Assessment influence on Project-Based Learning (PBL) environment perception

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Abstract

The purpose of this study is to identify the influence of portfolio assessments on engineering students' perceptions of their learning environment when being exposed to the Problem-Based Learning (PBL) approach for the first time.

Based on a three factorial PBL environment (consisting of learning facilitator support, student responsibility and project quality), data regarding students' perception was collected through a questionnaire survey before and after assessments (pre- and post-assessment analysis) and analysed by applying Confirmatory Factor Analysis (CFA).

The analysis revealed that it was only after assessment that students understood the importance of reaching learning outcomes (versus carrying out projects), the necessity of exerting personal effort (versus group effort) and the intentional low level of guidance by the learning facilitators better.

For engineering educators and educational institutions the findings suggest that the PBL approach needs to be explained to novice students repeatedly and clearly throughout the course, and not just initially.

Keywords: Problem-Based Learning (PBL), learning environment, student perception, assessment

1 Introduction

Problem-Based Learning (PBL) and similar learning approaches have found interest in recent years. This study aims at identifying engineering students' perception of the PBL environment before and after their learning outcomes were assessed (pre- and post-assessment perception) based on submitted portfolios when experiencing the PBL approach for the first time.

1.1 *PBL*

The PBL approach originated at McMaster University (Graaff and Kolmos, 2007; Richardson and Delaney, 2010) and different variations, models, and perspectives on PBL have emerged (Graaff and Kolmos, 2003; Savin-Baden and Wilkie, 2004; Savin-Baden, 2007) and led to approaches such as "Problem-Oriented and Project-Based Learning" (Lehmann, Christensen, Du and Thrane, 2008) and "Problem-Based Project-Organized Learning" (Garcia, Bollain and Del Corral, 2011). The common focus of the different PBL variations and models is learning around problem scenarios rather than discrete subjects (Savin-Baden, 2000, p.3) and PBL has been shown to stimulate critical thinking, self-learning skills, lifelong learning, self-achievement, self-regulation, self-efficacy, communication skills, interpersonal skills and students' motivation (Guerra, 2011).

1.2 Learning environment

The learning environment inevitably influences a student's learning performance and learning outcomes (Froyd, 2008; Ong and Cheong, 2009). Students' perception of their learning environment is likely to impact a student's approach towards learning more than merely the student's characteristics such as previous experience or current understanding (Groves, 2005). A reciprocal relationship between students' disposition towards learning and the learning environment as perceived by the students has been identified (Bogaard, 2012).

For the PBL environment, Boud and Feletti (1997) emphasized the importance of facilitators' own self-awareness and psychological sensitivity (Boud and Feletti, 1997, p.171) and the choice of problems as it relates to the curriculum (p. 93). These PBL environment characteristics are closely related to the key features of effective learning environments (Dochy, Segers, Bossche and Struyven, 2005).

1.3 Portfolio Assessment

It was shown before that assessment approaches should fit to PBL as well as the discipline and that a lack of clarity regarding assessment criteria leads to frustration among students (Savin-Baden, 2004). Analysis of the impact of assessment methods and procedures on students' learning revealed the high importance of continuous feedback, but showed also the disadvantage of high project workloads in that students tend to equate a lot of work with high marks (Fernandes et al. 2012). Another challenge is the fair assessment of a student's contribution to team work and team learning (Nepal 2012). The reliability of portfolio assessments has been questioned because of the qualitative nature of information in portfolios, different contexts of information and the necessary interpretation of information by the assessor (Moss in Tigelaar et al. 2005). Finally, students may have progressed in their learning, but may not have documented this in a sufficient manner. A learning context based on a language other than the students' mother tongue, may be especially prone to this. In summary, it can be expected that portfolio assessments of PBL courses have some impact on students' perception of PBL. However, how do portfolio assessments influence novice students' perception of their PBL environment? The next section describes the method chosen to answer this question, followed by the analysis and results, the discussion and the conclusion.

