Enhancing civil engineering surveying learning through workshops

Awange JL[1], Anwar AHMF[2], Forootan E[3,4], NikrazH[5], Khandu[6], Walker J[7]

[1]Associate Professor, Dept. of Spatial Science, Curtin University, WA, Australia. J.Awange@curtin.edu.au

[2]Associate Professors, Dept. of Civil Engineering, Curtin University, WA, Australia.F.Anwar@curtin.edu.au

[3]PhD, Dept. of Geodesy and Geoinformation, University of Bonn, Germany. forootan@geod.uni-bonn.de

[4]Cardiff University, School of Earth and Ocean Sciences, Cardiff, United Kingdom

[5]Professor, Dept. of Civil Engineering, Curtin University, WA, Australia. H.Nikraz@curtin.edu.au

[6]MSc, Dept. of Spatial Science, Curtin University, WA, Australia. Khandu@postgrad.curtin.edu.au

[7]BAppSc, Dept. of Spatial Science, Curtin University, WA, Australia. J.Walker@curtin.edu.au

Abstract

Civil Engineering Surveying unit at undergraduate level needs substantial amount of hands-on training to obtain adequate learning outcomes. Lecture-only mode of delivery does not provide adequate surveying skills needed by an engineering student. In 2009, workshops were introduced for this unit at Curtin University with the aim of offering students hands-on training in surveying to enhance their learning. This study analyses data collected from 160 students in 2012 and 2013 using confidence limits, correlations, frequency percentage distribution, and principal component analysis to evaluate if these workshops contributed to(i) enhancement of students' acquiring industry-based skills and (ii) enhancement of the students overall learning of engineering surveying, a practical oriented course. Additionally, qualitative analysis from Curtin's official eVALUate and examination results were used to verify the findings of (i) and (ii). The results indicate that workshops contributed to the development of the students' overall learning skills, with the top students' agreement being critical thinking skills (93.6%), handle problems (96.6%), and correlate theory (97.9%). Qualitative analysis of the 2013 data indicates that70% of the students' agreed that their overall learning skills were enhanced, while the workshop sessions prior to the assessed fieldwork of setting out a horizontal curve enabled students to enhance their communication and teamwork skills. Overall, 97.9% of the students were satisfied with the workshops and 98.9% said they would recommend it as an effective learning tool to their friends. The main lesson that can be learnt from the data presented in this contribution is that students were satisfied with the workshops and recognise/perceive them to contribute to the development of the learning attributes they need to acquire.

Keywords: Workshop; Civil Engineering; Surveying; Learning attributes; Fieldwork; Critical Thinking

Introduction

Nowadays, tertiary education institutions seek to refine their engineering curricula to suit the most up-to-date technology and globalisation. In today's competitive world, therefore, it is necessary that university engineering graduates possess not only moral and ethical responsibilities needed to build a better liveable environment, but also certain generic competencies such as communication skills, teamwork, right attitudes, problem solving, creativity and critical thinking, and practical skills. This is because these young trained engineers would act as the bridge between the society and modern development on the one hand, while on the other hand, they are expected to meet the diverse range of needs of industries, governments and communities whilst continuously developing their professional skills (e.g., Male et al., 2009; Webster, 2000). In collaboration with Industry Advisory Committee (IAC) in Australia, for example, Male et al., (2009) identified four key competency skills out of 64 generic competencies namely: communication, teamwork, self-management, and problem solving skills as the most critical in performing the job well.

Whereas the normal traditional method of teaching and learning surveying through lectures and tutoring are required to enhance the student's theoretical skills, they are in themselves insufficient to produce a well-educated engineering workforce that is fundamental to innovation and entrepreneurship, and one that would directly contribute to global economy, environment, security and health (see e.g., Campbell et al., 2009). Hence, industries today seek engineering graduates who possess skills far beyond their classroom knowledge.

One approach that has been adopted to expose students to a variety of opportunities and knowledge, including creating awareness of global science and engineering trends, development of teamwork skills, fostering interest and motivation and peer interaction, is the *collaborative learning environment* (e.g., Webb, 1989; Bourner and Flowers, 1997; Smith et al., 2005; Baroffio et al., 2006; Bartle et al., 2011). This approach enables these generic competency skills to be achieved through interactive learning methods such as face-to-face discussions (e.g., Ellis et al., 2008), project-based learning (e.g., Bartle et al., 2011; Fernandez-Samaca and Ramirez, 2010) and workshop-based learning (e.g., Anwar et al., 2012, 2013; Shelton and Hudspeth, 1989).

A workshop-based learning is an important component of collaborative learning method in the development of such skills in engineering learning (Shelton and Hudspeth, 1989; Anwar et al., 2012). It not only improves the student's overall performance through conceptual understanding, but also enhances their interest in the profession (e.g., Shelton and Hudspeth, 1989; Bourner and Flowers 1997; Anwar et al., 2012) and enables multiculturalism through close interaction with their tutors and colleagues (e.g., Watson et al., 1993). It makes them understand the real workplace environment and their role in the society better (Webster, 2000), while it also enhances the quality of tutor's teaching skills and understanding the student's problems, weaknesses, and how to solve them interactively (e.g., Pandachuck et al., 2004; Baroffio et al., 2006). This is demonstrated, e.g., in the works of Anwar et al. (2012), Fernandez-Samaca and Ramirez (2010), and Male et al. (2009), among others.

Workshops have been used in diverse professions to a diverse range of participants to enhance the learning outcomes (see, e.g.,Skillen et al.,1998, Fullilove and Treisman 1990, Laws 1991, Dori and Belcher 2005, Parcelll et at., 1998 and Davis et al., 1999). In engineering teaching and learning, workshops have helped to improve the performance of students by developing a better understanding of the concepts. This is shown, e.g., in Shelton and Hudspeth (1989) where academic excellence workshop program that focused on enhancing engineering concepts such as statistics and dynamics to the students in an Engineering Mechanics course was implemented in California State Polytechnic University, Pomona in USA in order to increase the number of successful under-represented minority engineering graduates. Similarly, excellent workshop programs have resulted in a strong retention tool in the Minority Engineering Program in the College of Engineering and Applied Sciences at Arizona State University (Adair et al., 2001). Additionally, the workshop program managed to serve as an assurance and recruit more students in engineering (e.g., Anwar et al. 2013). An e-workshop pilot program launched in Riga Technical University, Riga, Latvia (Peteris et al., 2012), which was introduced in order to make students ready for practicals, resulted in good feedback from local and foreign students as well as interests from other universities in the city. Workshops, therefore, could contribute towards satisfying engineering bodies in various countries (see, e.g., Felder and Brent, 2003).

Whereas the preceding paragraphs highlight the significance of workshops in enhancing engineering learning in general, its application to the teaching and learning of engineering surveying, a fieldwork-based unit, is less documented. Part of the challenge is posed by the practical/fieldwork nature of engineering surveying that requires students to undertake field practicals where they learn practical skills of infrastructure setup. In undertaking fieldwork, the students are expected to utilize their communication and teamwork skills as they work within group environments. At Curtin University, students undertaking Civil Engineering Drawing and Surveying (CVEN2000) unit had only an hour lecture and a two-hour practical, which was insufficient for the students to grasp the vast subject of surveying, which is one of the key requirements in a civil engineering profession (see, Millis and Barber, 2004; Scheofield and Breach 2007; Uren and Price 2010; and Walker and Awange 2017).

In an effort to reap the benefits of interactive learning methods, and to address the perceived shortage of teaching hours for a relatively huge number of students in CVEN2000 (a civil engineering surveying) unit at Curtin University, Australia, two-hourly workshop sessions per week were introduced in 2009 (see, e.g., Anwar et al., 2012). The workshop sessions aimed at providing students with more hands on knowledge on theoretical and practical skills in surveying needed to undertake a well-planned project, and also to provide them with a series of industry-based skills such as teamwork and communication skills (e.g., Ellis et al., 2008; Webster, 2000; Vora and Markozy, 2011), cross-cultural interaction (e.g., Watson et al., 1993), and many others (as identified in e.g., Male et al. 2009).

