A case study of a method for hybrid peer-evaluation in engineering education

Susan Vasana† & Albert D. Ritzhaupt‡

University of North Florida, Jacksonville, Florida, United States of America†
University of North Carolina Wilmington, Wilmington, North Carolina, United States of America‡

ABSTRACT: This case study addresses the call for alternative methods of assessment in engineering education by providing a systematic, hybrid Peer-Evaluation (PE) model that can be tailored to fit within virtually any engineering course. Seventeen students enrolled in a senior-level undergraduate digital signal processing class participated in a three phase PE process designed to formatively and summatively evaluate peers' course projects using well-understood criteria and reliable measures. The results show strong and positive correlations between the student PEs and the instructor evaluations. Further, the significance of a project proposal when formatively evaluated was positively related to structure, completeness, and overall quality of the final project report when summatively evaluated. Students were generally satisfied with the hybrid PE model, and practiced on how to give professional feedback and constructive criticism. This article adds to our understanding of the PE method and its use in engineering education.

INTRODUCTION

The necessity for quality instructional practice and assessment in engineering education is of paramount concern [1]. In particular, there has been a call in engineering education for more alternative (a.k.a. authentic) methods of assessment (e.g. portfolios), as opposed to traditional methods (e.g. exams) which have been rightfully criticised for a lack of validity in measuring students' ability to apply knowledge to real-world situations [2]. Alternative methods of assessment attempt to overcome the limitation by developing authentic contexts in which students can demonstrate their mastery. A method often overlooked in the context of engineering education includes the use of peer-evaluation (PE) as a mechanism to provide formative assessment to improve the quality of their peers' work and provide a summative assessment of the work according to guidelines which meet course objectives [1]. Indeed, meta-analytic studies have verified the use of PE closely resembles teacher assessment in higher education when judgments are made on well-understood criteria [1].

The term PE can have different meaning to different people. PE can also vary widely by educational context in that it could refer to differential grading of group projects based on peer judgments [3][4] or could refer to the assessment of their peers work according to some pre-defined guidelines [5][1]. Further, PE can be formative [6][1] and/or summative [1] in nature. This research adopts the definition that PE is the individual evaluation of a peer's work according to specific guidelines to evaluate their peers with the dual purposes of improving the quality of the work and providing an overall quality judgment of a peer's work.

The validity of PE is a major concern for educators. Across 48 different published manuscripts on PE, researchers found that peer marks closely resembled teacher marks when judgments are based on well understood criteria and when academic products and processes are evaluated as oppose to professional practice [1]. Further, multiple ratings were found to be better measures than single ratings [1]. Research also suggests that PE is of adequate reliability and validity in a wide variety of applications in higher education [7]. Research also finds PE has positive formative effects on student achievement and attitudes in that the information is provided to peers in a feedback loop; and the evaluations are as good as or better than the teacher evaluations [7].

Educational outcomes from PE can be both positive and negative. Positive outcomes include the improved quality of student work, more responsible and reflective learning experiences, diplomatic or constructive criticism, a heightened sense of professionalism, and the development of transferable skills to different contexts [6][8][9]. Students not only have the opportunity to learn from their peers by receiving their peers' constructive commentary of their work, but students also have the opportunity to learn from the peers' work they evaluate [10]. Some research also suggests that students find the PE process time consuming, dislike awarding a grade to their peers, find it intellectually challenging, and sometimes socially uncomfortable [6][9].

This article addresses the call for alternative assessment methods by developing and systematically evaluating a hybrid PE model. The purpose of this article is to provide a systematic model for hybrid PE in engineering education and to examine the relationships between the model and the quality of students' work, demonstrate the reliability of the model, and gauge students' satisfaction with the model.

