Flipping Homework: An Effective Homework Model

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Abstract

In this paper, a novel model for incorporating an effective homework component within an engineering course is proposed. In this model, a copy of the homework assignment is submitted electronically and students are asked to self-grade their original assignments using an instructor provided solution and a grading rubric. Students are also asked to provide detailed explanation for every correction they make. The purpose of this self-grading exercise is to motivate the engineering students to actively learn and develop their well-needed self-reflection and self-judgment skills. This approach will help maximize the effectiveness of the homework component and empower the students to learn from their own mistakes. In this model, students' grades are based on their ability to clearly identify their misconceptions, make corrections, and provide a clear justification for how they graded their homework problems. In addition, this model is sought to not only discourage plagiarism but also to provide an accurate indicator of the performance of every student in class. To validate our findings, we conducted both quantitative and qualitative assessments taking into consideration all the pertinent parameters involved in this model. The effectiveness of this model was quantitatively verified by assessing the student performance in pre- and post-exams. Qualitative assessment in a form of survey was conducted to measure the level of students' satisfactions with this model. Assessment results showed that students subject to this study were able to significantly improve their performance which confirmed the merit of implementing this flipped homework model.

Introduction

Homework is known to be an essential component in every educational process since it serves as an outside-the-classroom learning tool that solidifies learned concepts using problem solving[1]. Homework has also been used as a pre-indicator to monitor and assess students' performance[2]. Different flavors of homework were proposed throughout the years. For example, various types of online homework were proposed as models to simplify the grading process and increase the homework effectiveness[3]. However this type of homework could limit the student creativity to some extent since the questions are contained within a specific guided solution process[4]. Another proposed model to improve the homework effectiveness was the early homework bonus model[5]. In this model, homework submitted earlier than the due date was rewarded with bonus credit as an incentive, resulting in 50% of the homework submitted during the bonus period. However, time management and keeping up with the deadlines are still persistent issues for some students. Due to their engaging nature, online games were proposed as an approach to create a virtual learning community to encourage collaborative effort while attempting homework[6]. This model had positive impact on the students' performance due to their high-level of engagement while playing these games. On the other hand, scaling such a model to include large number of students or even different courses is not a trivial task. In addition, there are not too many games that can facilitate the learning process in all the various disciplines. At the other end of the spectrum, a study suggested eliminating the graded homework in engineering courses and replacing it with periodic quizzes[7]. This model might have been suitable for a specific setting, but it will be extremely hard to completely eliminate the graded homework component from the learning process without negatively affecting it. In other studies[8,9], the psychology of homework

and students' habits in attempting homework were addressed in an effort to develop a better understanding of this area. Only few recent papers addressed the topic of self-reflection and proposed models that adds this component to the homework[10,11,12]. Even with all these studies, the effectiveness of homework as an important tool in the learning process is still not improving; on the other hand, it has been declining due to the increase in plagiarism among students. Unfortunately, plagiarism is becoming a serious issue in academia since it is not only limited to few procrastinating students trying to academically survive but also used by high achievers to maintain their academic privilege. Copying homework without attempting to solve the problems obviously defeats its purpose. Therefore, a new approach for incorporating homework into the learning process in which students can have a meaningful and rewarding experience is strongly needed.

Flipped Homework Model

In this study, we propose a novel model based on flipping the homework in which the students are asked to self-grade their own homework assignments while the faculty can assess the students' ability to self-reflect and self-judge their own work. The rationales behind this model are as follows:

1. *Reduce or eliminate homework plagiarism*: this is achievable since the final homework grades are not going to assess how well the student attempted the homework but will assess how well they graded it and reflected on their mistakes. This will totally flip the homework from being an assessment tool to an active learning tool.

2. *Improve the effectiveness of the homework within the learning process*: this is achievable since homework is honestly attempted. In addition, the process of grading the homework requires a good grasp of the solution, which is only possible through outside-the-classroom learning.

3. *Develop the student self-reflection skill*: this is achievable since students will learn how to think critically when grading their homework and assessing their solution process.

4. *Develop the student self-judgment skill*: this is achievable since students will have to grade their own work using rubrics and performance indicators.

To achieve these objectives, a student-graded homework model was developed. In this model, the student is assigned a bi-weekly homework. The homework will be submitted electronically through course management software in order to keep a copy of the original submission to detect any future plagiarism. After the submission of the homework, the faculty posts the homework solution and the grading rubric. The students are asked to submit the physically graded copy of their homework within 3 days of receiving the grading material. The graded copy of their homework should have a numerical grade with one paragraph justification on every question discussing their solution and reflecting on their thought process for mistakes made. This copy of the graded homework is what the faculty grades for the official final grade. This flipped homework process usually takes a week followed by a quiz as a mean of formative assessment. The model flow is illustrated below in Figure 1.

