Enhanced project-based learning using peer-feedback

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Abstract – We report on an innovative approach to teaching Optics to Engineering students in the form of an enhanced class experience developed by project-based learning, presentations, and peer-feedback. In order to compensate for the lack of laboratory work, an optics project was introduced alongside class demos. In order to increase class interest in the project, a competition was declared and the winner(s) were chosen by the class, who judged student presentations according to preset criteria. The winners received small prizes in recognition of their performance. The project was an important step forward in the learning process; it was very enjoyable for the class, in spite of the substantial additional work. We report on the successes and shortcomings of the project-based peer-evaluation method used in the classroom. The project presentations and competition created an effervescent atmosphere and debates, and increased student interest and participation.

Keywords: Project-based learning, peer feedback, Optics, student competition, class experience.

INTRODUCTION

Teaching engineering and science without laboratory sessions is both challenging and of diminished value. It has been reported that project based learning increases interest in the taught topic, as well as the students' skills [1, 5, 8]. Epistemological beliefs and instructional goals can also be related to the use of laboratory activity [6]. Optics is particularly suited to experimental investigation as most of the information one learns comes through an 'optical channel'. Class demos are of great help in understanding concepts, but they lack the active learning component that students go through while experimenting and designing on their own.

In order to cope with the above mentioned problems, we decided to enhance student experience in the Optics class by introducing a project based learning component to the class requirements. Moreover, we chose to use a peer assessment method to establish the winner of the project competition. Although instructors are the ones evaluating student achievement, students are critical about themselves and often make a fair assessment regarding the rank of their colleagues within a given class. Lately, peer assessment has been used more often for assessment in classrooms [11]. Studies show that peer assessments closely resemble the instructor's, when well understood criteria are used [4]. Peer assessment may give non-standard evaluation ways but also meaningful indicators about student achievements [9]. It was also found that peer assessment is correlated with the enhancement of student learning by means of reflection, analysis and diplomatic criticism [3]. Nevertheless, there is resistance in the academia to using the peer assessment method [7] and some concerns about peer assessment have been reported in the literature [10]. We assumed that students will have a positive reaction to the new assessment technique and that it will help them become more responsible, as reported by others [2]. We assumed that the benefits of using peer assessment technique in the project evaluation will outweight other associated concerns and experimented the method in the Optics class.

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OPTICS DESIGN PROJECT

Optics is a 400 level, 3 contact-hours course curriculum requirement for Engineering and Engineering Physics students. Due to the lack of laboratory work in the Optics classes and given the reasons stated above about the role of experimental work in the development of skills and understanding of concepts, an experimental design project was introduced as a required component of the class work. In the initial experimental stage, the weight of the project was such that it would not drastically influence the final course grade, without being altogether neglectible. Therefore, a 10% weight of the final grade was chosen.

The course focused on geometrical optics with a survey of wave optics. A description of the project requirements was given, with a wide range of possible project topics, allowing students to work on a topic that is of interest to them rather than imposing a specific target to be achieved by students in different approaches. Students were asked to propose a topic for their project and discuss it with the instructor before pursuing experimental work. The topics could include the design of a simple optics-related device, alteration to a certain optical device with a particular purpose, or optics-related experiments meant to prove or measure a certain phenomenon or quantity. It was specified that the project could be stand-alone or part of a larger work such as senior design project. Students were allowed to browse for possible topics and refine their thoughts based on instructor's feedback. This initial stage of the project lasted about 2-3 weeks and enabled students to learn more about various Optics topics and experiments, the equipment available in the department, and their own resources. A target date was suggested for the project proposals but it was not enforced and no penalties were introduced for late submissions.

A project presentation in front of the class was required within the last week of school, along with a brief report documenting the project according to provided guidelines. It was suggested that the report should include the purpose of the experimental work, theoretical background, description of experimental work, calculations, explanations related to the work, pertinent diagrams and photos, conclusions, and references, all within 5-6 well structured pages. A competition with promised small prizes was declared with the purpose of increasing class interest and the winner(s) were to be chosen by the class.