HYBRID PEER-EVALUATION MODEL

The PE method has transferred to the online realm, which provides substantial benefits over the traditional paper-pencil process. Online PE provides the following minimal benefits: provides a way for students to submit and evaluate their peers' work on the web, provides teachers' access to the PEs at any point in the process, and decreases the costs associated with copying projects peers to evaluate [11]. This research adopted the use of both traditional and online PE methods to support the process; hence the term *hybrid peer-evaluation*. The goals of the hybrid model included creating a generic PE process that could be tailored to fit in any engineering course with a project component, to balance the amount of time students would spend evaluating their peers' work with the amount of time they would spend on their own projects, and to model an environment in which constructive criticism could be practiced. Using online PE models as a baseline [12][13], this research employed a three phase implementation. Figure 1 illustrates the model in terms of modality, evaluation type, evaluation criteria, and the deliverables.

Modality	**Online Process**				**Face-to-Face Process**
Evaluation Type	**Formative Evaluation**		**Summative Evaluation**		
Evaluation Criteria		▪Relatedness ▪Significance ▪Specificity ▪Clarity ▪Scope ▪Overall quality		▪Relevant literature ▪Accuracy ▪Structure ▪Clarity ▪Completeness ▪Overall quality	▪Organization ▪Use of visual aids ▪Preparedness ▪Answers to question ▪Extra effort/creativity ▪Overall quality
Deliverables	**Project Proposals**	**Proposals Evaluated**	**Final Project Report**	**Project Report Evaluated**	**Presentations Evaluated**

Figure 1: Hybrid peer-evaluation model.

In contrast to other PE models, the evaluation criteria used for the proposal, project report and project presentations were not the same. For a proposal, the important characteristics were the relatedness of the proposal to the course, the significance of the proposal, the specificity of the purpose and resources that would be used, clarity of written language, scope of the project given the timeline of the course, and the overall quality. For the project report, the relevant characteristics are the comprehensiveness of the literature review, the accuracy of the results, the organisation and clarity of the prose, the completeness in terms of addressing the items outlined in the proposal, and the overall quality of the course project. Finally, in terms of the student presentations, the relevant characteristics include the presentation organisation, use of visual aids, preparedness of the students, their ability to respond to questions, extra effort or creativity, and the overall quality of the presentation

RESEARCH METHODOLOGY

Participants and Course

The context of this hybrid PE case study is within a senior level digital signal processing course taught at a public, masters-large, south-eastern university in the United States. The course had $N = 17$ students enrolled during a summer semester. The course is a required course in an Accrediting Board of Engineering Technology (ABET) accredited electrical engineering undergraduate program. A major deliverable within this course (30% of the final grade) is an individual course project. The goal of this project serves dual purposes: 1) it provides individual students an opportunity to investigate an in-depth topic and 2) provides all students a breadth of knowledge in a diverse set topics related to the course. All projects required students to prepare three deliverables: 1) a two-page project proposal, 2) a project report that details the work, and 3) a project presentation to peers and the instructor.

All students were provided with examples of potential topics, such as the completion of a simulation of a system or a research of a new technology. Further, all projects were approved by the instructor before students proceeded. Each student was provided with a time in class to present their project ideas. The projects were diverse in topic yet all related to digital signal processing. For example, one student implemented a simulation of computer generated sound effects using MATLAB while another student conducted a literature review on cochlear implant devices and their designs. To avoid the potential unfairness of differential grading (e.g. one peer rates more conservatively than another), only the summative presentation evaluation that all students involved in evaluating everyone at project presentation phase was used to provide 50% of the grade to the course project. The instructor assigned the remaining 50% of the grade by using the summative PEs and comments and the instructor's independent assessment of the projects. The students received 10% of course grade credit after submitting all the evaluations on time.

Procedures

The online PEs were deployed using the Blackboard course management system. The project proposal and project report were made public; however, the student evaluations were only visible to the instructor and the student receiving his feedback. This practice was implemented to keep the evaluations confidential and to prevent peers from simply repeating the comments of their peers as part of their own critical evaluations. Students were assigned to three different peer projects to review on three occasions. Students first completed their project proposals and posted the proposals online. Next, students were instructed to review their peers' project proposal online using the formative evaluation instrument and to provide constructive comments on the project's direction, and how to improve the work. The instructor reviewed the survey responses and released the anonymous PEs to the students to incorporate the feedback into their final project reports. After the completion of course projects, students posted their final project reports online. Then, peers used the summative project PE instrument to evaluate the same three projects. Unlike the formative, students were instructed to evaluate the projects in a summative fashion and to justify their markings as feedback to their peers.

