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Self-Assessment of Homework Assignments in Civil Engineering Design Courses*

ASHRAF BADIR and ROBERT O'NEILL
Department of Environmental and Civil Engineering, Florida Gulf Coast University, 10501 FGCU Boulevard South, Fort Myers, FL 33965-6565, USA. E-mail: abadir@fgcu.edu, roneill@fgcu.edu

Although the educational advantages of student self-assessment have been generally documented and introduced into different universities' courses, the use of self-grading as a formative assessment tool in engineering design courses, where unique solutions are not frequently the case, has not been exploited by faculty. This paper reports an experiment in which students (n = 216) in two civil engineering courses; namely a reinforced concrete design course and a steel design course, were assigned the task to self-grade their homework. The study provides a comparison of students and faculty/teaching assistants (TAs) assigned grades and recommendations for future adoption of self-grading in design courses based on lessons learned.

Keywords: formative assessment; self-grading; self-assessment; homework grading; student perceptions; design courses; life-long learning

1. Introduction

ABET recognizes the ability to acquire and apply new knowledge as needed, using appropriate learning strategies as one of the engineering programs' student outcomes. The skill of self-assessment is vital in achieving life-long learning [1]. If we are aiming for the students to achieve a self-regulating learners' status, they need to be trained in the process of self-assessment.

The only way any of us can improve is if we develop a real ability to assess ourselves [2], if we cannot accurately do that, how can we tell if we are getting better or worse? Nicol and Macfarlane-Dick [3] conclude that while students have been given more responsibility for learning in recent years, there has been far greater reluctance to give them increased responsibility for assessment processes (even low stakes formative processes). Yet, if students are to be prepared for learning throughout their professional career, they must be provided with opportunities to develop the capacity to regulate their own learning as they progress through higher education.

Student self-grading has been recognized as a vital portion of formative assessment. It is not a recent teaching strategy, even in the beginning of last century, there were many authors endorsing students' self-assessment. Faculty frequently identify homework-grading to be a distinct task, accomplished by TAs and perceived as a separate entity rather than an essential element of their teaching and learning. Over 100 years of research on grading have been reviewed [4], considering different types of studies including early studies of the reliability of grades, quantitative studies of the composition of K-12 report card grades, survey and interview, studies of teachers' perceptions of grades, studies of standards-based grading, and grading in higher education.

In a critical review of research, conducted between 2103 and 2018, on student self-assessment, Andrade [5] concludes that although self-assessment can be summative; it is most beneficial, in terms of both achievement and self-regulated learning, when it is used formatively and supported by training. Taras [6] examined major issues that concern researchers into student self-assessment within the Anglophone world. These include whether students should grade their own work and if they do, whether accuracy of grading is important, and if self-assessment empowers. She concludes that much research remains to be done to add to our understanding of self-assessment.

The pedagogical gains of self-grading are based on the premise that students would justly evaluate themselves. Many researchers have raised doubt of students' impartial self-assessment. Particularly, there is an absence of consistency on the part of students. Previous studies have regularly concluded that less-accomplishing students usually puff up their scores. In opposition, top ranked students tend to underestimate their performance. However, the final rank of the students remained unaltered [6–10].

Beumann and Wegner [10] presented an experiment on self-assessment of homework assignments in a third-and-fourth year university mathematics course on functional analysis. Beumann and Wagner discussed first experiences with a new variant of self-assessment in higher mathematics education. They sought to correct the imbalance between student-centered learning arrangements

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and assessment concepts that keep the privilege to grade (or mark) completely with the teacher. They also compare tasks marked by the teacher and tasks marked by the students. Their experiments highlight that one cannot expect a priori that students will grade themselves honestly. The authors state in their paper [10] "*we like to mention once more that this small preview is intended as an invitation to other university teachers to contribute with their ideas and experience to the topic of self-assessment in mathematics.*"

In a recent work [11], an extensive literature review was presented describing previous studies related to student self-assessment, its techniques, and how self-assessment benefits the students when administered properly. Chang [11] conducted his study on homework assignment self-grading in a junior-level Fundamentals of Transportation Engineering course and evaluated how the additional effort of student-self grading contributed to their learning. The results were mixed, with some students seemingly focused on how the process could be streamlined from a submission and review standpoint rather than on the learning aspect itself. However, Chang states that "*it is worth considering how, if in any way, the impacts of self-grading in this transportation engineering course translate or transfer to other classes.*"

Jones, Campbell and Villanueva [12] studied the impact that self efficacy and topic emotions have on novice engineering students, when first exposed to an engineering design course. They concluded that self-efficacy increased over the course of the semester for freshman engineering design students.

