Portfolio Assessments for Problem Based Learning Courses

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***Abstract*—Problem-Based Learning is a student-centered teaching and learning pedagogy proven to be effective and applicable for wide range of domains. Problem based learning supports several forms of assessments like project work, case-studies, and reflections, all of them with the objective to improve problem solving, critical thinking and self-directed learning. Portfolios can be yet another way of supporting and designing assessments. This study proposes a research question to understand the impact of portfolio creation as an assessment method within Problem-Based Learning pedagogy and assesses its impact on students understanding and application of theoretical concepts in real world scenarios. With Reflective-Practice theory as conceptual framework, this work evaluates the effectiveness of the portfolios applied on a domain-based case study. Multi method was used as a research methodology for the study and self-selection was used as sampling technique for quantitative and qualitatively analysis respectively. The context of the study was VI semester algorithmic course students offered to students of circuit branches. Students were given several domains to create portfolios on and GitHub pages were used for the purpose. Students were guided with step wise process to create the portfolios. Scores of 83 students and interviews of 12 students were used for data analysis. With appropriate descriptive measures, statistical methods correlations, heat maps, student feedbacks, in-vivo coding and process coding, the collected data was analyzed for results and discussion. The results positively align towards the conclusion that portfolios can be an effective assessment method.**

***Keywords*—algorithms; assessments; portfolios; problem based learning**

ICTIEE Track: Assessment of Effective Teaching
ICTIEE Sub-Track: Diversifying Assessment Approaches: Success Stories

I. INTRODUCTION

ASSESSMENTS act as a tool to measure the intended learning outcomes identifying the areas of improvement for both teachers and students. Assessments are essential to ensure that students have acquired the necessary skills and knowledge for professional life (Shepard, 1989). They help to identify the areas of improvement. Assessments act as a feedback to students to improve on the areas of gaps and they act as a feedback faculty to review the student understanding and class materials. Assessments help to keep the curriculum relevant and effective (Linn, 2000). Assessments are needed for continuous improvement and ensuring that the students are well prepared for the present market needs. An assessment has to follow a structured framework to evaluate student understanding, identify the gaps and help them build the skills essential for this era (Blake, 2016).

The present generations of engineering students are usually referred as digital natives (Dingli & Seychell, 2015). They have grown up with and alongside the technology. Personalized experience has been part of their growing up and they are defined with their own characteristics (Dolot, 2018). The learning approach for this generation has to be certainly different from the predecessors and has to go beyond the student-centered pedagogies. Teaching methods are crucial, but equally significant are assessments. Projects, handwritten exams, reflections, lab exercises, and current practices require adaptation to align with professional advancements while keeping digital natives interactive and engaged (Cilliers, 2017). Assessments should be designed to challenge their problem-solving abilities and bring out the creativity. Assignments must cater to the unique needs and preferences of generation-z, enabling educators to create engaging and impactful learning environments. There must also be a pedagogy support to create meaningful assessments.

Selecting an appropriate pedagogy can encourage a classroom culture of interaction, assessments and adapt to dynamic needs of the classroom (Shulman, 2005). Pedagogies can help the faculty to understand how students acquire the knowledge and address the learning styles. Student-centered pedagogies have been popularly researched and explored; and Problem Based Learning (PBL) is one of the prominent one among them. Learning has to be relevant, meaningful and effective and bringing real world problems into the classroom can bridge the gap between theory and practice (Hung et al., 2018). A classroom delivery can be influenced by creating meaningful interventions. Pedagogy like PBL can help the faculty to design assessments and provide a context to it. To design assessments, faculty needs to consider the student needs, the context, culture, practices etc. The assessments can also be improvised in an iterative manner. It is essential to create a learning experience backed by the learning theories and guided by the pedagogical approaches, delivered through

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design of aligned assessments. One of the possible ways of assessing students and also helping them build a profile for professional growth is by helping them build portfolios. Portfolios are valued tools to present a student's understanding, analysis skills, expertise, achievements and learning over a period of time (Christy & Lima, 1998). Portfolios are a reflection of students' progress which presents their knowledge on the identified area. It helps students to demonstrate their understanding and the business cases they comprehend, connecting to the professional needs. Portfolios help students to showcase their abilities, problem solving skills and also creativity. They can examine the market gaps and showcase their potential solutions, which can appeal to the relevant companies. Portfolios serve as a form of assessment that offers instructors insights into student learning and course progress. The ability to demonstrate real-world skills and projects through code repositories, web pages, and applications provides a more persuasive picture of a student's abilities than traditional assessments like exams or quizzes.