In an earlier related study based on the 2012 survey of 67 students, Anwar et al., (2012) mapped workshop learning with Curtin's graduate attributes and found that most of the learning outcomes from workshop addressed Curtin's graduate attributes. In Anwar et al., (2013), based on the 2012 data,the workshop outcomes were assessed and found to enhance the development of fieldwork skills for Curtin students and to improve their overall learning as field surveying engineers, making them ready for industry. The present study goes beyond those of Anwar et al., (2012, 2013) by providing a comprehensive analysis of the overall contribution of workshops in engineering surveying teaching and learning based on a two-year survey of 191 students in 2012 and 155 students in 2013. The two main objectives of the study are (i) to assess the potential of workshop-based learning initiated in the Civil Engineering Drawing and Surveying (CVEN 2000) unit at Curtin in 2009 to enhance the students' achievement of industry-based skills such as teamwork and communication required by a graduate civil engineer, and (ii) assess the contribution of workshop-based learning to the students' overall learning of engineering surveying, a practical oriented unit. To achieve objective (i), a set of questionnaires were collected for the years 2012 and 2013 and analysed using statistical methods; correlation, percentage frequency distribution, and the principal component analysis (PCA).The findings of the questionnaire were complemented by the students' performances in both fieldwork and written examinations from 2009 to 2013, as well as qualitative data from Curtin University's eVALUate system (http://evaluate.curtin.edu.au/) from 2012 to 2013.

The study is organised as follows; first, the workshop learning experience at Curtin University is presented in detail starting with a background of the Civil Engineering Drawing and Surveying (CVEN 2000)unit, where engineering surveying is taught. This is followed by the contents, aims, and teaching of the workshops. Data collection, analysis methods and the resultsare then discussed before concluding the study.

Workshop learning experience

Background

Engineering surveying is the branch of surveying course normally taught to civil engineers and mine engineers (Walker and Awange 2017), and architectures in most universities worldwide, and is used extensively in building and construction, where angles, distances, and heights are required in the design and construction of civil engineering projects (see e.g., Uhren and Price 2010). In most universities, it is normally taught as a stand-alone unit for the entire semester with the aim of equipping graduate students with the skills needed to plan and design engineering projects, all which requires that students have knowledge and understanding of the surveying techniques and the associated instruments (Schoefield and Breach 2007; Uhren and Price 2010; Walker and Awange 2017).

At Curtin University (Australia), engineering surveying unit is offered as a sub-unit of Civil Engineering Drawing and Surveying (CVEN 2000)(previously known as Civil Engineering Methods 267) in the second year of study and comprises 1-hour lecture, 2-hours workshop and 2-hours fieldwork per week. Curtin University is committed to producing graduates who demonstrate the following graduate attributes: (i) applying discipline knowledge, (ii) thinking skills, (iii) information skills, (iv) communication skills, (v) technology skills, (vi) learning how to learn, (vii) international perspective, (viii) cultural understanding and (ix) professional skills (Graduate

Attributes Policy, 2006; Anwar et al. 2012). To realize these attributes, CVEN 2000 unit is designed to achieve the following unit learning outcomes (ULOs, i.e., what is expected of a student following a successful completion of the unit at Curtin University): (1) Interpret Civil Engineering drawings, including the use of plans, elevations, sections and details for structures, roads and drainages (2) produce drawings using CAD software (3) apply the theory and practice of surveying instruments as applied to civil engineering and construction projects (4) explain and apply related calculations and surveying techniques, and (5) describe the theory and practice of surveying instruments related to civil engineering and construction projects. Fieldworks assess the learning outcomes 3 and 4 and comprise 20% of the total marks while the examination assesses ULOs 3, 4 and 5, and comprise 30% of the marks (i.e., a total of 50% for the combined practical and exam marks from the surveying part of the unit). Of the 20% allocated for the surveying fieldwork, the students are expected to do three fieldwork worth 90 marks (i.e., 25 marks each for assessment 1 and 2, and 40 marks for assessment 3). Each assessment was first converted to a percentage, which was ultimately scaled to a final score of 20 marks. The remaining 50% of the marks comes from the drawing component of the unit and assesses unit learning outcomes 1 and 2.

Workshops: Aims, Contents and Teaching

To achieve ULOs 3, 4 and 5, civil engineering surveying students were required to carry out four assessed practicals; two of which were individual-based submissions, while the other two were group-based submissions. The workshops, (2hr duration) were aimed at (i) providing an in-depth exposition of the unit materials covered during the 1-hour lecture, (ii) instructing step-by-step four practical sessions, and (iii) enhancing students' critical thinking and computational skills through individual hands-on training. Two workshops per week were organized, with each workshop consisting of approximately 60 students, with two lecturers in charge. From an approximately 200 total number of students, each student was required to attend all the 6 workshops, where fivewere tailored towards the fieldwork while the remaining one focused on exam preparations.

The contents of the workshops were designed in such a manner that workshop 1 introduced spirit levelling as a survey technique for height measurements. In this workshop, students were introduced to field techniques, which demonstrated procedures for unpacking, setting-up, operating, and repacking levelling instruments. This workshop enabled students to use the Automatic Level instrument to undertake the first practical designed for the establishment of the vertical control. Workshop 2 followed on the first one by generating a digital terrain model (DTM) using the data collected from the first practical. During workshop 2, students were helped to understand the specifications of design surface parameters for vertical profiles of, e.g., roads or sewer lines. Workshop 3 was geared towards the establishment of the horizontal control and similar to workshop 1, introduced the students to traversing, a procedure for establishing of horizontal controls using angular and distance measurements using the Total Station instrument. Workshop 4 then presented and demonstrated the use of Bowditch method to reduce traverse field observations. Having gathered the theoretical and practical skills from the four workshops, Workshop 5 then prepared the students for their fieldwork examination that required them to set out horizontal curves using Total Stations (introduced in workshop 3) and handheld GPS receivers. Each student was given a section of the horizontal curve and asked to calculate the setting out parameters in order to develop his/her computational skill. Two lecturers present during the workshops offered help to the students during their individual calculations, moderating group discussions, and discussing potential field-related problems. Once the students understood how to calculate the setting out parameters of the horizontal curve, each group (of four) was given the parameters of a horizontal curve to set out during the fieldwork without the lecturer/tutors help. Once the students completed setting out the horizontal curve, they were assessed in the field where the assessment score was marked out 30, while the individual calculations were marked out of 10. A student's overall score in this assessment was therefore, 40 marks, i.e., 16% of the total marks of the CVEN 2000 unit. Since it was a group-based submission, the students were expected to work as a team, employing their critical thinking skills to set out the curve and also employ their communication skills within their group in order to complete the task to specification and in a timely manner. As already mentioned, all these virtues were emphasized during the fifth workshop, and as such, during the actual field examination, the lecturers did not give the students any help but expected them to make use of the workshop-based learning experience. Finally, the remaining sixth workshop was dedicated towards preparing the students for the exam as elaborated in (4) below (see Figure 1).

