AC 2008-1766: SMALL INTERVENTIONS, BIG IMPACTS: HOW MODIFICATION OF DELIVERY PROCESS OF IN-CLASS ACTIVITIES FOR FRESHMEN CAN DRAMATICALLY IMPROVE LEARNING

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Small Interventions, Big Impacts: How Modification of Delivery Process of In-class Activities for Freshmen Can Dramatically Improve Learning

Abstract

This paper discusses the impact of using informed instructional design and subsequent delivery processes of classroom activities on learning outcomes in first-year engineering classes. The paper shows how minor additions or changes done by the instructor can lead to noticeably better learning outcomes, and higher student satisfaction and perception. In this study, learning outcomes are evaluated by the instructor, while students' satisfaction and perception is measured using direct surveys. Four previously tested and two suggested example hands-on activities are discussed in the paper. In addition to the activities, the paper also addresses how instructor delivery of the activities influences learning outcomes in a typical classroom environment. The paper demonstrates the powerful influence of an instructor's teaching style and approach on class behavior and response, and hence, suggests careful and detailed design of the process of instructional delivery.

This study was performed on three workshops with average enrollments of 27 students each. While two of the workshops had almost equal gender compositions, with approximately 40% females, the third workshop was an all male workshop. One of the classes was taught on Wednesdays, and the other two were taught on Fridays. During the one-day time gap between the two classes, the instructor made minor adjustments of the delivery process, and then applied these during the Friday class. These adjustments were based on instructor reflections, peer suggestions, and students' feedback. The workshops are the active learning sessions for the "Engineering Exploration" class, which is a core introductory engineering course for all first-year engineering students at Virginia Tech. The study was performed over the fall semester of 2007. Statistical tests and measures show that while the two similar workshops belonged to the same population, with respect to means and standard deviations of the learning outcome measures, they significantly differed with respect to students' satisfaction. Statistical methods for appropriate analysis of data are also reported.

Background

The Engineering Exploration course is a mandatory core course to all engineering students at Virginia Tech, and is offered at the freshmen level. However, it is not uncustomary to find several sophomores registered for the course. The total number of students initially enrolled for this course in Fall 2007 semester was more than 1,350 students[1]. The number of students taking the final exam was more than 1,200 students, i.e. more than a 90% course retention level.

This course is a two credit hours course. It is taught in a lecture-workshop format, and was taught by 5 faculty and 16 graduate teaching assistants (GTA's). The students were divided among 8 lectures, i.e. around an average of 150 students per lecture, and 45 workshops, i.e. around an average of 27 students per workshop. Both lectures and workshops were delivered once a week. While lectures were 50 minutes and were typically taught by faculty, workshops

were typically taught by graduate teaching assistants (GTA's) and were 110 minutes long[2]. Within the context of this paper, the faculty leading lectures are called instructors, and GTA's leading workshops are called workshop leaders.

In general, lectures followed an instructor-based lecturing instructional style, and mainly focused on introducing students to the new topics being taught and providing them with the broader picture of why the topics taught are important to them as engineers. On the other hand, workshops followed a student-based active learning instructional style. In workshops, students were asked to perform several hands-on and problem solving activities, both individually and in groups. Students were also asked to give and evaluate presentations, in addition to watching videos, leading discussions, and others.

All personnel involved in teaching the course (faculty and GTA's) met regularly at the beginning of each week for an hour, in order to discuss any findings related to the previous week, to prepare the material that is to be taught in this week, and to collaborate on solving any course-related issues. Two faculty coordinated and prepared lectures. Two senior GTA's that were involved in teaching this course several times in the previous years were responsible for preparing the workshops' power point presentations used by all GTA's in their workshops. This material was usually emailed to all GTA's in the weekend preceding the meeting.

GTA's were given full freedom to modify the prepared power point presentation, through reordering the presentation, or adding and deleting content. In general, most GTA's regularly applied slight modifications to the provided presentations, with the greatest modification probably being to change a certain activity from being an in-class activity to an out-of-class homework assignment. In other words, students in all workshops were undoubtedly required to do the same activities, and solve the same problems, no matter which workshop they were assigned to.

Introduction

In this work, the authors are presenting the experience of one of the GTA's who was involved in leading 3 of the 45 workshops. The GTA taught the first workshop on the early mornings of Wednesdays (8:00 to 9:50 am), and the second and third on Friday mornings, the second being early in the morning (8:00 to 9:50 am), and the third being right after (10:00 to 11:50 am). In the 1-day time gap between the workshop taught on Wednesday and workshops taught on Friday, the GTA, if possible, modified the instructional delivery process of the activities, with the objective of improving the learning outcomes. The modified instructional delivery was based on the GTA's reflections, peer suggestions, and students' feedback. Course modifications are, in general, in accordance with the literature on human/student learning and teaching and curriculum strategies known to positively influence learning outcomes, especially in the sciences[3-5].

As discussed later, the modified instruction is evaluated based on the GTA's observation of the in-class energy levels, time required to complete activities, students perception, and direct students surveys. In addition, student satisfaction and content are further evaluated using the mid-semester students' evaluation feedback.

In the following sections, first the characteristics of each of the workshops are presented. Both the gender demographic characteristics, as well the learning outcomes characteristics (represented in assignment, quiz and test scores) are discussed. Next, detailed description of four experienced modified activities, along with the rationale behind and the benefits gained from these modifications, are presented and analyzed. Furthermore, suggestions to improve two other activities that were not modified during the semester are similarly presented and analyzed. Next, conclusions are drawn with respect to the high influence of the fine details of the instruction delivery process and the high impact an instructor has on the progress of the class. Finally, the paper ends with several suggestions for possible future research.

Workshops' profiles

Table 1 presents the gender demographic classification of the three workshops taught. Workshop 1 denotes the first workshop (taught 8 to 9:50 am of Wednesday mornings), workshop 2 denotes the second workshop (taught 8 to 9:50 am of Friday mornings), and workshop 3 denoted the third workshop (taught 10 to 11:50 am of Friday mornings). It can be seen that both workshops 1 and 3 are characterized by around 40% of the students being females, whereas workshop 2 is characterized by an absolute male population.

Table 1: Gender demographics of the three workshops

	Workshop 1		Workshop 2		Workshop 3	
	Number	Percentage	Number	Percentage	Number	Percentage
Females	9	35%	0	0	12	44%
Males	17	65%	25	100%	15	56%
Total	26	100%	25	100%	27	100%

Table 1 also presents the number of students per workshop at the end of the semester. It can be seen that the number of students per workshop at the end of the semester was almost equal, with an average of 26 students per workshop. It is also noted that in contradiction to the usual engineering schools' trend of higher male retention rates, in these 3 workshops, while 3 male students did not continue through the end and dropped the course; only 1 female student was not able to continue through the end, and mainly due to health problems.