This paper combines the components of PBL and portfolios as assessments to evaluate its effectiveness for the generation-z students. Section 2 presents the literature survey. Section 3 presents the research question and research design along with the model. Section 4 presents the results and data analysis. Section 5 presents the discussion and section 6 concludes the paper.

II. Literature Survey

This section surveys the literature on problem-based learning, assessments, and portfolios. While each of these sub-domains has been explored individually in specific contexts, an inherent relationship connects them. Although not all studies explicitly highlight this connection, they share a common focus on problem-solving. The reviewed works are largely from the field of computer science.

Originally developed in the medical field (Barrows, 1998), PBL has been adapted across various disciplines, tailored to specific needs. From engineering to social services, PBL consistently aims to develop problem solvers and lifelong learners. The professional demand for individuals who can think critically, collaborate, and solve complex problems aligns seamlessly with PBL's core principles. Research has also examined PBL's effectiveness and provided guidelines for creating engaging classrooms and assessments (Tan, 2021). With an engagement of students in real-world contexts and actively involving them in problem-solving, PBL bridges the gap between theory and practice, creating an interactive environment that prepares students for future professional challenges (Warnock & Mohammadi-Aragh, 2016). PBL variants include solving one problem a day and many problems a day (Hegade, 2019). Dublin descriptors have been used and studied for effectiveness to write outcomes in PBL context (Swaminathan et al., 2024).

PBL can effectively be an ideal pedagogy for self-directed learning, critical thinking and to be a lifelong learner (Azer, 2001). PBL is a pedagogical approach where learners construct knowledge using real-world scenarios and problems. Research substantiates that PBL stimulates towards higher order thinking skills (Moallem, 2019). Theoretical frameworks such as situated learning, constructivism, and cognitive apprenticeship provide a sturdy foundation for PBL (Dennen & Burner, 2008). These theories emphasize the importance of authentic contexts and social interaction in knowledge acquisition. PBL aligns with these principles by providing students a background of real-world scenarios and encouraging collaborative problem-solving (Woods, 2012). This approach enhances students' ability to develop and apply modeling skills, as they are tasked with designing, implementing, and improve models that represent and address complex challenges.

Problem cases and scenarios play an important role in shaping how students learn and transfer knowledge (Wood, 2003). Researchers have extensively discussed what students learn and how they learn in PBL environments (Hmelo-Silver, 2004), examining both the process and its effects on learning outcomes (Yew & Goh, 2016). Studies have looked at PBL from different angles to understand its effectiveness and the challenges of implementing it. It has been used at various levels, from individual courses to entire institutions, with its long-term benefits evaluated at each stage (Chen et al., 2021).

PBL has shown to encourage effective learning behaviors (Ghani et al., 2021) and has been linked to the development of critical skills like thinking critically (Nadeak & Naibaho, 2020). It has been combined with other learning theories and frameworks to improve outcomes, and its connection to learning styles and thinking skills has been explored (Islamiat et al., 2024). In computing, PBL has been studied for its practical applications and specific requirements (O'Grady, 2012). Assessments in PBL have also been a focus, including their evolution, different approaches, and future directions (Olds et al., 2005), along with authentic assessments in engineering education (Ullah, 2020).