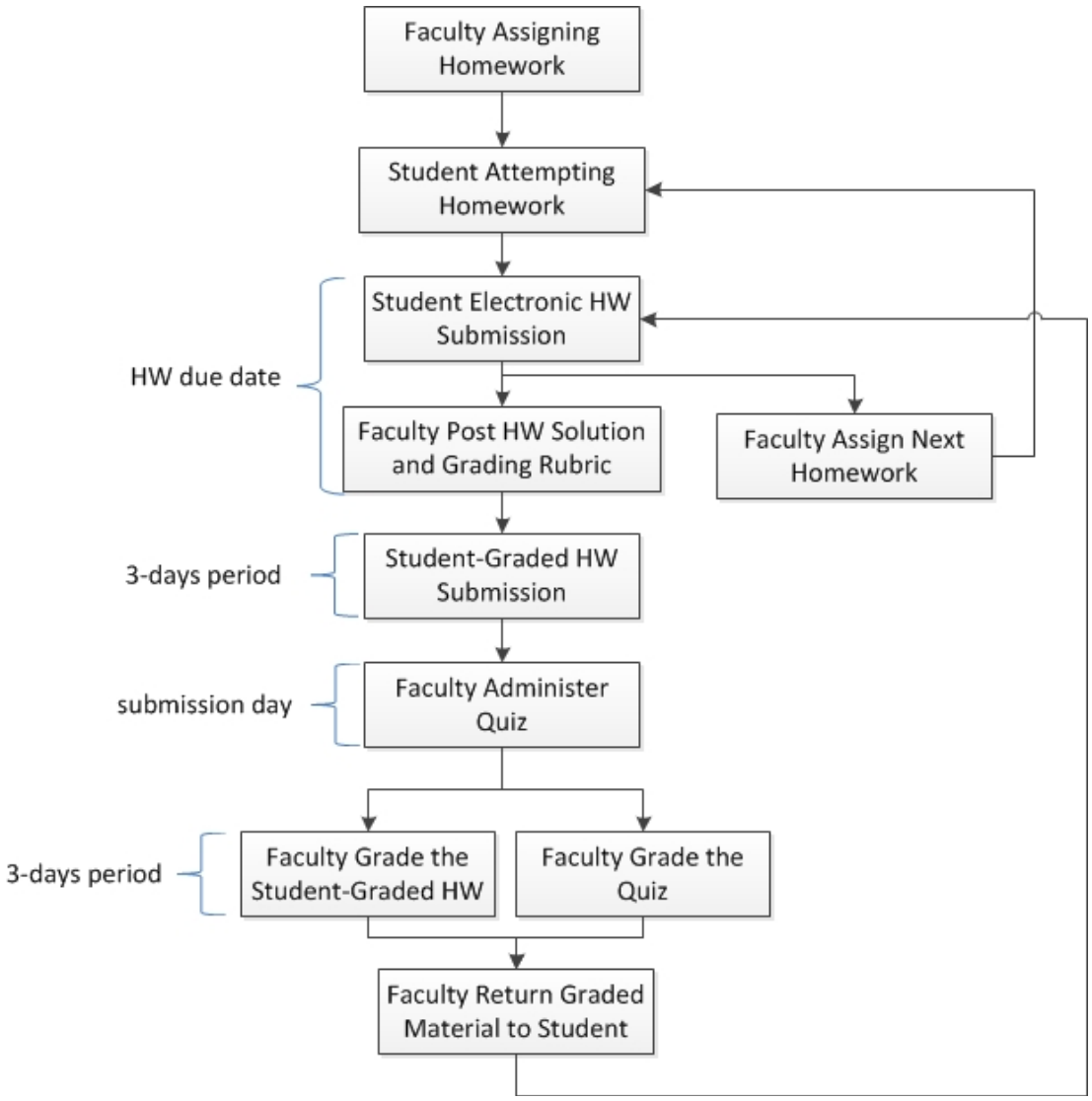

Figure 1- Student-Graded Homework Model

Implementation and Evaluation

The proposed flipped homework model was implemented in a senior level course. The students' performance improvement was indirectly assessed in a pre- and post-assessment analysis. This analysis utilized the students' performance in pre- and post-exams to quantify the effect of the new flipped homework model. Within the first half of the course, the traditional homework model was used, while the new flipped model was used for the remainder of the course. This course included a total of 9 homework assignments with the first 3 using the traditional model while the other 6 used the proposed flipped model. A total of 9 students were involved in this study. The results of the pre- and post-exams are displayed in Figure 2 which clearly demonstrates the significant improvement in the students' performance even though the post-exam addressed more advanced topics. However, the sample size was too small to infer such conclusion without any statistical analysis.

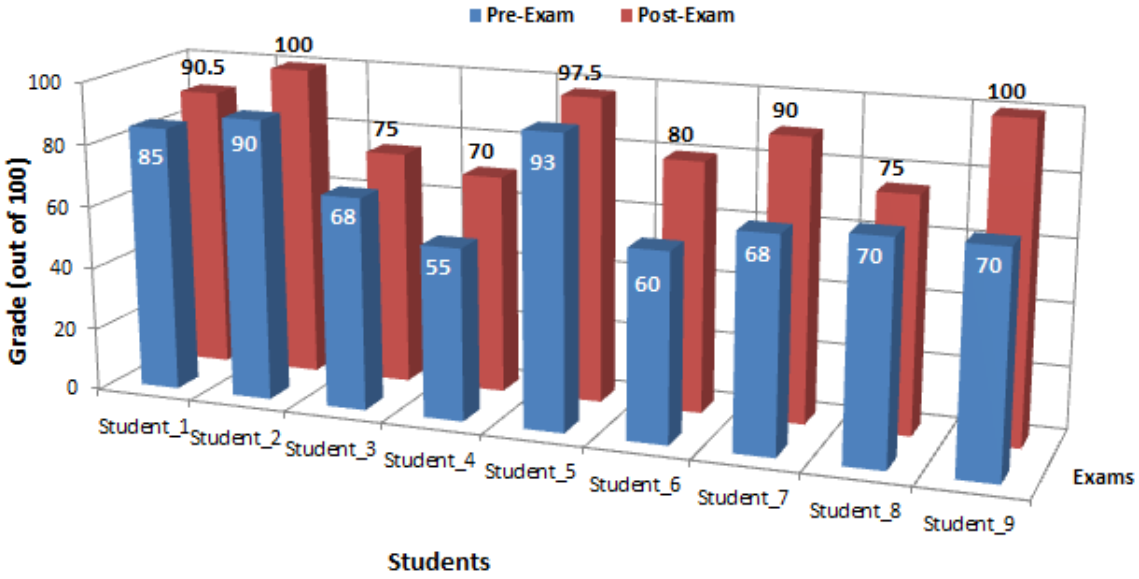

Figure 2- Students' Pre- and Post-Exam Grades

Next, the normal distribution fit for the results of the pre- and post-exams are illustrated in Figure 3. As shown, these distributions indicated a significant difference in the overall mean and standard deviation of the pre- and post-exam grades. These results supported the hypothesis that the new flipped homework model utilizing the self-reflection is different (better) than the traditional homework model.

