Effectiveness of various PBL feedback channels in engineering education

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ABSTRACT: Project-based learning (PBL) is a widespread method for teaching and learning in engineering higher education institutions due to its manifested effectiveness in producing long-life learners who are nowadays essential in a world witnessing an exponential technological growth. Although, many research studies targeted the elaboration of strategies, techniques and guidelines for an effective PBL facilitation, less studies focused on evaluating the effectiveness of such strategies from the perspective of PBL students. In this article, the authors investigate the relation between students' perceived learning and various feedback channels used by PBL facilitators through analysing validated results of a quantitative survey. The findings suggest that unofficial type of feedback, whether written or verbal, is the most preferred by PBL students.

INTRODUCTION

Project-based learning (PBL) is a relatively modern pedagogy originated in the 1950s. It is a student-centred learning method which aims to build problem-solving skills through self-learning and to promote sustainable learning and teamwork skills. In a project-based learning scenario, a well-designed project, usually extracted from real-life scenarios is set, and then introduced to students who work in groups to address the project requirements. The learning is structured around a project and the embedded problems that the students encounter during its conception, design, implementation and testing phases. PBL is believed to motivate students, trigger their critical thinking, promote collaboration, tie learned information to a vivid experience and most importantly, provide students with self-confidence and the necessary self-learning skills to transform them from *short-term* to *long-life* learners in their field of study [1].

With the increased demand for modern sustainable life and the greedy thirst for new technologies, engineering educators and institutions confronted the imperative need to equip their graduates with long-life learning skills to easily adapt to the increasingly dynamic markets. Hence, unsurprisingly, they are adopting PBL pedagogy to grant PBL-flavoured attributes to their graduates from one side and to implicitly embed flexibility to their curricula to rapidly cope with the exponential technological growth from the other side [2]. As such, in the past two decades, PBL has become a widespread method for teaching and learning in engineering higher education institutions [3-5].

Much PBL literature addressed the change process, models, peer interactions, student centred approaches, assessment frameworks, as well as many other techniques and strategies to support PBL practice in engineering education [6-9]. However, when it comes to the interaction between the educator and the students, the literature was somehow restricted to the assessment and identification of best approaches for effective feedback yet rarely within the context of PBL [10][11]. It is widely agreed that feedback has a positive effect on the learning curve of the students.

The roles and responsibilities of the educators towards the students, as well as the challenges and complexities confronting them in a student-centred pedagogy were also addressed [12-14]. It is commonly argued that a PBL teacher must act as a learning *facilitator* who guides the students to achieve their own conceived goals rather than orienting them towards his own pre-defined solutions. Some papers also tried to identify approaches to PBL facilitation [15][16], but unfortunately, less attention has been given to the students' perceived learning and satisfaction as a result of the various feedback approaches, techniques and communication platforms used by the facilitators within a PBL context.

To this end, the authors of this article investigated the effect of various feedback channels on the students' perceived learning and satisfaction within a PBL context, and present their findings here. At first, a literature review about educators' feedback and its various types, as well as the students' perception of learning is summarised. Second, the study

environment, model, assumed hypotheses and methodology are explained. Finally, the results are presented and thoroughly discussed to draw relevant conclusions.

A REVIEW ON FACILITATOR FEEDBACK AND STUDENT PERCEPTION OF LEARNING

Feedback is generally defined as the provision of information to a student to foster the student's learning through closing the gap between what is known and what is still to be learned [17][18]. When the communication channel that is used to convey the feedback to the student is of concern, feedback can be broadly classified into two categories: verbal and written. Within the context of PBL, both verbal and written feedback are intensively used to facilitate and promote active student-centred learning [12].