A literature review indicates that there is a lack of data in the use of self-grading as a formative assessment tool in civil engineering design courses, where unique solutions are not frequently the case. The main objective of this paper is to fill this gap by (1) investigating the feasibility of students' self-assessment using self-grading of their own homework in two civil engineering design courses. This feasibility is measured quantitatively by statistically comparing students' assigned grades with the instructor/TA grades (i.e., how consistent were the students in evaluating themselves); (2) getting students' perception about self-grading design problems; and (3) gaining learned lessons and providing adequate recommendations based on the findings, for better implementation, if future adoption is warranted. It does not study whether self-grading increased students' performance in the exams and no peers' assignment grading was introduced in this study.

This study was reviewed and approved by the university's Institutional Review Board, IRB Protocol ID# 2014–33.

2. Presentation

In a previous preliminary one-semester-study, Badir and O'Neill [13] conducted an experiment allowing twenty-seven students in a reinforced concrete design course (fall semester 2016) to grade their own homework. There was a very good agreement between the grades assigned by the instructor and the students. The difference was statistically insignificant, and since the homework in total counted 10 percent of the final grade, self-grading of homework did not alter the overall final course grade of any of the students. This good agreement enticed the co-authors to continue using self-graded homework in the same course during the subsequent three fall semesters (2017–2019). Moreover, self-grading was also adopted in a civil engineering steel design course taught in summer semesters (2017–2019). The steel design course homework was also graded by TAs for comparison with the students' reported grades over the three summer semesters.

The students participating in this study are all senior civil engineering majors. Both courses are three-credit hours taught in a combined lecture/lab environment. The reinforced concrete design course meets twice a week, each fall semester, for a total of four and a half contact hours. The steel design course meets twice a week, each summer semester, for a total of six hours and fifty minutes contact time. The course instructions closely follow the Excellence in Civil Engineering Education (ExCEEd) Teaching Model [14]. Since the courses are taught in the lecture/lab format, there is ample time and opportunity for active, hands-on learning during the class period. Students spend a good portion of class time working in groups to solve problems under the supervision of the instructor. Both instructors require attendance, take roll, and for students who have an excessive number of unexcused absences, there is a grade reduction outlined in the syllabus. The prerequisites for the courses are structural analysis and civil engineering materials, and students are expected to be proficient in these areas. Most of the students have no previous self-grading experience, although some students who first take the steel design course during the summer semester, have been exposed to self-grading before taking the reinforced concrete fall semester course.

At the beginning of the class period, the instructor displayed on the screen the solution of each problem. Students graded their own work based on a pre-allotted credit by the instructor for each segment of the solution. The students were encouraged to ask for clarifications regarding the solution and the grading scheme. The graded work was

collected, and the instructor had the opportunity to check, after the class period, the students' grading while briefly comparing the submitted written work with the previously uploaded one.

Different statistical methods can be employed to compare student's self-assessment with the teacher's assigned grade [15]. In this presented study, the "*t*-Test: Paired Two Sample for Means" data analysis using Microsoft Excel Spreadsheet Software was adopted.

Tables 1–3 show the study results for a total of 17 homework assignments, following the work presented by Simkin [16], in a business class environment. Nine reinforced concrete design assignments (fall semester 2017) are reported in Table 1. Eight steel design assignments over two summer semesters, 2018 and 2019, are reported in Tables 2 and 3, respectively. Students' self-grades are compared with the instructor grade for the concrete course, while TAs graded the steel design homework after the conclusion of the summer semesters.

As shown in the tables, assignments were worth different total amounts – values that were set according to the amount of problems required for each assignment (row 2). The total number of turned in self-graded assignments included in this study is listed in row 3, showing a total of 188, 114 and 159 (sum of count – row 3).

Tables 1–3 also display the maximum difference in student-grader pair of scores (row 4). Thus, the "Max Difference" value of "+2" for Assignment 1 of Table 1 was the largest difference observed between the student's grade and the instructor's grade for that homework. Similarly, the "Min Difference" was the smallest difference – i.e., the situation in which the grader awarded higher grade than the student did for his or her own assignment (row 5 showing a negative sign). The average difference between the instructor's grade and the student's grade for assignment 1 was 0.48 points, meaning that, on the average students graded themselves about 0.48 points higher than the instructor did.