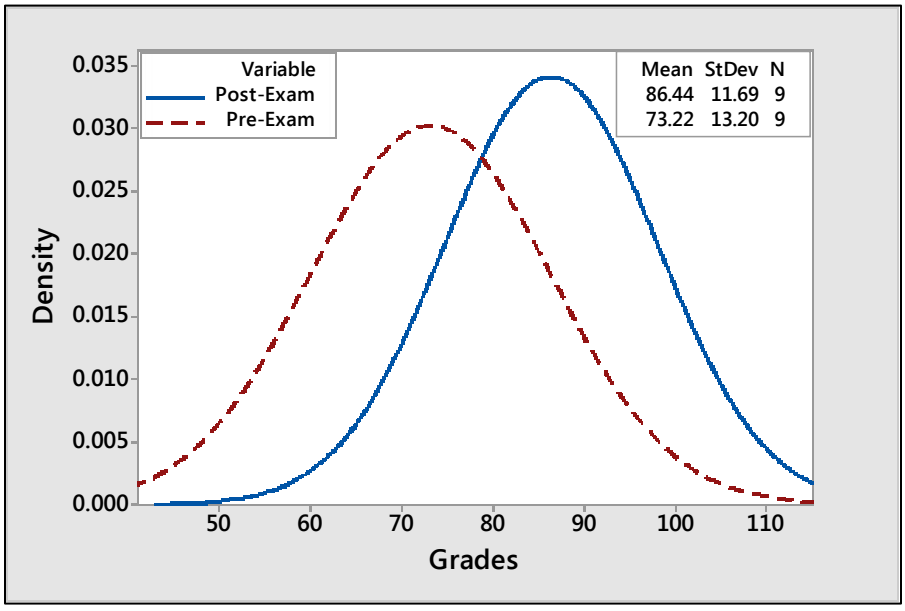

Figure 3- Fitting the Pre & Post Exam Grades into Normal Distributions

To verify and validate these findings, a thorough statistical analysis using the Minitab statistics software[13] was conducted. Our null hypothesis stated that there were no statistical differences in the students' grades from the pre- and post-exams. To test this hypothesis, we used the General Linear Model to analyze our data using a probability of error criterion with a significance level

of 1% (p=0.01). The response variable for this analysis was the students' grades obtained from both exams. As indicated in Figure 4, there are two main factors in this analysis.

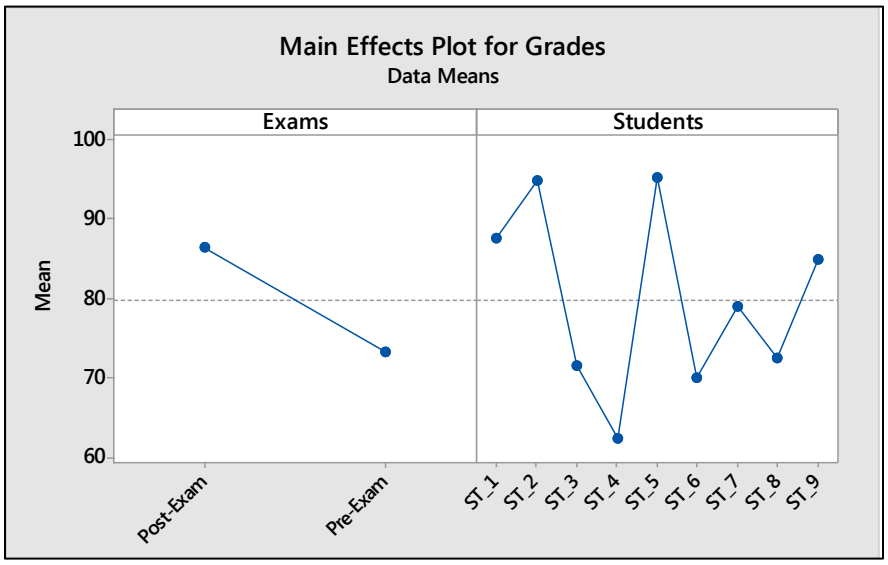

Figure 4 – Main Effect Plot Illustrating the Effect of Treatment and Students

The first factor is the treatment effect modeled by the difference in the pre- and post-exams' results. The second factor is the student effect modeled as a nuisance or blocking factor. The two-level treatment is the effect of introducing the flipped homework model. We considered the differences among students as a blocking factor to eliminate their induced variability to the response variable. The analysis, as shown in Figure 5, generated a p-value equal to **0.002** which is five times smaller than the **0.01** criterion for significance. Therefore, the null hypothesis can be rejected with a confidence level of **99.8%.** This result concludes that there is a statistically significant difference between the pre- and the post-exams which validates the effectiveness of the proposed model.

General Linear Model: Grades versus Students, Exams

Factor Information

Factor	Type	Levels	Values
Exams	Fixed	2	Post-Exam, Pre-Exam
Students	Random	9	ST_1, ST_2, ST_3, ST_4, ST_5, ST_6, ST_7, ST_8, ST_9

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Exams	1	786.7	786.72	19.07	0.002
Students	8	2156.3	269.53	6.53	0.008
Error	8	330.0	41.25		
Total	17	3273.0			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
6.42289	89.92%	78.57%	48.95%

Figure 5 – Outcome of the Two-way ANOVA Analysis

To further investigate this conclusion, we conducted a Fisher's comparison with a confidence level of **99%**. The outcomes of the Fisher's comparison, shown in Figures 6 and 7, also support the results obtained from the pre- and the post-exams indicating that they are statistically different and confirms that the students' performance was better using the flipped homework model compared to the traditional one.

