Effective Assessment Strategies for Project-Based Learning

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Abstract*—Rapid technological changes have radically changed the expectations of employers from the current generation of engineering graduates, necessitating educators to focus on the development of core subject comprehension and required skills among the students in their engineering programs. Research has shown that project-based learning (PBL) is an effective pedagogy to address this dual requirement of core technical knowledge and skills to effectively utilize this knowledge to solve problems. PBL is a pedagogical approach wherein students work to address real-world problems and challenges through the application of knowledge acquired in the class, unlike the traditional classroom approach involving lectures, studying, and taking tests. The core of every PBL course involves effective cooperation, collaboration, and communication among students and between students and faculty. It is believed that this hands-on learning through problem-solving, combined with the development of soft skills, helps enhance learning outcomes and elevates learning to higher cognitive levels. An innovative course titled "Engineering Exploration", taught and co-designed by a multidisciplinary faculty is offered at the authors' institution. The course is a core component of the first-year undergraduate engineering curriculum. During this course, students learn about and apply the full range of engineering design tasks, from the development of need statements and problem definition to virtual and physical prototyping, to solve real-world problems. A continuing outcome of this course is interdisciplinary problem-solving, engineering design process, and teamwork. Effective assessment of student learning is a challenge in PBL courses. To address this constant challenge, the authors have developed a comprehensive assessment strategy, incorporating summative, formative, and diagnostic assessments, to assess student learning throughout the course. This paper presents a discussion of these strategies, our experiences and observations, and strategies to incorporate the same into PBL courses.

Keywords— project-based learning, assessment, diagnostic assessment, PROBE

I. INTRODUCTION

The Contemporary employment market has placed an unprecedented demand on graduates due to the rapid transition to a global knowledge society. Working in today's world typically entails being able to operate in vague and constantly altering contexts, dealing with abstract work and other than routine processes, managing decisions, and responsibilities, and working in groups. As a result, graduate students must acquire higher-order abilities and fundamental knowledge relevant to their domain and various higher-order talents and attitudes. To achieve this, educators are focusing on developing and implementing 21st-century skills in an undergraduate engineering program. Project-based Learning(PBL) is one such method that can address core knowledge and 21st -century skills proposed by Bell S. (2010), Devkota et al.,(2017), Vijaylakshmi et al., (2021). PBL pedagogy entails a dynamic classroom PBL is a pedagogy that entails an energetic in-class approach, where students are provided with an opportunity to be actively involved in solving real-time problems. PBL is an inquiry-based and active learning style, and it emphasizes activities that are, student-centered, long-term, and interdisciplinary. Unlike in a traditional classroom, where students attend in-class lectures, take tests, and study. . In PBL, it is learning by doing an activity (LbD) where students get an opportunity to explore challenges and problems of real-world applications, which will increase the possibility of long-term retention of concepts and skills. The core of every PBL course is to bring positive connectivity and cooperation between the students and teachers to solve the problem. In PBL critical thinking helps in finding a solution to the problem, it also helps in connecting individuals to the real-world problem and projects. whereas creativity helps in imagining the practical solution. Communication and collaboration are also essential among the team members to incorporate the best of everyone's ideas into a collective solution.

In today's learning environment according to Dierick et al., (2001) assessment is not only seen as a coping stone but also seen as a building stone. It is widely thought and demonstrated that assessment modes significantly impact students' learning process (Gibbs, 1999; Scouller, 1998). As a result, the assessment is emphasized in a constructivist learning environment. An assessment approach must be followed inside the learning environment to acquire a better understanding of the learning process.

The KLE technological university offers an innovative course titled "Engineering Exploration," taught and co-designed by multidisciplinary faculty. This course is offered primarily to first-year undergraduate engineering students. Its enduring outcomes are interdisciplinary engineering, teamwork, problem-solving, and engineering design process. Students work right from need statement, problem definition, generating concept, product architecture, selecting concept, virtual prototyping, and physical prototyping. It is constantly challenging to assess students in project-based learning courses. To address this issue authors have developed a PBL assessment strategy to measure the student's understanding

from the beginning of the project until the end. Assessment strategies include Diagnostic assessments, formative assessments, and summative assessments. Diagnostic assessment helps in understanding students' current knowledge level. Formative assessment helps students with revision and improvement, while the students' skill acquisition, academic achievement, and student learning are assessed using summative assessment.