Their importance in competency-based learning has been emphasized (Henri et al., 2017), along with the challenges and opportunities they bring (Pellegrino, 2013). Meaningful assessments play a key role in education by offering insights into students' understanding and skills beyond traditional methods. They allow educators to evaluate how well students grasp concepts, apply knowledge, and think critically (Black & Wiliam, 1998). These assessments also boost student engagement and motivation by connecting learning to real-world contexts (Brown, 2019). They provide personalized feedback, helping students navigate their learning journey and develop self-directed learning skills (Nicol & Macfarlane-Dick, 2006). In engineering education, meaningful assessments are vital for equipping students to solve complex, real-world problems (Cruz et al., 2020).

Portfolios are classified as emerging learning environments in engineering education (Hadgraft & Kolmos, 2020). Portfolios have been used in numerous domains and applications creating e-portfolios (Mudau & Modise, 2022) and connecting them with a context (Martinsuo & Geraldi, 2020). Engineering students need portfolios to demonstrate their ability to integrate theoretical knowledge with practical skills, and showcase the problem-solving and project management capabilities. From a research perspective, portfolios provide a structured way to assess students' competencies and learning progress over time (Wilczynski & Knowles, 2016). Portfolios help to build a professional identity (McNair et al., 2017). Portfolios have also been designed and deliberated using industry collaboration (Hegade et al., 2022).

This paper combines the knowledge from the literature gaps and formalizes a research question to study the effectiveness of building portfolios for computer science engineering students with specific objectives.

III. Research Design

This section presents the research design along the research question, context, model, problem design, approach and other associated specifics.

A. Philosophical Assumptions

This study uses pragmatism (James, 2001) as its framework, which integrates both quantitative and qualitative approaches, focusing on practical relevance and real-world applications. The axiology is shaped by the reflections of both the researcher and participants, guiding the study's values. Ontologically, it views assessments as essential tools and evaluates their effectiveness in PBL as an intervention. An inductive approach is used to build knowledge, and a multi-method methodology combines qualitative and quantitative techniques to address the research problem.

B. Research Question

When PBL is used as pedagogy for delivery, the classroom is already introduced with the problems. Portfolios can help to aggregate all the knowledge into one problem application and provide a holistic perspective. The research question for the study is

RQ: "How does the creation of a portfolio as assessment method within a PBL pedagogy impact students understanding, application of theoretical concepts in real world scenarios?" In order to study from quantitative and qualitative focus, the question is further divided into two sub-questions.

RQ1: What are the measurable patterns in students' understanding and application of theoretical concepts, as reflected in their portfolios?

RQ2: What insights do students provide about their experiences in creating portfolios and how it influenced their understanding and application of theoretical concepts?

The study aims to explore the usage and benefits of creating portfolios by understanding their knowledge construction and transfer of knowledge.

C. Context of the Study

The context of the study is students from VI semester for the course offered from computer science and engineering from KLE Technological University, Hubli. It was an elective course which had screening exam and was attempted by 400+ students across the campus. A total of 83 students were shortlisted for the course based on their performance in a programming screening. The screening tested on the problem solving and algorithmic skills. For the 83 students the course was delivered in PBL mode. The course was for six credits and had six hours of engagement per week. The course delivery had several case studies and active engagement sessions. The course has competitive programming contests as exams and building a course portfolio was the final exam evaluated for 30 marks. The course had several graded activities and assignments for remaining 70 marks. The course used technology for design of several cases studies and for assessments. The content of the course is advanced algorithms and data structures.

D. Sampling Methods

All students participated in quantitative analysis. An informed consent was taken from the students that their data would be used for research work. The sampling method hence used was total purposive sampling (Sharma, 2017). For qualitative study, the sampling method used was self-selection (Wainer, 2013). Self-selection sampling is a non-probability sampling method where individuals voluntarily choose to participate in a study. An open invitation was given to the students and those interested and who agreed upon are part of the study. A total of 12 students participated in the interviews, and data collection was stopped due to data saturation, indicating that the data collected is sufficient to address the research question.