Project Proposals

Students likely found the choice of an experimental topic as difficult as the experimental project itself. There was a wide spectrum of proposals, from simple topics to advanced ones. Their guided research was productive and generated interesting project proposals: Optical Determination of Ethanol Content, Investigating Potential Materials for Sun and Stage Glasses, How Effective is Sunscreen?, Laser Infringement, Proving the Law of Reflection, Total Internal Reflection with Water Stream, The Effects of Aperture on Image Characteristics, Data Track Spacing on CDs and DVDs, Measurement of Light Intensity and Total Internal Reflection through Various Liquids, Stereoscopic Vision Illustration, Magnetic Optics, Depth Perception Using Digital Photography, An application of Malus's Law, Home Made LCD Projector, Behavior of the Inverse Square Law and Uniformity of Intensities with Multiple Light Sources, Adapting an Optical Mouse for Dead Reckoning Navigation. The proposals were accompanied by a brief description of the goals and experimental methods to be used. The project itself generated both student interest in various Optics topics along with a nice active and collaborative environment. Students shared information about technical resources, websites, and sometimes they helped each other with technical support.

Peer Assessment

The project competition rules were explained in advance; the oral presentations were to be evaluated and provided with feedback; the presentations had to include demos or proof (such as videos or photos) of student experimental work. The following pre-established criteria were used:

Students were provided evaluation sheets, which contained a choice of five categories for each of the above criteria: excellent, very good, good, poor, and very poor. A numerical score was associated with each of the categories as follows: E=excellent= 5, VG=very good=4, G=good=3, P=poor=2, and VP=very poor=1. The total evaluation score is obtained by the summation of the scores corresponding to each criterion (C1-C5) from all the peer assessors.

C1	overall structure; extent to which the presentation followed the guidelines
C2	clarity, coherence, intelligibility of the presentation
C3	quality of experimental work
C4	analysis/ interpretation of data/phenomena
C5	special merit, ingenuity/originality

Table1

In order to account for the uncontrollable number of students present during the presentations and peer evaluation period, as well as for occasional incomplete evaluations (for particular criteria C1-C5), a score averaging procedure was used. The number of responses-ticked categories (E, VG, G, P, VP) per each criterion (C1-C5) resulting from all the peer assessors was first calculated for each presenter. Each of the partly calculated responses was scaled to the number of responses corresponding to each criterion. For instance (see Table 2): if for C1 the presenter obtained N_E=6 E, N_{VG}=2 VG, N_P=1 P, N_{VP}=0 VP it means that a number N_{C1}=6+2+5+1+0 peer assessors evaluated the presenter on criterion C1. Then the scaled responses were obtained dividing N_E, N_{VG}, N_P, and N_{VP} by N_{C1}.and multiplying the result by 10. For instance, the scaled response for E category is $\frac{6}{14}\times 10 = 4.29$. The scaled results obtained are, to a certain extent, independent of the number of assessors and they can be used to obtain the total score corresponding to C1 category: S_{C1}=4.29x5+1.43x2+4+3.57x3+0.71x2+0x1. The total scaled score of presenter "*a*" is

$$S_a=S_{C1}+ S_{C2}+ S_{C3}+ S_{C4}+ S_{C5}.$$

	C1				
category	E(=5)	VG(=4)	G(=3)	P(=2)	VP(=1)
responses	6	2	5	1	0
scaled responses	4.29	1.43	3.57	0.71	0

Table2. Example of averaging the peer-assessed response technique

This scaling procedure renders a maximum possible score of (10x5)x5=250 and a minimum score of (10x1)x5=25. The averaging method was used for each of the presenters to obtain peer-evaluator quasi-independent scores. An Excel spreadsheet was programmed so that calculation time was minimized. The scaled scores were used for ranking student presentations and establishing the winners.