Section II discusses the past efforts carried out to assess the project-based learning activities. Section III and Section IV discuss the assessment strategy proposed and the outcomes of the assessment strategy. Finally, section V presents results and discussion.

II. Literature Review

According to Bender, T. (2012), PBL means working cooperatively to solve a problem. In PBL, working in groups is an essential parameter for the project; students must work in a team to solve the real-time problem. Bender mentions that working in a team makes students interact with peers in a social context. In addition to this, researchers have stated that students learning increases through shared cognition(Levine et al., 1993). The second important element of PBL is student voice and choice, in project voice is a natural motivator and even students feel that they are more in control of their learning. Even the students must be motivated to be independent in learning (Filsecker et al., 2014). It is the role of faculty to provide opportunities for voice and choice. Another element is technology, it's essential in developing 21st-century skills, and it may be in using the internet to gather information, using image/video editing software, or creating blogs for collaboration and reflection where the technology is emphasized. In addition to the elements discussed above, publicly presenting is also more important, which drives a student's motivation to feel a great sense of responsibility and ownership (Filsecker et al., 2014).

Since PBL, projects can vary and have diverse solutions. Assessing PBL projects is challenging; however, we need to make assessment an integral part of the PBL process to determine whether the objectives of the PBL are met. It inspires us to think if students are learning what they are supposed to learn and if are there better ways to teach the subject to promote better learning. Assessments affect decisions about curriculum, instructional needs, advancement, placement, and grades(Aydeniz et al., 2012; Dietel et al., 1991). Even though project-based assessment is student-centered, it needs reflection on content and process to be more meaningful. Hence, it is necessary to assess the PBL projects at various stages, like before delivering content to inspect the understanding level of the students about the current knowledge and misconceptions about the given topic. Then we need to do formative assessments to provide feedback on their learning of the subject. Finally, we need to do summative evaluations where we can judge the overall understanding of the students.

According to Black, P. (2002), formative assessment is superficial when assessing a particular task, whereas diagnostic assessment is a detailed inquiry. William and Thomson (2017) say diagnostic assessment needs to be considered when it provides information about the wrong things and formative when it gives guidance about what action to be taken. Bennet (2011) discusses the different issues in formative assessment. He concludes that the formative assessment approach should be conceptualized as a part of a comprehensive system, where all components work together to facilitate learning. Research carried out by Bulunuz (2016), where the data indicates that the study about formative assessment should be revealed pedagogical practitioners based on assessment strategy, which fosters the enhancement of the student's interpretation skills, explanation of things, and reasoning as well. In literature majority of the studies on project-based learning were based on the pre-test and post-test. Still, due to changes in technology and based on the ability of the teachers to scaffold the student's learning and support and provide guidance, there needs to be a balance between educational instruction with in-depth inquiry and well-defined assessment(Kokotsaki et al., 2016). Moreno-Ruiz et al., (2019) mention in their study that the formative assessment approach helps students to build self-awareness and strengthen their learning and self-control. Oliva states that in the learning process improvement grading process and verification are supported by formative assessment (Oliva et al., 2015). Along with formative assessment, diagnostic assessment is used to check students' metacognition skills and strategies, which they are aware of at the beginning of the project—diagnostic assessment helps the tutor recognizes when differentiated or personalized instruction is required for certain students. The final evaluation of the projects is carried out using summative assessments to check the performance of the students and assign grades. Summative assessment assesses both process and content of the project. From the literature, is been observed that for successful completion of project-based activity integrating proper assessment strategy is very important. This paper proposes a hybrid project-based assessment strategy to assess the student's project, which is discussed in the methodology section.