Fisher Pairwise Comparisons: Response = Grades, Term = Exams

Grouping Information Using Fisher LSD Method and 99% Confidence

Exams	N	Mean	Grouping
Post-Exam	9	86.4444	A
Pre-Exam	9	73.2222	B

Means that do not share a letter are significantly different.

Fisher Individual Tests for Differences of Means

Difference of Exams Levels	Difference of Means	SE of Difference	Individual 99% CI	T-Value	P-Value
Pre-Exam - Post-Exam	-13.22	3.03	(-23.38, -3.06)	-4.37	0.002

Simultaneous confidence level = 99.00%

Figure 6 – Outcome of the Fisher's Pairwise Comparison

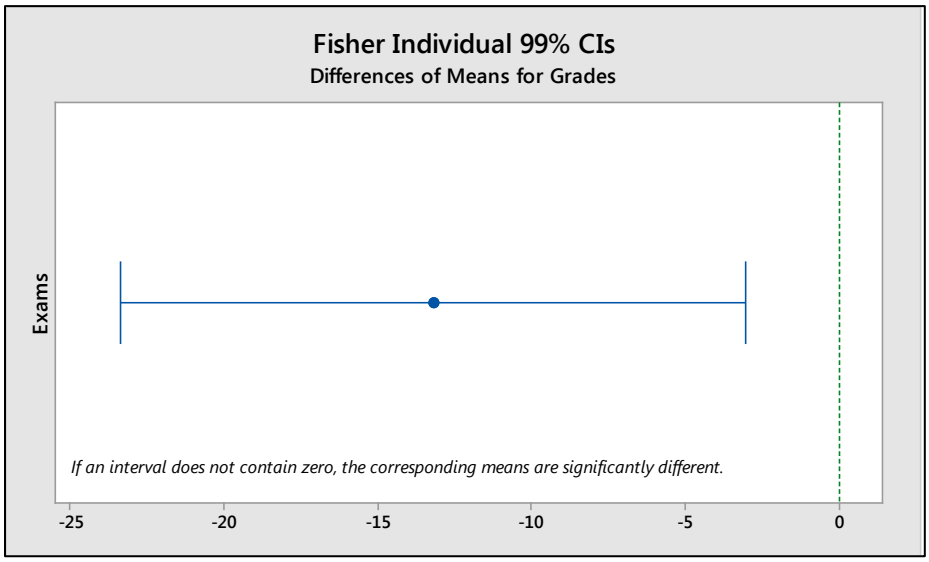

Figure 7 - Fisher's Pairwise Comparison Graphical Representation of the Pre- and Post-Exams

The residual error plots of this analysis are illustrated in Figure 8. As depicted, the normal probability plot of the residual followed a normal distribution. In addition, all the other plots supported this result indicating that the statistical model used was able to model the effect of the treatments very efficiently and the residuals represent pure noise.

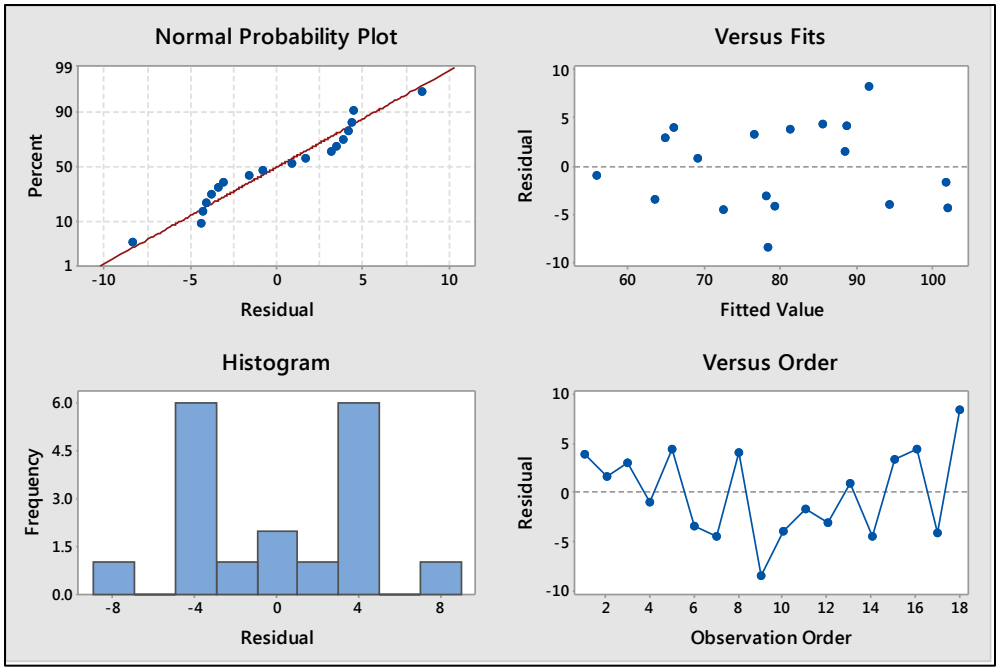

Figure 8- Residual Error Plots for the Pre- and Post-Assessment Analysis

It should be noted that in the first two homework assignments using the new model, the students' were not given a detailed grading rubric. As a result, the students, in general, under-estimated their performance when grading their homework as illustrated in Figure 9.