The matched pairs *t*-statistics in Table 1 is the "different-from-zero test," typical of matched-pairs tests, i.e. the null hypothesis was that there were no differences in the means of the designated grades by the students and the instructor. The *t*-statistics value of 2.23 for assignment 1 in row 8 is less than the critical value 2.85 in row 9 indicating that we would not reject the null that there is no difference between the students self-graded scores and the instructor graded scores. Similar results are obtained by comparing each *t*-statistic value in row 8 with its corresponding critical value in row 9 for all the assignments. The *p* value (row 10) for assignment 1 of Table 1, $p = 0.038$, for every other assignment in the same Table is greater than the set alpha value of 0.01, again indicating that the null hypothesis cannot be rejected. Since tutor assessment was shown to be inconsistent and often inaccurate [17], a strong accuracy of student grading is deemed secondary to the learning benefits of involving students within the assessment process. In this study, a widely used level of significance of 0.01 [18] is adopted.

Similar results were obtained for the same course taught in the fall semester 2016 [13]. Based on these results, the co-author teaching reinforced concrete design has only graded the first assignment during the subsequent two fall semesters (2018 and 2019), not reported here.

Tables 2 and 3 show no significant statistical difference in all the graded homework in the steel design course (summer 2018 and 2019), except for the first assignment of summer 2019 (Table 3). This might indicate that more detailed grading instruction/rubric should be given early in the semester.

Following the work of Chang [11] in a junior-level Fundamentals of Transportation Engineering course, Tables 4 and 5, and Figs. 1 and 2 summarize the average percentage and corresponding standard deviation of student self-graded scores with those of the TAs. The results indicate that in six of the eight homework sets, the average score between the student and TA varied by less than four percentage.

Table 1. Reinforced Concrete Design Fall 2017 – Assignment Grading statistics, using a matched-pairs test for each assignment

1. Assignment #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
2. Points	40	40	20	80	60	50	50	60	30
3. Count	21	24	24	21	22	22	21	19	14
4. Max Difference	2	4	2	6	8	7	4	5	4
5. Min Difference	–1	–2	–2	–4	–1	–6	–2	–4	–6
6. Average Difference	0.48	0.69	–0.08	0.70	1.05	–0.7	0.76	–0.63	0.86
7. Standard. Dev. Of Differences	0.98	2.01	1.28	3	2.08	3.03	1.73	2.72	3.06
8. Matched pairs t-statistics	2.23	1.68	0.32	1.09	2.36	1.13	2.02	1.13	1.05
9. *t* critical two-tail	2.85	2.81	2.81	2.85	2.83	2.83	2.85	2.88	3.01
10. *p*	0.038	0.107	0.753	0.289	0.028	0.272	0.057	0.274	0.314

Note: All results were statistically insignificant at an alpha level of 0.01.

Table 2. Steel Design Course Summer 2018 – Assignment Grading statistics, using a matched-pairs test for each assignment

1. Assignment #	1	2	3	4
2. Points	20	55	50	50
3. Count	34	29	30	21
4. Max Difference	8.5	18.5	17	15
5. Min Difference	–8	–19	–13	–10
6. Average Difference	0.456	0.431	2.8	1.69
7. Standard. Dev. Of Differences	3.21	9.21	7.0	5.91
8. Matched pairs t-statistics	0.83	0.252	2.21	1.310
9. *t* critical two-tail	2.73	2.763	2.75	2.845
10. *p*	0.414	0.803	0.035	0.205

Note: All results were statistically insignificant at an alpha level of 0.01.

Table 3. Steel Design Course Summer 2019 – Assignment Grading statistics, using a matched-pairs test for each assignment

1. Assignment #	1	2	3	4
2. Points	20	55	50	50
3. Count	33	43	42	41
4. Max Difference	8.5	20	15	26.5
5. Min Difference	–5	–20	–13	–18.5
6. Average Difference	2.4	–1.2	–1.9	–1.4
7. Standard. Dev. Of Differences	3.7	8.9	5.7	10.5
8. Matched pairs t-statistics	3.69	0.878	2.180	0.860
9. *t* critical two-tail	2.74	2.698	2.701	2.704
10. *p*	0.0008	0.385	0.035	0.395

Note: All results were statistically insignificant at an alpha level of 0.01, except for the first assignment.

It is interesting to notice that for half of the graded assignments, the TA average score was higher than the students' average self-graded score. Moreover, the overall average TA grade for the whole semester (last rows of Tables 4 and 5) was just 1.6% and 0.1% less than the students' self-grade for summer 2018 and 2019, respectively.