III. Methodology

This section discusses the assessment strategy for the Project-Based learning course, i.e., the Engineering Exploration course that we are offering at the KLE Technological university. Figure 1 shows the various modules of the exploration course. this course is offered to first-year engineering students and is of 3 credits. Baligar, P et al., used unique features to characterize the course, like promoting students learning by exploring and LbD.

It uses PBL pedagogy as shown in figure 1, that focuses on developing the design process and implementing a mechatronics prototype.

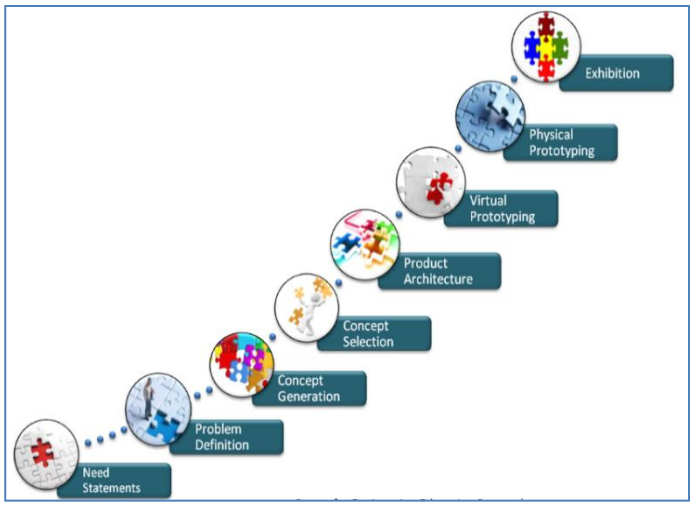

Fig 1. Engineering Exploration project design process and prototyping

In order to ensure the students learning, we are proposing a hybrid assessment model, which is shown in figure 2. Dilova, N. G. (2021) mentions that assessment has three types formative, diagnostic and summative assessment.

The Diagnostic assessment occurs before the instruction that assists teachers in understanding the students' current knowledge level on the project-related things. Even it will help us learn how to improve the gaps and the required resources to learn the concepts. This assessment is suitable for pre and post-assessments. We designed a Post-test activity for Reviewing Outcomes and gaining feedBack for student Engagement(PROBE) as a diagnostic assessment. These assessments include a mind map, quizzes, one-minute papers, exit tickets, and discussion forums.

The formative assessment occurs during the instruction, and the goal is to enhance the learning. For every module and in each session, a formative assessment is planned. This assessment method helps advance the learning and allows teachers to monitor and adopt new pedagogy in their instructions based on the students' performance. These assessments include taking home assignments, portfolios –ongoing, phase-wise submission of a project, Think-pair-share, critiques, peer review, informal presentations, and sketchbooks.

At the end of the activity or at a particular instance summative assessment helps to predict and judge the students' performance. The goal is to prove rather than improve the enactment. These assessments include teacher-created tests, Portfolios culmination, Multiple choice, Project Tests, prototype presentations, project presentations, and performance tests.

The hybrid assessment approach is applied to all the modules of the engineering exploration course where PBL pedagogy has been used. In this paper, we will be discussing a case study to explain the hybrid assessment model applied to the Mechanism module of the engineering exploration course. The module's learning outcomes are that the students should be able to explain the need for a mechanism, identify basic components of the linkage mechanism, and build a mechanism for a specified application.

Mechanism module hybrid assessment is as shown in figure 3. Before delivering any module content, a PROBE activity is conducted. Students will be assessed using the PROBE activity to check students' readiness for the upcoming class. The expectation of the PROBE activity about the mechanism module is identifying mechanisms for functions. Vijaylakshmi. et al., (2021) say in order to advance a rudimentary understanding of the mechanism module, students were asked to watch videos pertaining to the mechanism module posted in the Moodle-based learning management system(LMS). Once the students came to the class, first we conducted a PROBE activity, and we asked them to select one working function with motion activity and get one mechanism for each function identified. The function identified needed to have a mechanism to achieve its functionality. The students chose a function based on their understanding of the concept. The PROBE activity was graded at two levels for a total of 5 points. At Level 1 (worth 2 points) they were graded on their ability to identify a function and a mechanism to implement it. Grading at Level 2 (worth 3 points) was performed considering their ability to justify/defend the feasibility of the selected mechanism to implement their chosen function.