2 Method

2.1 Sample

The sample size consisted of 49 undergraduate engineering students (mechanical and civil engineering) enrolled in a third year PBL course "Engineering Skills" at a private college in the Middle East. The average age of the students was 23 years, 28% of the students were female students and 72% male students. For all students, it was the first time that they were exposed to PBL. The learning outcomes of the course are shown in Table 1 and learning was embedded in real-life scenarios, based on the following five group projects:

- Design, build and test a water filter;
- Research and present an engineering invention or disaster;
- Design, build and test concrete bricks for a building shelter in an earthquake area;
- Design, build and present a dancing robot; and,
- Develop and present a computer program based on a given technical standard.

Table 1: Learning outcomes

1	Discuss the role of a professional engineer within a business environment, showing an appreciation of the interactions between the technical aspects of the role and the social, cultural, environmental, economic and political contexts.
2	Investigate and select materials and processes for engineering applications and justify decisions made.
3	Apply information literacy skills and information technology skills to engineering projects.
4	Use drawing, modelling and simulation tools to analyse and present project outcomes.
5	Describe, apply and justify risk assessment and workplace health and safety in engineering activities.
6	Design, conduct and report on practical activities, including devising appropriate measurements and procedures, analysing and interpreting data and forming reliable conclusions.
7	Articulate an appreciation of the complex nature of engineering activities including ill-defined situations and problems involving uncertainty, imprecise information, and conflicting technical and non-technical factors.
8	Articulate and demonstrate personal application and development of the practice of professional engineering, including a professional attitude, problem solving skills, relevant technical knowledge, productive work practices and a commitment to lifelong learning.
9	Provide evidence of a professional capacity to communicate, work and learn; individually and in peer learning teams.

Student groups consisted of 4 to 5 students who received continuous formative feedback throughout the course as they worked and learnt based on their projects. At the end of the course each student was required to submit the following items for assessment (portfolio assessment):

- Reflective Journal showing thoughts on learning and the learning process;
- Workbook showing work related to the projects (incl. meeting minutes, sketches, project reports, etc.);

- Drawing Folder of technical drawings related to the projects;
- Peer- and Self-evaluation (one page report explaining strengths and weaknesses of self and peers);
- Individual Grade nomination (based on the assessment criteria); and,
- Reflective paper on a given engineering project.

The learning facilitators (one lecturer and two teaching assistants) evaluated the students' learning outcomes based on criteria reflecting acceptable, good and excellent learning. These criteria, as well as the PBL approach, the role of the projects (i.e. means of learning) and the learning outcomes, were explained to the students in week 3 and were then accessible to the students. The learning facilitators felt a reasonable degree of confidence after they had received training in portfolio assessment a year earlier and after assessing students' learning of the same course already a semester before.

2.2 Survey

During the last week of the semester and based on an anonymous questionnaire survey, the students were asked to identify the importance of 21 PBL environment characteristics on a 5-point response scale ranging from 1 (never) to 5 (always). These characteristics were taken from the Problem-Based Learning Environment Inventory (PBLEI) developed by Senocak (2009) because they have been proven to be stable and reliable. A factor analytical stability check, followed by an exploratory factor analysis (EFA), resulted in a three factorial learning environment representing 12 learning environment characteristics (Jaeger and Adair, 2012; Table 2). In order to measure students' post assessment perception, the survey has been repeated three weeks later after each student underwent an individual viva voce, which focused on their portfolio assessment results, and after students were informed about their final grades.

Table 1: PBL environment characteristics

Variable	PBL environment characteristic	Factor
v1	The teaching staff directed our thinking with some guiding questions.	Facilitator Support
v2	If I asked a question, the teaching staff gave me just a hint instead of the complete answer.	Facilitator Support
v6	The teaching staff asked us to show the approach of solving problems.	Facilitator Support
v8	I made enough effort to use various information sources.	Student Responsibility
v9	There were times when I had to make my own decisions.	Student Responsibility
v11	I evaluated the performance of my peers and myself.	Student Responsibility
v13	For group work, I collaborated with the other members of my group.	Student Responsibility
v16	For group work, I respected others' ideas in my group.	Student Responsibility
v17	For group work, I participated in group work as much as possible.	Student Responsibility
v19	The projects were easy enough to solve without any serious difficulty.	Project Quality
v20	The project descriptions were written in an understandable language.	Project Quality
v21	The projects were of the kind for which one can produce different solutions.	Project Quality

3 Analysis and Results

In order to overcome the weakness of other statistical methods when analysing variable relationships, such as multiple regression (Lehman, 1991; Byrne, 2001), a Confirmatory Factor Analysis (CFA) was conducted using LISREL, version 8.80 (Jöreskog and Sörbom, 1993). The analysis tests how far the collected data confirms a postulated path model, and for the situation analysed here, the path model is shown on Figure 1.

