Global Journal of Engineering Education

Characteristics of effective feedback in PBL: an exploratory study

Hassan Salti & Hania El-Kanj

Australian University
Mishref, Kuwait

ABSTRACT: Providing feedback to students is an integral part of any pedagogy. It even becomes substantial in a student-centred self-directed pedagogy, such as project-based learning (PBL). A PBL facilitator is required to closely monitor students throughout their learning journey to maximise their learning, ensure they are always on the right track, and hence successfully achieve the stated course's objectives. Feedback on the other hand can have various forms, such as synchronous, asynchronous, verbal, written, etc, and must suit the students' learning styles, perceptions and needs. This article investigates and compares the correlation between students' perceived learning and different feedback channels used in a PBL course through analysing validated results of a quantitative survey. It proves that ungraded feedback is essential to maximise students' learning in PBL environments, and explores other possible characteristics of effective feedback, such as the feedback frequency and the characteristics of the feedback communication channel.

Keywords: Feedback, ungraded feedback, learning, engineering education, project-based learning, PBL

INTRODUCTION

Engineering workplaces and projects are usually inter-disciplinary and require special engineering skills, such as critical thinking, collaborative work and self-learning. To nurture such skills in the attributes of their graduates, engineering higher education institutions (HEI) have given more attention in the recent years to student-centred learning approaches, such as project-based learning (PBL) [1] and conceive, design, implement and operate (CDIO) [2]. It is believed that such approaches cultivate students' engagement, promote their learning motivation and self-confidence, and foster their decision making, communication and self-lifelong learning skills [3]. It is also argued that such learning approaches add flexibility to engineering curricula, which allows educators to promptly respond to the rapidly changing needs of dynamic markets and the subsequent challenging ethical threats jeopardising humanity due to profit-oriented rather than sustainable engineering solutions [4].

Since its inception, PBL has been widely spread as an instructional approach in engineering HEIs all over the globe and has been extensively discussed in the literature. Whereas many studies advocated PBL as an effective student-centred and experiential learning approach towards *better learning* through exploring solutions for real-life challenges, projects and problems [5], other studies criticised PBL and questioned its effectiveness in enhancing the students' learning outcomes arguing that students must develop specific content knowledge prior to confronting real-life engineering projects [6]. Nevertheless, such criticism could not stand firm in front of PBL's popularity as a state-of-the-art pedagogical approach [7-9].

By reviewing the PBL literature over the past two decades, one may conclude that there is no consensus about PBL implementation. It is a dynamic pedagogy that motivates HEIs to innovate their own PBL model that best matches the needs of students, internal policies, markets, cultural beliefs, etc. Whereas some PBL design principles are commonly encountered in most of the developed PBL models, such as the use of projects to promote active learning, students' engagement, group and collaborative work, reflective learning, teacher's feedback, etc, there is still a considerable deviation among studies when it comes to implementing these principles [1].

As far as assessments and teacher's feedback are concerned, or the so-called facilitator's feedback in the context of PBL, many research studies highlighted how critical is the instructor's feedback to the student's learning and the importance of embedding feedback as part of the assessment strategies [10]. Many of them also concluded that quality

feedback is very time consuming and that further guidance on how to efficiently provide quality feedback to students is essential but is still not sufficiently covered in the literature [11].

In a recent research work, Salti and El-Kanj investigated the effect of various feedback channels on students' perceived learning within a PBL context. The quantitative results showed a strong correlation between students' perceived learning and the facilitator's feedback through all studied feedback channels. It also highlighted that among the studied feedback channels, the most preferred feedback channel among students was the chatting-based type and commented that such results may be linked to the *ungraded* nature of this feedback channel [12].

This article extends this previous work on a larger population to further investigate the correlation between student's perceived learning and the various feedback channels, while adding the *graded/ungraded* feedback dimension. It also explores the main features of various feedback channels as an attempt to define the characteristics of effective feedback in PBL. At first, the PBL and assessment model used to promote the facilitator's feedback is presented with special emphasis on the difference between formative and summative assessment components and consequently the difference between *graded* and *ungraded* feedback. The modifications on the student survey's study environment, model, hypotheses and methodology explained by Salti and El-Kanj are then highlighted, to finally present the results and draw relevant conclusions [12].