Sample question for the mechanism PROBE activity;

1. Identify the one function related to the motion for the given need statement.
2. Justify the feasibility of the selected mechanism for the defined problem statement.

A formative assessment was conducted to assess students' understanding of the concepts. The focus of the formative assessment is to assemble a simple robotic arm using a mechanism activity kit. The model should consist of all the mentioned links and motors as informed. The mechanism should be controlled in such a way that the two links connected to the motor rock/move in less than two seconds duration. This activity helps us understand whether students could select the components, build the model correctly, and integrate all the components to realize the application and functioning of the model is accurate.

The physical prototype developed based on the need statement given is assessed using a summative assessment model. The physical prototype should be a mechatronics prototype. This mechatronics prototype should include a mechanism. The students are evaluated based upon the overall functioning of the prototype, in that faculty is observing the type of mechanism used and conceptual understanding of the mechanism selected for the final prototype. Rubrics are used to grade the performance of the students.

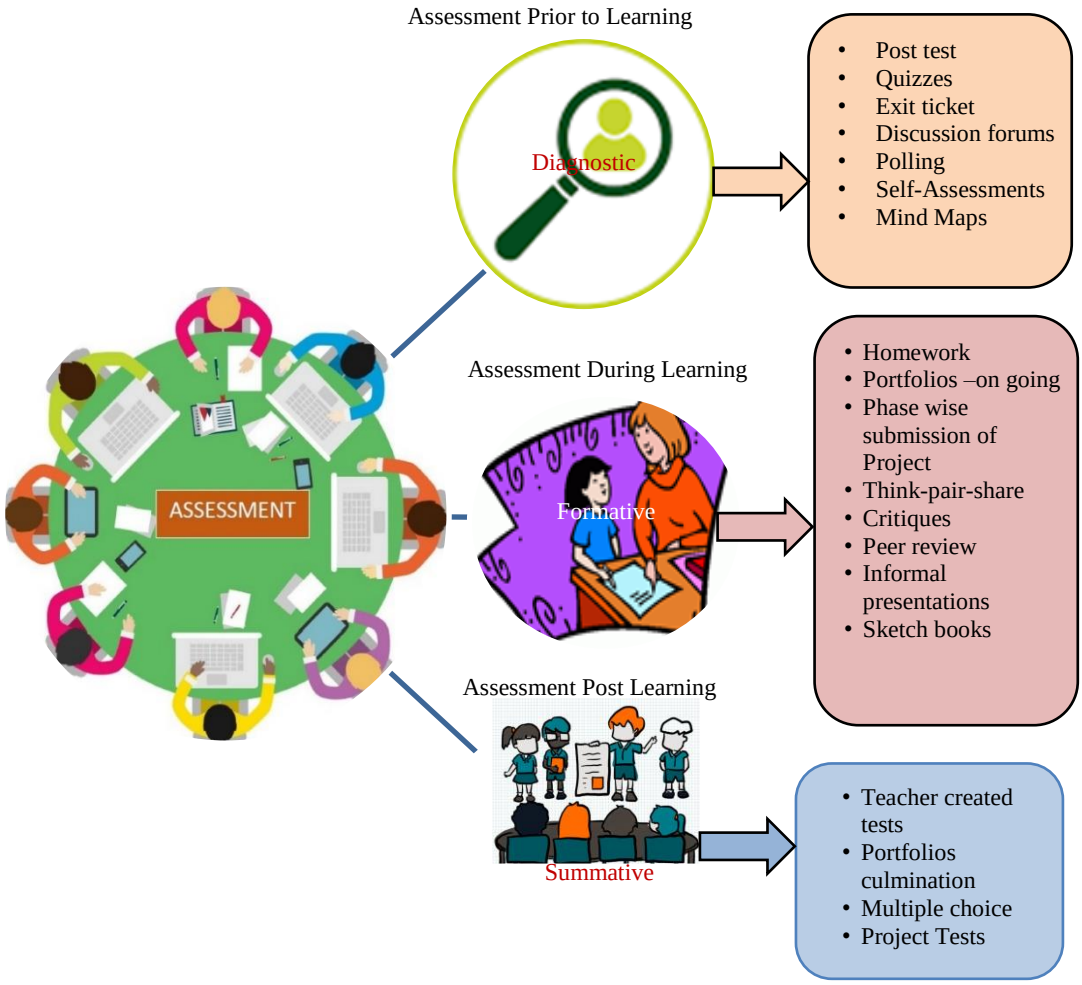

Fig 2. Hybrid Assessment Model

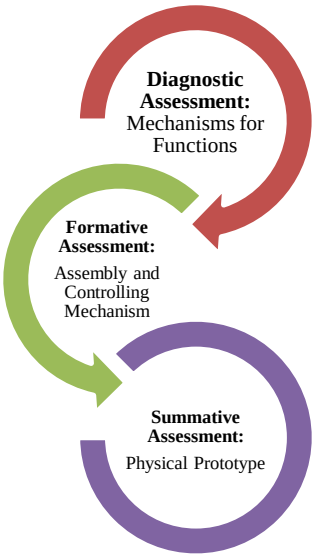

Fig 3. Hybrid Assessment model for Mechanism module

IV. Results and Discussions

The effectiveness of assessment in the PBL course is discussed in this section. As mentioned earlier, an Engineering Exploration course is delivered using PBL pedagogy, where each session will have a set of activities towards the project development. Figure 4 shows sample images taken during the activity. To inspect the understanding level of the students on the content delivered and their effectiveness towards the need statement to build a mechatronics prototype is assessed using the hybrid assessment model as discussed in the methodology section. Here we will be discussing the results emphasizing on the assessment of the mechanism module.