The final phase of the PE process was executed during the project presentations. Students were evaluated anonymously by all of their peers using the summative presentation PE instrument. The implementation of the hybrid PE model involved three rounds, as illustrated in Figure 1: the formative proposal review (online), a summative report evaluation (online), and a summative presentation grading (face-to-face). These cycles were followed by a satisfaction survey (face-to-face) designed to measure a student's satisfaction with the PE process. In total, the hybrid PE process took approximately six weeks to complete.

Measurements and Data Analysis

This case study employed five separate measurements to address the purposes of this research: a project proposal formative evaluation, a project report summative evaluation, a project presentation summative evaluation, a student satisfaction survey, and the frequency of the type student feedback provided in the PEs. The satisfaction survey was based on previous research [14] and modified to meet the needs of this research. The evaluation instruments were developed by the research team and traced to the project and course objectives. The data was analysed using descriptive and inferential statistics. Reliability was measured using internal consistency reliability for the satisfaction scales and generalisability theory for each of the PE instruments. Repeated measures Analysis of Variance (ANOVA) were used to test the differences between the formative and summative evaluations in light of the assumptions of the procedure. Pearson correlations were used to measure relationships.

The formative and summative comments were coded using an established framework for categorising feedback, which includes didactic, corrective, suggestive and reinforcing comments [15]. The comments provided on the formative and summative PEs were independently coded by two members of the research team until inter-rater agreement exceeded 85%, indicating sufficient reliability [13].

Table 1: Type of peer feedback analysed.

Type	Definition	Example
Corrective	If a student provides incorrect information or formatting, than a peer can provide feedback to point out and correct the mistake. This type of feedback should improve the accuracy of a student's project.	*Proposal does not have a timeline.* *The paper needed to focus in the main paragraphs.* *Try using '50' instead of fifty. If the number is greater than 10, don't spell it out.*
Reinforcing	Reinforcing feedback is provided to peers when the information is accurate and the goal is positive recognition to support the actions of a student in their project.	*The proposal is very well written and structured.* *The proposal is well formatted and addresses a topic with a rapidly increasing demand for superior performance and cost effective implementation.*
Didactic	Didactic feedback refers to length explanations that may serve to explain the inadequacy of information or relevance of a topic. This type of feedback attempts to direct peers in the right direction.	*Any idea what Digital Signal Processor you are going to research? Seemed like most of the proposal was just a reiteration of the guide for the proposal, you probably could have just cut that part out-fine the way it is without it.*
Suggestive	Suggestive feedback makes recommendations on how to improve the project or what could have been included. A peer may point out a problem without providing a direct solution to the problem.	*Make sure not to focus too much on the physics and mostly on the DSP [Digital Signal Processing] side.* *You should not use the word 'the' so much.* *The first paragraph was a repeat of the outline given to us and unnecessary.*

Table 1 illustrates the type of feedback, provides an operational definition [13][14], and provides examples from the dataset. On some occasions, the type of feedback could be classified into more than one category. For example, *This*

project has a nice scope, and needs to zero on a specific subject of the wireless system, and not focus so much on the communications part. In this case, this feedback was counted as both Reinforcing and Suggestive feedbacks.

CASE STUDY RESULTS

One student did not complete one of the formative evaluations, and thus, there were only 50 formative PEs (as opposed to 17 x 3 = 51). Consequently, one student only received two PEs during this phase. During the summative report evaluations phase, one student did not complete the summative report evaluations at all, and thus, three students received only two summative evaluations each. All other PEs were completed by students as assigned by the research team. The data were evaluated for normality on each of the dimensions across PE instruments, which showed no severe departures from normality (Kurtosis < 3 and > -3; Skewness < 2 and > -2).

