AC 2008-1453: PRACTICAL APPROACHES TO PROJECT-BASED LEARNING INCORPORATING PEER FEEDBACK IN ORDER TO ENHANCE CREATIVITY IN ENGINEERING COURSES

Adrian Ieta, Murray State University

Adrian Ieta holds a Ph.D. in Electrical Engineering (2004) from The University of Western Ontario, Canada. He also holds a B.Sc. in Physics from the University of Timisoara, Romania (1984), a B.E.Sc. in Electrical Engineering from the Polytechnical University of Timisoara (1992), and an M.E.Sc. from The University of Western Ontario (1999). He worked on industrial projects within the Applied Electrostatics Research Centre and the Digital Electronics Research Group at the University of Western Ontario and is an IEEE member and a registered Professional Engineer of Ontario. He taught at the University of Western Ontario and is now Assistant Professor at Murray State University, Department of Engineering and Physics.

Art Pallone, Murray State University

Art Pallone holds a Ph.D in Applied Physics from the Colorado School of Mines (2000) in Golden, CO USA. He also holds an M.S. in Applied Physics from Indiana University of Pennsylvania (1995) and a B.S. in Aerospace Engineering from the University of Michigan (1991). From 2000 to 2003, he held a Davies Fellows Postdoctoral Teaching and Research appointment cosponsored by the United States Military Academy and the U.S. Army Research Laboratory. He is now an Assistant Professor at Murray State University in the Department of Engineering and Physics.

PRACTICAL APPROACHES TO PROJECT-BASED LEARNING INCORPORATING PEER FEEDBACK IN ORDER TO ENHANCE CREATIVITY IN ENGINEERING COURSES

We report on innovative approaches to integrating student feedback into teaching engineering physics courses. Project-based learning, presentations, and peer-feedback contributed to an enhanced class experience. This interactive method was applied in Optics and Engineering Measurements courses. The Optics course was mainly focused on geometrical optics with a survey of wave optics. In order to compensate for the lack of laboratory work, an optics project was introduced alongside class demos. Students browsed for possible topics for a couple of weeks and then proposed one based on instructor's feedback. The project concluded with a short presentation of the work in front of the class and a brief written report. In order to increase class interest in the project, the presentation took the form of a competition and the winner(s) were chosen by the class, who judged the presentations according to preset criteria. Student feedback was recorded and quantized, and the peer evaluation and feedback were returned to the presenters. The winners received small prizes in recognition of their performance. Interesting project ideas were formulated and some were implemented, although not always with the expected outcomes. Students enjoyed the peer feedback system, which exposed them to a different perspective on and evaluation of their work. For the Engineering Measurements course, students did small group projects on topics of common interest to group members. Group oral presentations and individual written reports replaced the traditional final exam. Subjects included topics such as magneto-optics, urban astronomy, acoustics, electro-mechanics, solar power, stress-strain measurements, laser beam divergence, and Brewster angle for different materials. Faculty attended presentations and participated with the students in the evaluation of the presentations using evaluation sheets provided in advance. Students preferred this type of examination to the stress of the final exam, despite devoting at least as much time and effort to their project and presentation as they would to traditional final exam preparation. Peer and faculty feedback during the term was particularly effective in enhanced collaboration, negotiations, and task prioritizing for successful project completions. In both teaching approaches, the project presentations involving peer feedback and student competition created an effervescent atmosphere and debates, and maintained student interest and participation. In a collaborative yet competitive environment, students learned to use laboratory equipment as well as their own resources. We report on the enhanced class experience, successes, and shortcomings of the project-based peer-evaluation method used in the classroom. The effectiveness shown in the Optics and Measurements classes indicates that this teaching approach is more generally applicable to other project-based courses.

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]. Engineering Measurements and Optics are particularly suited to experimental investigation. 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.

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 academia to use of 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 the peer assessment technique outweight other associated concerns and used the technique in both classes.

OPTICS

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.

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.

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. 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:

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.

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.

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.

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.

PEER-ASSESSED WORK

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.