Fig 4. Sample Images of students doing mechanism activity

The data obtained from students' assessments were analyzed to see the effectiveness of the hybrid assessment approach. The student population was N=65 for which the assessment was conducted. The data analysis was done using IBMSPSS Version26.

Table 1 provides the statistical information of three different assessments. The weights for each assessment were measured from 1 to 5 and 5 being the highest and 1 being the lowest. The mean for student's assessment for PROBE activity was M= 3.43, whereas for formative assessment (Mechanism) and summative assessment (prototype) were M=4.22 and M=4.38, respectively. It was observed that the mean (M=4.38) for summative assessment was reported largest when compared to PROBE and formative assessment. The standard deviation for PROBE activity was S.D=1.060, formative assessment S.D.= .696, and summative assessment was S.D=.784. It can be observed that the standard deviation for PROBE activity was the largest.

TABLE I.
HYBRID ASSESSMENT STATISTICS

Statistics				
		Probe (Diagnostic Assessment)	Mechanism (Formative Assessment)	Prototype (Summative Assessment)
N	Valid	65	65	65
	Missing	0	0	0
Mean		3.43	4.22	4.38
Median		4.00	4.00	5.00
Mode		4	4	5
Std. Deviation		1.060	.696	.784
Variance		1.124	.484	.615
Skewness		-.706	-.319	-1.007
Std. Error of Skewness		.297	.297	.297
Kurtosis		-.110	-.877	.071
Std. Error of Kurtosis		.586	.586	.586

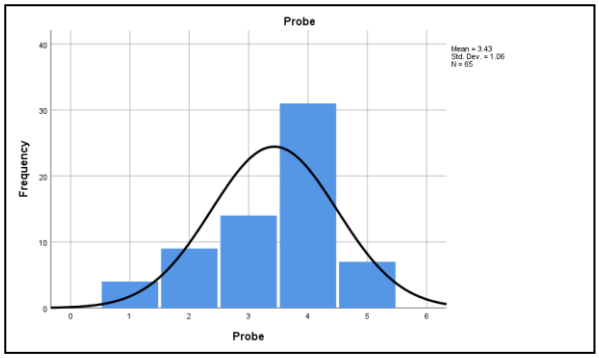

Fig 5. Score distribution for PROBE activity

Figure 5 indicates the student's score distribution for PROBE activity. As per the data, 6.2% of students scored 1, 13.8% of the students scored 2, 21.5% of students scored 3, 47.7% of students scored 4, and 10.8% of the students scored 5.