To achieve the aims of the workshops discussed above, the following tasks and activities were carried out during the workshops (examples are given for illustration purposes only):

1. During the workshop, first, a quick overview (about 10 minutes) of the materials covered during the 1-hour lecture was presented, followed by a demonstration of the required computational skills required to solve the fieldwork related problems for that week. No software tools were allowed during the workshops but rather, the emphasis was on manual computation in-order for the students to develop computational and critical thinking skills. For example, to adjust and correct angle and distance measurements, the students were introduced to the Bowditch's method. The lecturer demonstrated on the whiteboard all the computational steps required starting from measurements to deriving the final coordinates. Once this demonstration had been done and discussed with the students, a similar computational task was given to the students to solve individually. Two lecturers monitor their computational skills and helped them where necessary. One of the students was asked to demonstrate the solution on the whiteboard followed by a discussion by the rest of the students. In case of more complicated problems, the lecturer demonstrated the solution on the board. Besides just introducing students to solving problems and instructions given as is often done in traditional tutorial mode of learning, the workshops went way beyond the traditional tutorials by not only *incorporating components (2) and (3)* below, but also by demonstrating both field procedures and computational steps required to

process the observations, encouraging group-based discussions, and expounding on individual-based tasks.

2. In the last 30 minutes of the workshop, students were introduced to the aims and practical aspects of the fieldwork for that week. The field works were designed such that the students were able to apply their knowledge gathered from (1). For example, if the practical task required designing of a cycling path, students were expected to know how heights (known as reduced levels (RL)) were measured and used to draw the longitudinal and cross-sectional profiles, derive the formation (design) heights, and compute areas and volumes of earthworks. The computational skills obtained in (1) were thus used to employ critical thinking when calculating the design parameters of a given problem (see, e.g., Snyder and Snyder 2008; Walker and Awange 2017). In addition, the students were introduced to the relevant instruments, e.g., Total Station, and the preliminary handling techniques given.

3. In order to demonstrate computational, critical thinking, and instrument handling skills obtained in (1) and (2), the last fieldwork was conducted as a practical examination. However, one of the objectives of fieldwork was also to enable students acquire teamwork skills as Engineers Australia's Graduate Attributes emphasize the ability of graduate engineers to work in high performance teams (e.g., Anwar et al. 2012). Students carried out the tasks in a team but made their calculations both individually and in groups as already discussed. In order to develop teamwork skills, for example, the students were given parameters of a centreline to be set out during their fieldwork. In workshop 5, they discussed the procedures for setting out this curve in the field and distributed the tasks amongst themselves (i.e., entirely managed the work by themselves). For each team, during the workshop, the lecturers explained how best to exploit team spirit to achieve the desired outcome. Examples of photos of previous students working as a team were presented to motivate them. The workshop emphasised on the need for students to communicate amongst themselves in order to complete the task within the stipulated time and specification. From the assessment point of view, pre-defined standardized rubrics were given to each group showing how the marks were allocated for various tasks, some of which assessed the students' communication and teamwork skills. For example, the rubric specified the marks allocated for setting up the instrument (i.e., centering and orientation of the instrument, levelling circular bubble, and levelling plate bubble), a task that require teamwork. Furthermore, students had to communicate amongst themselves on how best to set out pegs at given radius. This required a well-thought strategy and clear communication through handsets and proper use of sign languages. Proper communication and teamwork scored high marks as specified in the rubric. Both verbal and written feedbacks were provided for both individual and teamwork skills during the field.

4. The last workshop was intended to revise the syllabus and prepare the students for the exams. Students were given questions that assessed their computational skills and abilities to think critically. The model questions covered the computational and necessary skills obtained in the previous workshops, lectures,

and the activities carried out in fieldwork. The students were then given 1-hour to solve the two problems individually. In the remaining hour, the solutions were discussed thereby providing the students with an opportunity for self-assessment and an opportunity to apply the knowledge of mathematics, science and engineering.

Figure 1

Methodology

Data collection

To achieve the first objective of the study, i.e., to investigate if the students' industry-based skills were enhanced through the workshops introduced in 2009, an anonymous questionnaire survey was conducted for all the students who took part in the workshops in CVEN2000 unit in 2012 (191 students) and 2013 (160 students) respectively. To validate the survey, both face validation (i.e., discussing with students who previously undertook the course) and content validation (i.e., having experts in the field review the questionnaire's contents) were adopted (see, e.g., OMB 2002). Face validity was aimed at determining whether the questions addressing the workshop learning contributed towards the students' industry-based skills development, and overall learning of surveying. The content validation aimed at assessing whether the survey fully captured and represented the concept that the workshop learning enhanced the achievement of necessary surveying engineering skills. To address the face validation, a group of 8 students who undertook the CVEN2000 unit in 2011 was randomly selected and the draft questionnaire was given to them for review. The students read the questions and put their agreement or disagreement in understanding the purpose of the survey, and also commented on whether the questions were clear or unambiguous. The suggestions obtained from the students were used to modify the questions until all the participants came to an agreement that the final modified questions were clear, unambiguous and captured the intended purpose.

Content validation then followed by having the outcome of the face validation above subjected to peer review by colleagues who were experts in the subject. The final questionnaire (i.e., the outcome of both face and content validation above) was then reviewed by the Dean of Teaching and Learning at Curtin University, and then sent to the ethics committee for approval. The approved set of questionnaire is presented in Table 1. These questionnaires were distributed to the students during the last (sixth) workshop. The last workshop was dedicated towards the exam preparation and it was likely to attract a maximum number of students, although it could be equally counterproductive since students could be busy with their final assignments that needed to be submitted during the same week. Nonetheless, the survey was conducted anonymously and the feedback method was similar to Curtin's online unit eVALUate system such as, "Strongly Agree-SA", "Agree-A", "Strongly Disagree-SD", "Disagree-DA and "Unable to Judge-UJ" (e.g., http://evaluate.curtin.edu.au/). Out of 351 students in 2012 and 2013, 67 in 2012 and 93 in 2013 students responded to the survey, giving a 46% response rate, which is above the Curtin University's 35% target rate in its eVALUate system. The higher response in 2013 compared to 2012 could be attributed to the fact that those students who attended the workshops in 2012 might have recommended the workshop to their 2013 friends. The data is analysed using techniques discussed later.

Table 1

To evaluate whether the workshops enhanced the students overall learning of engineering surveying, i.e., objective (i) and to some extent objective (ii), the 2012 and 2013 practical and examination results were also analysed together with the qualitative data from Curtin's eVALUate (http://evaluate.curtin.edu.au/). Curtin's eVALUate system provides students with the opportunity to provide feedback on selected items on a scale: "Strongly Agree-SA", "Agree-A", "Strongly Disagree-SD", "Disagree-DA and "Unable to Judge-UJ". Besides these, they are also provided with the opportunity to express the most helpful aspects that enhanced their learning as well as how the unit could be improved. In this study, these qualitative data were considered to further decipher on the effect of workshops on students' overall learning of surveying.

Data Analysis

Confidence Interval Estimation

In this study we analysed and compared the performance of the students between 2012 and 2013 based on the questionnaire survey data collected as discussed in the preceding paragraph. Since only 46% of the students responded to the survey, it was necessary to validate whether the survey results represented the total number of enrolments. To analyse this representation for both the years (2012 and 2013), confidence interval estimation was carried outfor the proportion, considering the total number of students enrolled to be finite. Confidence limit is a standard measure of accuracy of the results in a statistical analysis and is derived by first dividing the data into subsections and obtaining the mean. The confidence limit is then defined as a range of standard deviations from the mean (Huang et al., 2003). It is computed as (Heeringa et al., 2010):

$$p_{agree,N} = p_{agree,n} \pm Z\sqrt{\frac{p_{agree,n}(1-p_{agree,n})}{n}}\sqrt{\frac{N-n}{N-1}}, \qquad 1)$$

where $p_{agree,n}$ is the percentage of agreement for any attribute under consideration, n is the number of the students who responded to the questionnaire, N is the total number of the students enrolled in the unit, Z depends on the confidence level required, i.e., the value of Z becomes 1.96 for 95% confidence level. The confidence limits for the students enrolled are given by $p_{agree,N}$. The advantage of the confidence interval approach is that it provides an interval that reveals the uncertainty of the estimated value (i.e., the mean) as opposed to point estimation of the mean which produces only single values. The drawback of the approach is that its interpretation is not trivial since it does not take into consideration any prior information on the population mean.