THE PBL MODEL, ASSESSMENTS AND FEEDBACK

The PBL model used in this study is a course-based PBL model that started in 2015 at the Australian College of Kuwait which is now known as Australian University (AU) - Kuwait. In this model, the introduction of PBL in a particular programme is achieved by simply converting the delivery of a selection of courses that heavily rely on practical experience from traditional lecturing to PBL [4]. Since its introduction, many elaborations to this model have been established resulting in a PBL facilitator guide that documents the common PBL design principles at AU. However, to promote creativity, the implementation details of each PBL course is unique and strongly depends on its intended learning outcomes.

Under the context of this study, the Introduction to Computing with C++ PBL course is considered. It is a mandatory requirement in the third year of the Electrical and Electronics Engineering Technology programme. It aims at practicing and enhancing the programming knowledge and skills of students majoring in electrical and electronics engineering. It extends the basic programming knowledge that was previously acquired by students in a pre-requisite course (e.g. arithmetic operations, selections, repetitions and simple arrays) to more sophisticated programming concepts, such as manipulating complex data structures and creating sophisticated algorithms to resolve real-life problems.

At the beginning of the semester, all students are given a set of broadly defined requirements for a software program i.e. the project. They are divided into groups of five-six students and are requested to conceive, design, implement and operate a software solution using C++ programming language after a proper project planning. Although their work is fully autonomous, the students' work is closely monitored by the PBL facilitators.

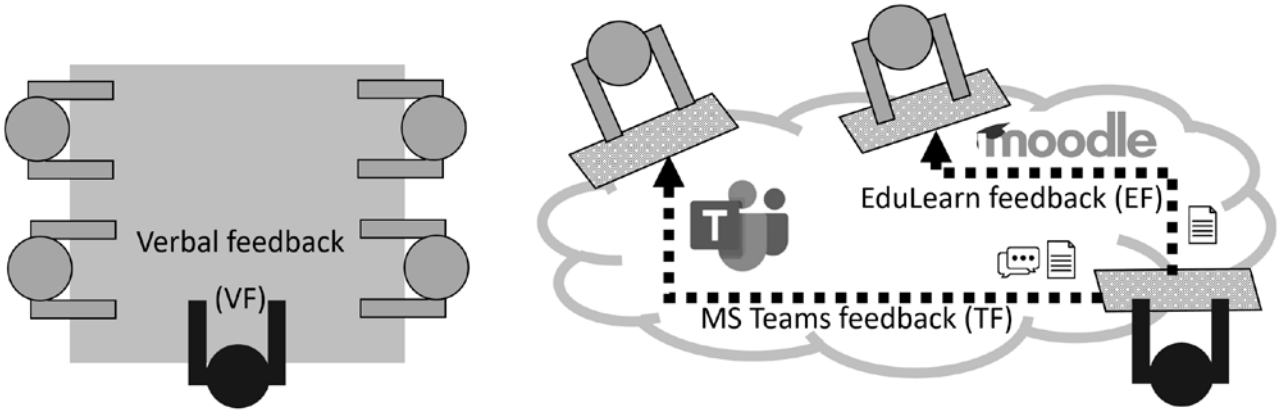


Figure 1: Feedback channels.

As illustrated in Figure 1, monitoring students is achieved through one physical channel, which is the PBL classroom; and two virtual on-line channels: Microsoft (MS) Teams and the course Moodle page called EduLearn. In the PBL classroom, the students conduct their physical meetings and/or meet with their PBL facilitators. On average, each group meets with the PBL facilitators at least twice a week for a total duration of around one hour per group per week. During these meetings, which are synchronous by nature, the facilitators provide verbal feedback (VF) to guide students on how to improve their learning and address their questions and enquiries. As for MS Teams, a private virtual channel is created for each group which is considered as the main communication platform between the students in that group. It is their private space where they can chat, conduct virtual meetings, share documents, etc, while maintaining the minimum required levels of professionalism.