Figure 1 demonstrates the performance of the three workshops with respect to learning outcomes. The figure depicts the scores of the three workshops based on three criteria, namely average assignment, quiz, and test grades. While both the average assignment and quiz grades are based on the average of 8 highest grades out of 9 submitted, the test grade, on the other hand, is based on the average of 3 tests (2 midterms and 1 final exam, which was a cumulative exam of everything studied during the whole semester). It is worth noting that the students were asked to take the quizzes online (through a course management system) and outside the classroom. Students were given a 1 week time interval to solve each quiz, and were also given the right to attempt each quiz several times. Assignments contributed to 10% of the students' total grade, quizzes contributed to 5% of the total grade, and the 3 tests, contributed to 65% of the total grade. Hence, since students are typically driven by grades[6,7], tests are practically the best reflection for learning outcomes. Nevertheless, the authors believe that examining all three criteria could add insight into the similarities and differences between the three workshops.
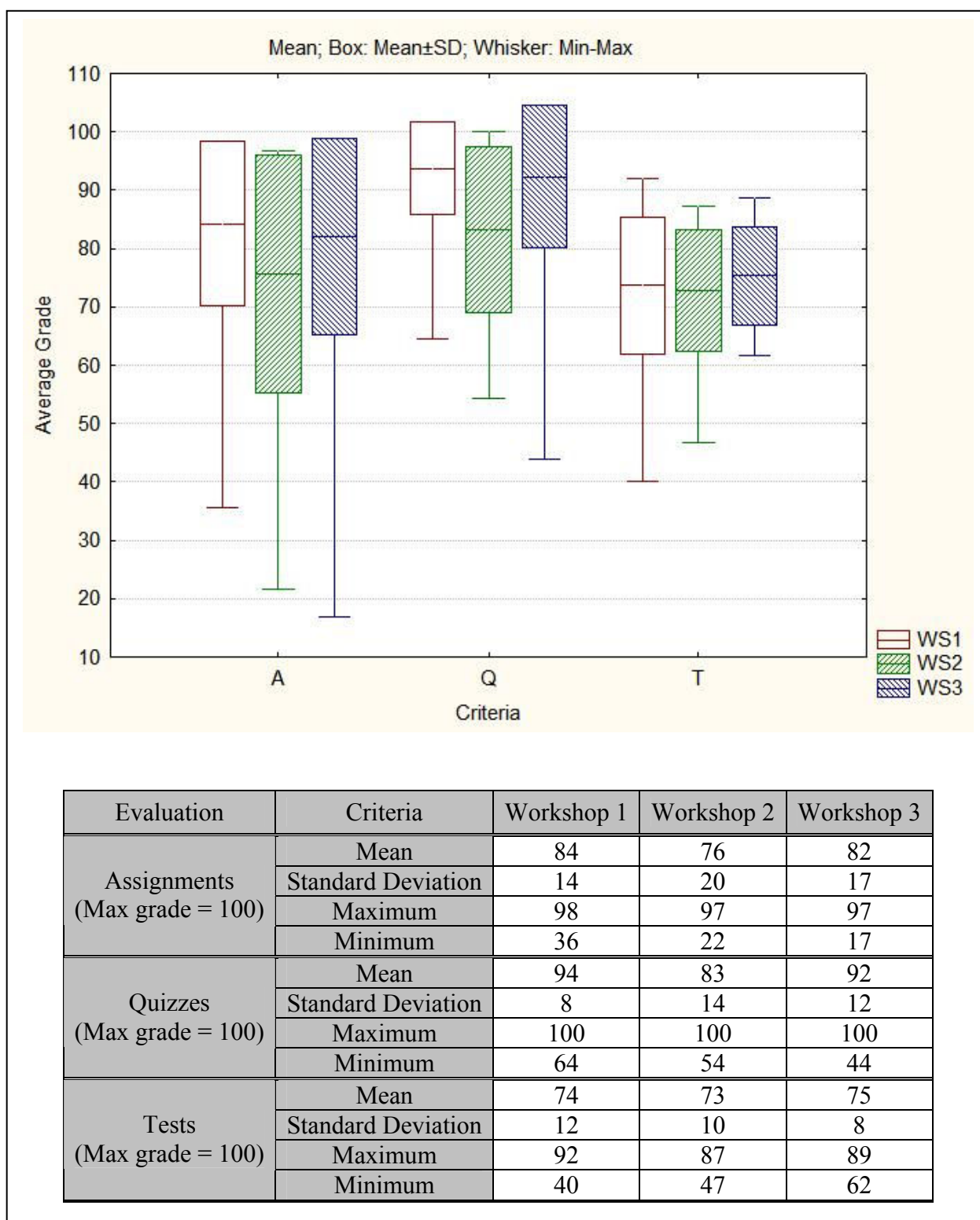
Evaluation	Criteria	Workshop 1	Workshop 2	Workshop 3
Assignments (Max grade = 100)	Mean	84	76	82
	Standard Deviation	14	20	17
	Maximum	98	97	97
	Minimum	36	22	17
Quizzes (Max grade = 100)	Mean	94	83	92
	Standard Deviation	8	14	12
	Maximum	100	100	100
	Minimum	64	54	44
Tests (Max grade = 100)	Mean	74	73	75
	Standard Deviation	12	10	8
	Maximum	92	87	89
	Minimum	40	47	62

Figure 1: Workshops' assignments, quizzes and tests scores comparisons

Figure 1 shows four descriptive measures for each of the three considered criteria, namely, the mean, standard deviation, minimum, and maximum scores. In addition, the specific distributions of each of the 3 criteria per workshop are provided in Appendix A. General visual examination of Figure 1 reflects how the three workshops have similarly performed in all three considered criteria. However, objective statistical analysis is provided in Table 2.

Table 2 presents the statistical p-values corresponding to tests of normality, equal variances (specific test based on the results of the normality test), and measures of central tendencies (specific test based on tests of both normality and equal variances), for the three criteria, based on the three workshops.

Table 2: Tests of normality, equal variances and equal central tendency measures

	Normality	Equal Variances	Equal means/medians
Assignments	<0.005* Anderson-Darling Test	0.259 Levene's Test	0.161 Kruskal-Wallis Test
Quizzes	<0.005* Anderson-Darling Test	0.009* Levene's Test	N/A
Tests	0.185 Anderson-Darling Test	0.256 Bartlett's Test	0.654 General Linear Model

* Significant evidence to reject the null hypothesis

Table 2 shows that there is strong evidence to reject the null hypotheses of normal distributions of both the assignment and quiz grades (p-value<0.005). On the other hand, the available evidence is not strong enough to reject the null hypothesis of normal test grade distribution. Since both the assignment and quiz grade distributions are believed to be non-normal, the Levene test was used to test the null hypothesis of equal variances between the three workshops. Levene's test results did not reflect any significant evidence to reject the null hypothesis of equal variances for the assignment grade distributions (p-value=0.259). Hence, equality of the median of the assignment grades of the three workshops was tested by the nonparametric Kruskal-Wallis test, which showed the lack of evidence to reject the null hypothesis of equal median values for the assignment grade of the three workshops. Since Levene's test reflected strong evidence to reject the null hypothesis of equal quiz grade variance between the three workshops, Bonferonni's standard deviation confidence intervals method was used to identify the workshop pairs that have significant difference quiz grade variances. Figure 2 shows that the standard deviations of the quiz grade of workshops 1 and 2 are significantly different at 5% level of significance. Since the workshops quiz grades turned out to have non-normal distributions that are also characterized by unequal variances – and by checking the distributions, provided in Appendix A, the distributions did not seem to look similar – there was no reliable statistical test available to compare the two distributions central tendencies. This phenomenon of significantly different quiz grade distributions may be reflecting how students reacted differently to the quizzes, because of their low share into the final total grade, or it could possibly be a random phenomenon which is causing a type I statistical error.

Checking the test grade statistics, on the other hand, reveals lack of enough evidence to reject the

null hypotheses of equal test grade variances and means. Hence, this reinforces the possibility of the three workshops belonging to the same population, with respect to learning outcomes. It is worth reemphasizing that the tests grade contributed to 65% of the students' total grade, and therefore, this criterion, and its corresponding test results, should have the most weight in the analysis.
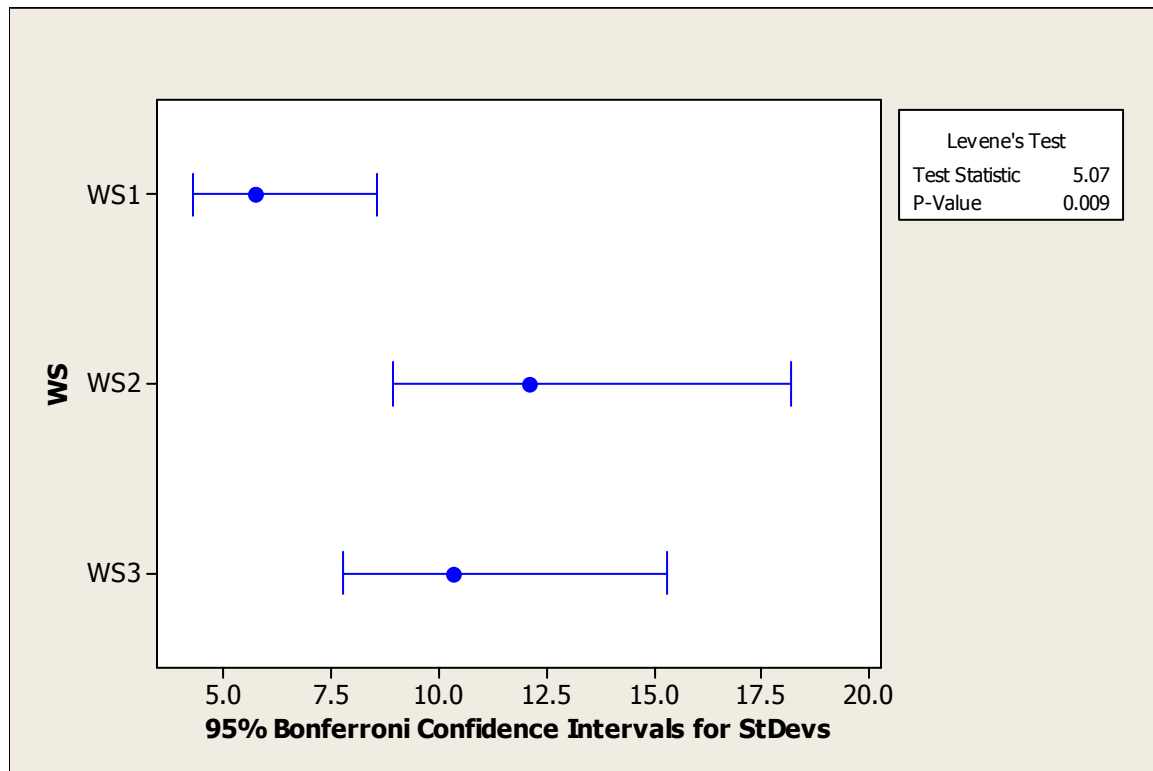

