6-14-2014

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## Abstract

In this paper, we discuss our approach on how to achieve adaptive teaching which leads to a more efficient learner-centered environment. Based on the Felder-Silverman learning styles model, there are four scales for the learning aptitude which are active/reflective learners, sensing/intuitive learners, visual/verbal learners, and sequential/global learners. The different conglomeration of these scales for the students in any cohort forms a specific cognitive profile. We used the Felder-Soloman index of learning styles survey to determine the dominant learning styles within a cohort of students. Knowing the students' cognitive profile helped us adapt our teaching styles to achieve an optimal learner-centered classroom. We mainly focused on activities that would engage the majority of the students, to help facilitate the learning process and consequently, improve the students' achievement. The effectiveness of this approach was quantitatively verified by assessing the students' satisfaction with the learning process using traditional non-adaptive teaching process and adaptive teaching process with activities tailored towards the students' learning styles.

## Introduction

With the recent focus on student achievement, teachers are striving to improve the quality of their instruction methods to achieve a learner-centric environment in their classrooms. The difference in the students' level of acquired knowledge in any specific course is mainly due to the difference in the students' aptitude for learning, prior preparation and the compatibility of their Learning Styles with the instructor teaching style[1,2]. Unfortunately, the static traditional teaching style "Chalk-&-Talk" which is still being used in engineering schools does not adapt to the changes in the cognitive profile of the student cohorts which reflects negatively on the students' achievement and performance, especially in engineering. In addition to this, the majority of the engineering faculty had never gone through a formal training in teaching and learning pedagogy. Therefore, faculty will mainly rely on the only two teaching approaches they know; 1) they will either teach in the same way that they were taught or 2) they will teach in the same way they learn the best. These two teaching approaches are not the most effective; in fact, they are among the most ineffective approaches due to the inherent gap in the learning styles between the new generation students and the faculty. With the increase in the diversity among faculty (more international faculty), the gap in the perception of what constitutes an effective learning environment is widened even more[3,4,5]. The teaching methodologies used in different countries around the world vary significantly. Teacher-centered classrooms are still the most dominant learning environment in many institutions in developing countries[6,7].

One of the most common weaknesses that the majority of the junior international faculty face is achieving an effective learning environment within their classrooms. Therefore, we are proposing an adaptive teaching process that will help any inexperienced (especially the international faculty) and even the experienced faculty adapt their teaching methodologies to be in-line with their students' cognitive profile. This will ultimately help them achieve the most effective learner-centric classrooms.

## Learning Styles

Many models for learning styles have been developed over the last 50 years such as the Myers-Briggs Type Indicator, Kolb Model, Felder-Silverman Model, and more others. In this study, we used the Felder-Silverman learning styles model to model the cohort cognitive profile. Based on the Felder-Silverman learning styles model, there are four scales for the learning aptitude which are active/reflective learners, sensing/intuitive learners, visual/verbal learners, and sequential/global learners. Active learners are applied learners. They learn by applying the knowledge either by solving problems or discussing the information. They also prefer to work in groups. On the other hand, reflective learners prefer to think and reflect on what they have learned first before they apply it. Reflective learners also prefer to work individually rather than in a group. Sensing learners learn best by learning facts in a very systematic manner, while intuitive learners prefer to learn by inquiry and achieving an Aha moment. Visual learners learn best by engaging their visual senses as much as possible .i.e. learning through concept figures, flowcharts, videos, and experimentation, while verbal learners would rather learn through spoken or written explanations. Sequential learners tend to learn gradually in logical steps, while global learners learn best by grasping the big picture. Global learners can engage their intellectual curiosity and easily find the underlying connection between different concepts[1].

The Felder-Soloman Index of Learning Style instrument was used in a wide range of studies some focused on the learning and teaching styles of the faculty and illustrated the mismatch between the engineering students learning styles and the faculty teaching styles[8], while others focused on the correlation between the student learning styles and the use of non-traditional instruction to bridge the gap and improve students' achievement[2,12,13,14]. We are proposing to use the Felder-Soloman Index of Learning Style instrument as a starting point to help us identify the type of instruction that will better match the cohort of students' learning style to initiate our adaptive teaching process.

