reveal a disturbing pattern of performance for non-dominant learners. As previously stated, student performance in engineering education is cumulative and poor performance in required, fundamental engineering courses, such as TF1, place a student in a increasingly disadvantageous position.

[4] Students who withdrew from the course are not included in this calculation, although a sub-analysis of what type of learners withdrew is performed. If students who withdrew from the course are included, the mean grade-point-average is 3.64, SD 1.144, N=511

Figure 6
Distribution of Learning Styles Within Grades



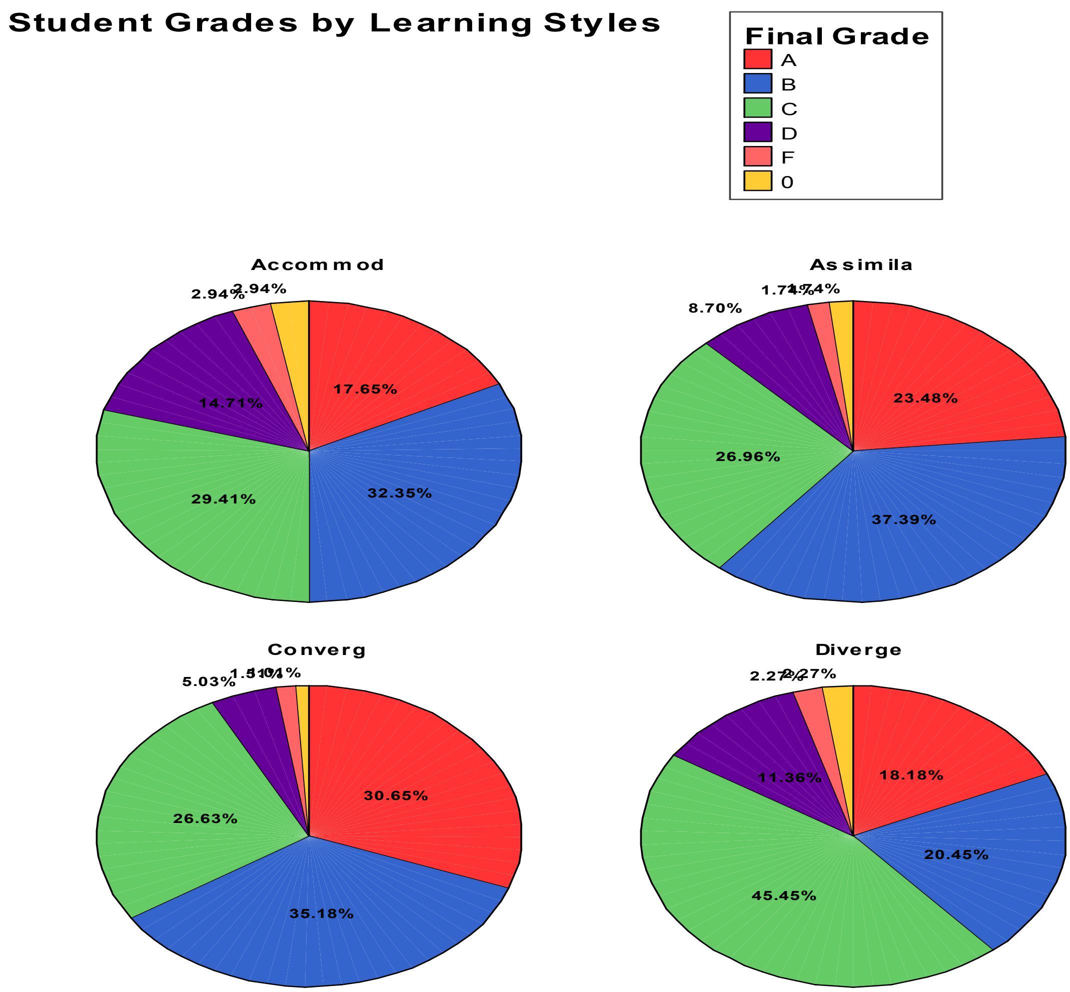
Overall, average grades by learning style are noted in Table 3. As expected, non-dominant learner styles (accommodators and divergers) receive the lowest average grades and dominant learning styles (convergers and assimilators) the highest. An analysis of variance indicates that there is a significant difference amongst the mean grade from the different learning style groups ($p=0.008$). In addition, the measure of association (Eta) shows a moderate but significant level of association between grades and learning style, as expected.