E. Reflective Practice - Conceptual Framework

This work uses Reflective Practice as a conceptual framework. This framework encourages students to reflect on their experiences in real-world engineering scenarios. Portfolios can be used to document reflections, providing insight into their learning and development. Reflections are one of the components of problem based learning that help to achieve self-directed learning and critical thinking (Urankar et al., 2024). Reflective practice in engineering education encourages students to critically analyze their learning experiences and train towards continuous improvement (Schön, 1983). The approach helps students connect theory with practice by reflecting on real-world engineering tasks, identifying strengths and areas for the growth (Johns, 2017). Reflective practice encourages self-directed learning and works towards improving the problem-solving skills. It helps students to learn and evaluate their decision-making skills (Moon, 2004). Assimilating reflective activities into the curriculum, the facilitators can help students develop a lifelong learning and adapting to the evolving field of engineering (Turns et al., 2014).

F. Study Model

The model used for the study is presented below in Figure 1. Reflections can be in, on and for-action (Burhan-Horasanlı & Ortaçtepe, 2016).

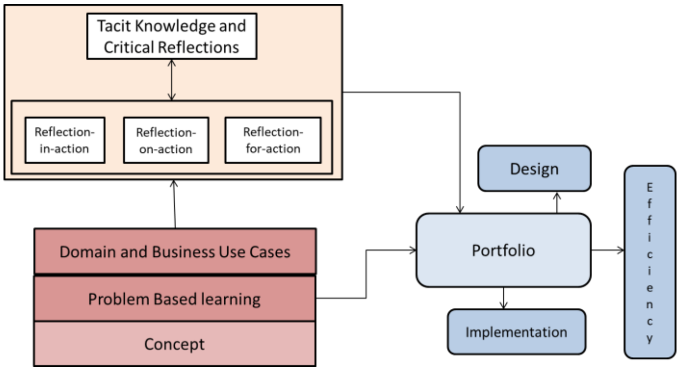

Fig. 1: Model for portfolio design and implementation

Students select a domain for which they want to apply the course knowledge. Using the different types of reflections, tacit knowledge and critical reflections, a portfolio is created. They were hosted using the GitHub pages as it is a professional version control tool used by the programmers. Portfolios majorly consisted of design, implementation and efficiency analysis. The components of reflections include what has been done, what has happened and what can happen in future. Reflections were used to capture the student's understanding during problem-solving (Torgal et al., 2024). Tacit knowledge is intuitive knowledge that professionals develop through experience. Reflective practice involves bringing this tacit knowledge to the surface and critically examining it (Schön, 1983).

G. Problem Domain Design

The phase wise design of portfolios is presented in Table 1 below. The steps were followed by all the students in portfolio creation. Sample portfolios can be checked here: https://abhijna107.github.io/ and another one here: https://jiyapalrecha35.github.io/Google.github.io/ for the reference.

TABLE I
PORTFOLIO CREATION PROCESS

Step	Process
01	A list of domains is provided and students select one either from the list or select one on similar lines.
02	Students identify at least 10 business cases that currently exist in the domain
03	Students identify at least 5 business cases that can help to grow in the market. The cases are backed up by the research.
04	Training on creating GitHub IO pages and a profile
05	Detailing the business cases with low level design and system approach
06	Identify the algorithms and data structure for each case (covered in syllabus or explore others)
07	Implement and perform efficiency analysis
08	Check if there are efficient alternative for the considered cases
09	Propose alternatives with their efficiency analysis
10	Build a story using the portfolio

IV. RESULTS AND DATA ANALYSIS

This section presents the results and data analysis of the portfolios that students created. The data analysis is presented in the sections of quantitative and qualitative.

A. Quantitative Analysis

The Table 2 below presents the descriptive statistics for the different components of the portfolio. The portfolio was evaluated on four major parameters namely: number of business cases identified, number of algorithms used and efficiency analysis, exploration of new algorithms and system design at low level. Each of them was normalized to 10 marks and further reduced to 30 marks scale.