RESULTS AND ANALYSIS OF PEER-ASSESSED WORK

Attendance of the presentation sessions was good: in a class of 16 students, there were 4 presentation sessions with 16, 15, 15 and 14 participants respectively. Demos, photos, and animation presentations were given. There were inquisitive questions from the audience and the presenters usually handled questions well; the atmosphere was both friendly and competitive. The average scaled responses ($10N_E/ N_{Ci}$, $10N_{VG}/ N_{Ci}$, $10N_P/ N_{Ci}$, $10N_{VP} /N_{Ci}$, i=1-5) of all presenters /students corresponding to each criterion (C1-C5) were calculated and plotted in Fig. 1. The graph in fact compares the frequencies of the number of "ticks" on each category (E, VG, G, P, VP) corresponding to each criterion. A few observations can be derived from the analysis of the plotted data:

1. Students more frequently assigned excellent (E) than any other category, irrespective of the criterion used (see also Fig. 2). The situation could correspond to a realistically very good student performance. Although many of the students worked hard, the quality of the results and presentations was not always justified as

‘excellent’ from the instructor’s point of view. We believe that the high frequency of the ‘excellent’ category is inflationary. A possible cause for this outcome is the fact that students did not have the chance to compare and evaluate all the presentations at once, as there were 4 presentation sessions scheduled. Therefore, the initial opinion of a good project presentation is created upon the first session and it may be contradicted by the next presentation session resulting into inflated evaluations and less room for discrimination among the top presenters.

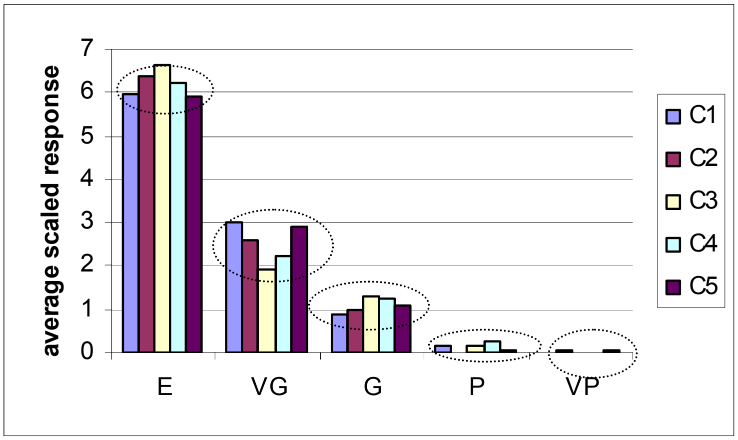

Figure 1. Comparison of average scaled responses for evaluation criteria

2. Criteria C1 and C5 appear strongly correlated from the students’ point of view. For both “excellent” and “very good” categories (which account for most of the peer assigned choices) the average scaled response is essentially at a similar level. Our interpretation of the result is that from the point of view of students the two criteria are strongly correlated and do not generate significant discriminatory information to help rank students. Criteria C2 and C4 provided close range scaled responses, although distinct. Therefore more rank resolution is added by this pair than by the C1, C5 pair.

The highest incidence of “excellent” responses was observed for criterion C3, referring to experimental work. This came at the expense of the “very good” category, which had the lowest relative frequency for C3. Although we believe the assessment to have an inflationary tendency, we also believe this to be a captured quantitative proof that students have gained appreciation for the experimental efforts of their colleagues as well as for their own.

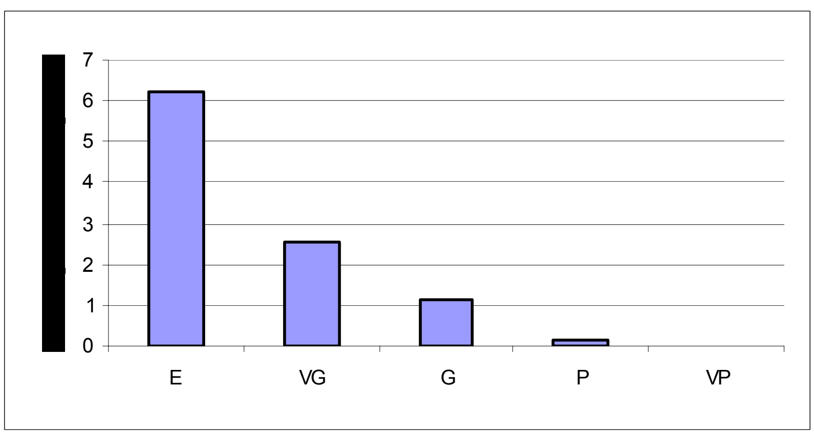

Figure 2. Comparison of average scaled response per category

3. Fig. 2 shows the scaled responses for categories (E, VG, G, P, VP) of all criteria (C1-C5). Categories “poor” and “very poor” were very rarely used by student evaluators. The situation corresponds to a certain extent with our impression, although with a perceived inflationary tendency. It is also apparent that: the