Formative and Summative Analysis

Generalisability coefficients, which measure the variability of across the PEs, were used to estimate reliability of the PE measurements [16]. The generalisability coefficients for formative evaluation, summative evaluation, and summative presentation evaluation instruments were 0.53, 0.84, and 0.90, respectively, for these data. The estimates were more than acceptable for the summative project and presentation PE measures. However, the formative PE reliability would reach an acceptable level (> 0.7) by increasing the number of student proposals each student has to evaluate to seven for these data. However, this level of internal control must be balanced with the practical nature of the hybrid PE model. Demanding seven or more evaluations from each student, as executed in some research [13], may not be a practical instructional intervention for engineering courses with heavy workloads.

Table 2 shows the descriptive statistics for the formative and summative PE evaluation criteria. Across projects and PEs, the average scores are greater than 4.0. The composite scores for the formative proposal, summative report, and summative presentation PEs are M=4.37 (SD=0.73), M=4.23 (SD=0.83), and M=4.39 (SD=0.70), respectively. Two evaluation criteria were consistent from the formative proposal evaluation to the summative project: clarity and overall quality. Clarity declined slightly from M=4.27 (SD=0.75) to M=4.14 (SD=0.72) and overall quality also slightly declined from M=4.35 (SD=0.74) to M=4.14 (SD=0.72). The data were entered into repeated measures ANOVA, and the results show no significant differences in clarity or overall quality at $F(1, 45)=1.39$, $p=.24$ and $F(1, 45)=1.03$, $p=.32$, respectively. A likely explanation for these declines is that the formative PE was based on a project proposal of two pages in length while the summative project report PE was based on the final project report which included substantially more information.

Table 2: Formative and summative descriptive statistics.

Dimensions	Min	Max	*M*	*SD*
Formative proposal peer-evaluations			*4.37*	*0.73*
Relatedness	3	5	4.72	0.53
Significance	3	5	4.59	0.57
Specificity	2	5	4.09	0.83
Clarity	2	5	4.27	0.75
Scope	1	5	4.24	0.95
Overall quality	2	5	4.35	0.74
Summative project peer-evaluations			*4.23*	*0.83*
Relevant literature	2	5	4.26	0.90
Accuracy	2	5	4.34	0.76
Structure	2	5	4.16	0.86
Clarity	3	5	4.14	0.72
Completeness	1	5	4.32	0.91
Overall quality	2	5	4.17	0.84
Summative presentation peer-evaluations			*4.39*	*0.70*
Organisation	2	5	4.42	0.67
Use of visual aids	2	5	4.36	0.78
Preparedness	3	5	4.43	0.69
Answers to question	2	5	4.20	0.80
Extra effort/creativity	2	5	4.46	0.61
Overall quality	3	5	4.46	0.64

Type of Student Feedback

Table 3 shows the type of feedback that emerged from both the formative and summative PEs. Students provided reinforcing and suggestive comments most frequently. The data were entered into a repeated measures ANOVA with the delta from the formative to summative peer-evaluation serving as a within subjects condition. Results show no significant differences for corrective, reinforcing, and didactic feedback from the formative to summative PEs at $F(1, 49)=0.06$, $p=.81$, $F(1, 49)=2.96$, $p=.09$, and $F(1, 49)=0.03$, $p=.86$, respectively. However, there was a significant decline in the frequency of suggestive feedback provided at $F(1, 49)=6.22$, $p=.02$. A plausible explanation for this finding is that second evaluation was purposefully summative in nature, and thus, students were less likely to make suggestions to improve the projects.

Table 3: Type of feedback for formative and summative peer-evaluations.