Verbal feedback involves any form of verbal communication that occurs between the educator and the learner, whether formal or informal, one-to-one or one-to-many, and synchronous or asynchronous [19][20]. Verbal feedback includes, but is not limited to, synchronous formal feedback sessions during pre-scheduled in class or office meetings, *ad-hoc* synchronous verbal chat or asynchronous video/voice recordings' sharing. On the other hand, written feedback refers to any form of feedback that is communicated in writing with the leaner whether formal or informal and one-to-one or one-to-many [21][22]. In contrast with verbal feedback, written feedback is always provided to the learner in an asynchronous manner. It includes, but is not limited to, course-related announcements, Web forums, grading criteria, assessments' ideal solutions, assessment templates, detailed feedback on assignments or any other form of assessment, or *ad-hoc* chat through chatting platforms. In a written feedback scenario, official communication channels are usually used by the educator to communicate with the learner, such as learning management systems (e.g. Moodle, Microsoft Teams, etc).

Moreover, student perception of learning is defined as the learner's opinions and views about the learning that have occurred. It is considered as a valid and core indicator of the learning process, and hence, it is generally used as mediator variable to link certain independent input variables affecting the learning process to students' satisfaction [23][24].

STUDY MODEL, HYPOTHESES AND EVINORNMENT

Under the context of this study, four independent input variables each depicting a type of feedback given by the PBL facilitator to the students are defined for the sake of assessing their impact on two main output variables, the students' perceived learning and students' satisfaction. Table 1 defines the variables that are used in this study along with their types, descriptions and abbreviations. Since written asynchronous feedback is relatively more time and efforts demanding than verbal feedback, three of the defined independent variables (MS Teams feedback - TF, EduLearn feedback - EF and official feedback - OF) are written feedback, whereas all forms of verbal feedback are grouped under one variable (VF).

Table 1: Types, abbreviations and descriptions of the study variables.

Variable type	Abbr.	Variable description
Independent/Input	VF	Verbal feedback in the form of synchronous formal or informal feedback sessions.
Independent/Input	TF	Asynchronous *ad-hoc* non-graded written chatting feedback through MS Teams; namely, MS Teams feedback, given in a private channel dedicated for each group.
Independent/Input	EF	Detailed written feedback on every weekly submittal. It is given in the form of constructive comments embedded within the submitted files and uploaded through the Moodle-based learning management system; namely, EduLearn feedback.
Independent/Input	OF	Official feedback sent to students in the form of individual or group e-mails or written announcements. It also includes facilitation material uploaded for students on the learning management system, such as grading criteria, templates, etc.
Mediator/Output	SL	Student perceived learning.
Dependent/Output	SS	Student satisfaction.

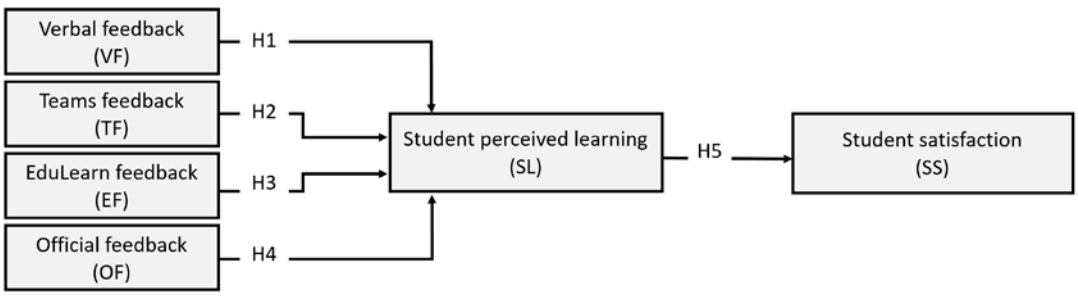

Figure 1: Study model.

As depicted in Figure 1, this study model assumes that each input variable (VF, TF, EF and OF) has positive impact on students' perceived learning (SL) which in turn affects positively the students' satisfaction (SS). This model is hence governed by the following five hypotheses:

- H1: Verbal feedback has positive effect on students' perceived learning (VF → SL).
- H2: MS Teams feedback has positive effect on students' perceived learning (TF → SL).
- H3: EduLearn feedback has positive effect on students' perceived learning (EF → SL).
- H4: Official feedback has positive effect on students' perceived learning (OF→ SL).
- H5: Students' perceived learning has positive effect on students' satisfaction (SL→ SS).