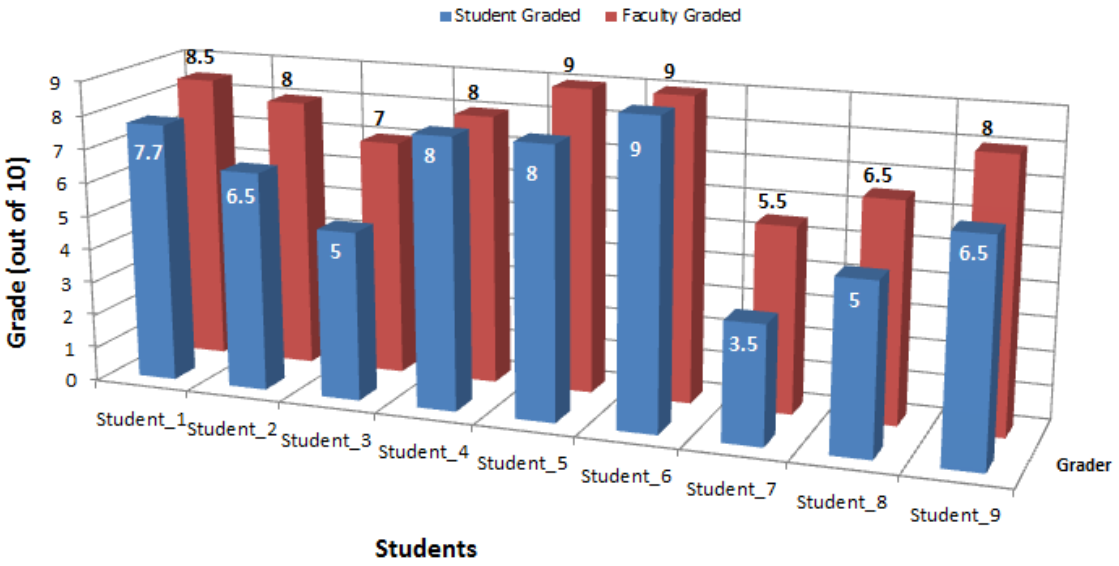

Figure 9- Students' Homework Grades based on the Graders' Perception

From Figure 9, it is evident that the students' perception of their performance, as represented by their self-assigned homework grade, was lower than what is perceived by the faculty. After that, more detailed rubrics on how to assess homework were provided to help students better develop their self-judgment skills.

The distributions of the grades obtained from students and faculty are displayed in Figure 10. These results posed the hypothesis that students' self-judgment skills are not very well developed as depicted from their low self-assigned homework grade.

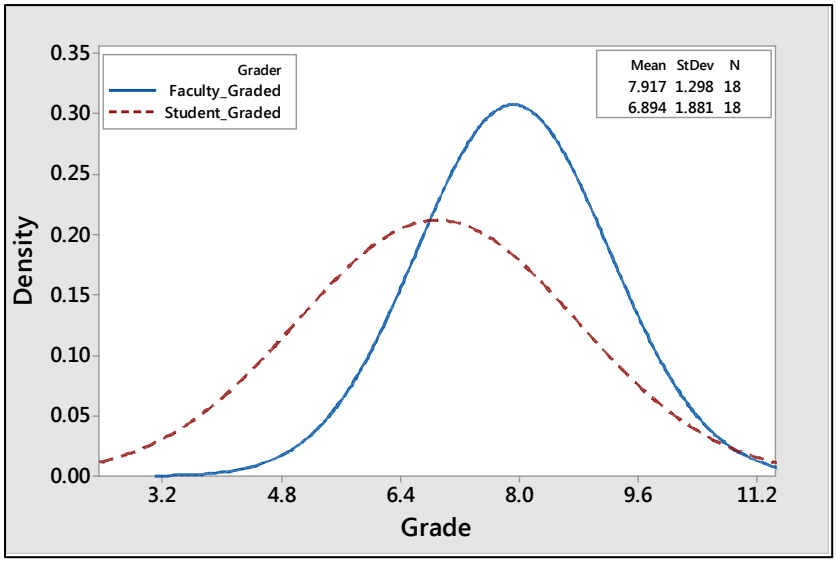

Figure 10- Normal Distribution Fit of the Students' Self-Assigned and Faculty-Assigned Homework Grades

Furthermore, the distributions shown in Figure 10 differ in the overall mean with the students' self-assigned homework grades being lower than the faculty-assigned homework grades. In addition, the students' self-assigned homework grades distribution has a higher standard deviation compared to the distribution of faculty-assigned homework grades. The reason for this higher standard deviation is mainly due to the variability in the students' ability to self-judge their work. Therefore, we can further claim that there is a strong correlation between students and their self-grading or self-judgment skills.

To further verify our findings, a thorough statistical analysis using the Minitab statistics software[13] was conducted. The null hypothesis states that there are no statistical differences in the grades obtained from the students' self-graded homework or the faculty-graded homework. To test this hypothesis, the General Linear Model was used to analyze the data with probability criterion of 1% (p=0.01) significance level. If the analysis results in a p-value less than the 0.01, then the null hypothesis could be rejected indicating that the students' self-grading and the faculty grading will in fact result in a different homework grade. The response variable in this analysis is the homework grade obtained from the students' self-grading and the faculty grading the same homework. As illustrated in Figure 11, there are three main factors in this analysis to consider. The first factor is the treatment effect modeled by students' homework grades. The two-level treatment is the effect of the graders' ability to accurately grade homework (student grading vs. faculty grading). The second and the third factors are the student and homework effects which are modeled as a nuisance or blocking factors to extract the variability due to the difference imposed by various homework and student populations.