Figure 2: Bonferonni 95% confidence intervals test for quiz grades standard deviations

Based on the fore discussion, it should be noticed that although most of the differences between the means and variances of the three considered criteria were not statistically significant, the authors included these results for the following two main reasons,

1. this proves that the three workshops were not significantly different, and that any observed or surveyed differences may not be attributed to different student populations; and

2. the authors never expected that the modification of four workshop activities could lead to significant test or HW score differences between the three workshops, especially, that the three workshops also belonged to three different lectures and were taught by three different faculty;

And the following 3 minor reasons,

3. at the most, the trend of the scores matches the personal evaluations of the teaching GTA;

4. the authors see that the trend of change across the semester matches the point of this paper; and

5. the authors believe that honest research should provide all available information.

Examining the student's test scores trend across the semester, in Table 3, it can be noticed that

although workshop 1 performed better than the other two workshops at the first test, in the second and third tests, while workshop 2 performed equally well as workshop 3, workshop 3 outperformed both workshops 1 and 2. On the other hand, the standard deviation of the first workshop remained almost equal through the whole semester, the standard deviation of the second workshop increased slightly, and the standard deviations of both the first and second workshops were almost equal. The standard deviation of the third workshop was initially higher than that of the other two workshops, then decreased dramatically by around 50% in the second test, and remained low through the third test. Interestingly, the first workshop had least HW standard deviation and the highest HW score.

Table 3: Workshops performance on tests along the semester

Evaluation	Criteria	Workshop 1	Workshop 2	Workshop 3
Test 1 (Max grade = 100)	Mean	69	66	67
	Standard Deviation	14	10	16
	Maximum	88	84	92
	Minimum	31	35	39
Test 2 (Max grade = 100)	Mean	77	76	82
	Standard Deviation	12	14	7
	Maximum	96	96	95
	Minimum	51	52	67
Test 3 (Max grade = 100)	Mean	75	76	77
	Standard Deviation	13	13	8
	Maximum	96	94	96
	Minimum	38	44	60

The table also shows that the performance of all workshops was worse on the first test than on the other two, and that the performance of all workshops on the later two tests was almost equal. Any or both of the following two reasons may be a logical explanation for this phenomenon,
1. the students did poorly on the first test because it was their first test in college, and they did not know what to expect or how to prepare for it; and/or,
2. the first test was harder than the other two.

It should be noted that although the GTA had constantly been observing high similarities (possibly repressed in classroom energy levels, in-class students' response and activity levels, and students' interactions with the GTA and between one another) between the first and third workshops, the GTA has always observed lower in-class performance of the second workshop. The authors believe that this may be mainly attributed to the difference of the workshops' gender composition. The authors believe that different gender compositions of workshops might have high impacts on the learning environments and consequently learning outcomes of such workshops. However, this is outside the scope of this article.

Nevertheless, as presented hereinafter, the GTA observations are further supported by the mid- and end- of-semester averages of the students' evaluations for each of the three workshops. The first, mid-of-semester, student evaluation form asked students to evaluate 19 aspects of the course on a scale from 1 to 4 each: 1 being the worst and 4 being the best. The aspects ranged

from being course-general as in the overall course satisfaction, to more course-specific as in the usefulness of the textbook, and more workshop-specific as in how the enthusiastic does the instructor seem, and if the classes start and end promptly. The measure selected for analysis represents the mean and variation of the answers of the 19th question, which was asking about the overall students' satisfaction from the course at this point in time. On the other hand, the second, end-of-semester, students' evaluation form also asked students to answer 19 questions. Most of the questions required students to select general evaluation levels from a set of given levels, such as pass, fair, good, and excellent for the fairness of assigned grades; or less than average, average, and above average for the time and effort required for this course, for example. However, for the last two of the nineteen questions, the students were asked to freely write feedback to the instructor. One of the two questions asked the students to write what they think the instructor did well, while the last question, asked the students to write what they think the instructor can improve. The measure selected in the following section to measure students' satisfaction is the seventh question, which asked the students to provide their overall rating of the instructor as a pass, fair, good, or excellent.

Obviously, the two selected measures do not specifically ask about students' satisfaction. However, the authors believe that the two measures may be highly correlated with students' satisfaction. Hence, the following analysis and results may be projected to students' satisfaction. In addition, the two measures are different from one another. This means that if the two measures were to be compared to one another, with the objective of following a time-series sort of a trend, this will be of no practical meaning. The authors would have liked to investigate the trend of students' satisfaction throughout the semester, the same way the test scores were investigated earlier. However, this is not possible with the available data. The authors have communicated this concern to the Department of Engineering Education, and new evaluations forms are currently being developed for this semester. Hence, the mentioned trend analysis will be possible in future similar publications.

Comparing students' satisfaction (reflected in the two chosen measures) across the three workshops in Figure 3, it is noted that workshop 3 indicated, in comparison to the other two workshops, higher satisfaction in both evaluations (mid- and end- of-semester). Workshop 2, on the other hand, indicated a mean satisfaction level that was higher than workshop 1 in the mid-semester evaluations, yet lower than the workshop 1 in the end-of-semester evaluations. These results reflect nothing, however, unless proven to be statistically significant. Hence Table 4 represents the computational results of the statistical tests.