Following the work of Chang [11], to assess overall student self-grading performance, the TA graded homework scores from all assignments in the steel design course of summer 2018 (ordered from lowest to highest) is shown in the top portion of Fig. 3 (extra credit was allocated to few assignments, resulting in a grade above hundred percent). The lower portion of the graphic identifies the percentage difference between the score graded by the student and then by the TA. As an example, the first set of data indicates that the TA assigned the student a grade of 40% for this homework set; this score was 29% lower than the score previously determined by the student.

As shown in the figure, the disparity between students' self-assigned grades and the TA grades occurred more frequently when students performed poorly and the score differential between the TA and the self-generous student generally decreased as students performed better. Of the 27 cases where the students received a grade less than 70%, there were only six cases in which the TA believed that the student deserved a higher grade. Similar results were reported [11] for a junior level Transportation Engineering course and [16] in an information systems class taught within the college of business administration. The highest discrepancies, in the cases where the TA felt students deserved a higher grade, occurred in the cases of students receiving a grade of 80% or higher.

Besides comparing students-instructor grading,

Table 4. Statistical comparison of student and TA grades – Steel Design course Summer 2018

HW#	# of Assignments	TA Grade		Student Grade	
		Average	SD	Average	SD
1	34	86.2	13.7	83.9	16.5
2	29	73.7	15.6	74.5	12.3
3	30	90.5	17.4	96.2	15.8
4	21	70.6	15.5	74	15.3
1 to 4	114	81.3	17.3	82.9	17.4

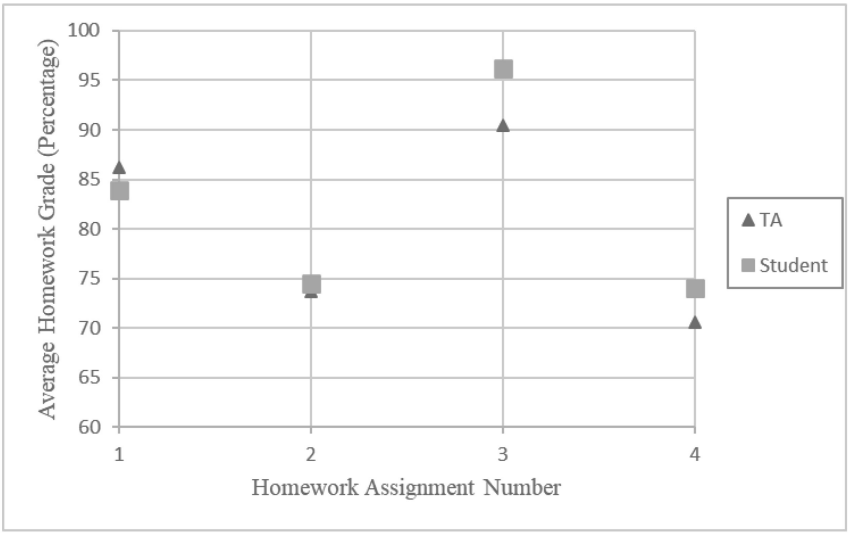

Fig. 1. Graphical comparison of TA and student grades – Steel Design course Summer 2018.

Table 5. Statistical comparison of student and TA grades – Steel Design course Summer 2019

		TA Grade		Student Grade	
HW#	**# of Assignments**	**Average**	**SD**	**Average**	**SD**
1	33	60.3	14.9	72.2	14.0
2	43	61.4	32.1	59.3	25.9
3	42	89.0	22.0	85.2	24.8
4	41	70.3	24.9	67.5	15.9
1 to 4	159	70.8	27.2	70.9	23.2

students' perception about self-grading their homework throughout seven semesters was assessed by an anonymous two open-ended questions survey: (1) "*What did you like best about grading your own homework?,"* and (2*) "What did you like least about grading your own homework?."* A summary of students' responses is listed in the Appendix, Tables A1 and A2. Overall, students were prone to like grading their own homework and discovering their mistakes, while some students expressed concerns about taking time away from the class, being not sure what grade to assign themselves and having to scan and upload the homework.