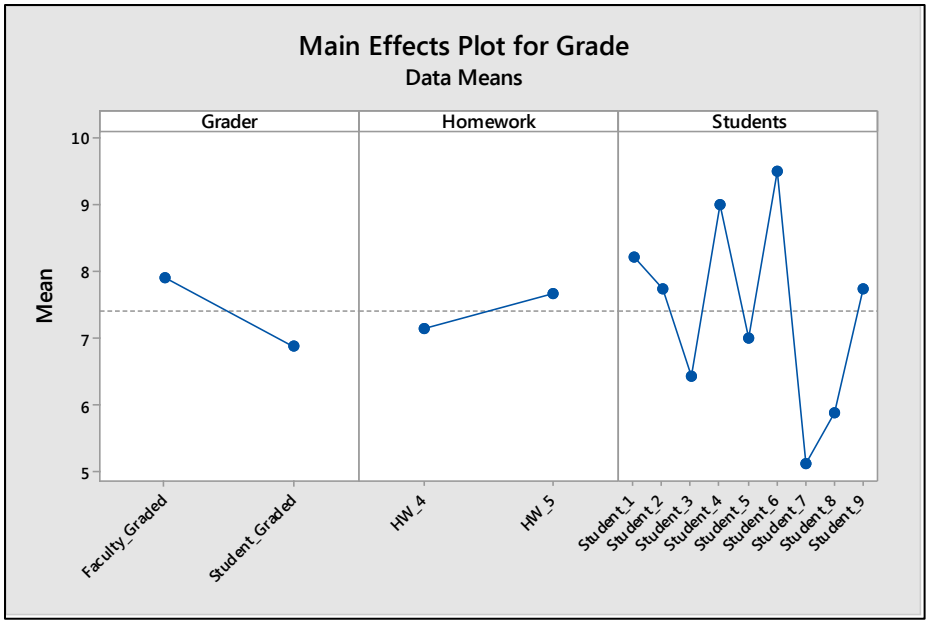

Figure 11- Average Students Homework Grade based on the Grader, Homework, and Student

The statistical analysis presented in Figure 12 generated a p-value equal to **0.002** which is five times less than the **0.01** criterion for significance. Therefore, the null hypothesis can be rejected with a confidence level of **99.8%** indicating the existence of a statistically significant difference in the grading of the students' homework based on whether the graders are the students or the faculty. This validated our hypothesis that students' self-judgment skill is not very well developed resulting into a harsher student self-grading.

General Linear Model: Grade versus Grader, Students, Homework

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Factor Information

Factor    Type    Levels  Values
Grader    Fixed        2  Faculty_Graded, Student_Graded
Students  Random       9  Student_1, Student_2, Student_3, Student_4, Student_5, Student_6,
                          Student_7, Student_8, Student_9
Homework  Random       2  HW_4, HW_5


Analysis of Variance

Source      DF  Adj SS  Adj MS  F-Value  P-Value
  Grader     1   9.404  9.4044    11.52    0.002
  Students   8  66.029  8.2536    10.11    0.000
  Homework   1   2.351  2.3511     2.88    0.102
Error       25  20.414  0.8166
Total       35  98.199


Model Summary

       S    R-sq  R-sq(adj)  R-sq(pred)
0.903647  79.21%     70.90%      56.89%
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Figure 12- Outcome of the ANOVA Analysis

To further investigate this conclusion, Fisher comparison was conducted with a confidence level of 99% as illustrated in Figures 13 and 14. The result of the Fisher's comparison, shown in

Figure 13, supported the conclusion that there is a significant difference in the assigned homework grade based on who did the grading.

Fisher Pairwise Comparisons: Response = Grade, Term = Grader

Grouping Information Using Fisher LSD Method and 99% Confidence

Grader	N	Mean	Grouping
Faculty_Graded	18	7.91667	A
Student_Graded	18	6.89444	B

Means that do not share a letter are significantly different.

Fisher Individual Tests for Differences of Means

Difference of Grader Levels	Difference of Means	SE of Difference	Individual 99% CI	T-Value	P-Value
Student_Graded - Faculty_Graded	-1.022	0.301	(-1.862, -0.183)	-3.39	0.002

Simultaneous confidence level = 99.00%

Figure 13- Outcome of the Fisher's Pairwise Comparison

The Fischer's pairwise comparisons in Figures 13 and 14 conclude that the students are tightfisted when grading their work compared to faculty. This is mainly due two reasons. The first reason is attributed to the lack of self-esteem, which results in students under-estimating their abilities. The second reason is attributed to the higher self-expectation of high-achieving students, which also results in a low self-assigned grade. Only very few students were able to demonstrate the ability to accurately self-judge their performance.

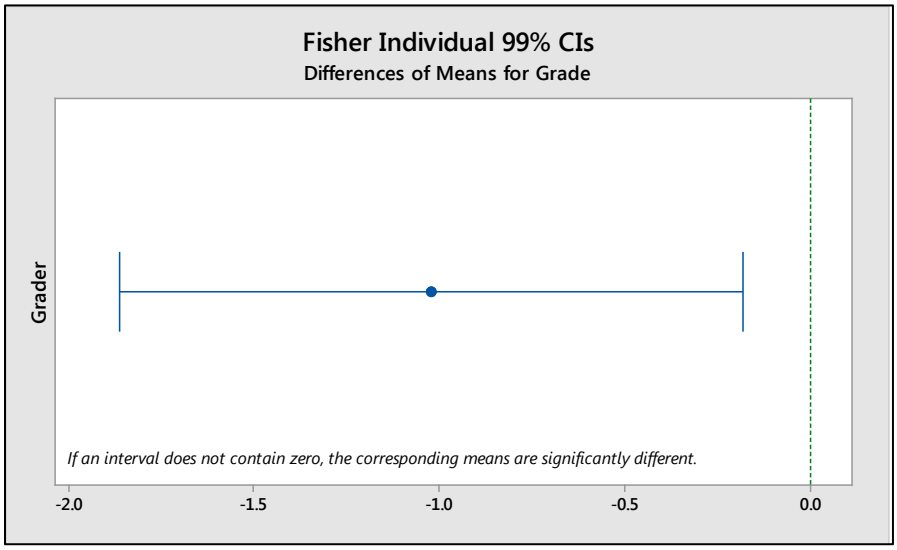

Figure 14- Fisher's Pairwise Comparison Graphical Representation of the Grader (Student vs Faculty) based on the Students' Homework Grades