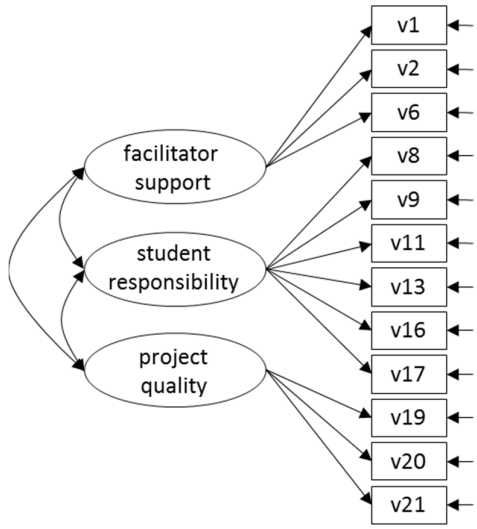

Figure 1: Path model of the 3-factorial PBL environment

The path model describes the relationships between the endogenous dependent variables (the factors of the PBL environment: *facilitator support, student responsibility, project quality*) and the corresponding indicator variables (the identified PBL environment characteristics v1, v2,…). It can be assumed that the three factors of the PBL environment influence each other and that measuring the shown indicator variables included measuring errors (residuals). It has been shown that ignoring residuals leads generally to inconsistent estimations (Bollen, 1989).

3.1 Confirmatory Factor Analysis of Pre-Assessment Perception

After six iterations and based on the *Unweighted Least Squares* estimation method (Jöreskog and Sörbom, 2001), LISREL estimated the parameters shown on Figure 2.

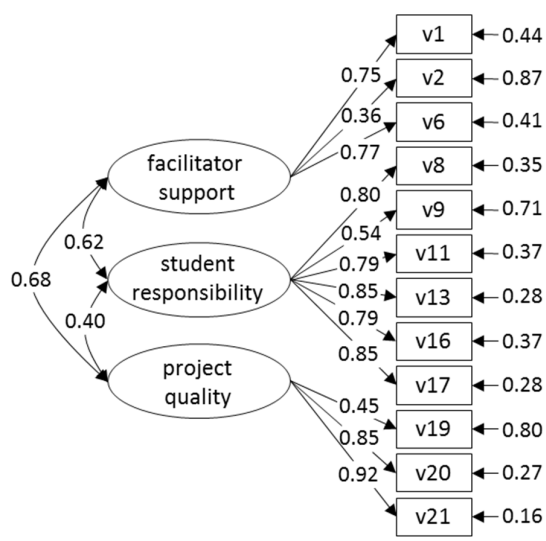

Figure 2: Estimated parameters of the pre-assessment evaluation

In order to determine the overall model fit, a wide range of indices is typically considered since the different indices reflect different aspects of the model. The indices are estimated by LISREL, shown in Table 3 and compared with generally recommended limits (Diamantopoulos and Siguaw, 2000; Shumacker and Lomax, 1996; Hair, Black, Babin and Anderson, 2009). The comparison indicates an acceptable to good overall model fit.

Table 2: Goodness-of-fit indices

Index	Recommended Values	Model Values	Model Fitness

Chi-square / degree of freedom	< 2	1.11	Good fit
Root Mean Square Error of Approximation (RMSEA)	0.05-0.08 (acceptable fit)	0.052	Acceptable fit
Normed Fit Index (NFI)	> 0.9	0.88	Moderate fit
Non-normed Fit Index (NNFI)	> 0.9	0.98	Good fit
Comparative Fit Index (CFI)	> 0.9	0.99	Good fit
Goodness of Fit Index (GFI)	> 0.9	0.98	Good fit
Adjusted Goodness of Fit Index (AGFI)	> 0.9	0.96	Good fit

In addition to considering the overall model fit, the estimated free parameters should be looked at (Leung, Wang and Olomolaiye, 2008). Their *t-values* and *squared multiple correlation* (R^2, reflecting the amount of variance in the dependent variables which is accounted for by the independent variables) of the independent variables are shown in Table 4.