Of the 83 data values present for each evaluation parameter, there were no missing values. Small standard deviation and variance from the above table indicate that the data points in a case study scores are clustered closely around the mean. They are not very high though the variance is corporately larger. Smaller values mean that they are relatively similar to each other and there is consistent pattern in the data. They are tightly grouped and specify high reliability or precision. The minimum marks earned for identifying business use cases is 5. It means that all students did an excellent job in identification part. Given that the skewness values, there are two positives and two negatives. Positive skewness means the tail on the right side of the distribution is longer. This suggests that there are a few larger values in the dataset that are pulling the mean to the right. Similar is the observation for the negative value to the other side.

TABLE II
DESCRIPTIVE STATISTICS FOR PORTFOLIO

Descriptive	Business Cases	Algorithms	Exploration	Designs
N	83	83	83	83
Missing Values	0	0	0	0
Mean	7.39	6.95	6.20	6.28
Median	8	7	6	5
Standard Deviation	1.65	1.89	2.17	1.86
Variance	2.73	3.58	4.70	3.47
Minimum Value	5	3	1	3
Maximum Value	10	10	10	10
Skewness	-0.226	-0.150	0.0238	1.06
Std. Error Skewness	0.264	0.264	0.264	0.264
Kurtosis	-1.24	-1.21	-0.598	0.0469
Std. error kurtosis	0.523	0.523	0.523	0.523
Shapiro-Wilk W	0.887	0.924	0.953	0.773
Shapiro-Wilk p	<.001	<.001	0.004	<.001

Kurtosis values are mostly negative. They indicate that data are platykurtic. Platykurtosis means the distribution has a flatter peak and thicker tails compared to a normal distribution. This suggests that there are more extreme values (outliers) in the data than would be expected in a normal distribution.

For dataset 1, The Shapiro Wilk W value is 0.887 which indicates a reasonably good fit to a normal distribution (Razali & Wah, 2011). But the p-value is less than 0.001, which is very low and hence we reject the null hypothesis. Therefore, despite the good fit indicated by the W value, we conclude that the data in case study 1 is not normally distributed. Similarly for data set 2, 3 and 4. Table 3 below presents the correlation matrix.

TABLE III
CORRELATION MATRIX

		Business Cases	Algorithms	Exploration	Designs
Business Cases`	Pearson's r	-			
	df	-			
	p-value	-			
Algorithms	Pearson's r	0.525	-		
	df	81	-		
	p-value	<.001	-		
Exploration	Pearson's r	0.339	0.083	-	
	df	81	81	-	
	p-value	0.002	0.458	-	
Designs	Pearson's r	0.349	0.315	0.046	-
	df	81	81	81	-
	p-value	0.001	0.004	0.679	-

Pearson's r measures the strength and direction of the linear relationship between two variables. A higher absolute value of r indicates a stronger relationship, while the sign indicates the direction (positive or negative). As we can see from the above table, all the values are low. For example between Designs and algorithms, the r value is 0.315 and p value is 0.004. Pearson's r of 0.31 indicates a weak positive correlation between the two variables. It means that as one variable increases, the other tends to increase slightly, but the relationship is not very strong. The p-value of 0.004 suggests that the correlation is statistically significant at a significance level of 0.05 (or lower). In other words, it is unlikely that the observed correlation occurred by chance. Overall, while there is a positive relationship between the two variables, it is relatively weak, and it is unlikely to be due to chance. This means that each evaluation pattern has its own influence on learning and is not common. Figure 2 below presents the heat map of them.

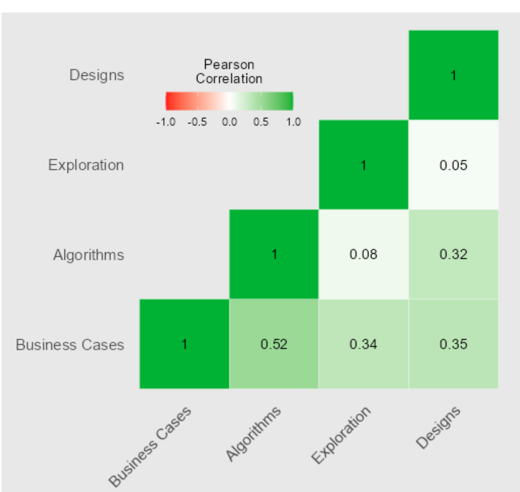

Fig 2: Correlation heatmap of evaluation components

Three feedback questions were asked to students to measure the effectiveness of the portfolios. The answers were collected on the Likert scale (Joshi et al., 2015) of 1 to 5 where 1 being highly ineffective and 5 being highly effective. Question 1 asked for effectiveness of portfolio in learning process and feedback is presented in Figure 3 below.