Tables 6–9 summarize the student responses to multiple choices questions: (1) "*How do you think grading your own homework and the questions/*

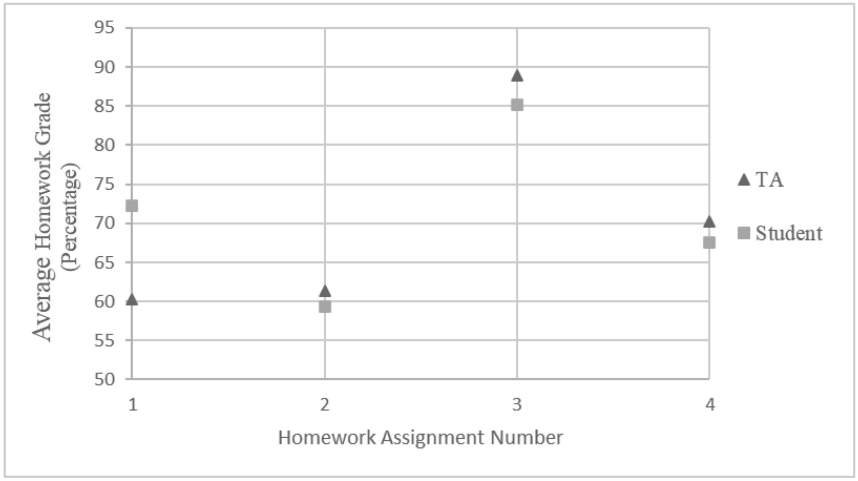

Fig. 2. Graphical comparison of TA and student grades – Steel Design course Summer 2019.

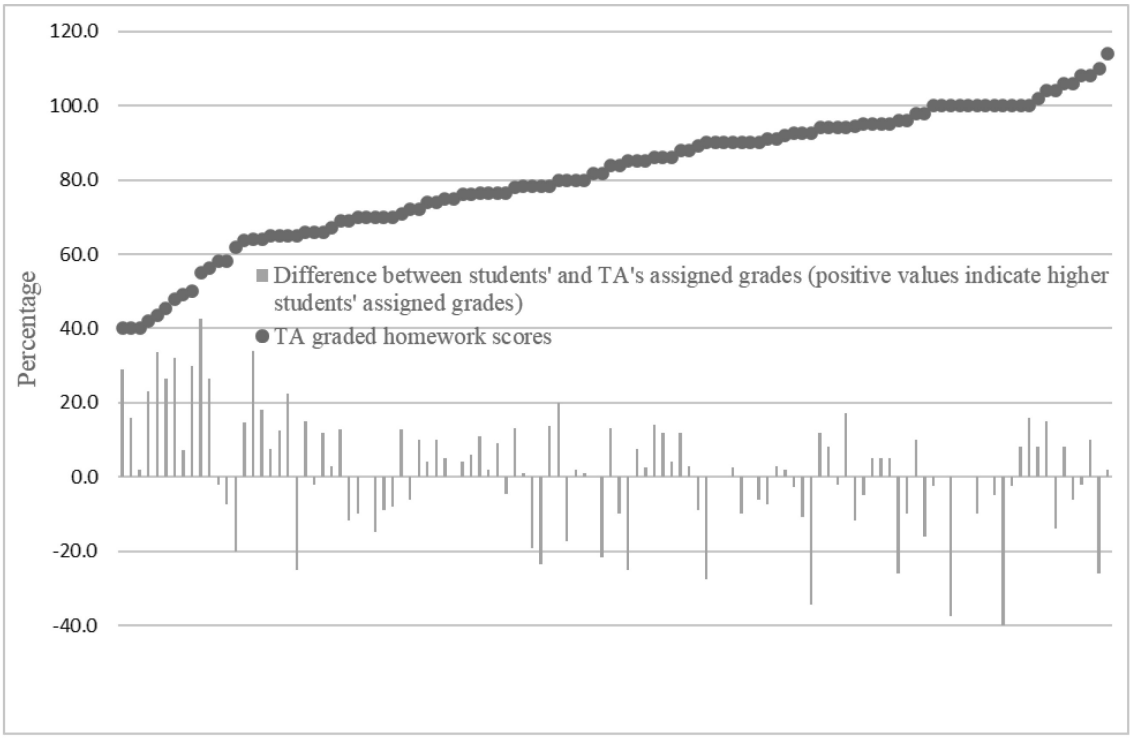

Fig. 3. TA graded homework scores and scoring differential between students and instructors (sorted from lowest to highest homework grade) – Steel Design course Summer 2018.

Table 6. Reinforced Concrete Design Course - How do you think grading your own homework and the questions/answers discussion during the grading affected your understanding of the topics and problems compared to being graded by the TA?

Response Option	n^a = 12 Fall 2016	n = 18 Fall 2017	n = 24 Fall 2018	n = 30 Fall 2019	Σn = 84 Fall 2016–2019
Much Higher	66.7%	50%	83.3%	43.3%	59.5%
About the Same	33.3%	50%	16.7%	53.3%	39.3%
Much Less	0%	0%	0%	3.3%	1.2%

[a]n = number of students.