The PBL facilitators are members of all groups' private channels and might chat with students at any time, to give them MS Teams feedback (TF) to motivate them, comment on their work and give them advice. The course Moodle page on the other hand, is considered as the official communication platform. It is used by students to access official material, such as project description, grading criteria, PBL guides, templates, announcements, etc. It is also used by students to track submission deadlines, officially submit their various assessment items (e.g. progress reports, meeting minutes, etc) and receive EduLearn feedback (EF) in the form of written comments embedded by their facilitators in their submitted files.

As part of their evaluation, students are assessed as groups and individuals throughout the semester using a variety of assessment tools: a written assessment in the form of a quiz usually towards the end of the semester, deliverables distributed evenly throughout the semester weeks (project plan, meetings minutes, individual reports, project code, project flowchart and program user manual), and oral examinations (interaction, mid and final presentations). For each of these assessment tools, students are given clear instructions, guidance and continuous feedback through the various communication channels discussed earlier. Although each of the previously listed assessment tools results in a quantitative grade that contributes to the final grade of a student, many of them have formative and summative assessment components.

As detailed by Subheesh and Satya , a formative assessment is an *assessment for learning*, whereas a summative assessment is an *assessment of learning* which, in contrast to a formative assessment, is usually translated to a quantitative numerical grade that contributes to the final student's grade [13]. As such, in what follows, feedback provided by the facilitator after a formative assessment is considered as *ungraded feedback*, whereas feedback following a summative assessment is treated as *graded feedback*.

Let us take for example the project plan assessment tool in the studied PBL course. Students work on their project plan during the first five weeks of the semester and are required to officially submit through the course Moodle page, a first draft version by the end of week three and a final version by the end of week five. For each of these official submissions, students receive EF. In between, students might present their drafts during any of their classes to receive VF or alternatively upload their draft files in their private channel in MS Teams to receive TF.

The project plan drafts submitted through any mean are hence considered as a *formative assessment* component of this assessment item and any associated feedback is considered as ungraded feedback. On the other hand, the final version of the project plan that is submitted officially by students by the end of this assessment period (i.e. end of week five) is considered as the summative component of this assessment since it is evaluated, and students are awarded a mark reflecting the level of their project planning skills. Any feedback resulting from the final project plan submission is hence considered as graded feedback.

STUDY HYPOTHESES AND METHODOLOGY

This study is an extension of the work presented by Salti and El-Kanj, where the three feedback channels defined earlier, VF, TF and EF, in addition to one more channel named official feedback (OF), were considered as independent input variables and were assessed for correlation with two output dependent variables, namely, student perceived learning (SL) and student satisfaction (SS) [12]. Since the model, hypotheses and methodology of the previous study were thoroughly discussed by Salti and El-Kanj, only their updates are presented here [12].

First, the OF variable and its corresponding hypothesis (H4) are discarded since OF was not applied on the new population. Second, one new input variable called ungraded feedback (UGF) is introduced to study its correlation with SL. Accordingly, the new model is governed by the following five hypotheses, four of which (H1, H2, H3, H5) are common with, and numbered alike, those by Salti and El-Kanj [12], and one is a new hypothesis (H6):

- 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).
- H5: Students' perceived learning has positive effect on students' satisfaction (SL➔ SS).
- H6: Ungraded feedback better effect than graded feedback on students' perceived learning (UGF ➔ SL).

On the other hand, the model also tries to investigate answers for the following exploratory question:

What are the characteristics of effective feedback in a PBL scenario?

A questionnaire consisting of four parts was developed. The first part was used to collect the population demographics. The second and fourth parts were used to test the validity and significance of hypotheses H1, H2, H3, H5 and H6, while the third part aims at exploring possible answers for the exploratory research question. The model is applied on the PBL model discussed earlier during the Fall and Spring semesters of the academic year 2022-2023. Whereas the students enrolled in the studied course in Spring filled the updated survey completely by the end of the Spring semester (week 12), those of Fall, who already filled part 1, 2 and 3 in Fall were called back in Spring to fill only part 4. The whole population of the study consisted of 61 students. In total, 59 students completed part 1, 2 and 3 of the survey with 97 %

response rate. As for part 4, only 48 students responded with a 79% response rate. There was a good balance between males and females and most of the participants were below the age of 22 (~63%) with a normal distribution of GPA.