frequency of "excellent" responses is about 2.5 times higher than the "very good" category; the frequency of VG responses is about 2.3 times higher than the G category; the frequency of G responses is about 8.8 times higher than the P category; the frequency of P responses is about 7 times higher than the VP category. A second order polynomial regression gives the following relation for the frequency of responses as a function of category $y = 0.5455x^2 - 4.755x + 10.265$ with an $R^2 = 0.9897$. However, for the first three categories (E, VG, G) an exponential fit is highly recognizable: $y = 14.613e^{-0.8653x}$ with an $R^2 = 0.9994$ ($R^2 = 1$ indicates a perfect fit). Moreover, the E, VG, and G categories account for 99% of all responses.

Competition Winners

The scores of the peer-assessed project work was computed and plotted in Fig. 3. It is noticeable that scores varied in a rather narrow range (172 to 245) compared to the capabilities of the scaling procedure which allows for a maximum score of 250. One can clearly distinguish from Fig. 3 the formation of four cluster scores. In terms of ranking student work, our opinion was in very good agreement with the 4 cluster classes obtained through the technique described in this paper. The scores were used for student ranking and for identifying the winners for the distribution of prizes. However, the scores were not used for assigning the grade for the project component of the course. The scores of the top student performers clustered around a value of 240-245. This situation created small resolution capabilities of the scale to establish the top winners. In addition, the highest score (Stereoscopic Vision Illustration) was not achieved for what both instructor and students (oral opinion) considered as the best project work. It was decided that the first prize will be shared by the top performers (Home Made LCD Projector and Stereoscopic Vision Illustration); the second and third prizes were also shared by two students each. A small amount of money was available for prizes and a green laser was purchased and given to one of the first prize winners (Home Made LCD Projector). The other prizes consisted in textbooks and T-shirts.

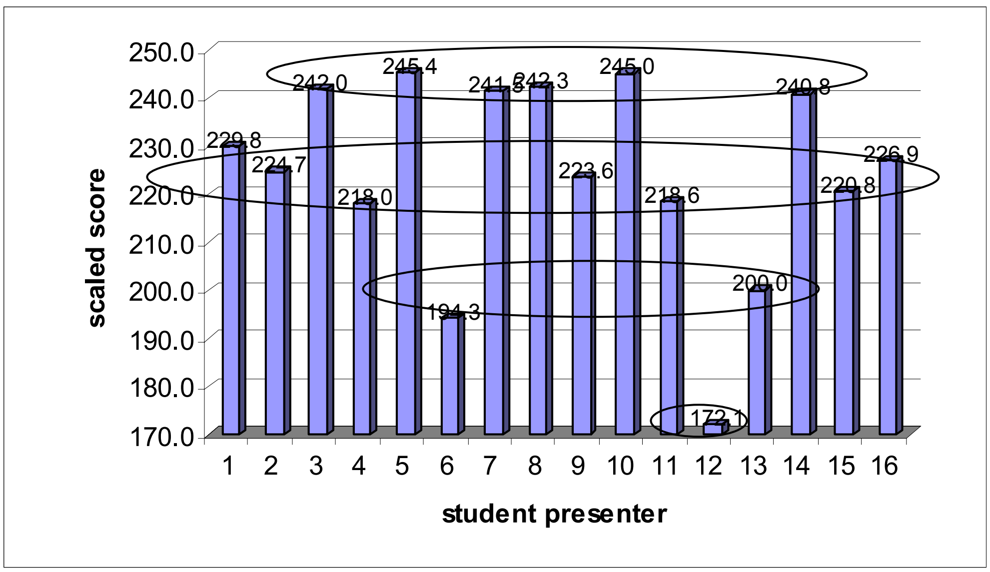

Figure 3. Scores of the peer-assessed project work.