	Formative Peer-evaluation						Summative Peer-evaluation				
	Min	*Max*	*Total*	*M*	*SD*		*Min*	*Max*	*Total*	*M*	*SD*
Corrective	0	4	30	0.60	1.01		0	5	28	0.56	1.05
Reinforcing	0	12	81	1.62	2.11		0	7	111	2.22	1.79
Didactic	0	2	16	0.32	0.55		0	2	15	0.30	0.58
Suggestive	0	4	54	1.08	1.07		0	4	32	0.64	0.92

Relationships among Measurements

The correlation between the scores of the formative and the summative PEs is statistically significant and moderately positive at $r=.32$, $p=.03$. Table 4 shows the relationships between the evaluation criteria from the formative and the summative PEs. As can be gleaned, the significance of the project proposal from the formative PE was significantly related to the structure ($r=.35$, $p=.02$), completeness ($r=.34$, $p=.02$), and overall quality ($r=.35$, $p=.02$) of the final project report. The quality of the literature review in the project report was significantly related to the specificity ($r=.29$, $p=.047$) and scope ($r=.31$, $p=.03$) of the formative PEs. Additionally, the relatedness of the project proposal topic was significantly related to the completeness of the final project report at $r=.31$, $p=.03$.

Another consideration was the relationship between the instructor's evaluation of a student's project and the summative report and presentation PE scores. The average summative PE score assigned to each project was correlated with the instructor's final assessment: the summative report score correlated at $r=.58$, $p=.01$; and the summative presentation score correlated at $r=.70$, $p<.01$. Both of these correlations are strongly and positively correlated, which lends credence to the validity of the model and is consistent with previous findings [1][7].

Table 4: Relationships between the formative and summative evaluation criteria.

	Summative					
Formative	Rel. literature	Accuracy	Structure	Clarity	Completeness	Over. quality
Relatedness	.14	.19	.20	.25	.31*	.18
Significance	.14	.18	.35*	.25	.34*	.35*
Specificity	.29*	.16	.05	.05	.22	.12
Clarity	.03	.19	.25	.29*	.17	.23
Scope	.31*	.18	.00	.09	.12	.18
Over. quality	.11	.28	.15	.23	.24	.10

*$p < .05$

Student Satisfaction with Hybrid Peer-Evaluation Model

Table 5 provides the student satisfaction descriptive statistics from the anonymous satisfaction survey administered to students upon completion of the PE process. The measure demonstrated a high degree of internal consistency reliability at $\alpha=.90$. The results demonstrate that 94% of the students were generally satisfied (somewhat satisfied to very satisfied) with having to evaluate three separate projects; and the level of ease associated with the process. Further, 100% were satisfied with the amount of time it took to complete the PEs; and the online surveys and criteria used to evaluate their peers. Far fewer students (47%) were satisfied with the quality of feedback received from their peers. This is an indication that students were satisfied with the hybrid PE model, but were, to a lesser extent, satisfied with the quality of the feedback they received from their peers. Most of the students (71%) either agreed or strongly agreed that they learned from their peers' projects as part of the PE process. More than half of the students reported enjoying the PE experience (53%), and feel more confident in providing constructive criticism (53%) as a result. However, only 47% of the students agreed that most courses would benefit from the PE process.

Table 5: Satisfaction item response frequencies and descriptive statistics.

First Section			% Response Frequencies				
Items	*M*	*SD*	1	2	3	4	5
The number of projects you had to review	4.47	0.62	0	0	6	41	53
The level of ease of the review process	4.35	0.61	0	0	6	53	41
The quality of the feedback you received from your peers	3.35	1.17	6	18	29	29	18
The amount of time it took to complete the review process	4.35	0.49	0	0	0	65	35
The surveys you used to evaluate your peers	4.53	0.51	0	0	0	47	53
M=mean; SD=Standard deviation; 1=Not at all satisfied; 2=Somewhat dissatisfied; 3=Neutral/Don't Know; 4=Somewhat satisfied; 5=Very satisfied							
Second Section			% Response Frequencies				
Items	*M*	*SD*	1	2	3	4	5
The peer-evaluation process was a good learning experience	3.41	1.28	12	6	35	24	24
I learned from my peers' projects	4.00	1.22	6	6	18	24	47
The feedback provided by my peers was helpful	3.12	1.41	18	12	35	12	24
The peer-evaluation process was clearly stated and easy to follow	4.47	0.87	0	6	6	24	65
Most courses would benefit from using peer evaluations	3.47	1.28	6	18	29	18	29
I enjoyed this experience	3.65	1.32	12	0	35	18	35
I feel more confident in providing constructive criticism	3.71	1.21	6	6	35	18	35
M=mean; SD=Standard deviation; 1=Strongly disagree; 2=Mildly disagree; 3=Neutral; 4=Mildly agree; 5=Strongly agree							