To test the distribution of the data used to assess the homework grader effect, the probability plot was generated as shown in Figure 15. As depicted, the students' grades relatively following the straight line representing the Normal distribution. This concluded that the data is a representation of a normally distributed population. The goodness-of-fit was quantified with a p-value over

0.127 and a low adjusted Anderson-Darling statistic (AD) of 0.574. This was another indicator that the students' grades were normally distributed.

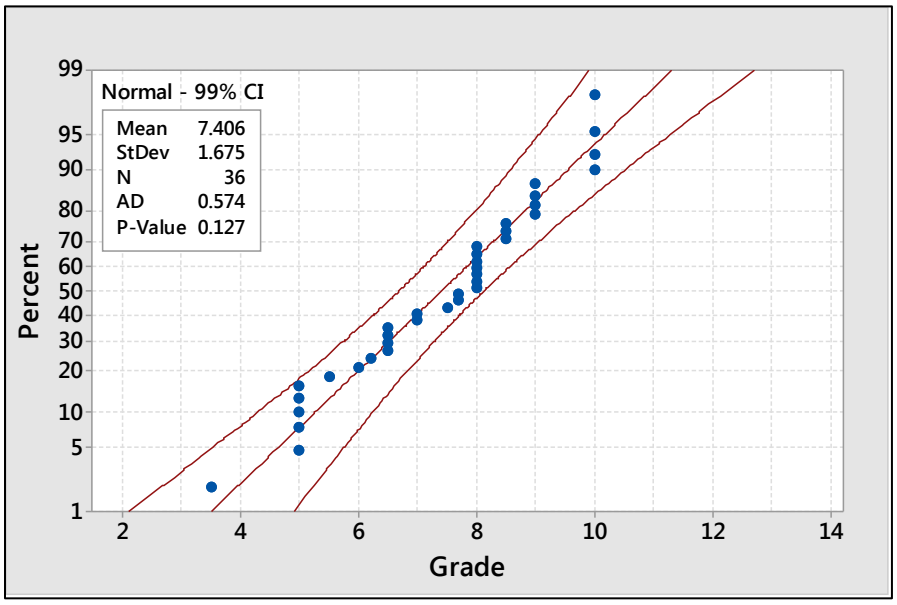

Figure 15- Probability Plot for the Grader Perception Analysis

Similarly, the residual error plots of the grader perception analysis are illustrated in Figure 16. As shown, the probability of the residual error followed a normal distribution. In addition, all the other plots supported this result indicating that the experimental model used was able to predict the effect of the grader (student vs. faculty) very efficiently and the residuals in this case represented a pure random noise.

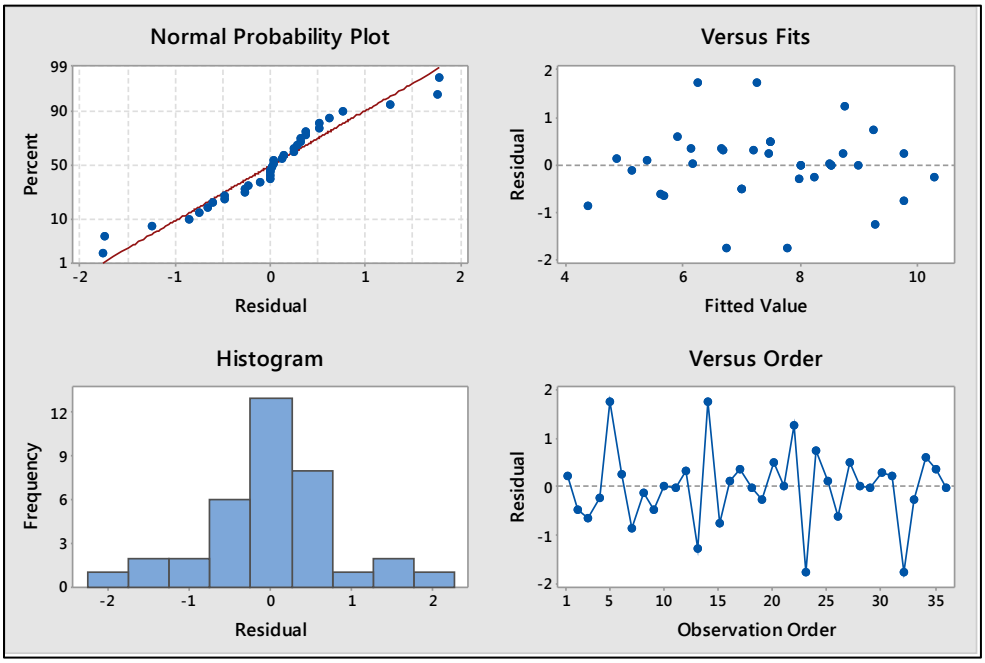

Figure 16- Residual Error Plots for the Grader Perception Analysis

Furthermore, a qualitative survey was administered at the end of the semester to record the students' perception and satisfaction regarding this new implemented flipped homework model. The following survey was administered using Google Forms to ensure anonymity. The students were asked to rate the following statements using a scale from 0 to 10, 0 being absolutely disagree while 10 absolutely agree:

1. Student-graded homework is a practical and useful activity.
2. I learned more by grading my own homework than having it graded for me.
3. Students are harsher on themselves when grading their own homework.
4. I recommend that student-graded homework become a standard activity.
5. Having a grading rubric is very important for student to grade.