Table 7. Steel Design Course – How do you think grading your own homework and the questions/answers discussion during the grading affected your understanding of the topics and problems compared to being graded by the TA?

Response Option	n^a = 34 Summer 2017	n = 40 Summer 2018	n = 52 Summer 2019	Σn = 126 Summer 2017–2019
Much Higher	41.2%	20%	38.5%	33.3%
About the Same	58.8%	70%	57.7%	61.9%
Much Less	0%	10%	3.8%	4.8%

[a]n = number of students.

Table 8. Reinforced Concrete Design Course – Overall, how would you rate your experience grading your own homework?

Response Option	n^a = 12 Fall 2016	n = 18 Fall 2017	n = 24 Fall 2018	n = 30 Fall 2019	Σn = 84 Fall 2016–2019
Very Good	33.3%	33.3%	62.5%	23.3%	38.1%
Good	41.7%	38.9%	37.5%	53.3%	44.0%
Neutral	25.0%	27.8%	0%	20%	16.7%
Bad	0%	0%	0%	3.3%	1.2%
Very Bad	0%	0%	0%	0%	0%

[a]n = number of students.

Table 9. Steel Design Course – Overall, how would you rate your experience grading your own homework?

Response Option	n^a = 34 Summer 2017	n = 40 Summer 2018	n = 52 Summer 2019	Σn = 126 Summer 2017–2019
Very Good	20.6%	12.5%	15.4%	15.9%
Good	58.8%	47.5%	51.9%	52.4%
Neutral	17.6%	22.5%	25.0%	22.2%
Bad	2.9%	10%	7.7%	7.1%
Very Bad	0%	7%	0%	2.4%

[a]n = number of students.

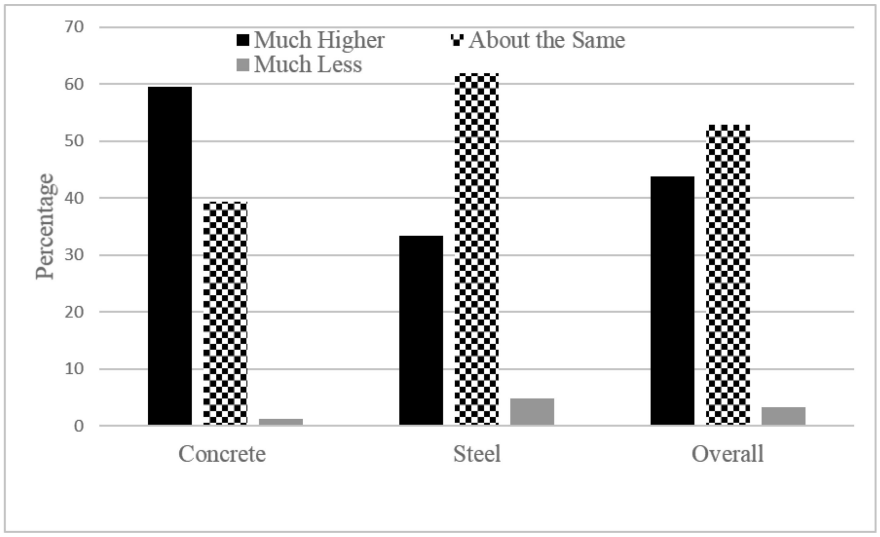

Fig. 4. How do you think grading your own homework and the questions/answers discussion during the grading affected your understanding of the topics and problems?