It can be seen from Table 4 that there is strong evidence (p-value<0.005) to reject the null hypotheses of normal distributions of either measures. Hence, the equality of variances was tested by Levene's test, which indicated that there is not enough evidence (p-value=0.595) to reject the null hypothesis of equal variances for the mid-of-semester students' satisfaction measure. Hence, the medians of the three workshops were statistically compared using the nonparametric Kruskal-Wallis test. The result of the test indicated some evidence (p-value=0.053) to suggest that the three workshops medians are not equal. Hence, suggesting that the difference between students satisfaction in workshop 3 might be significant in comparison to the students' satisfaction in workshop 1.
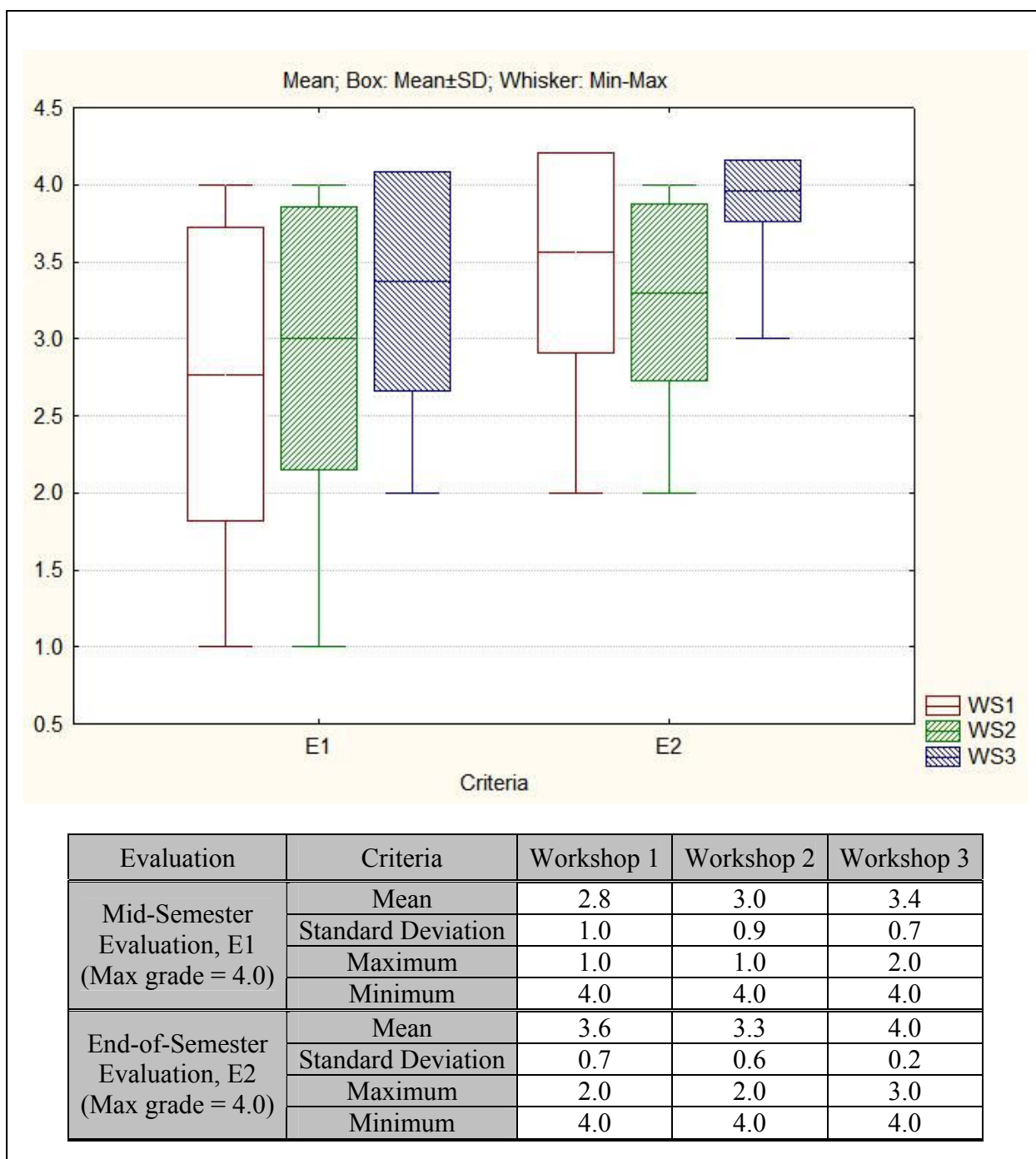
Evaluation	Criteria	Workshop 1	Workshop 2	Workshop 3
Mid-Semester Evaluation, E1 (Max grade = 4.0)	Mean	2.8	3.0	3.4
	Standard Deviation	1.0	0.9	0.7
	Maximum	1.0	1.0	2.0
	Minimum	4.0	4.0	4.0
End-of-Semester Evaluation, E2 (Max grade = 4.0)	Mean	3.6	3.3	4.0
	Standard Deviation	0.7	0.6	0.2
	Maximum	2.0	2.0	3.0
	Minimum	4.0	4.0	4.0

Figure 3: Workshops students' mid- and end-of- semester evaluation scores comparisons

Testing equal variances across the three workshops for the end-of-semester measure, on the other hand, using Levene's test demonstrated strong evidence (p-value=0.010) to reject the null hypothesis of equal variances across the three workshops. Figure 4 presents the results of Bonferonni 95% confidence intervals test for the end-of-semester students satisfaction measure's standard deviations. It can be seen from the figure that the standard deviation of workshop 3 is

significantly different than the standard devations of the other two workshops at a significance level of 5%. Whereas, Figure 4 shows that there is not enough evidence to reject the null hypothesis of equal standard deviations between workshops 1 and 2. Since the end-of-semester measure of students' satisfaction turned out to have a non-normal distribution which is also characterized by unequal variances – and by checking the distributions, provided in Appendix B, the distributions did not seem to look similar – there was no reliable statistical test available to compare the two distributions central tendencies.

Table 4: Tests of normality, equal variances and equal central tendency measures

	Normality	Equal Variances	Equal means/medians
Mid-Semester Evaluation	<0.005* Anderson-Darling Test	0.595 Levene's Test	0.053 Kruskal-Wallis Test
End-of-Semester Evaluation	<0.005* Anderson-Darling Test	0.010* Levene's Test	N/A

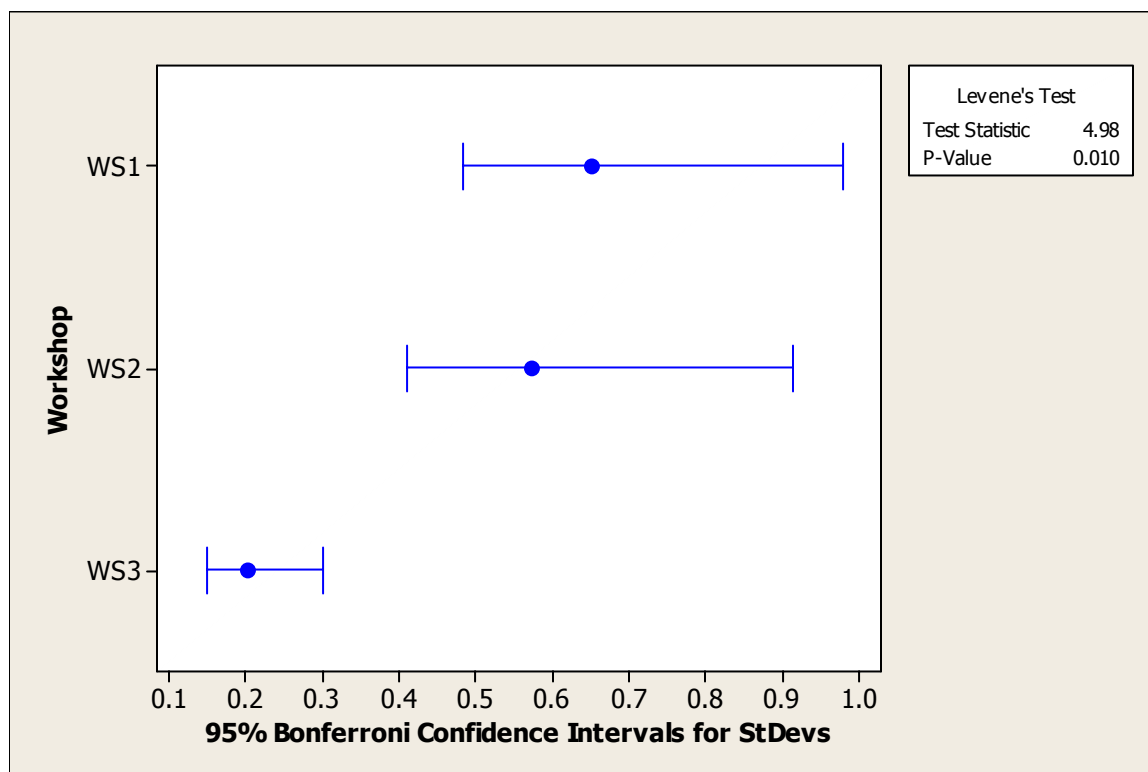* Significant evidence to reject the null hypothesis

Figure 4: Bonferonni 95% confidence intervals test for end-of-semester students satisfaction standard deviations

Finally, it is worth noting that students of workshop 3 demonstrated an extremely high level of satisfaction at the end-of-semester measure. The average of the measure was 4.0 out of 4.0.

From the above section the following is demonstrated,

1. Although all 3 workshops belong to the same population, mainly with respect to the tests scores, there was a significant student satisfaction difference between them, both at the mid- and end- of-semester evaluations;
2. Workshops 1 and 3 are probably very similar to one another, and any difference between them may be attributed to the modifications performed by the workshop leader during the 1-day time gap; and
3. Although workshop 2 also used to meet on Fridays, its different gender composition makes comparing it to the other two workshops inaccurate, and could possibly lead to false conclusions.

Experienced examples

In this section the authors present four examples of small instruction differences between Wednesday and Friday workshops. The authors believe that these examples and many similar ones are the main reason why students' satisfaction was significantly different between Wednesday and Friday workshops.