- Provide any additional comments:

The average results of the students' survey are summarized in Figure 17 which indicated overall student satisfaction. Over 81% of the students agreed that this model was practical and useful. In addition, over 83 % indicated that they have benefited from grading their own homework rather than having it graded for them. Furthermore, over 84% of the students actually under-estimated their performance and harshly graded themselves.

However, only 75% of the students thought that this model should not be standardized in all courses. A good reason to explain this is that high achieving students may have found this model (benefit vs. effort) not very beneficial since learning complex principles come natural to them. Also, unmotivated students may have also found this model to be time consuming since they are reluctant to do the extra work to push for that extra grade. On the other hand, the majority of the students (91%) agreed that having a rubric to grade homework is very useful since it provides a frame of reference and highlights the excellent elements in the performance indicators needed to accomplish a given task.

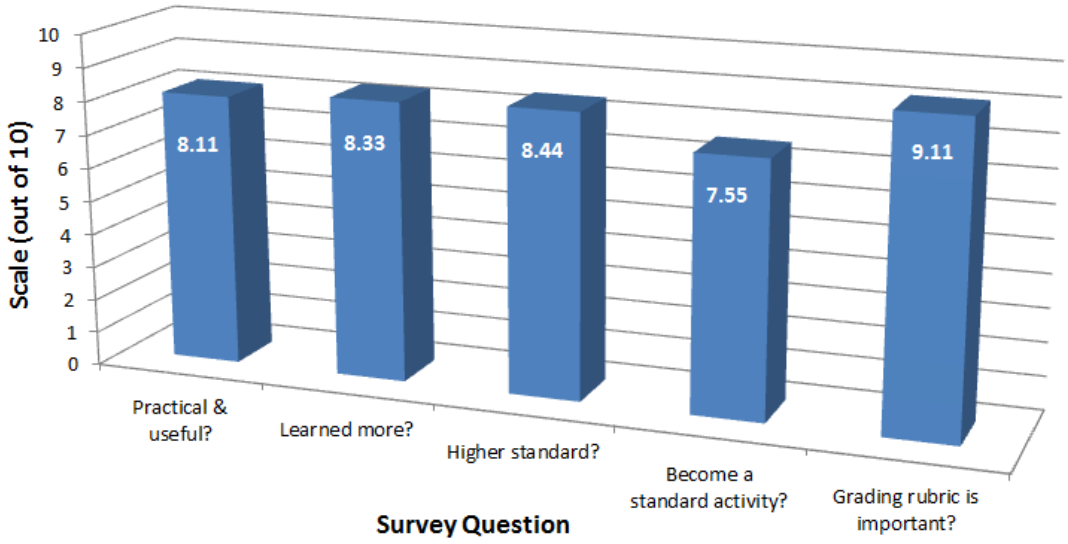

Figure 17- Students' Survey Results

In this model, the students' self-reflection on their homework is what the faculty assesses for the official homework grade. Assessing the students' self-reflection serves as an accurate performance indicator of the students' understanding of the topics learned since it allows the faculty to assess the students' solution process. It also serves as early intervention tool that can be used to adapt the learning process to improve the students' performance. Finally, since the faculty assesses the students' self-reflection on their homework, this significantly reduced homework plagiarism and made it harder to plagiarize and easier to detect any plagiarized homework.

Conclusions

In this paper, a novel flipped homework model was presented as a more effective teaching tool compared the traditional homework model. This model is based on the students' taking ownership in the process of assessing and discussing their performance in homework. In this model, the homework is submitted electronically and the students are instructed to self-grade the original copy of the homework using a provided solution and a grading rubric. The students are also asked to provide a detailed explanation for every question discussing his or her solution. By doing so, the students are not only able to understand the problem and its solution but also understand all the underlying principles to analyze and grade their homework. This has proved to maximize the effectiveness of the homework component within the learning process. In this flipped model, the indispensable role that homework can play as a teaching tool was emphasized and used to develop the students' self-reflection and self-judgment skills which in turn enhanced the learning process. This approach is sought to help eliminate homework plagiarism among students and also provided a more accurate indicator of students' performance since it illustrated the students' thinking process attempting the homework. In addition, the implementation of this model indicated that students are usually harsher on themselves than the instructor when grading their own work. To validate these findings, both quantitative and qualitative assessments were conducted taking into consideration all the parameters involved in this process. The effectiveness of this model was verified quantitatively by assessing the students' performance in pre and post exams. Qualitative assessment in a form of survey was conducted to measure the level of satisfaction among students using this model. Assessment results revealed that students subject to this study were able to improve their grades and score higher on a major exam than they previously did, thus confirming the merit of implementing this flipped homework model. It was also concluded that this model improved the students' academic performance since it limited plagiarism and helped develop their self-reflection skill (Higher-order cognitive skill). In addition, the students were found to be punctilious in grading their own homework and tightfisted when assigning grades. All these results were inferred using a statistical analysis with a 99% confidence level. The results of this study reinforced the importance of flipped homework as a student-centric approach in administering and incorporating homework within the learning process. The flipped homework model did not generate more work for the faculty implementing it. The only difference is that the faculty has to grade the student grading instead of the actual problems. The only limitation in this analysis was assuming normality for a statistically small-sized population sample. However, recently similar results were obtained for a flipped homework model which had a much larger population using the same assessment thus validating the normality assumption.

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