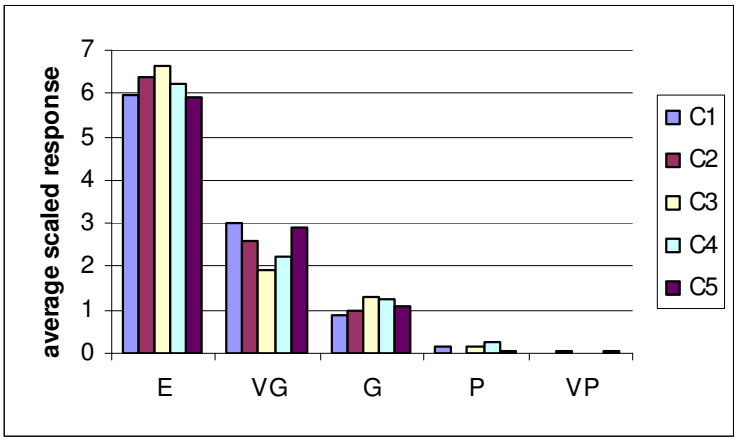

Figure 1. Comparison of average scaled responses for evaluation criteria

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.

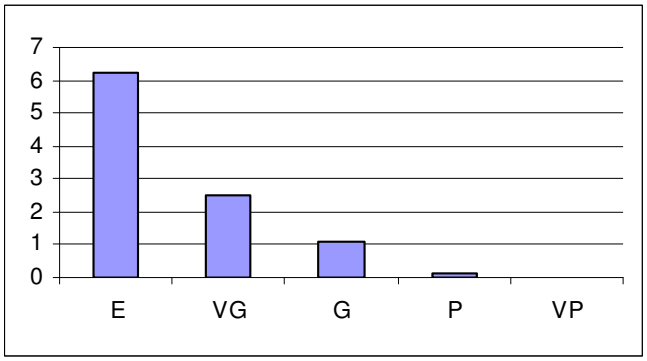

Figure 2. Comparison of average scaled response per category

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.

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; 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.

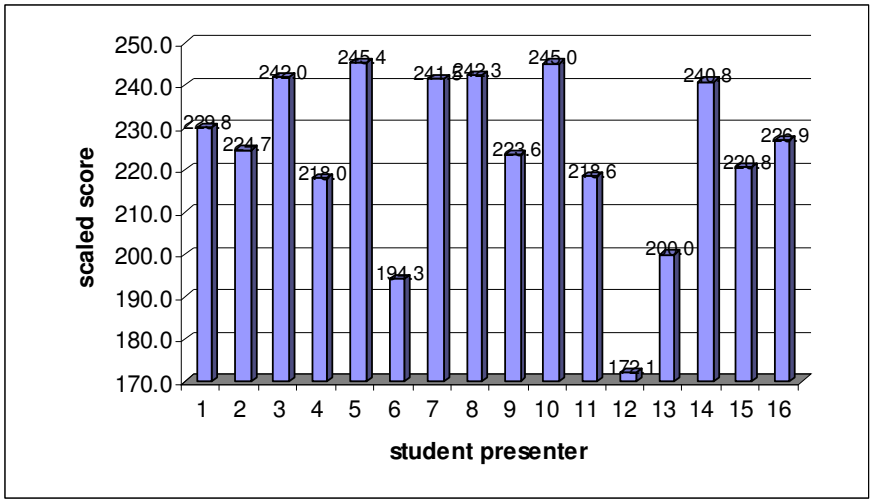

Figure 3. Scores of the peer-assessed project work.