Frequency Percentage Analysis

The questionnaire data aimed at achieving objective (i) was analysed using the statistical frequency percentage method. In this approach, the total number of responses (Tr) per question item given in Table 1 was identified. Within each item, the total number of responses to the criterion, i.e., SA, A, SD, D and UJ is then divided by the total number of responses per questionnaire item (Table 1) and multiplied by 100 to give the equivalent percentages, which are plotted as bar graphs (see e.g., Figure 2). For the SA criteria for example, the process of creating a percentage frequency distribution involved first identifying the total number of students who responded to a questionnaire item (Tr), then counting the total number of students who chose SA for that questionnaire item (TSA) and then dividing and multiplying by 100 (e.g., TSA/Tr x 100). Details on the method and its limitation are presented, e.g., in Heiman (2011). Whereas this was done for each criterion item as shown in Figure 2, a more representative value of agreement was obtained by combining Agree (A) and Strongly Agree (SA) criteria to give the percentage of agreement shown in Figure 3, i.e., (% agreement=(A+SA)/Tr x 100). The advantage of percentage frequency distribution is that it provides visual displays that organise and present frequency data in a manner that is easier to interpret and compare data sets. However, this method may not provide a rigorous statistical approach for comparing specific characteristics of distributions such as the means and standard deviations.

Correlation Analysis

The feedback from the participants was analysed for the dependence of one or more attributes to the other remaining attributes. This dependence between the attributes was statistically analysed with the help of correlation analysis. Correlation analysis based on the statistical method of the principal component analysis (PCA) is discussed next. The advantage of the correlation analysis is that it provides the relationship between variables. The correlation analysis was carried out based on the Pearson's product moment coefficient (r):

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{n\sum x^2 - (\sum x^2)}\sqrt{n\sum y^2 - (\sum y^2)}}, \quad 2)$$

where the correlation coefficient (*r*) is computed between two attributes (*x,y*) for *n* number of respondents considered in this study. The correlation values obtained in Eq. 2 was tested for their significance using a simple Students *t-test* by calculating a test statistic (t):

$$t = \frac{r}{\sqrt{(1-r^2)/(n-2)}} \quad 3)$$

Based on the calculated value of *t,* a p-value is determined from a t-distribution with *n-2* degrees of freedom. If the p-value is less than 0.05 (i.e., at 95% confidence level), it indicates that there exists significant relationship between the two learning attributes. For example, students who had good instrumental knowledge tended to perform relatively better at fieldwork while those who possessed high critical thinking skills tended to handle unseen problems better in the fieldwork.

Principal Component Analysis (PCA)

Principal Component Analysis (PCA) is a variable reduction procedure, which is useful in extracting the main variance of datasets. In the context of a questionnaire survey, it may be expected that a pair of highly correlated attributes serve more or less the same purpose, thus there is a need for excluding some of them or combining them for further analysis or evaluation. The PCA method used here was based on eigenvalue decomposition of the data-derived auto-covariance matrix. The retained components serve as the dominant satisfactory factors, while those excluded most often correspond to the lower correlation with the overall score. Note that it is common in qualitative researches to use statistical approaches (e.g., Cronbach's alpha) for evaluating the internal consistency of the designed questions. In this study, however, such approach was not used since it was felt that the questions were designed based on Curtin's eVALUate program (http://evaluate.curtin.edu.au/) and adequate validation process was used as discussed earlier.

To prepare the data for PCA, we first entered the values of 2012 and 2013 in a matrix $X$with separate columns for each variable to ensure that each row corresponded to the responses from one attribute. Missing data values in each column were filled by the mean of the corresponding column. Since the number of missing values was minimal, the impact of data filling was negligible. Before implementing PCA, each column was sorted with respect to the magnitude of the scores from 5 (the most satisfactory) to 1 (the less satisfactory). The PCA method thus enabled the analysis of the combined 2012 and 2013 data sets together rather than done separately as performed by the other methods discussed above. The data matrix X was decomposed by PCA as

$$\mathrm{X} = \overline{\mathrm{P}_\mathrm{k}}\mathrm{E}_k^T, \quad 4)$$

where $\overline{P}$contains normalized principal components (PCs), and the columns of Econtains the corresponding orthogonal eigenvectors known as empirical orthogonal functions (EOFs) see, e.g., Jolliffe (1986). The advantage of PCA is that one does not require a priori information of the underlying distribution of the sample collected. The drawback of the method, however, is that even when the underlying features of a system are known, they cannot be incorporated into a parametric model. North et al. (1982)'s rule of thumb was used to decide on the number of the dominant components (the subindex$k$ in Equation 4) retained for the final interpretation.

Examination and eVALUate analysis

Investigating whether the workshop-based learning method actually enhanced the students' overall learning of engineering surveying i.e., objective (ii)) was performed through the analysis of the students' academic record for the respective years (e.g., examination and field practical results) for the period 2009-2013. Such analysis is based on the fact that students attended the workshops prior to their introduction in 2009. The number of the students who attended the workshops, however, varied from year to year (but has been above 80% in all years).

Furthermore, it should be pointed out that the exam questions were not similar over the years and their complexity varied. Nonetheless, the exam questions and field practicals assessed similar outcome each year, e.g., whether the students were able to undertake a levelling exercise (exam assessment) and to provide vertical controls and longitudinal and cross-sectional profiles (fieldwork assessment). It is therefore, sufficient to assume that based on the more than 80% attendance of the workshops and given that the exams and practicals both assessed similar outcomes each year, their analysis to infer on the impact of the workshops on the students' learning could be justified. The analysis results should, however, be interpreted with caution as the students performances may have varied depending on other factors such as the complexity of the exam questions and the students' state of mind during the exam.

The analysis is achieved by considering the number of students who scored over 50% in a given year in each component, i.e., 50% in the practical as well as 50% in the examination, and also in the final marks (combined practicals and examination). The practicals constituted 40% of the final marks while the written examination constituted 60%. This threshold was chosen since the students needed to score 50% or more in the unit to pass. In addition, a task of setting out horizontal curves in the field was assigned to each group of four students. Within this group, as explained earlier, each student was given a set of design parameters for a portion of the horizontal curve and was asked to compute the setting out parameters of the curve. This provided an assessment of the student's understanding of the task that was explained during the workshop. This was then followed by setting out of the center line of the portion of the horizontal curve as a group. The whole task required group teamworkand communication skills on the one hand, and critical thinking and problem solving skills on the other hand in order to best set out the curve to the required specification. Through this task, the performance of the students in the field practical enabled the evaluation of the role played by the workshops in enhancing the students' teamwork, communication, problem solving, and critical thinking skills.

To comprehend the findings of this study, an analysis of the post workshop qualitative data from Curtin's eVALUate system was also carried out to evaluate objective (ii). To analyse the qualitative data from Curtin's eVALUate system where the students were asked to comment on the most helpful aspects of Civil Engineering Drawing and Surveying (CVEN2000) unit, qualitative data for statements that mentioned workshop as having enhanced their learning in one way or another, e.g., the "*workshops were very helpful*", "*Workshop is a great place to ask doubts from lecturers and most of the problems are solved with the help of lecturers*", "*the workshops for the surveying. Made all the tasks and methods for evaluating data very clear*", etc., from the 2012 and 2013 data were counted. The total number of these comments was then divided by the total number of qualitative responses and multiplied by 100 to obtain a percentage value. This was repeated for those aspects the students thought could be improved in the unit. In 2012, out of all the 89 responses (cf. 61 in 2013), 65 responded (cf. 41 in 2013) to the positive aspects of the unit while 58 (cf. 53 in 2013) to those aspects that they thought could be improved. The advantage of eVALUate system is that the data is directly obtainable online from the university system in graphic form and does not need further processing, and also the fact that the students can complete the questionnaire at their own time makes it more attractive. However, the number of responses were found to be normally low and often attracts extreme (e.g., happy students and unhappy students will generally tend to be the respondent)responses.