Anecdotal Observations on Classroom Behaviours

The same instructor at the same institution has taught the course in the case study for several semesters. The instructor noted several key differences as result of implementing the hybrid PE process that were different from the previous semesters. Perhaps the most important observation is that students placed more time and effort in their course projects, and as a direct consequence, the average project quality had increased from the previous semesters. Further, because of the rigid deadlines associated with a formal PE process, more students attended classes regularly and submitted their projects on time to the course management system. A final important observation was that students were generally more prepared for their project presentations. Though these observations cannot be stated scientifically, they are important notes for instructional practice, and potentially, for future research efforts.

DISCUSSION

The current article adds to the understanding of the PE process by providing a systematic, hybrid model that employs both traditional and online PEs as an alternative method of assessment. The hybrid model was designed to be generic enough to fit in any engineering course with a project component while balancing the time-constraints associated with the PE process. Of course, the results of this study must be interpreted in light of the limitations. This case study has been conducted using data that were collected during one semester with a relatively small sample size. Further, the degree of accuracy of the measures may also be questionable since the items are self-reported measures and since the PE process was not truly anonymous as students may or may not have shared their identity. Last but not least, this was the first time for most students to practice giving PEs and providing comments on engineering projects. The instructor pointed out a few major inappropriate types of evaluations and comments during the second stage of the PE process, such as casual and unprofessional wording.

In evaluating the formative and summative peer evaluations, students generally had assigned their peers high marks on each phase of the process as evidenced by the high composite scores (> 4). Though the analysis did not detect any significant differences on clarity or the overall quality from the formative proposal PE to the summative project PE, a slight decline was noted. A probable explanation is that the final project reports were substantially longer and more comprehensive than the project proposals. The most common types of feedback provided to peers were reinforcing and suggestive in nature in both the formative and summative evaluations.

The analysis also revealed that the instructor's evaluation of a final project report was strongly and positively correlated with the summative PEs. This finding is consistent with previous research that suggests PEs closely approximate the evaluations of the instructors when clear guidelines are available [1][7]. Further, the finding also demonstrates the robustness of PE as an alternative method of assessment in engineering courses. In contrast to a traditional method of assessment (e.g. exams), the hybrid PE model encouraged constructive criticism as a goal for modelling real-world activities in the practice of engineering. Thus, the hybrid model of PE presented addresses the call for more alternative methods of assessment and reinforces the practice of engineering instructors using the PEs to partially determine grades.

Students were generally satisfied with the hybrid PE model. Specifically, the results show that students were satisfied with the PE process, the instruments employed, and the number of proposals each student had to evaluate. These are important considerations when attempting to implement practical and replicable instructional practices. However, the results also showed that only 47% of the students were satisfied with the quality of feedback received from their peers. There may be a sense of cognitive dissonance in that a student may have put ample effort into providing critical feedback to their peers and received feedback that may not have been as critical in nature. Another observation is that some students provided casual and negative feedback which might have discouraged the students who received those comments. In future practice, the instructor could review and potentially edit the comments before releasing them to the students. Further, the instructor should provide examples of professional and constructive comments at the beginning of the evaluation process as students may lack of such experience.

In closing, the authors believe engineering educators should be mindful of a student's perception of the assessment methods employed within their courses, and can take careful steps in the integration of alternative methods based on sound empirical evidence. While this research has provided evidence to demonstrate the instructional value of a novel, hybrid PE model, more work needs to be done. For instance, replicating the hybrid method in different classroom environments, both inside and outside of engineering, is necessary to generalise findings and develop best practices to inform practice.

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