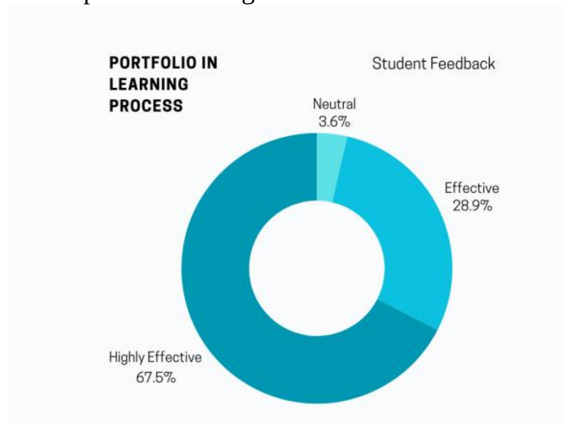

Fig 3: Feedback for portfolio learning effectiveness

The second question asked for ability to transfer the course knowledge into new domain and its effectiveness in learning. The feedback is presented in Figure 4.

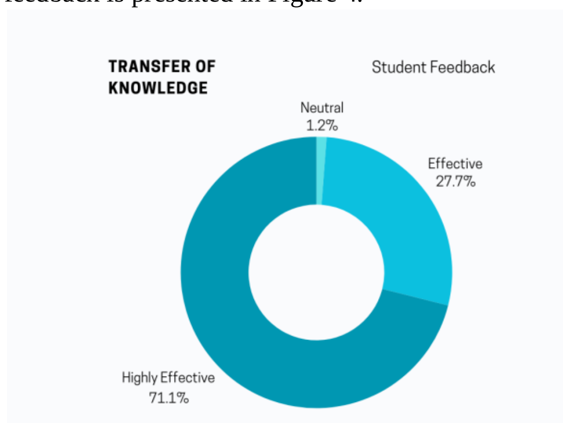

Fig 4: Feedback for transfer of learning

The third question as for effectiveness of design skills. The feedback is presented in figure 5 below.

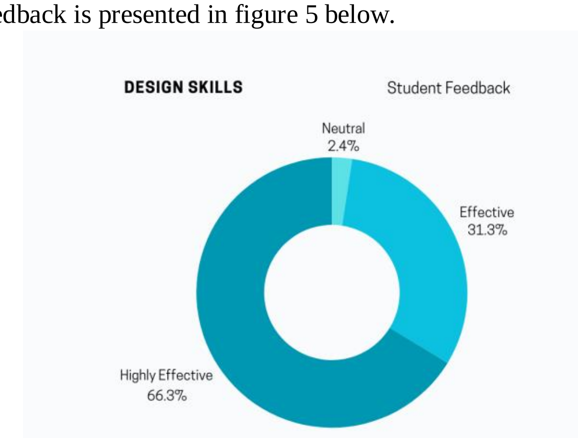

Fig 5: Feedback for design skills

As we can see from the three figures, the results are positive and the class of 83 students agree that portfolio creation was an effective process in the learning.

B. Qualitative Analysis

Semi-structured interviews were conducted to understand the thought process of portfolio creation and the transcripts were coded using in-vivo and process coding methods (Saldana, 2014). In in-vivo we code from the phrase as is and in the process coding we code based on the conceptual framework. The question asked for the interview was 'Can you describe your journey of portfolio creation? How did you select the business cases?' Based on the answers, further trigger questions were asked for example: 'Can you elaborate more? How did it help? Why did you select that? etc. Few examples of the assigned codes are presented in the Table IV below. The codes indicate the analysis of the portfolio process. The codes have been categorized as ANALYSIS, TRANSFER, APPLICATION, SYNTHESIS and DESIGN. They are formed based on conceptual framework and effectiveness evaluation.