Table 3
Average Grades by Learning Style
N= 392

Learning Styles	Mean	Std. Deviation	Range
Accommodator	3.38	1.206	5
Assimilator	3.67	1.090	5
Converger	3.85	1.027	5
Diverger	3.34	1.119	5
Total	3.70	1.085	5

A closer look at the distribution of grades for each type of learner further affirms the pattern of disadvantage for students with non-dominant learning styles. With the information on entering SAT scores for students, this would not have been predicted. Nonetheless, the data associate consistently lower grades for non-dominant learners in this typical engineering course. Looking more specifically at the distribution of grades within a learning style category, half of accommodators receive an A or a B in the course. This attests to Kolb's theory that some learners can move within the quadrants to accommodate a specific learning situation. Here at least half of the accommodators appear to be more flexible than divergers in assessing their own learning style needs and adapting their learning to the dominant mode. This is encouraging and reaffirms Kolb's ideas about learner flexibility. Still, that leaves the other half of accommodators receiving a grade of C or lower. Proportionately, accommodators receive a higher percentage of D's than any other group: with only 9% of the overall grade distribution attributed to D's, accommodators take the lion's share at receiving nearly double the D's or 15% of those D grades. Divergers, on the other hand, appear to be at the greatest disadvantage in this engineering curriculum: their grades, despite observation over several semesters with numerous students, are consistently lower. A diverger is proportionately more likely to receive a grade of C than any other type of learner. On the other hand, C's are equally as likely to be given to either accommodators, assimilators or convergers. Looking at the dominant learner, the majority of highest grades are awarded to convergers. Convergers and assimilators are proportionately more likely to receive an A or a B with over 60% of each learning style obtaining such high grades.

Figure 7
Distribution of Student Grades By Learning Styles



More robust analyses reveal that learning styles are highly correlated with grades with non-dominant learners receiving significantly lower grades than dominant learners (-.158** Correlation is significant at the 0.001 level/2-tailed). The results show statistically significant differences in academic achievement between the dominant and non-dominant learning groups along the dimensions of learning styles (see Table 4).

Table 4
GPA by Dominant and Non-Dominant Learning Styles (N= 392)

Learning Styles	**Mean**	**Std. Deviation**	**Range**
Dominant	3.79	1.052	5
Non-Dominant	3.36***	1.151	5
Total	3.70***	1.085	5

***p< .001 significance between groups in a two-tailed t-test

Further analysis tested for the effect of instructor on grade distribution. Six different instructors participated in the study, several teaching either more than one section per semester or several sections over several semesters. By including instructors across semesters and across sections of the course over time, the independent effects of particular classroom or instructional anomalies are considerably controlled lending more explanatory power to any findings. The independent effects of instructors on student grades and of student learning style on grades were highly significant (respectively, .001 and .027.) However, the interaction effect of instructor and student learning style did not reach significance (.463). This implies that grade distribution does depend on the individual instructor, as expected, but that learning style has an independent and significant influence on grades. In other words, dominant and non-dominant learners are likely to fair equally well or equally poorly regardless of instructor. One explanation for this may simply be that the course is highly structured, with little latitude for individual instructor preference in designing assignments and setting grading criteria. Also, the instructor's teaching style may be independent of (or unresponsive to) the student's unique learning preference. Further research should explore this latter observation.

Discussion

Significantly better grades were observed for the dominant learners in this fundamental engineering course. The convergers, who constitute 51% of the sample population, received, on average, the highest grades. Convergers enjoy problem solving, decision making, and practical applications. The group with the next highest grades were the assimilators, who constitute 29% of the population. Assimilators enjoy creating models and using inductive reasoning. They are likely to prefer theories to interacting with people. Accommodators and divergers received the lowest grades. Divergers (11% of the population) are imaginative and creative and often prefer to work with people. They are likely to want to keep questions open rather than make decisions. Accommodators (9% of the population) are typically action-oriented and open to new experiences. They tend to rely on "gut" feelings rather than formal theories.