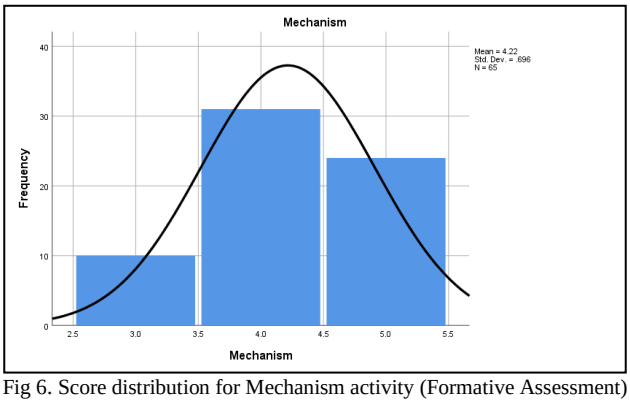

Fig 6. Score distribution for Mechanism activity (Formative Assessment)

Figure 6 indicates that for mechanism activity (formative assessment), 15.4% of students scored 3, 47.7% of students scored 4, and 36.9% percent of students scored 5. Based on the

data it can be said that for formative assessment where most of the students scored in the range of scores 4 and 5.

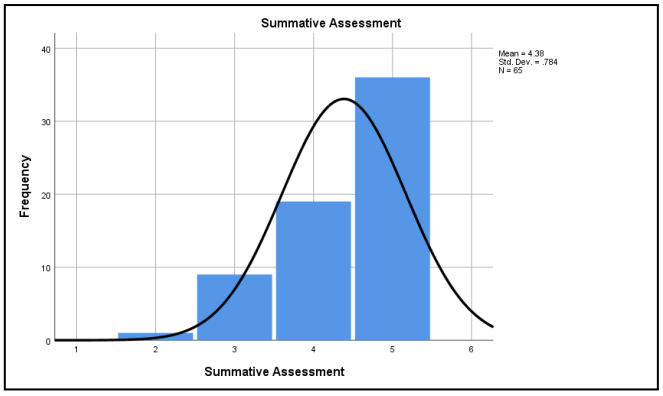

Fig 7. Score distribution for Prototype activity(Summative Assessment)

Figure 7 indicates the student's score distribution for the Physical prototype (summative assessment). As per the data reported 1.5% of students scored 2, 29.2% of students scored 4, and 55.4% of students scored 5.

Based on the analysis it can be observed that students' scores varied throughout the assessment process. As previously stated, the core idea behind conducting a PROBE/Diagnostic assessment was to understand students' readiness/preparedness for the upcoming class. Subsequently, based on the student's performance on the PROBE assessment, the content was modified predominantly focusing on improving students' understanding of the concepts in which their performance was low. Subsequently, a formative assessment was conducted to check the student's understanding of the concept. Finally, a summative assessment was done to analyze students' overall understanding of the course. According to the data, we found in the formative assessment number of students who scored 5 has a 26.1% increase when compared to PROBE. Similarly, when we compared summative assessment with formative, we found the number of students who scored 5 increased by 18.5%. The standard division for the PROBE (S.D = 1.060) is the largest when compares to the other two assessments indicating larger dispersion in the student's score in PROBE data. Based on the data we can deduce that the process of implementing PROBE activity before class can help faculty in understand students' level of the content to be delivered. Based on that faculty can change the pedagogy and content to help students to understand the concepts better and improve overall performance in the activity given. In this paper, the focus was on checking the effectiveness based on the scores obtained by the assessment strategy adopted. In the future, the study will be focused on obtaining students' and faculty perspectives on the hybrid assessment approach qualitative and quantitative approaches.

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