STUDY 1: HYPOTHESES VALIDITY

The data of parts 2 and 4 of the questionnaire were used to study the five pre-defined hypotheses. Part 2 comprised nine questions (VF1-VF3, TF1-TF3, EF1-EF3) aiming at assessing the feedback means (VF, TF, EF) on students' perceived learning and satisfaction (SL, SS) like done earlier by Salti and El-Kanj [12]. Part 4 included five questions (UGF1-UGF5) aiming at assessing ungraded feedback (UGF) on students' perceived learning (SL). All questions were 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 s*trongly agree*. Data has been analysed using the statistical software SPSS 29.0.0.0 version.

Initially, a validity test has been conducted through the inter-item correlation matrix, which has been obtained by correlating each question's score with the overall questionnaire score and tested for significance with 95% confidence levels [14]. The validity results were positive. Following the validity test, a reliability test has been implemented by assessing the value of the Cronbach's alpha extracted to estimate the internal consistency and reliability of the 14 questions. The obtained Cronbach's alpha is 0.878, which indicates that the model's results are highly reliable.

After ensuring the reliability and the validity of the data collected, descriptive results and hypothesis testing are examined. Table 1 shows a summary of the descriptive statistics of the data collected. Verbal feedback scored the highest mean followed by EduLearn feedback then MS Teams feedback, with an overall mean of 4.08, 3.99 and 3.8, respectively, while standard deviations are of at most 1.4 and negative skewness for all items. The results are consistent with the ones obtained earlier by Salti and El-Kanj [12] indicating that students mostly agree that all studied feedback channels affect positively their learning experience. The ungraded feedback questions scored a mean of 4.01, which also indicates that students mostly agree that ungraded feedback positively affects their learning experience.

Table 1: Descriptive statistics summary.

Feedback type	Items	N statistic	Minimum	Maximum	Mean
VF	VF1, VF2, VF3	59	1	5	4.08
TF	TF1, TF2, TF3	59	1	5	3.8
EF	EF1, EF2, EF3	59	1	5	3.99
UGF	UGF1, UGF2, UGF3, UGF4, UGF5	59	1	5	4.01

Table 2 shows a summary of the test of correlations for the five studied hypotheses. Comparing the new results to what was obtained earlier [12], when the population increased, most correlations between the studied feedback channels and students' perceived learning went from moderate to strong at 95% confidence level. This strengthens the conclusion stating that all feedback means affect positively the students' learning, which in return reflects positively on students' satisfaction. Moreover, the results show that the correlation between ungraded feedback and students' perceived learning is the strongest, which means that students strongly believe that ungraded feedback enhances their learning. Interestingly, TF achieved the strongest correlation with SL among all other feedback channels in contrast to VF which has a moderate correlation with SL.

Table 2: Test of hypotheses.

Hypothesis	Correlation between	Result	Correlation level	Supported by significance
H1	VF➔ SL	r = 0.615	Moderate correlation	Yes
H2	TF➔SL	r = 0.737	Strong correlation	Yes
H3	EF➔SL	r = 0.729	Strong correlation	Yes
H5	SL➔SS	r = 0.788	Strong correlation	Yes
H6	UGF➔SL	r = 0.772	Strong correlation	Yes

STUDY 2: EXPLORATORY RESEARCH

The previous part of this study confirmed a strong correlation between students' perceived learning and most of the feedback channels, as well as ungraded feedback. It also showed that, MS Teams feedback acquired the strongest correlation with students' perceived learning in contrast to verbal feedback, which is the only channel achieving a moderate correlation with the same. Does this confirm that MS Teams feedback is the best from the perspective of students only because it was used to provide ungraded feedback? Or are there other hidden characteristics for effective feedback in a PBL scenario?

To answer this question, one needs to consider both the possible characteristics of the feedback itself and those of the communication channel. Under the context of this study and as far as the communication channel is concerned,

VF channel is time/location-bound since it is provided generally in class. TF and EF on the other hand, use MS Teams and Moodle as communication channels and are generally accessible by students anytime and anywhere due to their on-line nature. On the other hand, looking at the feedback characteristics, its frequency of occurrence could be an important factor to consider. Table 3 illustrates the maximum possible occurrences of graded and ungraded feedback per channel for a selection of assessment tools used in the studied PBL course.