In Thermal and Fluids Engineering I, the grading was based solely on the ability of the student to complete short, closed-ended engineering problems; thus it is not surprising that the convergers and assimilators out-performed the divergers and accommodators. Referring again to Figure 2, it is seen that the majority learners (convergers and assimilators) fall in the bottom half of the diagram while the minority learners (divergers and accommodators) fall in the top half. Students in the bottom half prefer abstract conceptualization (thinking) while those in the top half prefer concrete experience (feeling).

These results raise questions related to the design of the learning environment in fundamental engineering courses. Thermal and Fluids Engineering I is typical of many analysis-based courses, which tend to dominate engineering curricula, while being distinctly different from typical laboratory and design courses. Clearly, the skills emphasized by all four learning styles are useful in engineering practice. Yet, a curriculum which systematically "weeds out" imaginative and intuitive thinkers does a disservice to the field of engineering in particular and to society in general.

At least two alternative interpretations of the results are possible. A course like the one examined here is appropriate because the logical and problem-solving skills favored by the majority learners are critical to all engineers. Under this interpretation, accommodators and divergers who cannot easily cross over into the majority learning style should be discouraged from continuing in engineering.

A second interpretation is that imagination and intuition are as important to an engineer as are logical and problem solving skills. In this scenario, the curriculum should be adjusted to allow a balanced emphasis on all four learning styles. Courses like the one examined here could be redesigned to include assignments and exercises which favor minority learning styles. As illustration, Hartman (1995) applied Kolb's learning styles to instructor teaching styles providing examples of how each might be addressed in the classroom: for concrete experience, the lessons should include laboratory experiences, field work and other types of observation; for the reflective observer, journal, logs or even brainstorming provide the best match of teaching and learning styles; for the abstract conceptualizer, lectures, reports, papers, analogies are best suited; for the active experimenter, simulations, case studies, homework. Obviously, matching the teaching style to learner characteristics in each and every lesson is improbable. However, by only providing one type of learning experience, instruction will favor only a certain type of student based on learner characteristics.

Future research will examine the effects of learning style on performance in laboratory and design courses, testing the hypothesis that the minority learners will have an edge in these environments. Also, the effects of interventions in and augmentations to the learning process will be examined.

The results of this study indicate that students with non-dominant learning styles consistently perform less well than their dominant learning style peers in engineering education. Yet their previous academic performance indicator, SAT scores, would indicate that their academic ability is well up to the task of mastering the materials. That leaves the mode of instruction suspect. Recognizing that instructional styles may discriminate against particular students with learning styles that are not being accommodated, future research should explore the potential of matching instructional and learning styles. Additionally, as the learning experience extends beyond the confines of the given subject and, as outlined by Felder (1996), should include affective experience (attitudes, expectations, frustrations), research should explore the extended learning experience. Recognizing the potential academic as well as the affective consequences of education that does not match the learner, may potentially reduce high attrition rates as well as provide for more incentive to join engineering as a field of study.

Concluding Remarks

This case-study aimed to explore engineering student's perceived learning characteristics in order to inform learning and teaching. While there is widespread use of terms like "student-centered-learning," there appears to be little dialogue about student characteristics that influence successful learning, especially surrounding curriculum design. Armed with the information that a certain percentage of students learn in a manner often ill-served by the traditional engineering lecture-type classroom, instructors and curriculum designers can begin to address not only various forms of active learning, but also learner characteristics that influence the learning experiences. This study carefully examined evidence of a link between student learning characteristics and student academic success. The results strongly suggest that recognizing this association between learning styles and academic success will necessarily lead to both more perceptive teaching and also more responsive learning. This, in turn, will provide insight into how to address the diverse learning styles of engineering students, particularly those whose learning style is often at odds with the traditional engineering curriculum. Continued research on the connections between learning styles and student success in engineering curricula are warranted.

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