Using Fuzzy Analytic Hierarchy Process to Assign Weights to Project Based Learning Outcomes in the Perspective of the Industry Professionals

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Abstract
Course learning outcomes (LOs) should be the centre of attention when it comes to achieving the intended learning of a subject utilizing a Project Based Learning (PBL) approach. The learning outcomes of the PBL courses are oriented towards achieving an array of goals including the enhancement of industry through preparing the student for real life scenarios that can be faced in the industry. Since increasing industry relevance is one of the biggest drives of PBL courses, this study aims to improve grading quality through assigning weights to learning outcomes by the industry professionals to reflect each learning outcome’s importance in the practical setting of the industry. Next, the learning outcomes weights shall be compared with the perspective of the PBL facilitators who assigned weights to the same learning outcomes in a previous study conducted by the authors. The objective of this comparison is highlighting any minor and major differences in the perspectives between the industry professionals and the facilitators of PBL courses.

Keywords: Project Based Learning (PBL), Fuzzy Analytic Hierarchy Process (Fuzzy AHP), Learning Outcomes (LOs), grading, Industry perspective

1 Introduction
The decision-making process could be originated on either an objective or subjective basis. The objective decision-making process depends on clearly defined and measurable attributes that carry numerical values while subjective decision-making is rather qualitative and could be variable based on different perceptions. Undoubtedly, subjective opinions cannot be measured on an arithmetic basis in decision making. Nonetheless, the Analytic Hierarchy Process (AHP) attempts to convert these intangible attributes through using structured pairwise comparisons with numerical judgments in order to reach the preferred decision (Bhushan and Rai, 2007). An absolute scale is used to compare the difference between two
options and illustrate their significance based on pre-set criteria that are deemed necessary for the decision in hand. Pairwise comparisons are measured using a scale that could be formulated through various approaches (Dong et al., 2008). AHP has been successfully applied in various fields including manufacturing, government and education (Ho, 2008). AHP is primarily found on fundamental components including a multi-level structure with pre-set goals, decision criteria and an aggregation method to acquire the final composite vector of priorities (Saaty, 1990). AHP has established its degree of effectiveness when it comes to making decisions concerning specific and well-defined issues rather than generic issues (Lam and Zhao, 1998).

At the beginning of the decision-making process, AHP compares the alternatives through choosing a number from an absolute scale based on knowledge and experience within the relevant domain. Experts interview is a common data collection method in the AHP. These interviews are potentially accompanied with the Delphi technique which is a systematic and interactive forecasting method that depends on a panel of specialists for taking a decision through several iterations (Elmer et al., 2010). The person directing the Delphi technique is known as a facilitator, and supports the responses of the panel of experts. These opinions are coined in the comparison matrix which illustrates the homogeneity, reciprocity and consistency of the collected data. Typically, the participants’ subjective judgements would potentially carry inconsistency unless these opinions are moderated in an artificial manner.

2 Course Evaluation

Two PBL courses were studied for this research. “Project Planning” and “Project Implementation” represent the two parts of the graduation project required for the students to complete their studies. Both courses are delivered through a PBL approach in the Higher Education Institution that was observed. The outcomes of these courses emerged to satisfy the graduate attributes of Engineers Australia for the purposes of acquiring accreditation for the institution. These learning outcomes are assessed as either “unacceptable – acceptable – good – excellent” based on the student’s performance. Further elaboration is provided for each learning outcome in order to assess the student’s performance in a clear manner. For instance, the expected performance criteria of (LO2) in the “Project Implementation” would set the guidelines for the students to pursue a certain grade within the studied PBL course.

Student assessment by the PBL facilitators expands further to cover informal formative assessments. This is reflected through the weekly monitoring of the students learning based on the student performance and self-reflection. On the other hand, the formal summative
assessment requires that the student would prepare a portfolio that is submitted and graded at
the end of the semester. This portfolio should reflect the student’s reflection on learning,
weekly reports and actual project work completed (including a technical report and technical
drawings). The final portfolio is usually accompanied with an oral exam by an examination
panel of at least three faculty members to confirm the sincerity and ownership of the
submitted work following a presentation by the students showing their work. Additionally,
and to provide an early feedback to the student, a mock assessment is done for the portfolio to
illustrate the current student performance and manage their expectations for their final grades.