## Cohort Cognitive Profile

The different conglomeration of the Felder-Silverman learning scales for the students in a cohort forms a specific cognitive profile. We propose to use the Felder-Soloman index of learning styles (ILS) survey to determine the dominant learning styles within a cohort of students. The Felder-Soloman index of learning styles survey consists of 44 multiple choice questions. The survey has 11 forced-choice questions that address each scale. Each item has only two possible choices (a) and (b) that corresponds to either one of the two categories in a specific scale. The (b) responses are subtracted from the (a) response to generate an odd score that ranges between -11 to 11[1]. For every survey, a score will be obtained for every scale out of the four scales. Figure 1 illustrates an example of the scores obtained after filling the online ILS survey.

```
ACT        X                                        REF
   11   9  7  5   3   1   1   3   5   7   9   11
                     <-- -->

SEN           X                                     INT
   11   9  7  5   3   1   1   3   5   7   9   11
                     <-- -->

VIS           X                                     VRB
   11   9  7  5   3   1   1   3   5   7   9   11
                     <-- -->

SEQ           X                                     GLO
   11   9  7  5   3   1   1   3   5   7   9   11
                     <-- -->
```

**Figure 1- Felder-Soloman Index of Learning Style Survey Scores**

If the score of a scale obtained from the ILS survey is in the range of 1-3 this means that the learning style is well balanced between the two dimensions of that scale. If the score of a scale obtained from the ILS survey is in the range of 5-7 this means that there is a moderate preference for one dimension of that scale and the learning will be optimized in a teaching environment that favors this dimension. Finally, if the score of a scale obtained from the ILS survey is in the range of 9-11 this means that there is a strong preference to one dimension of the scale, therefore teaching for that specific dimension is necessary to maintain a learning environment[9].

## The Adaptive Teaching Process

We used Google Forms to model the Felder-Soloman Index of Learning Styles survey as an alternative to the online survey provided by Felder mainly to centralize the process of collecting and processing the information. Since this process is assessing the students' learning styles/cognitive profile and comparing them with the faculty learning style, we used the same standard set of questions across all the surveys conducted in order to have a common basis for comparison in this study.

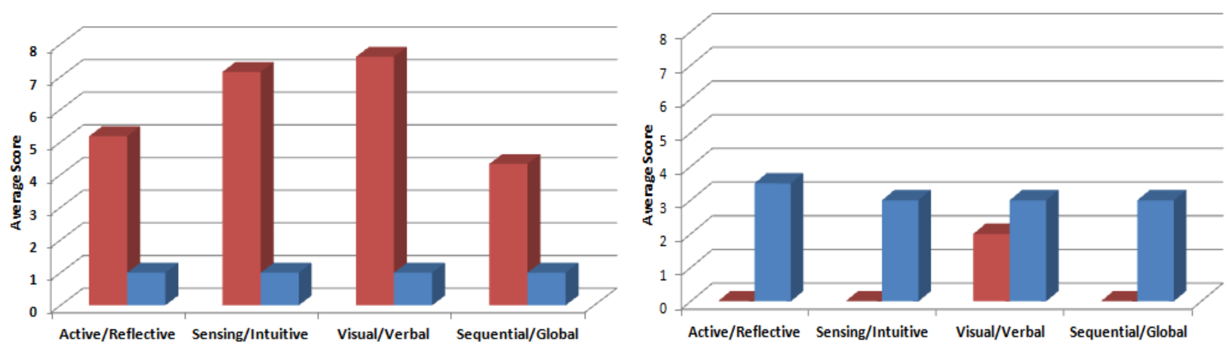
The Index of Learning Style survey was only conducted once at the beginning of the semester to map the cognitive profile of the students and the faculty. However, the main purpose of this survey is not the absolute cognitive profile but the relative difference between the students' learning styles and the faculty learning style. The difference in these profiles is considered a very good starting point when adapting the teaching styles for the first time. A series of student feedbacks are conducted throughout the course to regularly adapt the teaching style and achieve a total convergence.