ENGINEERING MEASUREMENTS

Engineering Measurements students work in groups of three to four students to complete structured laboratories throughout the term. Each group performs one or more oral presentations during the term based on the structured laboratories. The Engineering Measurements rubric is more specific in its evaluation criteria than the Optics class rubric. The level of specificity requires a different approach to the evaluation process to be effective. The rubric is divided into three categories as shown in Table #. The Content category is worth 60 percent, The Format category is worth 20 percent. The Style category is worth 16 percent. The remaining 4 percent is allotted to time with penalties assessed for durations less than 5 or more than the 10 minutes. Within each category, the individual criteria are rated on the same scale as the Optics criteria where 1 is "very poor" and 5 is "excellent." During any one presentation, members of each group are only responsible to evaluate the presenters in one category. The category responsibilities change for each group with each presentation so that every group performs peer evaluations for every category of the rubric by the end of the presentations.
Individual evaluation criteria are too specific to determine statistically significant trends; however, general trends do appear at the category level as shown in Figure 4.
Comparison of the criteria within the categories to the Optics course criteria indicate a correspondence between the Content category and the combination of C1, C3, and C4 Optics criteria. Similarly, the Format category corresponds to the Optics C2 criterion. There is no apparent correspondence between the Style category and the Optics criteria. The peer evaluations for the Content and Format categories show a similar, though somewhat lesser trend toward higher ratings as in the Optics class; however, our assessment of the data differs from that for the Optics class. Faculty evaluations indicate that the student assessment of their peers is not inflation but rather an accurate representation of student comprehension of subject matter and organizational ability. The cluster of VP ratings in the peer evaluations is not a student misperception. It agrees with faculty evaluation of the relative performance of one of the five groups. The distribution in the Style peer evaluations indicates that students were not as uniform in their

expectations for this category. This interpretation is supported by the faculty evaluations and comments.

Faculty scores were weighted in a 2:1 ratio to the average of the student scores. As indicated in Figure 5, students were more critical of one another than the faculty were on the laboratory exercises that occurred during the term; however, the situation is generally reversed for the term-end presentations. We believe that the reversal was primarily due to three factors. First, students discussed their respective grades with one another. The term-end peer evaluations reflect student overcompensation in their attempt to align their ratings of one another with their anticipation of faculty ratings. To a lesser degree, different faculty evaluated a given group at the term-end presentations than during the term. Although the rubric is very detailed, the expectations for a given rating within each evaluation criterion of the rubric may have varied among the faculty. Finally, many of the students in Measurements were about to graduate and had already accepted offers for employment or to graduate school at the time of the term-end presentations.

Content
Overview. Presented a general overview and current state of understanding of the topic. (+3) Explained the motivation for investigating the topic. (+3) Briefly described the methodology/approach to studying the topic. (+2) Briefly stated what conclusions would be reached in closing. (+2)
Experiment. Explained the procedure by which data was collected. (+9) Explained how the equipment/technology works or operates in terms the audience can understand. (+4) Explained any limitations of the equipment/technology. (+3) Identified alternative equipment/technology and why did not choose it. (+2)
Theory. Explained the underlying physics/engineering principles including any assumptions. (+8) Explicitly identified the meaning of symbols in equations. (+2) Explained the derivation of the final equation/model including any additional assumptions. (+8)
Results and Conclusion Results based on the final equation/model presented in Theory. (+7) Conclusions supported by the results. (+7)
Format
Introduction. Did the students introduce themselves? (+1) Did the introduction identify the purpose of the oral report? (+2) Was an outline or agenda for the oral report presented? (+1)
Sequence. Does the oral report convey information in a logical, meaningful sequence? (+4)
Visual aids. Could everyone read the visual aids (pictures not too small, font size correct, etc.)? (+2) Did the visual aids present relevant information to the oral report? (+2)
References. Were all references listed and displayed in a proper format (MLA or APS standard)? (+4)
Closing. Did the presenters summarize the report or present any conclusions? (+2) Did they ask for questions? (+2)
Style
Physical Behavior. Was eye contact maintained with the class? (+2) Was there excessive references to slides or notes? (+2) Were there any physical gestures made that distracted the audience (playing with pointer, excessive hand waving, etc.)? (+2) Did the presenters speak to the class or to the screen? (+2)
Voice. Was the speaking voice an appropriate volume? (+3) Were words enunciated clearly? (+2) Did the presenters display confidence in their knowledge of the material? (+3)
Time. (+4) -1 for every 30 seconds under 5 or over 10 minutes to maximum of -4.