Results and Discussions

Enhancement of industry-based desired skills.

Confidence limit analysis

Compared to 2012, the number of students enrolled in engineering surveying unit reduced in 2013 from 191 (2012) to 160 (2013). However, in 2013 majority (93 out of 160) of the students responded to the survey anonymously compared to 63 out of 191 in 2012. The confidence limit for 15 questionnaire items shown in Table 2 was assessed to test if the survey represented the overall student population. From Table 2, it can be seen that the lower confidence limit increased in 2013 for most items, probably due to the higher number of responses received compared to 2012. The lowest confidence limit is seen for 'handling unseen problems' and 'communication skills' in 2012 and 2013 respectively. The lower and upper confidence limit increased by 24% and 9%, respectively, in 2013 (compared to 2012) for "handle unseen problems" and 20% and 7% for "communication skills".The higher number of responses in 2013 could be attributed to the increased number of students attending the workshop. In the 2012 survey, 93.4% of the students had indicated that they would recommend the workshops to their friends and 99% of them indicated the same in 2013, thus indicating that these workshop sessions were gaining popularity with students as those participants inform their friends of the potential benefits to the learning outcome of the unit.

Table 2

Frequency Analysis Results

The overall response of the participants for 2013 is presented in Figure 2 (those of 2012 are not shown). In general, it is observed that workshops have helped in enhancing the students' learning skills in almost all aspects except in 'communication skills' and 'handle unseen problems', which recorded slightly higher disagreement (Figure 2). The frequency percentile results of questionnaire survey items (Table 1) based on the feedback of 67 students out of 191 students in 2012 and 93 out of 160 in 2013 are summarized in Table 2 and Figure 3. The frequency percentile method was applied for all the items in the survey questionnaire (see, e.g., Heiman, 2011 for discussions on the procedure). The values shown in Figure 3 indicate the percentage of the combined students who chose Agree (A) and Strongly Agree (SA) to the questionnaire items. The 2012 results (Figure 3) revealed the students' perception that skills relating to 'correlate theory (97%)', 'instrument knowledge (89.6%)', and 'critical thinking skills (91.1%)' were well achieved. Based on the students' feedback of 2012, the class size of the workshops were reduced in 2013 by adding an extra 2-hour workshop per week leading to three 2-hour workshops per week rather than two as was the case in 2012. This provided more flexibility for students to balance their working hours and the need to attend the workshops. As mentioned earlier, the 2012 group also indicated the possibility of recommending the workshops to their friends. This additional workshop time and the recommendation of the 2012 group to their friends resulted in increased attendance in 2013. This can be reflected in improved number of respondents (67 in 2012 and 93 in 2013) and also in increased scores, i.e., 'correlate theory (97.9%)', 'critical thinking skills (93.6%)', as well as for other items listed in Table 2. As argued by Tek-Yew (2012), several methods could be adopted in order to enhance students' "critical thinking" (see, e.g., Snyder and Snyder 2008), a fact supported by this study, based on the students' perception that critical thinking skills can be achieved not only through teaching but also through other development methods (Jawarneh et al., 2008; Khasawneh, 2004) such as workshops.

In 2012, "communication skills" received 68.7% of the overall students' agreement. This relatively low agreement indicated that the workshop learning process needed further development of communication skills. In 2013, some improvements were made in providing students' feedback and encouraging communications during the workshops and the fieldwork. It was observed that during the fieldwork, students tended to group themselves based their ethnicity and culture (i.e., Asian students tended to group together). During the 2013 workshops, students were encouraged to intermingle within the groups as they discussed how to tackle a given field problem. In the 2013 survey, therefore, communication skills showed improvement by receiving 77.2% of the students' agreement, which although is remarkable (i.e., 12.4% increase from 2012), is still relatively low compared to the other surveyed items (see Table 2). This relatively low agreement indicates that the workshop learning process still needs further development on communication skills. Another survey item that showed a relatively low score in the 2012 survey that needed improvement was 'handling problems during the fieldwork' (i.e., with only 67.2% of students' agreement). In the 2013 workshops, discussing the potential field problems and presenting students with solutions before they undertook their fieldwork made improvements. For example, students were informed that when setting out horizontal curves in the field, one of the main problems is usually the confusion between the centerline and tangent points of the curve. Students were thus advised on how to avoid this confusion through checking out of the curve's radius during the 30 minutes field demonstration (see item 2 under Workshops: Aim, Contents and Teaching above). It should be pointed out that such information could be delivered not necessarily in the workshop but also during the lecture. However, as pointed out earlier, the lecture time was only 1 hour and not all unseen problems could be addressed during that short period of time. Following such improvements, handling field problems scored 77.4% of the students' agreement in 2013. This is still relatively low compared to other items, indicating a need of further attention in future workshops. In general, the overall students' satisfaction based on frequency distribution analysis increased from 97% in 2012 to 97.9% in 2013.

The workshops were also seen to assist students in their assignments, with over 90% of students in 2013 agreeing that the workshop helped them in both their individual as well as group assignments. This is not a surprise since a more informal workshop-based learning helps them to understand and relate their problem solving skills to fieldwork tasks. Students also agreed that other factors such as the 'duration of workshop', 'size of the class' and 'feedback from the workshop' helped to contribute to their overall learning experience. Feedback from workshop thus increased by over 9.5% in 2013 showing that the number of students who answered the survey and that perceived the feedback as helpful increased in 2013 compared to 2012 survey. Nonetheless, this aspect still needs further improvement.

Figure 2

Figure 3

Correlation Results

A simple correlation analysis (Eq 2) was carried out between the different learning attributes to assess how they relate to each other in learning. The results of the correlation analysis are provided in Table 3, where correlation coefficients greater than 0.5 are considered to be significant at 95% confidence level. From the 2012 results in Table 3, it can be seen that critical thinking and instrument knowledge indicates the strongest correlation coefficient (0.82),suggesting that the workshops could have contributed to enhancing the students' critical thinking leading to a better handling the instruments during field practicals. This is supported by a correlation coefficient (0.63) between correlating theory and fieldwork, which clearly indicated that workshops helped students to think critically and obtain necessary skills to practice. Instrumental knowledge was found to directly translate to fieldwork with a correlation a coefficient of 0.52, while fieldworks tended to benefit individual assignments showing a correlation coefficient of 0.52 between them.

In the 2013 survey, the results of Table 3 indicated correlations of 0.6 between 'field practical' and 'correlating theory', 0.58 between 'critical thinking' and 'instrument knowledge', further suggesting that the workshops were able to help enhance fieldwork performances. A low correlation between 'fieldwork' and 'handling unseen problems' (i.e., 0.28 in 2012 and 0.33 in 2013) is understandable given that real world problems are often difficult and requires much more than what is usually taught in the class or discussed indoors. Fieldworks' knowledge acquired during the workshops and actual undertaking of the field tasks seem to be contributing to 'exam preparation' as seen from correlations of more than 0.5 in both 2012 and 2013.