The final grade calculation is done through multiplying the number of learning outcomes by
the performance level (6 for acceptable, 8 for good, 10 for excellent). For instance, if a
student received an acceptable level in five learning outcomes and a good level in 3 learning
outcomes, the resulting percentage grade would be: 
\[(5 \times 6 + 3 \times 8) / 8 \times 100 = 67.5\%\]

This approach of assessment conveyed certain challenges within the process. The most
significant challenge was the fact that all the PBL facilitators agreed that the learning
outcomes do not represent the same significance based on their industry experience
(Mughrabi et al., 2017). A representative sample of PBL facilitators were requested to
indicate the relative importance of different learning outcomes and the results show how all
the participants recognize that learning outcomes should not be treated equally and should not
carry the same weight of the final PBL course grade (Mughrabi et al., 2017).

It is a rather unique approach for an institution to possess a systematic and regulated approach
to allocate weights to PBL learning outcomes based on their importance. Nonetheless, this
approach has focused solely on the insights of the PBL facilitators and did not allow industry
professionals to express their opinions of the varying significance of PBL learning outcomes.
Since preparing the students for the challenges of the workplace is prioritized in a PBL
course, this study will also consider the perspectives of the industry professionals within the
studied domain to ensure the alignment between the learning outcomes weights and the
industry requirements. The following methodology section shows the application of the Fuzzy
AHP approach in order to highlight the main differences in the ranking and significance of the
PBL learning outcomes in the perspectives of the industry professionals and the previous
results of the PBL facilitator.

3 Research Methodology
The usage of AHP for ranking diverse criteria was regarded as one of the most vital applications of the method (Saaty, 2003). However, it was observed that the conventional AHP process lacks adequacy for complex and ambiguous situations (Pang, 2006) where the fuzziness of the human’s selection would have a high degree of collision on the decision-making process. In such scenarios, it is more effective to use the Fuzzy AHP process to conclude an adequate decision concerning an inexplicit matter (Buckley, 1985). The case study research method used illustrates how the Fuzzy Analytic Hierarchy Process (Fuzzy AHP) was used in ranking and appointing weights to the learning outcomes of two different PBL courses through extracting and aggregating the perspectives of industry professionals. These perspectives shall be then compared with the previously discovered perspectives of PBL facilitators who expressed their opinions concerning the weights of the same PBL LOs in the study conducted by Mughrabi et al. (2017). This attempt should highlight how aligned the current learning outcome weights in PBL courses are with the industry needs and requirements as indicated by the industry professionals. This comparison between the perspectives of the PBL facilitators and industry professionals would in turn enforce the industry relevance of the delivered PBL courses that are delivered in the School of Engineering of a Higher Education Institution located in Kuwait. Figure 1 shows the learning outcomes of the “Project Implementation” course while Figure 2 shows the learning outcomes of the “Project Planning” course.
LO1: Demonstrate a capability to apply to a substantial degree the Engineers Australia generic attributes for engineering technologists to an engineering project.

LO2: Implement the plan prepared for the project, monitor and review project progress, and take initiative to resolve problems, adjust project strategies and maintain work and reporting schedules.

LO3: Work and learn autonomously and in a professional manner and communicate effectively using formal and informal progress reports, professional presentations and project documentation.

LO4: Gather, evaluate and extract relevant information from key sources and relevant authorities and use information effectively to justify analysis, project choices and decisions.

LO5: Think critically, demonstrate sound analysis, make sound judgements in all stages of the project and articulate decisions and supporting thinking in project working documents for the project supervisor and in final reports & presentations.

LO6: Solve technical problems and issues that arise, explain judgements made based on technical knowledge and standard practice.

LO7: Identify and comply with relevant safety, risk, sustainability and other professional requirements.

LO8: Evaluate project processes, technical outcomes of the project and the lessons learned from the project experiences.

LO9: Write a formal technical report and dissertation describing the project, the issues faced and the choices made in managing or implementing the project, the reasons for making choices, project evaluation and what was learned from the project experiences.

Figure 1: Hierarchy of “Project Implementation” Course Learning Outcomes
3.1 Data Collection

A questionnaire survey was distributed to a sample of twelve industry professionals who are currently employed at engineering related companies or self-employed and competing in the engineering domain. The sample included a varying range of different years of experience, engineering subdomains, positions of employment and organisational size. The data collection was conducted through face to face interviews to increase the response rate and answer any questions concerning the content of the survey itself such as explaining the intended meaning of each learning outcome. The interviewees would typically indicate their preference between the compared learning outcomes on a qualitative scale known as the AHP scale (Bhushan and Rai, 2007).