Table 3: Graded versus ungraded feedback per assessment per communication channel.

Assessment tool	Weight	Feedback type	Occurrences		
			PBL classroom (VF)	MS Teams (TF)	Moodle (EF)
Project plan (PP)	5%	Graded	0	0	1
		Ungraded	4	Occasionally	1
Meeting minutes (MM)	5%	Graded	0	0	1
		Ungraded	3	Occasionally	2
Individual reports (IR)	20%	Graded	Occasionally	0	2
		Ungraded	Occasionally	0	0
Presentations (PRES)	30%	Graded	2	0	2
		Ungraded	2	Occasionally	0

Considering the project plan as an example, students receive ungraded VF for up to four times (one per week), one ungraded EF upon submitting a first draft of the plan (in week 3), and occasional ungraded TF whenever they share a draft in their private channel in MS Teams. Finally, they receive one graded EF after submitting their final project plan version by the official submission deadline (in week 5). By analysing Table 3, one can note that TF is always considered ungraded in contrast to VF and EF, which are graded in some occurrences and ungraded in others. One should also note that the frequency of occurrence of feedback through the studied channels is non-uniform.

Part 3 of the questionnaire aims at exploring possible answers for the posed research questions. The students were asked to rate from a scale of 5 how helpful was the feedback received through each of the feedback channels (VF, TF and EF) to enhance their performance in each of the selected assessment tools (PP, IR, MM and PRES), where 5 represents *extremely helpful*, 4 represents *very helpful*, 3 represents *somehow helpful*, 2 represents *slightly helpful* and 1 represents *not helpful*. This resulted in a set of 12 questions, one for each combination (PP-VF, PP-TF, PP-EF, IR-VF, IR-TF, IR-EF, MM-VF, MM-TF, MM-EF, PRES-VF, PRES-TF, PRES-EF). Highly reliable results (0.874) were obtained from Cronbach's alpha internal consistency reliability test of these 12 questions. Positive validation test results were also noted from the Pearson correlation matrix. This indicates that the questions' results are highly reliable and valid.

Figure 1 summarises the descriptive mean results of the 12 questions classified by assessment tool. Interestingly, VF and EF always scored averages higher than TF, which suggests that on average, students saw that EF and VF helped them enhance their performance in the various assessment tools more than TF. Besides, VF scored the highest means for the presentation (PRES) and project plan (PP), whereas EF scored the highest means for the meeting minutes (MM) and individual reports (IR) assessment tools.