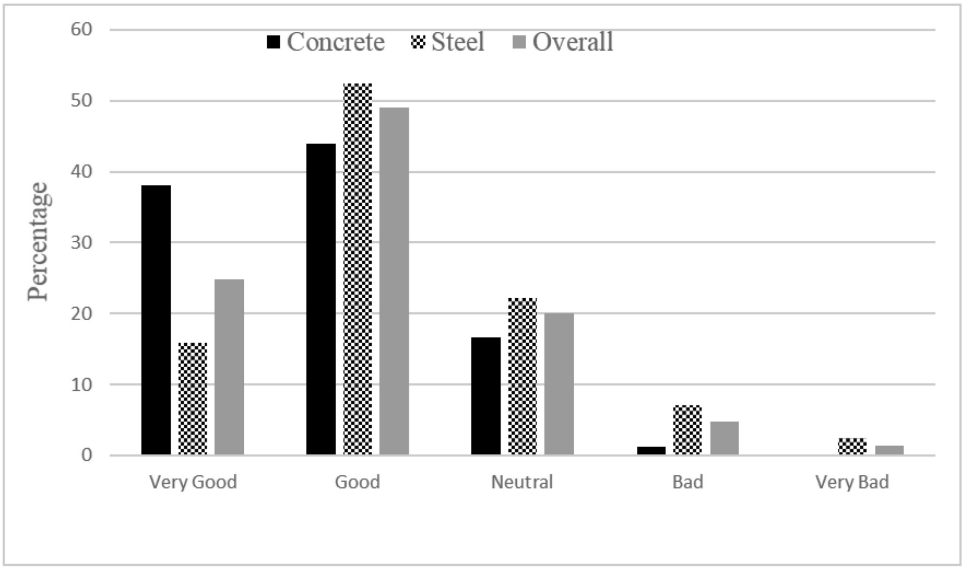

Fig. 5. How would you rate your experience grading your own homework?

answers discussion during the grading affected your understanding of the topics and problems compared to being graded by the TA?" About 60% of all the students who took the concrete design course over the four fall semesters believed it increased their understanding and only about 1% believed it had reduced it (last column of Table 6). One third of all the students who took the steel design course over the three summer semesters believed it increased their understanding and about 5% believed it had

reduced it (last column of Table 7); (2) *"Overall, how would you rate your experience grading your own homework?"* Eighty two percent (concrete design, Table 8) believed it was either good or very good, and 1% believed it was bad, while 68% (steel design, Table 9) believed it was either good or very good, and 9.5% believed it was bad or very bad.

To assess the overall students' perception about the effect of self-grading on their understanding of the content of the course and their self-grading experience, Figs. 4 and 5 depict an aggregate view of the 210 students' responses presented in the previous tables.

3. Discussion

A one semester, one course study of students' homework self-grading that initiated in fall 2016 [13], has been extended to include six additional semesters for two civil engineering design courses; namely reinforced concrete design and steel design, where a unique solution of homework problems is not always the case. The results of this study suggest that there are opportunities to empower students with a greater role in assessment of design problems, with a potential for saving precious TAs time that can be spent otherwise in offering new TA face-to-face or virtual office hours, additional review sessions, and assistance to students in solving problems during class time.

An experiment has been adopted in which students in civil engineering design courses were assigned the task to grade their own work. Students scanned and uploaded their assignment on CANVAS (learning management software) by the deadline, usually the starting time of the class. At the beginning of the class period, the instructor displayed on the screen the solution of each problem. Students graded their own work based on a pre-allotted credit by the instructor for each segment of the solution. The students were encouraged to ask for clarifications regarding the solution and the grading scheme. The graded work was then collected, and the instructor had the opportunity to check, after the class period, the students' grading while briefly comparing the submitted written work with the previously uploaded one. The assignments for this course used either the end-of-chapter problems from the adopted class textbook or custom questions created by the instructor. The homework questions represented 10% of the overall course grade. Moreover, the instructor or the TAs graded all homework, and their assigned grades were compared with students self-scores for the purpose of this study.

This study showed overall very good agreement between the grades assigned by the instructor/TAs and the students. The difference was statistically insignificant, emphasizing the feasibility of students' self-assessment in design courses as a formative assessment tool to support and enhance learning in design courses.

Students' perception was mixed; however, most of the students showed positive attitude towards self-grading; summing-up its benefits as "*seeing the mistakes, better understanding, instant grade*," while others' main complaints were "*it took time out of class, turning it online, not sure how many points to take off.*"

It is the co-authors belief that, although self-grading takes time from class, a legitimate worry; it is in many instances a well invested time that reinforces the understanding of the students, clarifies areas that were not well understood by some, and introduce students to alternative problem solutions. Instructors could also choose one or more of the following options depending on their time constraints: (1) explore hybrid approach, where students would access the homework solutions at home (after the submission deadline), review it before formal in-class grading, in an attempt to give the students more time ahead to discover their mistakes; (2) self-grade only one or two undisclosed selected problems, i.e., students would not know ahead which problems will be graded; and (3) adopt self-grading only during review sessions that are usually held before exams, incorporating known challenging problems as identified by the experienced instructor.

For this technique to be successful, the authors recommend giving precise and detailed instructions to the students, especially at the beginning of the semester (first assignment), when the self-assessment may be an uncharted task to many students. While this seems to be a logical suggestion, it was reinforced during open discussion between the reinforced concrete instructor and the students after the first two self-graded homework. Moreover, reviewing all the students' self-assessment and making corrections to their self-assigned grades in the first assignment would prove beneficial in the subsequent homework. It is worth noting that this study confirms the findings of previous other researchers in non-design courses, including that students whose performance was below par generally were more generous in their self-assessment. Moreover, some of the accomplished students might tend to underestimate their grades.