The students receive an email with the Felder-Soloman Index of Learning Style survey attached in it. This survey will be considered their first assignment for the semester. They have until the beginning of the next class to fill the survey. This will give students enough time to submit their responses without disturbing the learning process during the lectures. After the submission of the responses, the faculty will have a Google Spreadsheet populated with all the responses. The next step is to obtain the students survey scores as discussed earlier. From these scores, the average of each learning style is calculated. Table 1 illustrates an example of a learning style profile evaluated for a class of 14 students.

| | Scale #1 | | Scale #2 | | Scale #3 | | Scale #4 | |
|---|---|---|---|---|---|---|---|---|
| **Student** | **Active** | **Reflective** | **Sensing** | **Intuitive** | **Visual** | **Verbal** | **Sequential** | **Global** |
| **1** | 3 | | 3 | | 11 | | 1 | |
| **2** | 3 | | 3 | | 9 | | 1 | |
| **3** | 9 | | 5 | | 5 | | | 1 |
| **4** | | 1 | 7 | | 9 | | 5 | |
| **5** | 7 | | 9 | | 9 | | 7 | |
| **6** | | 1 | 5 | | | 1 | 1 | |
| **7** | 3 | | 9 | | 7 | | 5 | |
| **8** | 1 | | 11 | | 7 | | 5 | |
| **9** | | 1 | 11 | | 7 | | 7 | |
| **10** | 9 | | 3 | | 3 | | 5 | |
| **11** | 1 | | | 1 | 9 | | | 1 |
| **12** | 11 | | 9 | | 9 | | 9 | |
| **13** | 5 | | 9 | | 7 | | 5 | |
| **14** | 5 | | 9 | | 7 | | 1 | |
| **Total** | 57 | 3 | 93 | 1 | 99 | 1 | 52 | 2 |
| **Average** | **5.1818** | 1 | **7.153846** | 1 | **7.6154** | 1 | **4.333333** | 1 |

**Table 1- Example of how the Students' Survey Scores Generate the Learning Styles Profile**

The calculated averages will represent the student learning styles profile as illustrated in Figure 3-a. For the purpose of demonstrating how significant is the gap between the learning style profiles for students compared to faculty, we evaluated the learning style profile for four international faculty members as illustrated in Figure 3-b.




**(a)** **(b)**

**Figure 3- (a) Example of Students' Learning Style Profile, (b) Example of Faculty Learning Style Profile**

Comparing Figures 3-a and 3-b, it is clear how different is the students' cognitive profile as compared to the faculty's cognitive profile. The students' cognitive profile is predominantly favoring the active, sensing, visual, and sequential scales, while the faculty cognitive profile is mostly balanced with slightly favoring the reflective, intuitive, verbal, and global scales.

Finally, to adapt the teaching process, we included a formative feedback process. The feedback included questions regarding the content, the presentation of the content, the delivery of the content, and the level of student engagement. Based on the weekly feedback responses obtained from the students, the faculty will address any needed modification to achieve a learner-centric classroom. This adaptive teaching process is illustrated in Figure 4.