1. World-map activity

This activity was designed with the objectives of helping students acquire global perspectives on the population concentrations and trends around the globe, as well as the oil productions and consumptions, and its abundance and scarcity for different countries across the globe. It was hoped that the students would see and comprehend the relations between the populations, population trends, and oil productions and needs of several countries, and reflect on this information. The students were handed an activity sheet with specific activity instructions, an A-1 paper sized world map, and plenty of colored Lego blocks. The students were also asked to use their laptops to access the CIA's website in order to find exact value answers for the questions on their activity sheets. The activity was performed by groups of 4 students each.

In spite of the expected students' satisfaction and gains from this activity, when the students were asked to report their satisfaction and perceived gain from the performed activity using a direct oral survey (in the 1st workshop), the students reported convenient satisfaction, yet low perceived gains. Since this result did not make sense, especially that while the students were working on the activity, the GTA was roaming around, and heard a few students comment on how unaccepted the values were turning out to be. So, for Friday workshops, the GTA added a tiny modification to the delivery process of this activity, with the hope of overcoming the low students' perceptions of gains out of the activity.

For Friday's workshops, before starting the activity, the GTA asked the student to spend five minutes trying to guess as many answers of the activity's questions as they could. After the five minutes were over, the students were asked to resume the activity normally, in the same manner followed on Wednesday's workshop. The students were asked to give their group one point for every guessed answer that is even close to the right answer, i.e. it does not have to be the same answer. During the activity time, the GTA sensed higher energy levels in the classroom, and

after the activity was over, the students were surveyed orally on their satisfaction and perceived gains from the activity. In both Friday workshops, the students reported high levels of both satisfaction and perceived gains.

It is worth noting that although the GTA tried to push the student groups to compete against one another by asking to find which group will end up having the highest number of points, close to right answers, the students did not comply with the GTA's trial, and were only interested in finding the right answers and evaluating their guesses. The reason behind the GTA's trial was to encourage students to take the guessing task seriously with respect to the quality of their guesses, and to add an incentive for students to utilize the five minutes interval efficiently by guessing as many answers as they could.

The GTA was also able to utilize the additional five minutes interval by assigning to it an additional learning objective. Since the students were targeting guessing as many answers as they could in a limited time interval. Some students divided the work among them and ended up guessing much more answers than other groups that did not divide the work. The GTA made sure to ask groups how many guesses were they able to guess in the time interval, and asked the groups that accomplished more to explain to the whole class how they did it. Hence, emphasizing to the whole class how cooperative work can increase efficiency.

Although all workshops were asked to do almost the exact same activity, Fridays workshops learnt much more than Wednesday's workshop, and reported significantly different perceived gains. This can only be attributed to better activity design: only because students were explicitly faced with their real level of knowledge, did they appreciate the knowledge they gained from the performed activity.

2. Design-project category selection

The GTA was asked to divide the students within each workshop into groups of threes or fours. Hence, with an average of 27 students per workshop, each workshop was to be divided into an average of 7 to 8 groups. Each group was supposed to pick one renewable energy source from a total of five energy sources, namely: wind, hydro, solar, biomass, and geothermal energy sources. The GTA was expected to distribute the 7 to 8 resulting groups per workshop, among the entire five categories, i.e. each workshop was expected to have a minimum of one group assigned to each of the five categories.

For Wednesday workshops, students were given a short introduction on the five renewable energy resources, and their global and national shares in consumed energy resources. Following, each student was asked to choose one of the five categories, then students choosing the same categories were asked to sit together and form teams of 3 or 4 members, at the most. It turned out that only one out of the 26 students picked the geothermal category. As mentioned earlier, the GTA was supposed to distribute the students among the five categories, and hence the resulting distribution was unsatisfactory. Therefore, the GTA had to come up with either a way to influence the students' self-distribution for Friday workshops, or to forcefully distribute the students among the five categories, even if it meant that students might have to work within energy categories that they do not prefer.

In order to solve this problem, the GTA performed minor modifications to the instructional delivery process of the global and national shares of the five renewable energy resources to the total consumed energy resources (for Friday workshops). When presenting the global and national shares of the biomass and geothermal energy resources, the GTA stressed how both resources are characterized by such low shares. The GTA pointed out that this may be attributable to the embedded challenge for utilizing such resources, and pointed out the possible gains from a successful completion of a project within these two challenging fields. So, the GTA advised the students to consider choosing the project carefully; for they could pick an easy project category that will be characterized with tough competitions, or they could pick a challenging energy category that will be characterized by an easy competition. The reader should be aware that from the 360 – 400 projects (45 workshops × 8 to 9 projects each), the students were aware that 30 projects were to be selected for the finals, and 3 projects from these finals are to win prizes.

As a result of this minor instructional delivery modification, the students within each of Friday's workshops divided themselves fairly among the five energy categories. Hence, just as required, this produced at least one team per renewable energy category.

This example demonstrates the great influence an instructor has on the class s/he teaches. It also shows how minor modifications to the instructional delivery strategy can have big impacts on the instructional progress within a classroom.
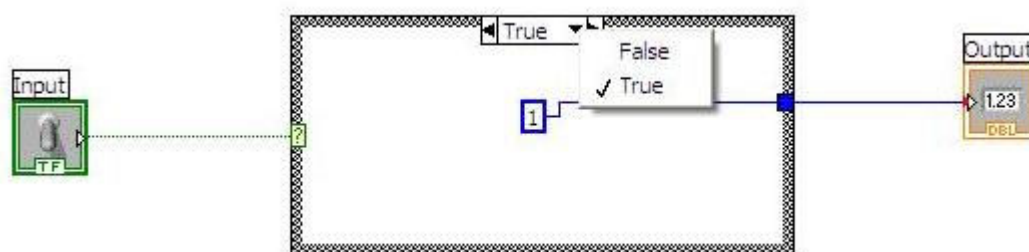
3. Case structures

The students were to learn how to use case structures in LabView 8.2. Case structures have the same function as nested if functions. Figure 3 presents an illustration example of a case structure. In this example, the case structure assigns a value of either 1 or 0 to the *Output* variable based on the value of the *Input* variable. In this case the *Input* variable is a Boolean switch, which can only pass either a *True*, or a *False* value. Hence, the used case structure can only have two case scenarios: a case scenario for a *True* input and a case scenario for a *False* input. Checking the two cases, Figure 3a illustrates that in the case of a *True* input, the case structure will pass the value of 1 to the *Output* variable. On the other hand, Figure 5b illustrates that in the case of a *False* input, the case structure will pass the value of 0 to the *Output* variable.

During Wednesday's workshop, the GTA presented examples of the function and possible usages of case structures. This presentation lasted for around 45 minutes. As usually happens, when the students were asked if they had any questions about the lectured material, no hands were raised. Next, the students were asked to solve a hands-on in-class activity which required them to use case structures. The GTA noticed that most of the students did not get the idea of case structures and were facing serious failures in performing the requested activity.

In Friday's workshop, the GTA spent the same exact 45 minutes presenting case structures, and their usages. Again, none of the students had any questions about case structures. However, before the students were asked to work on the hands-on in-class activity, the GTA did one extra task. The GTA pointed out that before starting to use case structures, the students should first try

to figure out what are the input and output variables. The GTA pointed out that the students should reflect back on the main function of case structures: they should change their output values, based on certain input values. Hence, the students should first identify their desired input and output variables. Surprisingly, based on this minor modification, which lasted less than a few minutes, the GTA noticed significant performance difference in Friday's workshop, in comparison with Wednesday's one. A much higher percentage of students seemed to solve the assigned problem in less time and without difficulty, and only a few students seemed to face trouble.

a) Snap-shot of the Case Scenario of a *True* Input
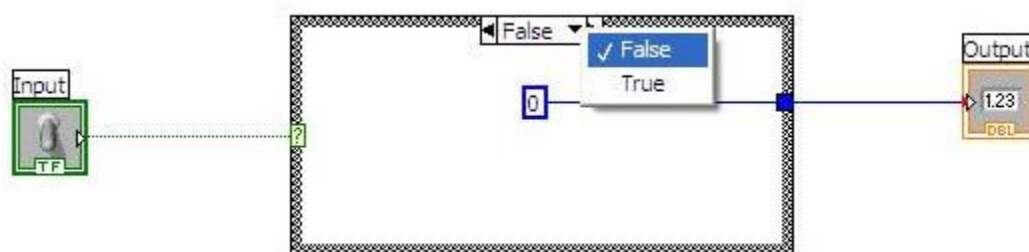
b) Snap-shot of the Case Scenario of a *False* Input

Figure 5: Example of a LabView Case Structure

The above example presents another demonstration of how minor interventions of the instructional delivery can cause significant impacts on the learning process. The only difference between Wednesday's and Friday's workshops was a tiny hint on were to start the thinking process. Although this hint seemed to have been basically logical from the GTA's point of view and based on the GTA's level of knowledge, yet obviously, from the students' level of knowledge this hint was significant and not basically logical. Furthermore, although this additional hint consumed a few minutes from the class time, yet it resulted in much more time gains, represented in the less time the students needed to complete the activity.