Table 2: The Engineering Measurements presentation rubric includes weight factors used to calculate grades in parentheses. Ratings range from 1 (very poor) to 5 (excellent)

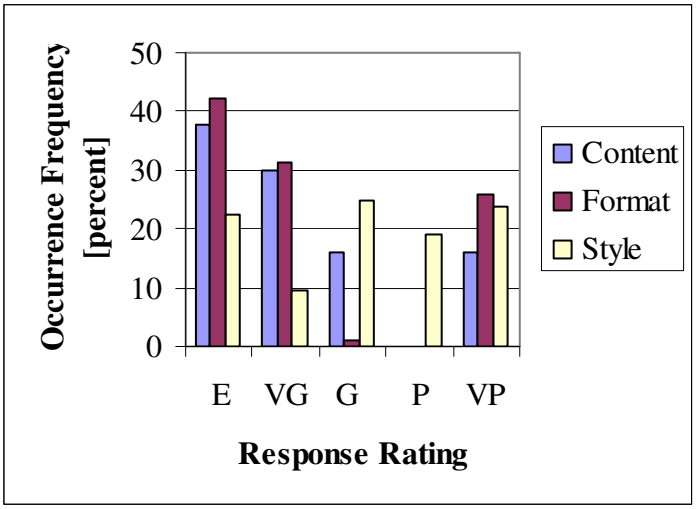

Figure 4. Student peer evaluations of lab exercises presentations in Engineering Measurements course

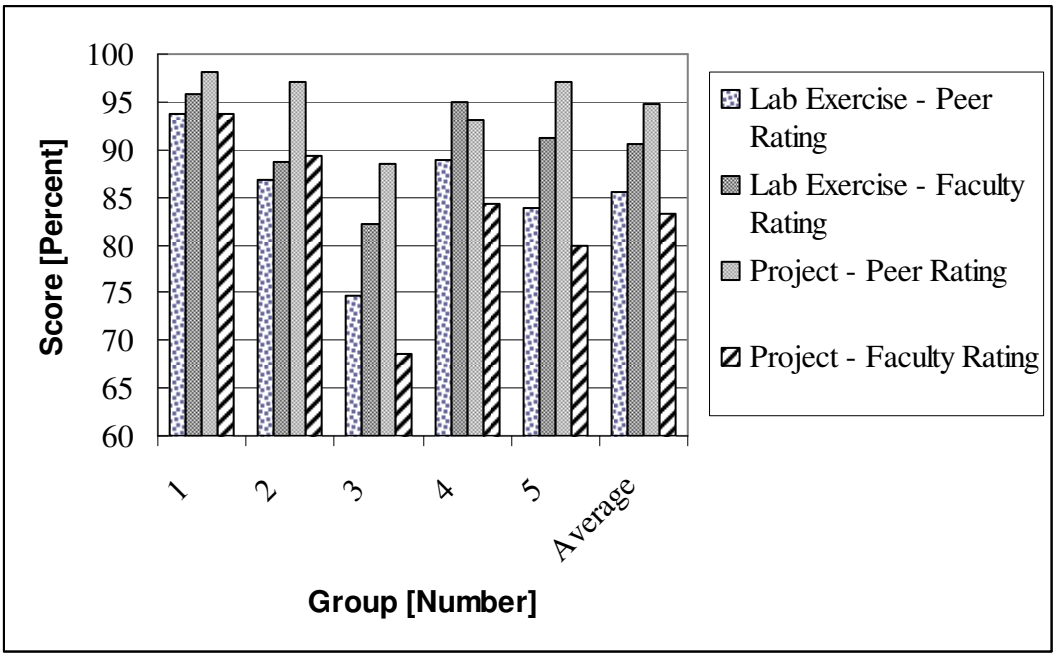

Figure 5. Comparison of student peer-assigned grades with faculty assigned grades in the Engineering Measurements course

CONCLUSIONS

We investigated how project based learning is enhanced by peer-feedback. Students enjoyed the peer evaluation system which provided a different perspective on and feedback relative to their work. They also acted responsibly and came to appreciate the work of others and their own. The instructors noticed an overall significant improvement in student analysis and presentations skills.

In both classes, there were a few students who chose not to commit much time or effort on this course component. This translated into their lower peer and instructor assesments. Since peer-assessment can be unintentionally misleading, an instructor should manifest his judgment and right to override results of that assessment. Both quantitative analyses of student responses and our perceptions indicate that peer-assessment was an effective learning experience that outweighed some inherent difficulties. The method appeared highly rewarding in terms of instructional gains. It should be continued to be used in the Optics and Measurements classes and potentially expanded into other classes.

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] 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.