The model is applied on the course 21SELE311 - Introduction to Computing with C++ during the fall academic semester of the academic year 2022-2023. The course is a mandatory requirement of the Bachelor of Electrical and Electronics Engineering Technology programme at the Australian University in Kuwait. Students who are enrolled in this course have basic C++ programming background that is acquired from a pre-requisite programming course. Whereas the pre-requisite knowledge is restricted to basic arithmetic operations, selections, repetitions and simple arrays, this course has learning outcomes that extend to manipulating complex data structures and creating sophisticated algorithms to resolve real-life problems. The course is delivered using PBL approach, where students are divided into groups of five-six students to conceive, design, implement and operate a computer program with broadly defined features using C++ high level programming language.

Each group of students meet with their instructors at least twice a week to receive verbal feedback and guidance to facilitate their learning and project progress. They also receive guidance through written feedback as described in Table 1. In addition, as part of their PBL learning experience, students are required to lodge various submittals related to the project and their progress, such as project plans, meeting agendas and minutes, research summaries, workbooks, code progress, reflections and self/peer-assessments, then receive written and verbal feedback about each of these items within one week of the submission date. To foster learning and formative feedback approach, submittals are fairly distributed among the study weeks to balance the workload throughout the semester. Students also receive written and verbal feedback at least three times on draft versions of their submittals prior to submitting their final version that is used to evaluate them. As such, the first graded submission occurs in the fifth week of study.

METHODOLOGY

A questionnaire consisting of two parts was developed based on the proposed study model to test the validity of the assumed hypotheses. The first part aimed at collecting demographics, such as age, gender and cumulative grade point average (GPA). The second part aimed at assessing the feedback means (VF, TF, EF and OF) on students' perceived learning and satisfaction (SL, SS). It consisted of 12 questions, three for each input variable, all designed based on a Likert scale from 1 to 5.

A pilot study was conducted prior to the distribution of the questionnaire to explore whether any question was not clear and to identify any areas of improvement. Two random students were asked to fill the survey and some comments were raised and addressed. After the pilot study, an updated version of the questionnaire was distributed over the whole population, i.e. the 37 students enrolled in the course 21SELE311 - Introduction to Computing with C++. The data was collected towards the end of the semester (week 12) and a response rate of 94.5% has been achieved.

Data were analysed using the SPSS 29.0.0.0 version. Frequency and descriptive tests were implemented to extract basic statistic values, such as means, counts and standard deviations. Next, reliability and validity tests were conducted to ensure that the data collected could be used to draw valid conclusions. Finally, the five hypotheses were tested for correlation.

RESULTS

Demographics

The whole population of this study were all the students enrolled in the course 21SELE311 - Introduction to Computing with C++ at the Australian University in Kuwait in fall 2022 semester, i.e. 37 students. Thirty-five students participated in the questionnaire with quite a good balance between males (51%) and females (49%). Most of the participants are below the age of 22 (69%) with a normal distribution of GPA.

Descriptive Statistics

As explained earlier, the second part of the questionnaire aims at assessing the feedback means (VF, TF, EF and OF) on student perceived learning and satisfaction (SL, SS) using 12 questions (items), three items for each input variable (VF1, VF2, VF3, TF1, TF2, TF3, EF1, EF2, EF3, OF1, OF2, OF3), all designed based on a Likert scale from 1 to 5, where: 1 represents *strongly disagree*, 2 represents *disagree*, 3 represents *neutral*, 4 represents *agree* and 5 represents *strongly agree*. Table 2 shows the descriptive statistics of the data collected. Verbal feedback items scored the highest

mean (M = 4.08, SD = 0.997) followed by EduLearn feedback (M = 3.86, SD = 1.014), which scored the same level as official feedback (M = 3.86, SD = 0.882). The lowest mean scores were obtained from MS Teams feedback (M = 3.70, SD = 0.990). Almost all means are negatively skewed with the minimum mean as 3.63, which indicates that all items can be considered as close to 4, which represents an *agree*. This gives an indication that students agree that all feedback means have positively impacted their learning.