Therefore, it is inevitable for good instruction to consider the students level of knowledge and apprehend the possible differences between what might seem logical for an instructor, versus what seems logical for students. Also, probably the better organization and more time spent in the introduction of new concepts would probably result in less student problems and reduced problem solving time, i.e. better perception.

4. Teammates

Another interesting experience demonstrates the power an instructor has on his/her class, and the trust bond that builds between an instructor and his/her students. This experience also illustrates how if an instructor was always alert and conscious of the dynamics inside the classroom, the instructor can stealthily lead the classroom to follow his/her desires without needing to explicitly use his/her powers; hence, leading to a healthier class environment[8].

At the beginning of the semester, when the students of each workshop were required to be divided to several groups, the GTA asked the students if they liked to pick their teammates, or if they would rather be divided randomly. Since this class is a freshmen general Engineering class, most of the students did not know one another. So, at that time, only a few students chose to pick their teammates (probably picking their friends). The same scenario occurred in all three workshops.

In the following workshops, the GTA explained to the students that there is a lot of research going around regarding teaming, and that the current research understanding leans to the indication that heterogeneous teams tend to outperform homogeneous ones[9]. Hence, it might be better for them to team with other classmates rather than friends. Since friends are usually quite similar and not heterogeneous. The students complied with this and did not reject being randomly assigned into groups.

After a couple of workshops, by mid-semester, the students had for several times experienced both working with the students sitting next to them, which were usually their friends, as well as being randomly assigned into teams, hence, working with non-friends. At that time, the GTA expected that if students were asked the same question they were asked at the beginning of the semester: if they liked to pick their teammates, or if they would rather be divided randomly, in opposition to their choice at the beginning of the semester, the students would choose random team assignments. This expectation was based on the assumptions that i) the students have experienced random assignment several times and did not face any trouble, ii) the students will probably like to get to know more of their class mates and extend their social network, iii) with the equal percentage of males and females there is a high chance they would like to know one another, and iv) the students would have probably noticed the gains from working with other different students, with regards to intellectual approaches.

In Wednesday's workshop, the GTA asked the students if they would like to be randomly assigned to teams for the in-class exercise, expecting that they would. Getting no response, and in a last trial, the GTA asked that whoever wants to be randomly assigned to teams to raise their hands, but no hands were raised. Complying with the students desires, the GTA asked the class to split into groups of three's of their choice. However, the GTA did not feel that the students were happy to select their own teams, and did not think that the above mentioned assumptions were wrong. So, in Fridays workshops, the GTA asked the same question, but in an opposite manner. The GTA asked the students if they would like to be pick their own teams. Again, the students showed no response, and when asked to raise their hands if they wanted to pick their own teams, just like with the opposite question in Wednesday's workshop, no hands were raised. Hence, the students were randomly assigned into teams.

The authors believe that possible explanations for the reactions of both workshops may be attributed to the following two observations, i) the students realized the benefits of working in random teams, so in Friday's workshops they did not mind working in random teams, ii) probably as is the case with most people, students still enjoyed discussing common subjects with their friends while working, so they did not mind working with their friends. In addition, these two explanations might be specifically relevant in this particular case where, i) the students were only asked to work in teams for a short in-class time period, ii) the activity was only a practice activity that had almost no effect on their course grades. One last reason which may be relevant to this analysis is that by mid-semester the trust bond between the students and the GTA was high enough that the students did not mind following their instructor's instructions and believed they were all for their benefit. Although another possible explanation which some might think is that the students were acting in a negative manner, not interested in active participation by responding to the raised questions, the authors believe that this is least likely. This view is mainly because the workshops were generally characterized by high energy levels, and active student participation.

Intentionally, the GTA wanted the class to work in random groups, not with their friends. Some of the main reasons for this intention included anticipated, i) better performance[9], ii) practice of working with non-friends, and iii) enhancement of students social development[10], as well as the benefit of extending the students' social networks. The GTA believed that once the students have tried working with random groups, they would realize the benefits they gain out of it, and would prefer to continue working this way, rather than with their friends. However, had the GTA not realized the dynamics behind Wednesday students choice, the GTA would have assumed that this belief was not correct. While in fact, based on the above analysis, the belief seems to be reasonably correct. Hence, this is another clear example of the power and influence an instructor has on the class s/he teaches, as well as how small interventions can always lead to major differences in classroom dynamics.

Suggested examples

In this section, the authors present another two small instructional interventions which, just like the earlier four examples, can be sources of different students' satisfaction. Unlike the earlier four examples, the following two examples were not tested in any of the workshops. Hence, there is actually no evidence they are better than the currently adopted strategies. However, should the GTA have another chance to teach the workshops again, these would be a couple of small possible interventions which could possibly improve the quality of teaching, as discussed hereinafter.

1. Sketching

In this activity, the students were asked to construct any structure they like using a minimum of ten Lego pieces. The students were asked to also use a minimum of three shapes of the Lego pieces, so that they do not end up building a cube-like structure. The main objective of this activity was to help students practice sketching both isometric and orthographic views. The idea

of using the Lego pieces was to facilitate the students' visualization process, since they were asked to sketch a structure they were very familiar with – they are the ones who selected and constructed it.

As interesting as the original activity currently is, the authors believe that this activity can be further expanded. The proposed replacement activity is actually identical to the original activity; however, with a couple of additional tasks. In order to keep the activity time requirements short, the authors suggest using less Lego blocks, possibly five blocks might be reasonable. In the proposed replacement activity, after the students have finished sketching the isometric and orthographic views of their Lego structure, the students will be asked to exchange their sketches with another class mate. So, each pair of students will end up exchanging sketches with one another. In the mean time, the students will be asked to keep their original constructed Lego structures intact. The students will be given a new set of Lego pieces, and each student will be asked to build the structure sketched on the sheet s/he got from the other classmate. After the students are done constructing the exchanged sketches, they will be asked to compare their constructed Lego structure with the original Lego structure, which was created by their classmate they exchanged their sketches with. At this point, each student will be asked to analyze the differences between the Lego structures constructed from the sketch versus the original Lego structure constructed by the classmate. Each student will be responsible to figure out sources of errors: either being in the sketching phase, or the construction phase. In addition, each pair of students will be responsible to communicate and discuss their findings with one another. At the very end of the activity, it is possible to ask any pair of students who might have experienced interesting errors to present their findings with the whole class.

In addition to the basic benefits of the original activity mentioned earlier, the proposed replacement activity has a few more benefits. The authors believe that these added benefits could (if not improve the learning outcomes) engage the students more and would result in higher students satisfaction. The proposed replacement activity should i) practice visualization of engineering sketches into three dimensional structures; ii) help students see the real world significance of engineering sketching, as being a universal engineering communication language; iii) help students develop higher cognitive skills: analysis of possible sources of errors; iv) help students know their classmates, and the sequential benefits of expanding their social networks as well as enhancing their social development; and v) help students practice communication skills with their classmates.

Unlike the previous four experienced small instructional interventions, a few might see this example as a major intervention. However, the authors believe that this proposed replacement activity is actually nothing but an expansion of the original activity. The authors believe that coming up with the original activity is the major instructional design, whereas developing and expanding on it is nothing but a minor, small intervention to the original activity. Nevertheless, the authors believe that this small intervention, could lead to a big impact.

2. Graphing

One of the learning objectives of the course was "*to graph numeric data and derive simple empirical functions*. One of the in-class activities adopted to achieve this learning objective was

as following. The students were given a table of two variables, the first being the water height above the crest of a weir, and the second being the discharge of water from this weir. The students were asked to a) plot the two variables on log-log, and semi-log graphing paper, b) decide which plot looks more linear, in order to select the suitable form of empirical function, c) calculate the parameters of the empirical function using the Method of Selected Points, and the Least Squares Linear Regression Method, d) calculate the percentage difference in the slope parameter, based on the two calculation methods. It should be noted that during the earlier weeks of the semester, the students have had both hands-on and computational experience working on a problem where water flowed out of a nozzle at the bottom of a tank. They measured as well as calculated the time required for the water level to descend from an initial to a final height inside the tank. Hence, the idea of the activity under discussion was familiar to the students.