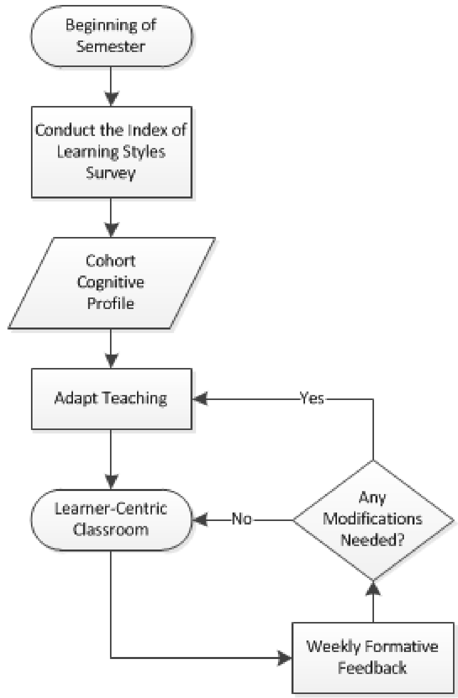



**Figure 4- The Adaptive Teaching Process**

## Process Implementation and Assessment

The impact of introducing this adaptive teaching process was indirectly quantified by assessing the improvement in the students' performance. The undergraduate engineering students' performance was assessed using a test group and a control group. The test and the control groups were two different sections of the same course taught by the same faculty. We used the Introduction to Computer Engineering course to implement the proposed process and assess its effectiveness. There were a total of 22 students in the control groups (Section A) while the test group had a total of 44 students (Section B). The majority of students were freshmen while few were sophomore. The control group was instructed without using the proposed adaptive process, while the test group was instructed using the proposed adaptive process. Table 2 illustrates the details of the process implementation.

| | **# of Students** | **ENGR 2332 Course** | **Instructor** | **ILS Survey Used** | **Adaptive Teaching Used** | **Performance Assessment** |
|---|---|---|---|---|---|---|
| **Control Group** | 22 | Section A | Same Instructor | No | No | Yes |
| **Test Group** | 44 | Section B | | Yes | Yes | Yes |

**Table 2- Summary of the Proposed Process Implementation**

The ILS survey was used to model the cohort cognitive profile as illustrated in figure 5. The cohort cognitive profile was used to initially adapt the teaching style. Figure 5 illustrates that the test group students' cognitive profile is predominantly favoring the active, sensing, visual, and sequential scales.

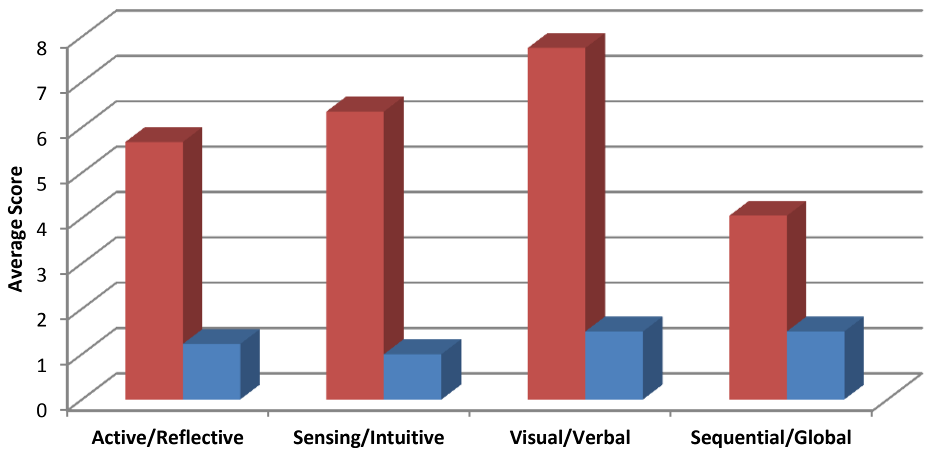



**Figure 5- The Test Group Learning Style Profile**

We used instruction methodology that matched the cohort cognitive profile. We used a problem-based approach coupled with the use of simulations tools to instruct this course. We paired every two students together to form a group (Active). At the beginning of every new topic, each group was given a comprehensive problem based on real-life application (Sensing) that addressed the main concepts of the topic to be discussed. Each group attempted these problems before the topic is discussed to give them an opportunity to see the big picture and understand the sequence of steps required to solve such problems (Sequential). Throughout the topic instruction the students solved the problem step-by-step to solidify the main concepts discussed within the lecture (Sensing). The lectures also involved simulation demonstration and the use of visual aids to illustrate some of these concepts (Visual). Every week was concluded with a homework relevant to topic discussed in that week. A weekly 5-min quiz was administrated at the beginning of each week to provide a formative feedback to monitor the students' performance. Finally, an anonymous bi-weekly electronic feedback was administrated using Google Forms to get the students feedback to help adapt the faculty's teaching style. The feedback questionnaire consisted of 11 questions related to the content, teaching style, presentation, engagement, and overall satisfaction. Some of the most common feedback comments received addressed the pace of instruction, and the different means to better engage the students. The use of simulation tools to demonstrate the digital circuits designs were also introduced as a result of these comments.