Table 3

PCA Results

The results of PCA (Eq. 4) are summarised in Figure 4, which shows the first dominant component (EOF1 and PC1) corresponding to 90% of total variance retained based on the North et al., (1982)'s rule of thumb. EOF1 (Figure 4a) indicated that "Correlate Theory" and "Exam Preparation" were the two dominant attributes in the questionnaire, while "handle unseen problems", and "communication skills" were the two items that have less correlations with the scores. PC1 (Figure 4b) indicated that 145 out of 160 (corresponding to 90%) responses have a magnitude of greater than 3. The cross-correlation results (Figure 5), at 95% confidence level, showed that the dominant items: "correlate theory", "critical thinking skills", "handle unseen problems", "feedback on the workshop", "group assignments", and "overall satisfied" can be used to assess the benefit of the workshops (see Figure 5). They corroborate the results of Table 3. The motivation to apply the PCA method here is its capability to assess the items that are similar both in 2012 and 2013 workshops. The outcome of this test evaluates whether common items represent a consistent impact on engineering surveying learning, considering two independent groups in 2012 and 2013, and different workshop programs. The limitation of such assessment, however, was that the results were only representative for the items that were repeated in the 2013 workshop.

Figure 4

Figure 5

Enhancement of students' overall learning.

Examination and eVALUate Results

Independent of the questionnaire administered during the last workshop, investigation of whether workshop learning contributed towards enhancing the students' overall learning of engineering surveying following their introduction in 2009 was done. To do so, the students' performances both in the exams and fieldwork assignments from 2009 to 2013 were analysed. Figure 6 shows the possible impact of workshops on the overall students' performance in the examinations and field practicals. The workshop learning and teaching materials in 2009 was not fully developed since the workshops had just been introduced. Moreover, multiple tutors marked the fieldwork reports, which provided high marks in 2009 as can be seen from Figure 6. To the contrary, the performance in the exam part (30% of the unit) clearly revealed that the students' performance was low compared to the fieldwork, as the pass rate in the exam was less than 20%. Overall, the pass rate was about 69% because of high marks obtained in the fieldwork reports. The data of 2009 thus serves as the baseline upon which fully developed workshops that started in 2010 onwards were compared. The pre-workshop data of 2008 were also included to highlight the inconsistency that existed between fieldworks and exams.

These findings were taken into account and the workshop learning platforms were redesigned by putting appropriate learning resources and providing useful feedback with the objective to achieve Curtin's learning outcomes. These are clearly reflected in the results of 2010-2013, indicating a slightly lower achievement in fieldwork. The students' performance in the exams (closed book exams) however, increased by 3 times in 2010, potentially due to the new workshop learning platform. From 2010 onwards, more than 50% of the students achieved the desired pass mark (50%) of the examination. The overall students' performances were also found to slightly vary in different years because of the number of enrolled students. Since the number of students has been increasing continuously since 2009, lecturers face more challenges in assessing the fieldwork reports. It is critical to consider whether group submissions or individual submissions of a group work could provide sufficient learning outcomes. This issue will be reported in our forthcoming contribution. As to the possible impact of the workshops on the students who fail the unit, Figure 6 offers some insight. By comparing the fieldwork and the exam scores, it is seen that the scores of the field work tend to be higher than those of the written exams, implying that the workshops more than the examination tend to influence the practical aspects of the students who fail the unit. This deduction should however be interpreted cautiously as other factors such as the physical and emotional state of the students during the exam could influence the outcome. Besides, it is normal for students to have higher marks from their fieldwork relative to exam due to time constraint in the exam and as such, the failing aspect might not be a direct consequence of using workshops.

Comparing the performance of 2012 to that of 2013, the periods over which the survey was undertaken, it is seen that the overall performance improved in 2013. In the fieldwork, the performance increased from 74% in 2012 to 91% in 2013. The exam performance also increased from 51% in 2012 to 70% in 2013. This remarkable improvement could be attributed to the fact that students' feedback from the 2012 survey were taken into consideration while undertaking the 2013 workshops. As stated earlier, the potential field problems were discussed during the workshops. Students were also encouraged to embrace multiculturalism and communication within their groups in order to handle potential field problems and communication skills effectively.

Finally, the qualitative analysis of the eVALUate results from 65 respondents in 2012 and 41 respondents in 2013 data indicated that 61.2% and 70% of the students, respectively, found the workshops to be the most important component contributing to their learning skills of theCVEN2000 unit. This provides additional evidence of the workshops' contribution to enhancing the students' overall learning of engineering surveying besides the questionnaire surveys. The improvements from 2012 to 2013 by 13.8% could be attributed to the improvement made in the workshops following the feedbacks from 2012 survey. Of the 2012 and 2013 qualitative comments on what could be improved on the unit in the Curtin University's eVALUate data; there was no negative comment on the workshops requiring improvement. Comments on improving the workshops were thus obtained in the 2012 study questionnaire survey and utilized in the 2013 workshops.

Figure 5

Enhancing Communication and Teamwork Skills

To indicate if workshops enhanced the overall learning of engineering surveying and as well as the industry-based desired skills of communication and teamwork, the final fieldwork wasa group assessment. The task involved setting out a horizontal curve using various surveying equipment (e.g., Total Stations, Tapes, and global positioning systems(GPS) receivers) with no help from the lecturers. Each group was given specific set of parameters (e.g., curve radius, deflection angle, formation width of the road, etc) for setting out a road centreline using a hand-held GPS receiver. Intense communication, teamwork, and critical thinking skills were essential and necessary for a successful completion of the task.

For example, in the 2012 task of setting out horizontal curves, there were 182 students in the field practical. This task was marked out of 40 with the highest student scoring 40 while the least student obtained 15. The class average was 30, which support the argument that the students were able to link their critical thinking skills to instrument knowledge (i.e., correlation of 0.82; significant at 95% confidence level), communicate amongst themselves, and correlating theory to fieldwork (i.e., a correlation of 0.63). In 2013, out of 155 students assessed for a similar fieldwork marked out of 40, the highest student scored 40 while the least student obtained 10, with the class average being 31, thus further supporting the fact that workshops could have played a crucial role in enhancing the teaching and learning of engineering surveying (CVEN2000) unit at Curtin University. In particular, the most significant field observable practise was the manner in which students grouped themselves in mixed cultural backgrounds. In these groups, students were asked to discuss the practical challenges of setting out their horizontal curves in order to assess their communication skills, some of which could have been acquired in the workshops. As previously mentioned, a standardized marking rubric was given to all groups.

Conclusion

The workshops were designed in a way that provides scenarios reflecting tasks that could be reasonably expected out of an on-site junior civil engineer or a field surveyor, and were therefore, directly related to the fieldwork. The expectations were clearly enunciated, and the aims of the exercises were generally well understood. The results of this study revealed that the students were satisfied with the workshops and recognised that it contributed to developing the different learning attributes and, therefore, would recommend it to their friends. Workshops may be used as a good learning platform for civil engineering surveying unit, which often comprises of fieldworks. The workshops were found to enhance all engineering surveying industrial-based learning skills. From the frequency distribution analysis, most students agreed that workshops contribute to the first three items "correlate theory", "critical thinking skills", and 'instrument knowledge' in 2012. The drop in score for instrument knowledge from 96.6% to 85.9% in 2013 needs to be investigated further in order to improve in the future workshops. A relatively low agreement was found for "communication skills" and "handling problems". The workshop learning mechanisms as a distributed learning tool will in future be improved to address these areas that received low agreements. Independently, the qualitative eVALUate data and the examination results showed that workshop is an important tool for enhancing the overall learning of engineering surveying, which help them prepare for workforce challenges that require strong teamwork, working within a multicultural society, and good communication skills. The workshop appears to have some impacts on these three attributes, as seen during the fieldwork assessment of setting out horizontal curves. In this assessment, students worked in groups to undertake the setting out task, which required them to communicate among members of different ethnic backgrounds to undertake the task. Furthermore, it is worth pointing out that the success of the workshops motivated similar introduction in Mine Surveying and GIS (for Mine Engineering degree) and Satellite Positioning for Mining units (for Mine and Engineering Surveying degree) at Curtin University. Finally, we point out that the results should be interpreted with caution since the analysis presented here was limited to only few years of data. Nonetheless, the results of the study highlight the benefits of having workshops to supplement the teaching of engineering surveying.