TABLE IV
INTERVIEW CODES

Phrase	Code
Found out what key functionality platform has	ANALYSIS
It was an experience to even learn more	TRANSFER
Going further I want to understand deeper about few features	APPLICATION
Usage helped me identify features	ANALYSIS
Created connection between algorithms and my use cases	SYNTHESIS
I used papers to deepen my understanding	TRANSFER
It helped me learn many algorithms in depth	TRANSFER
I took a domain because it had plenty of data	ANALYSIS
It changed my approach of problem solving	DESIGN
Unlike projects, it helped me identify the key challenges in my domain	ANALYSIS
It is crucial to understand a problem before solving it	ANALYSIS
Research helped me to select my use cases	ANALYSIS
I got to know the business impact	APPLICATION
I saw technology in terms of user benefits	SYNTHESIS
I could see the impact of algorithms in real life	TRANSFER
It was challenging and engaging to apply what I had learned	ANALYSIS
Understood about the large scale systems	ANALYSIS
I want to explore more advanced algorithms	TRANSFER
I looked for better alternatives for each case	SYNTHESIS

The study did bring in several perspectives of each component.

V. DISCUSSION

The quantitative results indicate that the correlation is minimal between all the parameters of evaluation. The heat map conveys the same pictorially. This signifies that each parameter has its implication in learning and they all signify different aspects of knowledge construction. All the four measured parameters are not the same and are required in the learning process. The student feedback is positive as well.

The qualitative results support this theory. All the coded words cater to different levels of learning. There is synthesis that has happened from understand level to create level. This can help the faculty to achieve the intended learning outcomes. Students have expressed that 'I want to explore more/advanced algorithms/more cases' etc. This is a positive indicator of their engagement with the subject matter and their potential for deep learning. Such students are likely to be self-directed learners who enthusiastically seek out new information and opportunities for growth.

"It changed my approach of problem solving. Unlike projects, it helped me identify the key challenges in my domain"- the statement suggests that the experience has shifted the student's problem-solving strategy from a project-based approach to a more focused approach on identifying core challenges within their field. This transition indicates a deeper understanding of the underlying issues and a more strategic approach to problem-solving, which are essential skills for research-oriented endeavors.

Students shared that they gained valuable insights into selecting appropriate business use cases and identifying parameters for evaluating them. They highlighted the importance of learning to filter out irrelevant details, enabling them to focus on the core aspects of a problem. This process helped them distinguish key features from non-essential ones, and sharpen their ability to prioritize effectively. They also realized how smaller components of work are achieved in real-world scenarios, improving their understanding of practical applications. The activity allowed them to connect the most suitable algorithms to the use cases they identified and designed, adopting a deeper grasp of algorithmic thinking. It also helped them recognize their limitations and identify areas for further exploration to achieve better results. Each student presented their work, creating a tangible outcome they can confidently showcase, even in their resumes, as evidence of their skills and understanding. This strengthened their technical knowledge and furthered their ability to communicate their achievements in professional situations.

CONCLUSION

Portfolios are effective as assessment tools in engineering education, which offer a comprehensive way to evaluate students' understanding and skills. Portfolios enable students to connect classroom learning with real-world applications, which makes them apply theory knowledge to practical applications. This helps students internalize engineering concepts and prepares them for professional environments making them interview-ready. Portfolios help in showcasing their competencies to potential employers. Both qualitative and quantitative results support the effectiveness of portfolios, demonstrating that they enhance students' problem-solving abilities and readiness for real-world challenges. As an assessment method, portfolios provide an all-inclusive view of a student's learning journey, connecting the gap between theoretical knowledge and practical applications.

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