Table 3: Path parameters estimates and its t-values (in brackets, for p≈0.05)

Independent Variables	Dependent Variables (Factors)			R2
	Facilitator support	Student responsibility	Project quality	
V1	0.75 (8.92)			0.56
V2	0.36 (6.72)			0.13
V6	0.77 (9.16)			0.59
V8		0.80 (11.53)		0.65
V9		0.54 (10.68)		0.29
V11		0.79 (12.40)		0.63
V13		0.85 (13.61)		0.72
V16		0.79 (12.17)		0.63
V17		0.85 (12.83)		0.72
V19			0.45 (6.07)	0.20
V20			0.85 (10.36)	0.73
V21			0.92 (10.51)	0.84

The independent variables *v2, v9 and v19* show a clearly lower R^2 than the other independent variables, which indicates that they explain a smaller portion of the variance of the dependent variables. In order to improve model fit, relationships could be eliminated from the model (Diamantopoulos and Siguaw, 2000). However, when there is no theoretical justification for eliminating any of the assumed relationships, it is better to retain them and accept a lower R^2 (MacCallum, 1995; Leung et al., 2008). Here, no theoretical justification could be identified since these variables were earlier identified as characteristics of the corresponding factors (Jaeger and Adair, 2012) and clearly describe aspects of the corresponding factors. The results will be discussed and interpreted later in the discussion section after the results of the post-assessment evaluation have been analysed.

3.2 Confirmatory Factor Analysis of Post-Assessment Perception

For the CFA of students' post-assessment evaluation, LISREL estimated the parameters shown on Figure 3 after eleven iterations and based on the *Unweighted Least Squares* estimation method (Jöreskog and Sörbom, 2001).

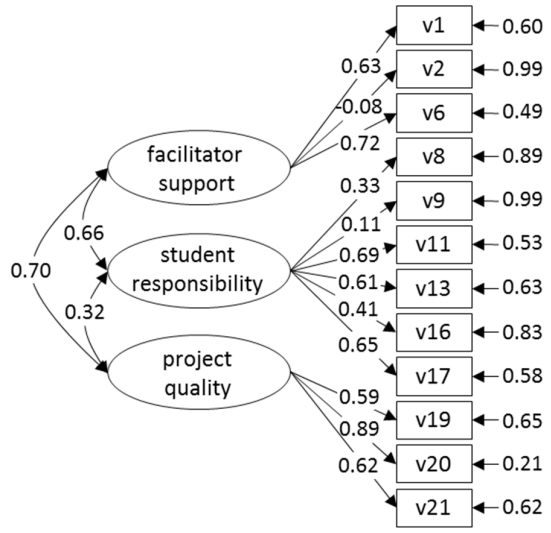

Figure 3: Estimated parameters of the post-assessment evaluation

The model fit indices are estimated again by LISREL, shown in Table 5 and compared with generally recommended limits (Diamantopoulos and Siguaw, 2000; Shumacker and Lomax, 1996; Hair et al., 2009). The comparison indicates an overall insufficient model fit and, therefore, a further consideration of the *t-values* and *squared multiple correlation* has been omitted.

Table 4: Goodness-of-fit indices

Index	Recommended Values	Model Values	Model Fitness
Chi-square / degree of freedom	< 2	1.38	Good fit
Root Mean Square Error of Approximation (RMSEA)	0.05-0.08 (acceptable fit)	0.092	Unacceptable fit
Normed Fit Index (NFI)	> 0.9	0.65	Unacceptable fit
Non-normed Fit Index (NNFI)	> 0.9	0.81	Unacceptable fit
Comparative Fit Index (CFI)	> 0.9	0.86	Unacceptable fit
Goodness of Fit Index (GFI)	> 0.9	0.93	Good fit
Adjusted Goodness of Fit Index (AGFI)	> 0.9	0.89	Unacceptable fit

4 Discussion

Since the post-assessment evaluation model has been found to reflect the surveyed data insufficiently, a comparison of the absolute parameter estimates is not conclusive. However, a comparison between the pre-assessment model and the post-assessment model regarding clear qualitative changes of the parameter estimates is conclusive and gives insight into the influence of the assessment on students' perception of their PBL environment.