Acknowledgements

Authors would like to acknowledge the financial support provided by the Faculty of Science and Engineering at Curtin University under the Scholarship of Teaching and Learning (Project No. SMEC-101-11). The authors also would like to thank the reviewers for their valuable comments on the paper.

References

Adair, J. K., Reyes, M. A., Anderson-Rowland, M. R. and Kouris, D. A. (2001). Workshops vs. tutoring: How ASU's minority engineering program is changing the way engineering students learn. Frontiers in Education Conference, 2001. 31st Annual, Vol (2). DOI: 10.1109/FIE.2001.963659

Anwar, A. H. M. F.,Awange, J., Arora, B, Nikraz, H., and Walker, J. (2012). Mapping workshop learning to graduate attributes for Civil Engineering surveying, In Proc. of AAEE Conf., Melbourne, Dec 3-5.

Anwar, A. H. M. F., Awange, J. L., Hamid, N., and Forootan, E. (2013). Learning surveying and developing fieldwork skills through workshop.Proceedings of the 24th Annual Conference of the Australasian Association for Engineering Education AAEE2013.

Baroffio, A., Nendaz, M. R., Perrier,A., Layat, C., Vermeulen, B. and Vu,N. V. (2006).Effect of teaching context and tutor workshop on tutorial skills.Medical Teacher, 28 (4, pp. 112--119, Informal UK Ltd UK (http://www.ncbi.nlm.nih.gov/pubmed/16807161).

Bartle, E. K., Dook, J. and Mocerino, M. (2011).Attitudes of tertiary students towards a group project in a science unit. Chemistry Education Research and Practice, 12: 303-311. DOI: 10.1039/C1RP90037D.

Bourner, T. and Flowers, S. (1997). Teaching and learning methods in higher education: A glimpse of the future. Reflections on Higher Education, 9: 77-102. DOI: 10.1.1.117.6294

Campbell, D., Dawes, L., Beck, H., Wallace, S., Boman, M., &Reidsema, C. (2009). Graduate attribute mapping with the extended CDIO framework.*In Proc of AAEE Annual Conference*, Adelaide, 599-604.

Davis, D., O'Brien, M.A.T., Freemantle, N., Mazmanian, P., and Taylor-Vaisey A. (1999) Impact of formal continuing medical education. Do conferences, workshops, rounds, and other traditional continuing educational activities change physical behaviour or health care outcomes? 282 (9): 867-874.

Dori, Y. J. (2005) How does technology-enabled active learning affect undergraduate students' understanding of electromagnetism concepts? The Journal of the Learning Sciences 14(2): 243-279

Ellis,R. A., Goodyear, P., Calvo, R. A. and Prosser, M. (2008). Engineering students' conceptions of and approaches to learning through discussions in face-to-face and online contexts. Learning and Instruction 18(3): 267–282.

Felder, R. and Brent, R. (2003). Designing and teaching courses to satisfy the ABET Engineering criteria. Journal of Engineering Education 92(1), 7-25.

Fernandez-Samaca, L. andRamírez, J.M. (2010).An approach to applying Project-Based Learning in engineering courses.IEEE, pp.1-6, 15-17 Sept. 2010. DOI: 10.1109/ANDESCON.2010.5630007.

Fullilove. R.E and Treisman, P. U (1990) Education mathematics achievement among African American undergraduates at the University of California, Berkeley: An evaluation of the Mathematics Workshop Program. The Journal of Negro Education, Vol. 59, No. 3, pp. 463-478

Graduate Attributes Policy, (2006). Curtin, Australia.

Heeringa, S. G., West B. T. and Berglund P. A.(2010). Applied survey data analysis. Boca Raton: Chapman & Hall/CRC, ISBN: 978-1-4200806-6-7

Heiman, G. W. (2011). Basic statistics for the behavioural sciences.Sixth Edition.Wadsworth Gengage Learning, Belmont USA.

Huang, N. E., Wu, M., Long, S. R., Shen, S. S., Qu, W., Gloersen P. and Fan K. (2003).A confidence limit for the empirical mode decomposition and Hilbert spectral analysis. Proc. R. Soc. Lond. A 2003 459, 2317-2345, DOI: 10.1098/rspa.2003.1123

Jawarneh, M., Iyadat, W., Al-Shudaifat, S. andKhasawneh, L. (2008).Developing critical thinking skills of secondary students in Jordan utilizing Monro and Slater strategy, and McFarland strategy. International Journal of Applied Educational Studies 3 (1): 82-91.

Jolliffe, I. T. (1986). Principal Component Analysis. Springer-Verlag, pp. 487. DOI: 10.1007/b98835. ISBN 978-0-387-95442-4.

Khasawneh, R. (2004).Developing history course for tenth-grade in light of basic learning standards and testing the effectiveness of scientific unit in students' gains and improving critical thinking.Unpublished Doctoral dissertation, Yarmouk University, Jordan.

Kilminster, S., Hale, C., Lascelles, M., Morris, P., Roberts, T., Stark, P., Sowter, J. andThistlethwaite, J. (2004). Learning for real life: Patient focused interprofessional workshops offer added value. Medical Education 38: 717–726. Doi: 10.1046/j.1365-2923.2004.01769.x.

Laws, P. W. (1991) Calculus-based Physics without lectures. Physics Today 44: 24-31.

Male, S. A., Bush, M. B., and Chapman, E. S. (2009).Identification of competencies required by engineers graduating in Australia. 20th Annual Conference for the Australasian Association for Engineering Education, 6-9 December 2009: Engineering the Curriculum.

Mills, J. and Barber, D. (2004).Geomatics Techniques for Structural Surveying.Journal of Surveying Engineering 130 (2): 56-64. DOI: 10.1061/(ASCE)0733-9453(2004)130:2(56).

North, G.R., Bell, T.L., Cahalan, R.F. andMoeng, F. J. (1982).Sampling errors in the estimation of empirical orthogonal functions. Mon Weather Rev 110:699–706. Doi:10.1175/1520-0493(1982)110<0699:SEITEO>2.0.CO;2

OMB (2002). Administering or validating surveys:two protocols for use in conducting Medicaid external quality review activities. Department of Health and Human Services Centers for Medicare & Medicaid Services. Final Protocol Version 1.0.No. 0938-0786.Retrieved: July 30, 2012 from http://dss.mo.gov/mhd/mc/pdf/p-surveyadmin.pdf.

Pandachuck, K., Harley, D. and Cook, D. (2004). Effectiveness of a brief workshop designed to improve teaching performance at the University of Alberta. Acad. Med. 79(8): 798-804.

Parsell, G., Spalding, R., and Bligh, J. (1998) Shared goals, shared learning: evaluation of a multiprofessional course for undergraduate students. Medical education 32: 304-311.

Peteris A., Ansis A. and Leonids, R (2012). Remote workshop for practical knowledge improvement in electrical engineering education: Computer control of electrical technology. Proceedings of the 15th International Conference on Interactive Collaborative Learning (ICL), 2012.26-28 Sept. 2012.

Riesen, E., Morley, M., Clendinneng, D., Ogilvie, S. and Ann Murray, M. (2012). Improving inter professional competence in undergraduate students using a novel blended learning approach. Journal of Inter professional Care, Informal Healthcare London (http://www.ncbi.nlm.nih.gov/pubmed/22559163)

Schofield, W and Breach, M (2007) Engineering Surveying. Taylor & Francis, Sixth Edition, 622 pp.

Shelton, M.T. andHudspeth, M.C. (1989).Cooperative learning in engineering through academic excellence workshops at California State Polytechnic University, Pomona. Frontiers in Education Conference, 1989. Proceedings., 1989, 35—39,IEEE, DOI: 10.1109/FIE.1989.69367

Skillen, J., Merten,M., Trivett, N. and Percy, A. (1998). The IDEALL approach to Learning Development: a model for fostering improved literacy and learning outcomes for students. AARE 1998, University of Adelaide, SA.