CONCLUSIONS

The paper discussed a project based learning experiment enhanced by peer-feedback used for ranking students. Students were exposed to the challenges of selecting a project based on available resources and of applying the theoretical knowledge acquired in the course to the real world. Some interesting project ideas were formulated and some were actually implemented, although not always with the expected outcomes. Students enjoyed the peer evaluation system, which exposed them to a different perspective and feedback relative to their work. They also acted responsibly and came to appreciate the work of others and their own. The instructor noticed an overall significant improvement in student analysis and presentations skills. Students learned to use laboratory equipment as well as their own resources.

Given the relatively small weight of the project work there were a few students who were not ready to spend much time on this course component, and this fact also translated into their peer and instructor feedback. Peer-assessment can be unintentionally misleading. The best project, as assessed by the instructor and by the class's oral comments, came second according to scores from peer evaluations. When peer assessment is used, the instructor should manifest his judgment and right to override possible situations of high discrepancies between numerical results and instructor and student perceived performance. The method appeared highly rewarding in terms of instructional gains, with the caution that at times the instructor should follow "common sense" rules regarding the outcomes and should override possible aberrations.

In our experiment grades for the project and project presentations were not tied to the peer-evaluation scores, but they were in agreement with the ranking provided. The strong correlation between responses to C1 and C5 and to a lesser extent between C4 and C2 indicates that the number of evaluation criteria can be reduced in the future by eliminating one of the C1 and C5 pair or by merging them. Some ranking resolution is added by C4 and C2, but they could be merged with predicted increase in ranking resolution. Our analysis of peer feedback shows that students exponentially decreased their willingness to assign lower category values (E, VG, G) and extreme reluctance to assign P and VP categories to their colleagues' performance. It is the instructors' belief that both the experimental part and the report can be improved in future experiments by increasing the percentage weight of the project component. Some overlapping topics created debates relative to what should be covered by each student. This can be easily avoided in the future by approving only well formulated, distinct topics.

Both quantitative analyses of student responses and our perception indicate that the peer-assessed project was an effective learning experience which, in our opinion, by far outweighed some inherent difficulties. Some students developed their initial Optics project into projects related to other courses. Others have developed it into Senior Design Projects and are still working on it. Many of the students in that class have already graduated and found jobs and a few are pursuing graduate studies.

REFERENCES

[1] Cheville, R. A., A. McGovern and K. S. Bull, "The light applications in science and engineering research collaborative undergraduate laboratory for teaching (LASER CULT) - Relevant experiential learning in photonics," *IEEE Transactions on Education*, 48.2 (May 2005): 254-263.

[2] Dochy, F., M. Seger and D. Sluijsmans, "The use of self-, peer and co-assessment in higher education: a review," *Studies in Higher Education*, 24 (1999): 331.

[3] Falchikov, N., "Peer feedback marking - developing peer assessment," *Innovations in Education and Training International*, 32 (1995): 175.

[4] Falchikov, N. and J. Goldfinch, "Student peer assessment in higher education: A meta-analysis comparing peer and teacher marks," *Review of Educational Research*, 70.3 (2000): 287-322.

[5] Gott, R. and S. Duggan, "Practical work: Its role in the understanding of evidence in science," *International Journal of Science Education*, 18.7 (1996): 791-805.

[6] Kang, N. H. and C. S. Wallace, "Secondary science teachers' use of laboratory activities: Linking epistemological beliefs, goals, and practices," *Science Education*, 89.1 (Jan. 2005): 140-165.

[7] Liu, N. F. and D. Carless, "Peer feedback: the learning element of peer assessment," *Teaching in Higher Education*, 11.3 (July 2006): 279-290.

[8] Macias-Guarasa, J., J. M. Montero, R. San-Segundo *et al*., "A Project-Based Learning Approach to Design Electronic Systems Curricula," *IEEE Transactions on Education*, 49.3 (August 2006): 389-397.

[9] McDowell, L., "The impact of innovative assessment on student learning," *Innovations in Education and Training International*, 32 (1995): 302.

[10] Papinczak, T., L. Young and M. Groves, "Peer assessment in problem-based learning: A qualitative study," *Advances in Health Sciences Education*, 12.2 (May 2007): 169-186.

[11 5] Wen, M. L., C. C. Tsai and C. Y. Chang, “Attitudes towards peer assessment: a comparison of the perspectives of pre-service and in-service teachers,” *Innovations in Education and Teaching International*, 43.1 (Feb. 2006): 83-92.

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