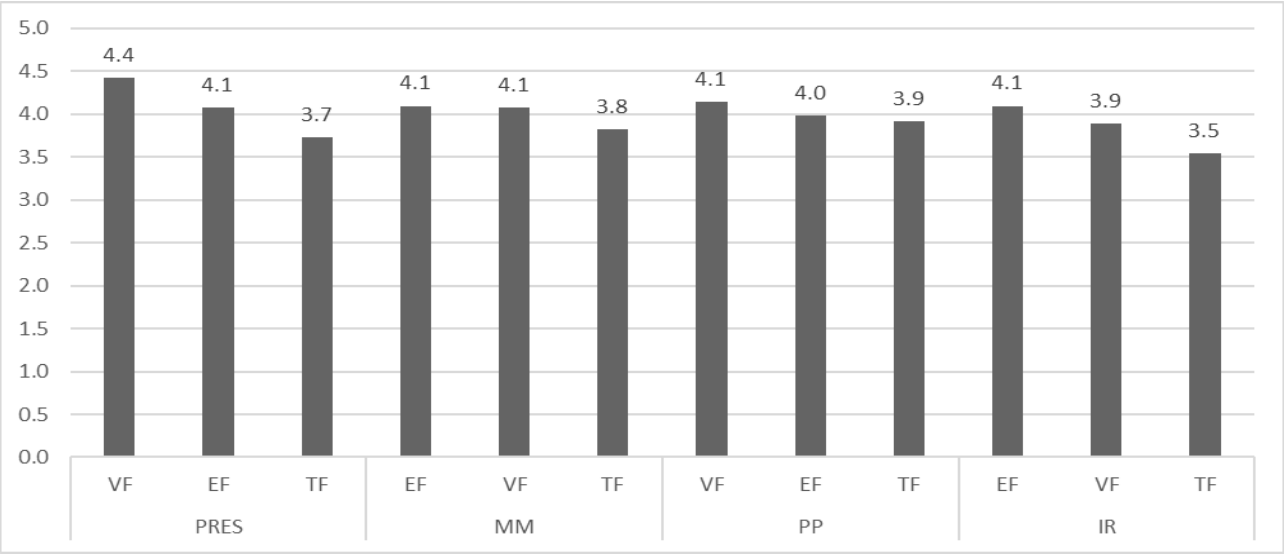


Figure 1: Descriptive statistics summary.

One might relate the results to the frequency of feedback illustrated in Table 3. For instance, the students receive frequent feedback about the project plan (PP) through VF (up to 4 times), less frequently through EF (2 times, one of

which is graded feedback), and occasionally through MS Teams, which matches with the order of means of these channels in Figure 1. As for the individual reports (IR), the students receive EF more frequently than the VF which is also compatible with the order of means of these channels in Figure 1.

DISCUSSION AND CONCLUSIONS

The hypotheses tests of this study showed a strong correlation between students' perceived learning and the various studied feedback channels, which suggests that students appreciate receiving any type of feedback, whether it was in class, on-line, verbal, written, chatting based or official comments. The strongest correlation was obtained between students' perceived learning and ungraded feedback, which indicates that students prefer ungraded feedback that results from formative assessments more than graded feedback following a summative assessment.

Comparing the correlations between students' perceived learning and the various feedback channels, the results showed that MS Teams feedback has the strongest correlation with students' perceived learning in contrast to the verbal feedback, which was moderately correlated with the same. A further exploratory step towards exploring the reason behind such results revealed that the feedback received through MS Teams was estimated as the least helpful from the perspective of students. One may hence conclude that there are additional hidden characteristics for an effective feedback channel in a PBL scenario other than the feedback being ungraded.

Indeed, the correlation between students' perceived learning and the various feedback channels might be affected by both the characteristics of the communication channel itself (location/time-bound, ease of use, etc) and those of the feedback itself (occurrence, readability, graded/ungraded, etc). Taking MS Teams feedback channel as an example, the students might have seen that this communication channel is very convenient for their learning since the characteristics of the communication channel are very advantageous compared to the others (unofficial, chatting based, on-line, accessible anytime and anywhere, etc) and because they always receive ungraded feedback through it. However, from their perspective, the feedback through MS Teams was not as helpful as other communication channels to improve their performance in their assessments, which might be linked to the low frequency of feedback they received through this channel.

As a conclusion, this study identified one important characteristic of an effective feedback channel in a PBL scenario which is the ungraded feedback. The PBL facilitators are advised to provide students with as much ungraded feedback as possible to maximise their learning. Students should be given the opportunity to try, reflect and improve with the support of their PBL facilitator who assesses formatively, provides continuous ungraded feedback, before finally evaluates and provides them with a grade reflecting the level of learning of a specific course outcome.

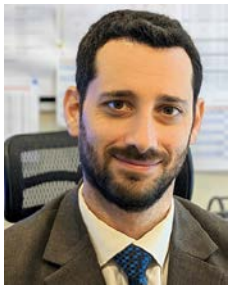
As far as the effectiveness of feedback channels is concerned, the exploratory research in this study revealed that this depends on the characteristics of both the communication channel itself and the feedback provided through it. It also highlighted that an important factor that might affect students' perceived learning is the frequency of feedback and the flexibility offered by the communication channel. More research is hence recommended to dig further into these dimensions and identify more unveiled characteristics for an effective feedback channel in a PBL scenario.