Smith, K. A., Sheppard, R. D., Johnson, D. W. and Johnson, R. T., (2005), Pedagogies of engagement: Classroom-based practices, *Journal of Engineering Education* 94: 87-101.

Snyder, L. and Snyder, M. (2008).Teaching critical thinking and problem solving skills. Delta Pi Epsilon Journal 50 (2): 90-99.

Tek-Yew, L. (2012). Exploring the relationship between the Lecturer's approaches to teaching and students' approaches to Learning. Retrieved May 31, 2012,

(http://www.curtin.edu.my/tl2011/download/papers/nonrefereed/T%20L%20Paper%20CSM%20Lew%2020 11.pdf).

Uren J and Price W. F. (2010) Surveying for Engineers. Palgrave Macmillan Limited, Fifth Edition, 806 pp.

Vora, D., andMarkoczy L.(2011). Demographic faultiness and group performance: The role of communication. International Journal of Human Resource Management: 1-19.

Walker J and Awange J (2016) Surveying for Civil and Mine Engineers. Theory, Workshops, and Practicals. Springer, in press.

Watson, W., Kumar, K. and Michaelson, L. (1993). Cultural diversity's impact on interaction process and performance: Comparing homogenous and diverse task groups. Academy of Management Journal 36(3): 590-602.

Webb, N. M. (1989). Peer interaction and learning in small groups. International Journal of Educational Research 13: 21-39.

Webster, J. (2000). Engineering Education in Australia. International Journal of Engineering Education 16(2): 146-15

Table 1: Qualitative questionnaire survey items for assessing the contribution of workshops to enhancing industry-based desired skills. Here, critical thinking skills assessed the student's critical thinking in regards to problem solving both in the written assignments and in the field practical work.

Learning attributes	Description
Correlate theory	Did workshop helped in correlating theory to the field work?
Instrumental knowledge	Could workshops provide sufficient knowledge about the surveying instruments?
Critical thinking skills	Did workshops enhance student's independent learning and critical thinking skills?
Field work	Did the quality of teaching in the workshop help to achieve the learning outcomes for the field work?
Self assessment	Were discussions during the workshop appropriate to assess the student's knowledge and understanding of the field work?
Handle unseen problems	With the aid of the workshops, could the students effectively learn to handle unseen problems which occurred during the field work?
Communication skills	Was it possible to achieve the communication skills during discussion in the workshop?
Duration of the workshop	Was the duration of the workshop appropriate to achieve an understanding of the materials?
Size of the class	Was the size of the class for the workshop appropriate to achieve the learning outcomes of the workshop?
Feedback from the workshop	Did the feedback on the workshop help the students to achieve the learning outcomes?
Individual assignments	Did the workshops help the students in their individual mode of assignments?
Group assignments	Did the workshops help the students in their group mode of assignments?
Exam preparation	Were the workshops useful in preparing the students for the Surveying exam?
Recommend to friends	Would the students recommend the workshops to their friends?
Overall satisfied	Overall, were the students satisfied with the workshops?

Table 2: The confidence limits for the questionnaire survey items for the students enrolled (N), N=160 (2013) and 191 (2012) based on the sample (n), n=93 (2013) and 67 (2012). Percentage of agreement refers to the total number of students who chose Agree (A) and Strongly Agree (SA) to a given item over (n) x 100.

Questionnaire Survey Items	% Agreement		Lower Confidence limit (%)		Upper Confidence Limit (%)	
	2013	2012	2013	2012	2013	2012
Correlate theory	97.85	97.01	96.00	93.80	99.70	100.00
Instrument knowledge	85.87	89.55	81.30	83.70	90.40	95.40
Critical thinking	93.55	91.05	90.40	85.60	96.70	96.50
Field work	94.51	91.05	91.50	85.60	97.50	96.50
Self-assessment	90.10	89.56	86.10	83.70	94.10	95.40
Handle unseen problems	77.42	67.16	72.00	58.20	82.80	76.10
Communication skills	77.17	68.65	71.70	59.80	82.70	77.50
Duration of workshop	94.57	94.03	91.60	89.50	97.50	98.60
Size of the class	89.01	86.57	84.90	80.10	93.20	93.10
Feedback on the workshop	84.95	77.61	80.30	69.60	89.60	85.60
Individual assignments	93.33	89.56	90.00	83.70	96.70	95.40
Group assignments	90.32	82.09	86.50	74.80	94.10	89.40
Exam preparation	98.90	98.50	97.50	96.20	100.00	100.00
Recommend to friends	98.91	93.75	97.60	82.40	100.00	100.00
Overall satisfied	97.85	97.02	96.00	93.80	99.70	100.00

Table 3: Correlation between all the attributes in Table 2. Dark grey areas represented the correlations in 2012 while the light grey area represents the correlations in 2013. The correlations above 0.5 are bolded to indicate their significance.

Learning Attributes	Correlate Theory	Instrument knowledge	Critical thinking skills	Field work	Self assessment	Handle unseen proble	Communication skills	Duration of workshop	Size of the class	Feedback on the workshop	Individual assignments	Group assignments	Exam preparation	Recommend to friends	Overall satisfied
Correlate Theory	1.00	0.58	0.49	0.60	0.26	0.31	0.27	0.36	0.42	0.40	0.37	0.26	0.49	0.43	0.55
Instrument knowledg	0.56	1.00	0.58	0.57	0.39	0.50	0.37	0.47	0.48	0.53	0.34	0.37	0.36	0.46	0.59
Critical thinking skills	0.57	0.82	1.00	0.50	0.31	0.46	0.43	0.39	0.28	0.49	0.40	0.30	0.33	0.29	0.47
Field work	0.63	0.51	0.50	1.00	0.49	0.33	0.47	0.54	0.49	0.50	0.40	0.37	0.52	0.62	0.67
Self assessment	0.39	0.41	0.31	0.45	1.00	0.38	0.60	0.44	0.48	0.43	0.55	0.61	0.36	0.45	0.51
Handle unseen problems	0.26	0.42	0.25	0.28	0.27	1.00	0.32	0.34	0.37	0.46	0.28	0.49	0.14	0.31	0.53
Communication skills	0.34	0.44	0.38	0.25	0.29	0.24	1.00	0.43	0.35	0.47	0.52	0.47	0.32	0.34	0.38
Duration of workshop	0.41	0.38	0.35	0.39	0.50	0.27	0.29	1.00	0.46	0.47	0.48	0.44	0.56	0.61	0.55
Size of the class	0.45	0.38	0.37	0.41	0.49	0.09	0.30	0.57	1.00	0.31	0.37	0.47	0.36	0.37	0.54
Feedback on the workshop	0.19	0.33	0.28	0.33	0.17	0.36	0.35	0.31	0.35	1.00	0.47	0.33	0.41	0.41	0.56
Individual assignments	0.57	0.24	0.24	0.52	0.43	0.19	0.18	0.37	0.45	0.30	1.00	0.70	0.51	0.47	0.59
Group assignments	0.42	0.29	0.35	0.41	0.37	0.15	0.20	0.34	0.38	0.36	0.63	1.00	0.29	0.44	0.54
Exam preparation	0.58	0.39	0.39	0.60	0.54	0.16	0.21	0.41	0.54	0.31	0.54	0.47	1.00	0.75	0.64
Recommend to friends	0.72	0.60	0.64	0.62	0.74	0.19	0.57	0.74	0.74	0.29	0.82	0.52	0.95	1.00	0.75
Overall satisfied	0.65	0.43	0.41	0.58	0.42	0.19	0.25	0.44	0.57	0.19	0.57	0.40	0.66	0.72	1.00