Table 2: Descriptive statistics.

Item	N statistic	Minimum	Maximum	Mean	Standard deviation	Skewness
VF1	35	1	5	4.09	1.121	-0.974
VF2	35	1	5	4.11	0.932	-1.393
VF3	35	2	5	4.03	0.954	-0.705
TF1	35	2	5	3.77	0.942	0.041
TF2	35	2	5	3.63	1.031	-0.026
TF3	35	1	5	3.71	1.017	-0.269
EF1	35	2	5	4.03	0.954	-0.490
EF2	35	1	5	3.66	1.083	-0.579
EF3	35	1	5	3.89	0.993	-0.715
OF1	35	2	5	3.94	0.873	-0.167
OF2	35	2	5	3.77	0.973	-0.119
OF3	35	3	5	3.86	0.810	0.274

Table 3: Item reliability and validity: Pearson correlation matrix (confidence level > 95%).

	VF1	VF2	VF3	TF1	TF2	TF3	EF1	EF2	EF3	OF1	OF2	OF3
VF1	1.000	0.722	0.602	0.486	0.430	0.435	0.572	0.606	0.643	0.425	0.689	0.111
VF2		1.000	0.624	0.599	0.637	0.501	0.461	0.419	0.523	0.225	0.362	0.378
VF3			1.000	0.400	0.280	0.615	0.419	0.437	0.624	0.179	0.229	0.348
TF1				1.000	0.667	0.728	0.498	0.440	0.317	0.319	0.198	0.149
TF2					1.000	0.625	0.489	0.462	0.344	0.204	0.294	0.357
TF3						1.000	0.554	0.576	0.578	0.213	0.310	0.335
EF1							1.000	0.550	0.562	0.179	0.387	0.500
EF2								1.000	0.783	0.584	0.549	0.344
EF3									1.000	0.542	0.428	0.372
OF1										1.000	0.643	0.529
OF2											1.000	0.555
OF3												1.000

Table 4: Items autocorrelation.

Item	Scale mean if item deleted	Scale variance if item deleted	Corrected item - total correlation	Squared multiple correlation	Cronbach's alpha if item deleted
VF1	42.40	46.894	0.536	0.726	0.861
VF2	42.37	48.123	0.571	0.623	0.858
VF3	42.46	46.491	0.689	0.681	0.851
TF1	42.71	48.151	0.561	0.697	0.859
TF2	42.86	47.538	0.547	0.658	0.860
TF3	42.77	45.005	0.758	0.814	0.845
EF1	42.46	46.726	0.670	0.628	0.852
EF2	42.83	45.970	0.629	0.771	0.854
EF3	42.60	46.482	0.658	0.797	0.852
OF1	42.54	52.020	0.285	0.690	0.874
OF2	42.71	51.387	0.290	0.680	0.875
OF3	42.63	50.417	0.461	0.580	0.864

Reliability and Validity Tests

For the reliability test, Cronbach's alpha was extracted to estimate the internal consistency reliability. The obtained Cronbach's alpha for the whole questionnaire was 0.869, which indicates that the model's results are highly reliable. For the validity test, Pearson correlations have been obtained by correlating each question's score with the overall

questionnaire score and tested for significance with 95% confidence levels [25]. Table 3 shows the correlation matrix. As not all questions are correlated, it is quite normal to find acceptable correlation for some items (e.g. VF1 and VF2 are correlated at 0.722) and relatively non-correlation for others (e.g. VF1 and OF3 are correlated at 0.111). Table 4 shows each item's autocorrelation. All items' Cronbach's alpha after item deletion are 0.845 and above, which indicates that all items are reliable and none of the items needs to be removed from the analysis.