The sample courses were senior engineering ones, in which almost all the students had previously attended one or two courses with the same instructor in a relatively small university, where faculty-student interaction is stronger than a larger size university with more students attending classes.

Due to the specific two design courses and small number of participants, the findings of this study may not be generalized. However, the outlined statistical information may entice many educators willing to transfer the findings to their own engineering design courses. Duplicate studies are required to confirm the results of this study and identify other classes that may profit from this strategy, including sophomore introductory engineering design courses.

4. Conclusions

This study suggests that self-evaluation of engineering design problems, where unique solutions are not frequently the case, is a conceivable path for providing meaningful formative assessment that can positively influence students' learning, without jeopardizing the integrity of the students' overall semester grade.

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Ashraf Badir is an Associate Professor in the Environmental and Civil Engineering Department at the U.A. Whitaker College of Engineering in Florida Gulf Coast University. He earned his BSc (1982) in Civil Engineering and MSc (1985) in Structural Engineering from Alexandria University, Egypt. He also holds a MSc (1989) and a PhD (1992) in Aerospace Engineering from Georgia Institute of Technology. He is a civil engineering program evaluator for ABET, a member of the American Society of Civil Engineers (ASCE), the American Concrete Institute (ACI), and the American Society of Engineering Education (ASEE). Dr. Badir is a licensed Professional Engineer in Florida.

Robert O'Neill is a Professor in the Department of Environmental and Civil Engineering, U.A. Whitaker College of Engineering, Florida Gulf Coast University. He received a BS from the United States Military Academy in 1975, an MS in Structural Engineering and an MS in Geotechnical Engineering from Stanford University in 1984 and a PhD in Structural Engineering from Kansas State University in 1993. Prior to his coming to FGCU he was a Professor of Engineering at Roger Williams University and an Associate Professor and Director of the Civil Engineering Analysis Group at the United States Military Academy. Dr. O' Neill is a retired Lieutenant Colonel, U.S. Army Corps of Engineers. He has been active at the national level with ASCE's Committee on Accreditation Operations (COAO), Technical Council on Computing and Information Technology (TCCIT), Committee on Faculty Development (CFD) and Excellence in Civil Engineering Education (ExCEEd) initiative. Dr. O'Neill is a licensed Professional Engineer in California, Florida,

Nevada and Virginia. He is a civil engineering program evaluator for ABET. He is an American Society of Civil Engineering Fellow (ASCE), a member of the American Society for Engineering Education (ASEE), and Phi Kappa Phi National Honor Society.

APPENDIX

Table A1. What did you like best about grading your own homework?

"I liked that I was able to make notes for myself it acted as a study technique."
"I got to reflect on how well I thought I did."
"It allowed me to be more interactive with my homework results. I'm able to see where I may have done something wrong and have the opportunity to raise my hand and ask. Whereas if I received my homework back with a grade I might be less likely to come to office hours to discuss it."
"When self-grading there's a higher chance of me actually looking at the homework solution and compare my work. If a TA would have graded I just would have done the work and turned it in and just forget about it."
"I was able to use my engineering judgment to whether or not a part of the question was worth more or caused more of an impact to the final result."
"Going through all the problems helped me understand them more."
"It provided an efficient way of being able to go over the problems in class and make sure any uncertainties were cleared up. It is an excellent system."
"The leisure to compare correct answers of the instructor to my own design was very fascinating that there can be several answers for designing something."
"less stressful, and better going through it together as opposed to just receiving a grade and reviewing it alone"
"Being able to see first-hand where I made mistakes and making annotations that i would understand later was the most beneficial thing for me."
"Grading myself made me want to work harder and get the best possible grade."
"That I could judge myself."

Table A2. What did you like least about grading your own homework?

"Scanning and handing in."
"Watching my homework grade drop."
"Sometimes the answers would be close to being correct and it was hard to decide whether the answer was right or wrong."
"That it took time out of class."
"I would see how dumb I was while grading it and feel disappointed afterwards."
"Psychologically difficult to reduce one's own grade."
"How fast you scrolled through the problems."
"Turning it online."
"Not really being sure how many points to take off."
"I do not have anything negative to say about it."
"Have to submit electronic copy and physical copy."
"It's hard to do partial credits because I want to be hard on myself but also don't want to have a bad grade."
"Sometimes I didn't know how to grade it but it was not a big problem."
"The only draw back was that there was less time to do problems in class."