Apart from the direct learning outcomes achievable from doing this activity, such as, i) practicing the need for graphing in order to find out the kind of relation between the two variables, ii) practicing graphing on both log-log and semi-log graph paper, iii) practice using the Method of Selected Points, and the Least Squares Linear Regression Method to estimate function parameters, and iv) reflect on the differences between the two methods, the students should have also gained a few other indirect learning objectives. For example, the students were introduced to weir structures. They learnt what a weir structure is and what is it used for in real life. This subtly serves another learning objective of this course: *demonstrate a knowledge of the disciplines of the Virginia Tech College of Engineering*. In addition, the context of the problem, being a real-life problem rather than a hypothetical one, helps the students see the actual benefit they gain from this knowledge.

In spite of all the above mentioned benefits, there is probably nothing that could not be improved. *Teaching is a lifelong learning process*[11]. In the following few paragraphs the authors propose a replacement activity which, at the least, serves the learning objectives just as good as the original activity. However, the authors expect that the replacement activity could significantly improve students' satisfaction.

The suggested replacement activity is presented in Figure 4. It can be seen from the figure that the activity has a *Guess Who* title. Just like in the original activity, the students are given two variables and are asked to figure out an empirical function that related them to one another. However, in this case, the given variables are the radius of a circle and the corresponding area of the circle. During the workshops the GTA had noticed that students were getting quiet bored from the repeated time versus water height problems (water tank and weir), and this was decreasing the students enthusiasm for solving the assigned activities. In addition, the authors believe that contrary to the benefit the students get from the real world weir problem, the students do not actually gain as much insight into the benefits of graphing and estimating relations, since they do not have experience in the practical application and importance of figuring out the relationship between the time and water height in case of water tanks or weirs. In addition, this lack of experience affects the students' apprehension of the resulting empirical function. They practically have very little knowledge, which results in minimal expectation and judgment abilities; hence, leading them to accept any resulting empirical function.

GUESS WHO?
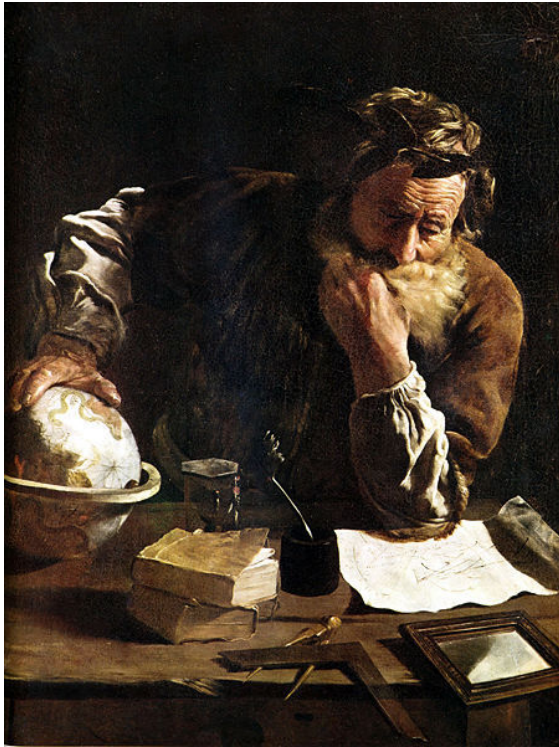
You are required to find out who is this person in the picture.

Hint

This person was able to develop a relationship; you have been constantly using for so long, between the following pair of data sets,

R	A
2	12.6
4	50.3
6	113.1
8	201.1
10	314.3
12	452.6
14	616.0
16	804.6
18	1018.3

In order to find out who this person is you can follow the following steps,
1. Find what kind of relation exists between R and A.
    a. Is it a linear relation?
    b. Is it an exponential relation?
    c. Is it a power relation?
2. Once you find out the shape of the relation, you need to derive the mathematical formula that represents this relation
    a. You can use the quick method of selected points first, and see if it will turn out to be any formula you know well. If you couldn't recognize the formula, then,
    b. You can use the least squares linear regression method.
3. If you failed to figure who this person is, then is it possible you mixed up the dependent and independent variables?
4. What happens if you mix the dependent and independent variables in the,
    a. Method of least squares linear regression?
    b. Method of selected points?
    c. How about if the relation was exponential? Why?

Figure 4: Replacement Graphing Activity

Therefore, the suggested replacement activity is mainly proposed to overcome the above mentioned limitations. By overcoming these limitations, the authors believe that the students should be more interested in the activity and this should result in higher students' satisfaction. In addition since the proposed activity is based on a function which the students are quite familiar with, the authors believe that the activity may be expanded to help students reflect on more graphing principles, uses and applications.

The authors believe that the proposed replacement activity, unlike the original activity, will not serve the other learning objective – knowledge of the engineering disciplines. It will only serve the graphing learning objective. However, the authors believe that the replacement activity will serve the graphing learning objective much better than the original activity; with respect to both students' satisfaction as well as learning outcomes. In addition, the knowledge of engineering disciplines learning objective was only subtly covered.

As could be seen from Figure 4, the proposed replacement activity will have kind of a game atmosphere, where students will be asked to figure out the name of a person in a given picture. The students are given a hint which points out that this person was able to figure out the relationship between two given variables, variable R and variable A. The hint also mentions that the relationship developed by this person has been constantly used by the students for a long time. The authors believe that this game atmosphere could ignite the curiosity of students and help them get engaged with the activity.

Other benefits of the proposed alternate activity include the familiarity of the students with the relationship. Since the students are now trying to find out a relationship which they supposedly know pretty well, this should help them better judge the empirical formula which they are going to get. If after estimating the parameters of the empirical function, the students were not able to identify the relationship; this would mean that their solution is not correct. This should also help students work on the activity more seriously, because they are not going to report their final answer except after examining it and checking if it is identifiable to them.

Another benefit from asking students to estimate a relationship which they have been constantly using is relevance. After students succeed in solving the problem, they will possibly reflect back on the exercise and learn from it. The authors believe that there is a higher chance for students to gain insights into the benefits and usages of graphing and estimating functions in this case, in comparison to the original case where the students would be blindly reporting their estimated functions without actually reasoning the benefits behind getting this function. The authors believe that with a few possible leading questions from the instructor, the students should be able to see the practical benefits of graphing and estimating empirical functions.

Furthermore, since the relationship under investigation is one which the students should be able to identify, the authors believe that a little more can be added to this activity. The authors believe that working on this activity, the students will actually experience, rather than calculate, the difference between using the Method of Selected Points and the Least Squares Linear Regression Method. Using the first method, the students will probably fail to identify the relationship, while after using the latter method; the students should quite easily identify the relationship. The authors believe that after the students experience this with their own hands, they should probably

autonomously reflect on and discover the difference between the two methods. Another possible addition to the activity would be exploring the difference between using the Least Squares Linear Regression Method for Y on X versus X on Y. The students will find out that the relation they are seeking is only possible if they model for Y on X. This should help raise the students' curiosity and yield them more open and eager to the explanation.

Figure 4 also shows an additional extension in the proposed replacement activity. With the intention of helping students comprehend the practical meaning of a log-scale, the students are finally asked if mixing the dependent and independent variables (X on Y, versus Y on X) when using the Method of Selected Points in a log-log relation as well as a semi-log one. This question should help students reflect on and gain more insight into the practical meaning of log scales. Furthermore, it should help students also reinforce their understanding of the differences between the two methods used for parameters estimation.

Limitations

This research was subject to several limitations. The authors believe that these limitations should be brought to the reader's attention, and therefore are listed and discussed below.

- The first and third workshops are characterized by different meeting days and times. While the 1st workshop met around the middle of the week, Wednesday, the 3rd workshop met at the end of the week, Friday. If this difference can be a reason for different student behavior, then it may have been a reason for different learning outcomes and instructional experience.

- The first and third workshops met at different times of the day. The scheduled time for the 1st workshop was in the early morning, 8 to 9:50 am, while the scheduled time for the 3rd workshop was later in the morning, 10 to 11:50 am. This difference could be a reason for different students' attitudes towards the assigned in-class activities, and consequently, different instructional and learning experiences.