Test of Hypotheses

Table 5 shows a summary of the test of correlations for the five hypotheses. All feedback means showed moderate correlations with student perceived learning at 95% confidence level. The relationship between students' learning and students' satisfaction scored a strong correlation value (0.745). This means that all feedback means affect positively the students' learning, which in return reflects positively on students' satisfaction. This is consistent with what was found in the literature [10].

Table 5: Test of hypotheses.

Hypothesis	Correlation between	Result	Correlation level	Supported by significance
H1	VF→ SL	r = 0.613	Moderate correlation	Yes
H2	TF→SL	r = 0.677	Moderate correlation	Yes
H3	EF→SL	r = 0.673	Moderate correlation	Yes
H4	OF→SL	r = 0.542	Moderate correlation	Yes
H5	SL→SS	r = 0.745	Strong correlation	Yes

Comparing the results, one can notice that the least correlation value was scored from the relationship between the official feedback and students' learning (0.542). As mentioned earlier, this feedback concerns any type of official written announcements, pre-prepared documents, such as guides, grading criteria, templates, etc. A moderate correlation between the official feedback and student's learning means that this feedback is important, yet it is the least preferred by the students. This can be related to the written language used by the facilitator, which is usually at a higher level than what can be clearly understood by the students [11].

On the other hand, the other three types of feedback (VF, TF, EF) scored relatively close correlation values with students' learning (0.613-0.677), where interestingly, the highest score was achieved by the *ad-hoc* written feedback through chat in MS Teams. Indeed, in a private channel dedicated for each group in MS Teams, the students were communicating with each other, sharing files, references, and any other learning material, and were receiving *ad-hoc* feedback from the instructor in the form of files with corrections or short written guidance, recommendations for improvements, etc.

The facilitators were using their free office hours' time to skim students' collaborations and give their quick feedback. More importantly, the feedback given by the facilitator in these private teams' channels was not part of any assessment grade and hence, have no correlation ever with the students' grades. This suggests that students appreciate the most a non-graded prompt feedback and consider it to serve the most their learning curve. As students were receiving such type of non-graded feedback verbally (VF) and through EduLearn (EF) as well, these two scored similar correlations with students' perceived learning. For instance, students were receiving continuous non-graded feedback whether verbally in class or written in the form of feedback files with comments through EduLearn about any submittal at least twice prior to submitting their final graded versions. However, and since they were also receiving feedback about their final version of submittals and about their grades through these two channels, they considered MS Teams as a more effective way to enhance their learning.

CONCLUSIONS

It is widely argued that feedback given by the instructor to the students has a positive impact on the teaching and learning process whatever was the teaching pedagogy. In a student-centred learning approach, such as project-based learning this is further emphasised and is more challenging as the instructor must play the role of a learning facilitator who motivates students, trigger their thinking, and guide them to achieve their goals without interfering with their learning styles and their own way of addressing the problems that are embedded in the project. As such, PBL facilitators use a variety of feedback styles and communication channels.

The study presented in this article compared various feedback channels and their effects on students' perceived learning and satisfaction. The investigated feedback channels were either verbal (all forms) or written in the form of official feedback files on students' submittals, *ad-hoc* chatting through MS Teams and official general documents/ announcements. Results showed that students' satisfaction is strongly correlated with student perceived learning which is consistent with the literature. Moreover, the comparative results indicated that students appreciate the least any form of pre-prepared documents and official announcements, and consider them to contribute the least to their learning, which may be related to their language and technical complexity compared to other feedback means. Finally, written feedback in the form of chatting manifested as the most preferred feedback means from the perspective of students.

This was linked to the non-correlation between this type of feedback and the students' grades in contrast to all other studied feedback channels. As such, one may conclude that students perceive that they learn the most from the facilitator's feedback when it does not affect their grades. Further studies are hence recommended to validate this new hypothesis.

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