Looking at the post-assessment model, the relationships between the factors of the PBL environment and their characteristics are all smaller than the same relationships of the pre-assessment model – except the relationships between v19 (The projects were easy enough to solve without any serious difficulty) and v20 (The project descriptions were written in an understandable language) on the one side and *project quality* on the other side. These relationships have become stronger after the assessment which may be a consequence of students realizing that the assessment was not primarily about their project work, but about the learning outcomes. Before the assessment, they may have been more hesitant to consider the projects and project descriptions as easy since they may have had insufficient understanding regarding the impact of their project work on the assessment. The relationship between v21 (The projects were of the kind for which one can produce different solutions) and *project quality* became weaker after the assessment, which may have been related to the same reason as before: Focus of the assessment was on the learning outcomes and not on any outstanding feature of the projects carried out. This interpretation was confirmed qualitatively by students' entries in their Reflective Journals, their self- and peer assessment and by verbal statements

after their viva voce: Concluding remarks in their Reflective Journals showed repeatedly that they perceived themselves working a lot on the projects and, therefore, expected a high grade (confirming findings of Fernandes et al., 2012). Furthermore, the self- and peer assessments included comparisons with their peers regarding involvement in project work. Finally, after their viva voce a number of students voiced dissatisfaction with their prospective grades and claimed that they contributed more to the project work than other students, but received lower grades.

Regarding the relationships between *facilitator support* and its characteristics, all relationships became weaker after the assessment. After the assessment, students may have realized that the mentioned actions of the learning facilitators (i.e. v1: directing students' thinking, v2: giving students a hint, v6: asking students to do something) had a less positive impact on their grades than they may have thought. Since students came from a rote-learning background and were used to an environment where instructors told them exactly what to do in order to pass with high grades, they were somewhat discouraged that their grades were below the grades they expected (as indicated in their individual grade nomination). This interpretation was confirmed qualitatively by the students' course evaluation where students expressed repeatedly their frustration about the low level of guidance they received during the course from the learning facilitators.

Regarding the relationships between *student responsibility* and the characteristics, again, all relationships became weaker after the assessment, which may reflect that students understood from the assessment that their personal effort was not high enough in order to pass with high grades as they did in previous years. The three variables with the largest parameter value decrease (v8, v9, v16) seem to confirm this interpretation since all three variables are independent from the performance of group members or the overall performance of the group. Independent of their individual groups, students

- could have made more effort to use various information sources (v8);
- could have developed more frequently their personal decision (v9); and,
- could have considered ideas of group members more seriously (v16).

Although the influence of the students' culture is beyond the scope of this study, it may have encouraged students to rely on their groups' consensus. Students' Reflective Journals showed clearly that decisions and learning were usually based on group processes and that personal critical reflections did virtually not exist. However, they seem to have realized the necessity to increase personal effort within a PBL environment which was also confirmed qualitatively by related reoccurring remarks during their *viva vice*.

The relationships between the three factors *facilitator support*, *student responsibility* and *project quality* was qualitatively similar, although the relationship between *student responsibility* and *project quality* became weaker after the assessment. Again, this may have been the consequence of understanding more clearly that the learning outcomes were assessed - and not the project work.

It can be concluded that the portfolio assessment may have led to three causes which contributed to the changed perception. First, students may have realized through the assessment that the course was not primarily about carrying out projects, but about learning while carrying out projects. Second, students may have understood more clearly through the assessment that the PBL course was intentionally based on a low level of guidance by the learning facilitators. Third, students seem to have understood that their personal effort was not replaced by group effort. Although these aspects have been explained to the students at the beginning of the course, this has obviously not been sufficient and it may be suggested to reemphasize these aspects repeatedly throughout delivery of PBL courses.

5 Limitations and future research

The following potential threats to validity of results have been identified. The construct validity of the research presented here might be limited since evaluation of personal perceptions is a difficult concept which can only be captured with subjective measurement instruments. Furthermore, although the conducted validity calculations (goodness-of-fit indices) reflect a conclusive model for the pre-assessment evaluation, one limitation of this study is the small sample size which is below the recommended minimum sample size of 50 respondents (for models with few factors; Tabachnick and Fidell, 2001). Therefore, the results require verification with a larger sample. The exploratory character of the research presented here needs to be recognized and following further investigations might lead to more generalized future results.

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