3.2 Data Analysis

The data analysis process initiates with creating a pair-wise comparison demonstrating the relative importance of $N$ number of criteria. The comparisons are structured into a square matrix where the diagonal elements of the matrix are equal to 1 since the criterion would be
compared to itself in these elements. The matrix should be created through a custom that the $(j, i)$ element of the matrix is consistently the reciprocal of the $(i, j)$ element (Bhushan and Rai, 2007). The value of the element $(i, j)$ is more than 1 when the criterion in the “$i^{th}$” is considered more important than criterion in the “$j^{th}$” column. The value of the element would be less than one of the opposite scenario was indicated by the participant. The Eigen-vector of the matrix would then be created and normalized to designate the comparative weight of the criteria being compared.

The consistency of the resulting weights should then be checked and reviewed to compensate for the relative subjectivity of the decision-making process. That would be done through calculating the Consistency Index (CI) and the Consistency Ratio (CR). The CR should not exceed the consistency threshold of 10% to be considered valid (Saaty, 1990). If this threshold is surpassed, the participants judgement is allegedly inconsistent and lacks trustworthiness. Based on this threshold, one participant’s response was eliminated from the aggregated opinions since it was highly inconsistent (CR= 20%). The remaining participants provided perspectives that proved consistent and was eventually used for the ranking of LOs thus resulting in having eleven respondents per course. A sample that is sufficient since fuzzy AHP does not necessitate a large sample of participants (Lam and Zhao, 1998).

After gaining the perspectives of the participants, aggregating the opinions of the industry professionals would be needed to produce the ranking and weighting of the learning outcomes through summarising the AHP weight known as the aggregate crisp judgment matrix (Xu, 2000). This method requires that all the weights illustrated through the participants’ perspectives to be added and averaged then finding which average is comparatively highest to determine the ranking. Figures 3 and 4 show the calculated aggregate crisp judgement matrix of both the “Project Implementation” and “Project Planning” courses in addition to showing the overall weights represented by the normalized Eigen-vectors. The bigger the weight the higher the ranking of the LO.

Clearly, the participants ranked LO1 as the least substantial in both courses. This may be caused by the perceived redundancy of LO1 which is a summary of the remaining LOs yet it apparently comes across as unclear to the interviewees.
When comparing the results with the perspectives of the PBL facilitators as produced by Mughrabi et al. (2017), it is worth mentioning that the weighting of the industry professionals is distributed more evenly. This indicates that the industry professionals do not recognize how certain LOs are largely more significant than the others. For instance, even though both the industry professionals and PBL facilitators recognize that LO7 in the “Project Implementation” course is more important than LO1, the difference in weighting varies considerably. The PBL facilitators see that LO7 is twenty-two times more important than LO1 while the industry professionals see that LO7 is approximately twice as important only.
This could be sourced to the variation of perspectives where PBL facilitators are more familiar with Engineer’s Australia graduate attributes thus could express a judgement with additional decisiveness. Nonetheless, since both the PBL facilitators and industry professionals perceives LO1 as unworthy and the least noteworthy LO in both courses, the institution should consider eliminating it from its delivered PBL courses to enrich the content and industry alignment.

On another note, the industry professionals ranked LO7 as the most significant learning outcome in “Project Implementation” and LO8 as the most important in “Project Planning”. On the other hand, PBL facilitators ranked LO7 as second in “Project Implementation” and surprisingly ranked LO8 as the fifth most important learning outcome in “Project Planning”. Evidently, the industry professionals perceive that learning about safety is the most important aspect within PBL courses which is reflected through the high prioritization of LO7. The industry professionals also value high communication skills and abilities above all when it comes to the “Project Planning” thus collectively have chosen the LO8 as the most significant learning outcome. It is understandable that the industry professionals and PBL facilitators would not necessarily agree on the ranking of LOs.

4 Conclusions

The opinions of the industry professionals who possess extensive experience in engineering domains were collected and aggregated through the fuzzy AHP method concerning the LOs of two PBL courses that are delivered in a Higher Education institution. These opinions were contrasted against the opinions of PBL facilitators who are employed within the institution and the results show that the perspectives of both parties vary when it comes to the significance of the learning outcomes. Agreement on ranking was not the aim of this study rather than enhancing the alignment of the learning outcomes with the industry requirements. Industry professionals clearly indicates their preferences through prioritizing safety knowledge and communication skills and illustrating that they need to be covered within a PBL course. The institution should adequately introduce the opinions of the industry professionals within PBL courses to widen the prospects of its engineering graduates and provide them with the competitive edge that the graduating students actually needs.
References