To assess the effectiveness of this proposed adaptive process, the overall performance of the students in the control and the test groups were compared. The overall performance of the two groups was analyzed using a statistical model. Figure 6 shows the normal distribution fit for the overall performance of the control and test groups.

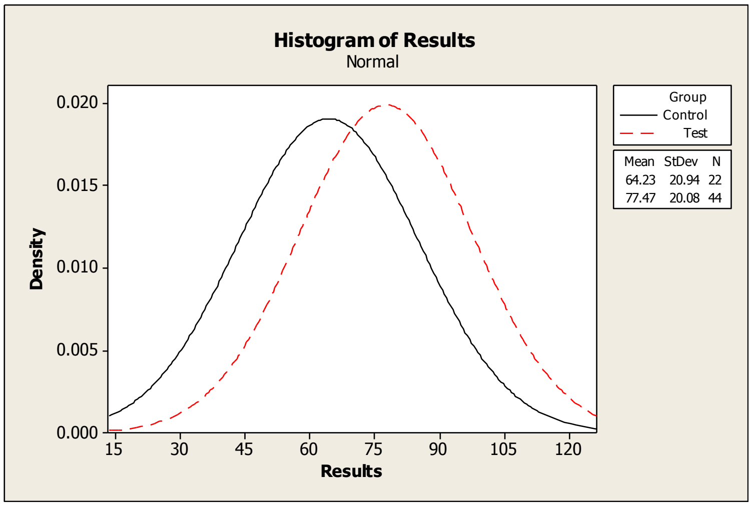



**Figure 6- Fitting the Control and Test Groups' Overall Grades into Normal Distributions**

To statistically verify our findings, we conducted a thorough statistical analysis using the Minitab statistics software. Our null hypothesis stated that there were no statistical differences in the students grades obtained from the control and test groups. To test this hypothesis, we used the General Linear Model to analyze our data with probability criterion for the significance level equal to 5% (*p*=0.05). This means that if the analysis generates a p-value less than the 0.05, then the null hypothesis can be rejected indicating that adapting the teaching style based on the proposed process is in fact useful. The response variable was the control and test group student grades obtained in the course.

The first factor was the treatment effect modeled by the difference in the control and test group overall grades. The two-level treatment was the effect of adapting the teaching style based on students' learning style using the proposed adaptive teaching process on the students' overall achievement. The analysis, as shown below, generated a p-value equal to **0.015** which is ten times smaller than the **0.05** criterion for significance. Therefore, we can reject the null hypothesis with a confidence level of **98.5%** and conclude that there is a statistically significant difference between the control and test group results which validates the effectiveness of the proposed process. To further investigate this conclusion, we conducted a Tukey's comparison with a confidence level of **95%**. The outcome of the Tukey's comparison also supported our conclusion that the results obtained from the control and the test groups are statistically different.

## Conclusion

Adaptive learner-centric classrooms proved to be one of the most efficient student learning environments. The interactive nature of these environments significantly assists in improving the students' performance. To achieve a true adaptive learner-centric classroom, an insight into the students' cognitive profile should be readily available. This paper presented an implementation of a systematic adaptive teaching process using the Felder-Soloman Index of Learning Style to map the students' learning style profile and a regular set of formative student feedbacks. Control and test groups were used to measure the effectiveness of this process. We concluded that this process is effective, which was also inferred by the statistical analysis with 98.5% confidence level. In addition to mapping the students' cognitive profile and provide the faculty with an idea of how to instruct courses effectively, this process will help faculty; especially the international faculty; to adapt their teaching as they go by incorporating a regular formative student feedback to achieve an adaptive learner-centric classrooms.

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