REFERENCES

1. Kokotsaki, D., Menzies, V. and Wiggins, A., Project-based learning: a review of the literature. *Improving Schools*, 19, **3**, 267-277 (2016).
2. Malmqvist, J., Edström, K. and Rosén, A., CDIO Standards 3.0 - updates to the core CDIO standards. *Proc.16th Inter. CDIO Conf.*, Bankok, Thailand: Chulalongkorn University (2020).
3. Stolk, J.D. and Martello, R., Can disciplinary integration promote students' lifelong learning attitudes and skills in project-based engineering courses? *Inter. J. of Engng. Educ.*, 31, **1(B)**, 434-449 (2015).
4. Salti, H., Farhat, M., Abdel Niby, M. and Zabalawi, I., Towards a flexible 2+2 hands-on engineering technology curriculum, *World Trans. on Engng. and Technol. Educ.*, 19, **4**, 404-409 (2021).
5. Pellegrino, J.W. and Hilton, M.L., *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century*. Washington, DC: National Academies Press (2012).
6. Peterson, B.W., Uncovering the progressive past: the origins of project based learning (2012), 03 October 2023, http://gse.hightechhigh.org/unboxed/issue8/uncovering_the_progressive_past/
7. Uziak, J. and Luyckx, M., Project-Based Learning - analysis and synthesis of mechanisms for awning window linkages. *World Trans. on Engng. and Technol. Educ.*, 6, **2**, 257-261 (2007).
8. Yan, J., Applying PBL to the teaching of a computer network technology course. *World Trans. on Engng. and Technol. Educ.*, 12, **4**, 743-747 (2014).
9. Mitchell, J.E. and Rogersb, L., Staff perceptions of implementing project-based learning in engineering education. *European J. of Engng. Educ.*, 45, **3**, 349-362 (2020).
10. Jonsson, A., Facilitating productive use of feedback in higher education. *Active Learning in Higher Educ.*, 14, **1**, 63-76 (2012).
11. Carless, D., Salter, D., Yang, M. and Lam, J., Developing sustainable feedback practices. *Studies in Higher Educ.*, 36, **4**, 395-407 (2011).

12. Salti, H. and El-Kanj, H., Effectiveness of various PBL feedback channels in engineering education. *World Trans. on Engng. and Technol. Educ.*, 21, **1**, 12-17 (2023).
13. Subheesh, N.P. and Satya, S.S., Learning through assessment and feedback practices: a critical review of engineering education settings. *EURASIA J. of Mathematics, Science and Technol. Educ.*, 16, **3** (2020).
14. Taber, K.S., The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research on Science Educ.*, 48, 1273-1296 (2018).

BIOGRAPHIES



Hassan Salti graduated as Electrical Engineer from the Lebanese University, Lebanon, and completed his Doctor of Philosophy degree in electronics from the Institut National des Sciences Appliquées de Rennes (INSA Rennes), France, in 2007 and 2010, respectively. After completing a post-doctoral fellowship at the Commission of Atomic Energy in Grenoble, France in 2011, he worked as an assistant professor in the Faculty of Computer Studies at the Arab Open University, Kuwait Branch, between 2011 and 2014. Passionate about engineering education, he later joined the Australian University, Kuwait, as an assistant professor in 2014 and was appointed as the Deputy Head, then the Head of the Electrical and Electronics Engineering Department in 2016 and 2018, respectively, and is still holding this position to date. He has a record of over 25 publications in peer reviewed conferences and journals in the fields of microwave antennas, as well as engineering education pedagogies, such as e-learning, project-based learning (PBL), and conceive design implement and operate initiative (CDIO). He is a charted professional engineer by Engineers Australia, member of the Lebanese Engineers Society, the IEEE and a CDIO leader.

Hania Ghazi El-Kanj graduated with a Bachelor of Electrical and Electronics Engineering from Beirut Arab University, Beirut, Lebanon, in 2005, and completed a Master's degree in management from Maastricht University, Netherlands, in 2014. She worked as an adjunct instructor and laboratory engineer at Jinan University and City University, Tripoli, Lebanon, respectively, between 2005 and 2010 and was appointed as a full-time instructor at the Lebanese International University, Tripoli, Lebanon, in 2007. In 2010, she relocated to Kuwait and started as a laboratory engineer at the Australian University, where she grew academically until she reached her current position of a senior instructor at the Electrical and Electronics Engineering Department. In addition to teaching in academia over the past 18 years, she has been engaged in many research projects and has over 16 publications in different topics related to renewable energy, learning management systems, engineering education and digital transformation. She is also a member of the Lebanese Engineers Society, Kuwait Society of Engineers and the IEEE.