- The authors believe that different gender compositions can lead to different instruction experience and learning outcomes. Hence, the authors believe that any conclusion based on comparing the 2nd workshop to either the 1st or the 3rd workshops, might lead to erroneous conclusions.

- Students of each of the 3 workshops attended lectures taught by different faculty. This discrepancy might have been influenced students' preparedness and attitudes in workshops.

- Mid-semester students' evaluation forms are not designed for workshop evaluation. Hence, students' evaluations (stated numbers) are probably evaluating other aspects that are not workshop related. For example, the relevance and usefulness of the course textbook. The authors would have appreciated students' evaluations that would be explicitly designed to evaluate students satisfaction and perceptions of activities administered only in workshops.

- The authors would have liked to investigate the students' satisfaction trend across the semester. However, this was not possible because the mid- and end- of semester student

evaluation forms were characterized by different questions, that were not possible to compare to one another.

Conclusions

In conclusion, the authors believe that all instructors have high influence on the instruction and learning experience of the students they teach. Instructors can highly influence the propagation and decision made within their classrooms, as well as students' perception and satisfaction, with very little modifications to the instructional delivery process. The authors hope that by now the readers agree to this point of view, and are aware that in order to dramatically improve the instruction and learning experiences of the students within classes, no major entire course re-design or modifications need be applied, but only minor modifications and further care to the detailed design of the instruction delivery process can do the trick. The authors would finally like to stress the limitations embedded within these reached conclusions, which undoubtedly points out the definite need for further research.

Possible further work

Following is a list of possible future research that could help further confirm or defer the above conclusions,

- The effect of different workshop scheduled meeting days and/or times on workshops' performance may be a good starting point that could lead to significant implications on school schedules design.

- The effect of different workshops' gender compositions on workshop performance could be further studied, and may lead to better understanding of workshop performance dynamics.

- It is possibly useful to investigate the possible differences resulting from using workshop-directed evaluation forms for students' evaluations. This should lead to better understand students' evaluations and set reliability standards for using such evaluations for further research.

- It should be useful to study the effect of different faculty lecturing the same content to different students, in parallel, on the performance of these students, and consequently on the performance (instructional and learning experiences) of the workshops encompassing these students.
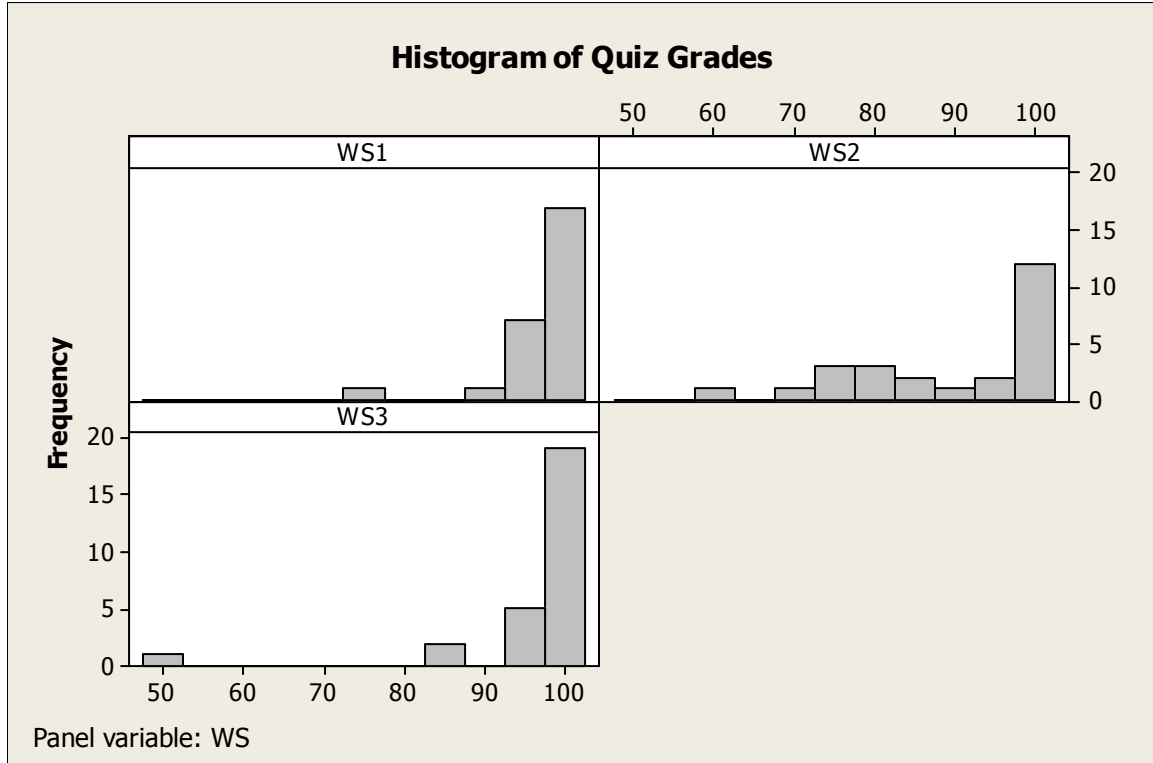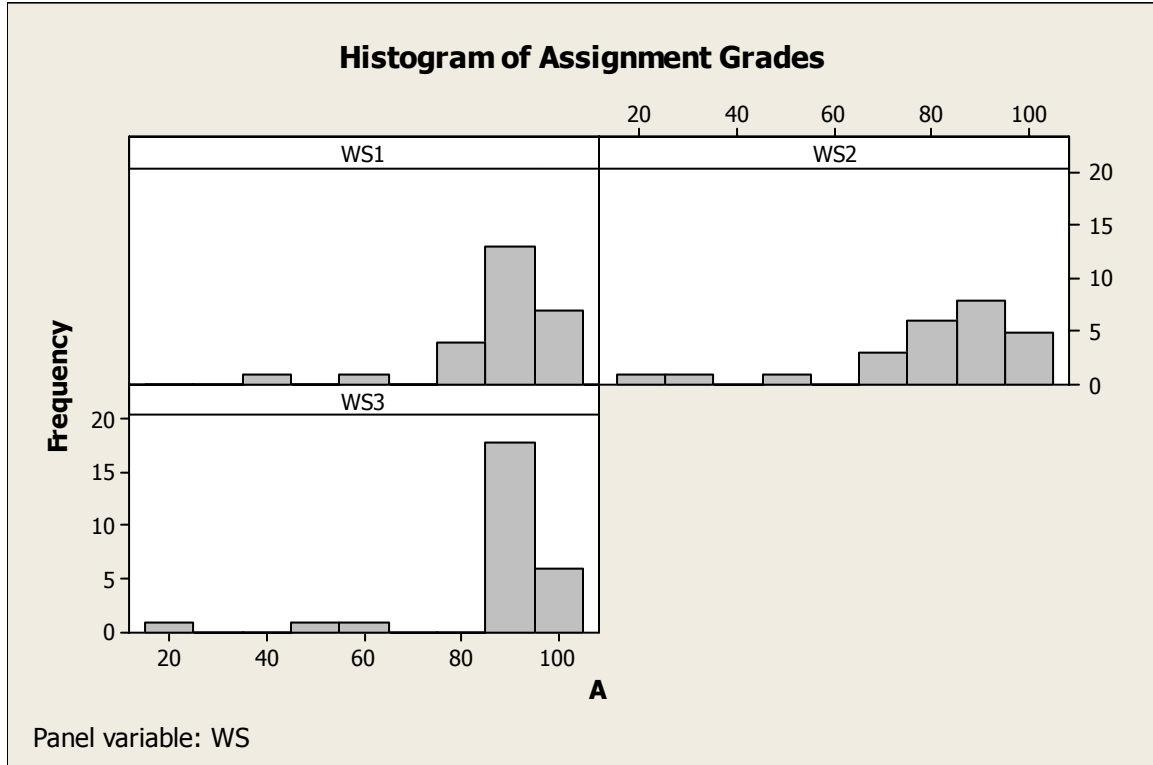
Acknowledgments

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Appendix A

Histogram of Assignment Grades
Panel variable: WS

Histogram of Quiz Grades
Panel variable: WS

Appendix B

Histogram of Mid-of-Semester Evaluations (E1)

Histogram of End-of-Semester Evaluations (E2)