Journal of Engineering Education Transformations,
Volume No. 37, January 2024 Special Issue, eISSN 2394-1707

Reflections and Abstraction in Problem Based Learning

Sandeep Urankar[1], Prakash Hegade[2] and Ashok Shettar[3]
[1, 2, 3]KLE Technological University, Hubli, India
[1]01fe21bcs419@kletech.ac.in
[2]prakash.hegade@kletech.ac.in
[3]ashok@kletech.ac.in

***Abstract*—Problem Based Learning has extended its scope from the medical domain to every other domain, bringing out the learning benefits and connecting with real world applications. Reflections are one of the components of problem based learning that help to achieve self-directed learning and critical thinking. There are several ways to solve a problem in problem based learning, and one way to enhance the process is to use computational thinking. The abstraction can help in knowledge construction and writing reflections that can connect beyond the systems of study. This study proposes to design case studies for reflections with and without abstraction. The data of 37 students was analyzed qualitatively and quantitatively to understand the nature of the reflections. Model problems were used as case studies. A qualitative study was carried out using descriptive, in vivo, and focused coding methods, arriving at themes, and ttest performed on two sets of quantitative results. The work brings out some intriguing results that are presented in this paper. Abstraction in reflections can positively contribute to generalizing the system and connecting to the real-world applications beyond the case study that is under consideration. Abstractions help in knowledge construction and application extension.**

***Keywords*—Abstraction; Computational Thinking; Problem Based learning; Reflections.**

***JEET Category*—Research**

I. INTRODUCTION

BEING inspired by the medical domain, from the 1960's, Problem Based Leaning (PBL) today has diffused into many other degree programs (Barrows, 1998). A problem plays a major role in PBL pedagogy. With the tech-savvy set of students who walk into degree programs with high expectations, a classroom needs to go beyond the chalk-and-talk learning styles. Generation-Z students have their own characteristics, and their learning styles need new philosophies to meet their learning needs (Seemiller & Grace, 2015). In PBL, 'problem' is the major constituent that motivates the learning process and engages the students. Literature and research classify the problem taxonomy from structured to ill-structured, and ill-structured category is demonstrated to be effective in PBL processes (Jonassen, 2000). Ill-structured means abstraction.

The field of engineering education is undergoing a transformation, placing emphasis on empowering students and actively involving them in the learning journey. The prevailing belief is that students grasp concepts effectively when they can apply them to real world situations. A teaching method that aligns seamlessly with this philosophy is, off-course PBL. PBL is centered on students collaborating in groups to solve problems. In PBL, students are in charge of identifying problems, gathering data, developing solutions, and assessing their own solutions. Reflection plays a role in PBL, as it empowers students to ponder their acquired knowledge and explore its applications in scenarios.

Whether carried out individually or within groups, reflection can take forms ranging from informal to formal. Students can engage in journaling, writing essays, or participating in discussions as some methods of reflection. An approach known as Computational Thinking (CT) helps students with concept comprehension, system design, and problem solving. It is a talent necessary for thriving in the outside world. The foundation of CT is the idea that problems can be overcome by being divided into smaller, more manageable parts. It also involves developing algorithms, identifying patterns, and representing data (Wing, 2008). In the field of CT, abstraction is important. It entails simplifying ideas by emphasizing key elements while ignoring irrelevant details. The importance of abstraction in CT lies in its ability to focus on specific aspects of a problem and generate reusable solutions. Abstraction helps in the knowledge construction process. We abstract the patterns to put them to future use. It helps us focus on important information and discard the irrelevant ones.

Studies have been carried out to evaluate the effectiveness of PBL and computational thinking in the algorithmic domain (Chen, 2017). When problem based learning is integrated with computer science, its effects and attitudes have been discussed (Kwon et. al., 2021). A discussion of relationship between computational thinking and computer science has been deliberated (Selby et. al., 2013). Several aspects of how computational thinking is interconnected with problem solving have been studied over a period of time. This work puts together problem based learning, abstraction of computational thinking, and reflections.

The paper is further divided into following sections: section II presents the literature survey; section III presents the research design; Section IV presents the methodology; section V presents the results and data analysis; section VI presents the discussion, followed by conclusion in section VII.

II. Literature Survey

This section reviews the literature in front of PBL, CT, and reflections. CT refers to the processes and abilities used to formulate problems and solutions in a manner that can be effectively executed by computers—the thought process as done by humans. CT involves thinking, breaking down tasks into smaller parts, finding patterns, and abstraction. (Selby & Woollard, 2013). However, it cannot be mastered in isolation. It necessitates an approach that encourages learners to actively participate in meaningful and real world activities that incorporate CT.

One effective approach is PBL, which is a teaching method that presents students with genuine and complex problems, prompting them to engage in inquiry, collaboration, and reflection to discover solutions. PBL aims to enhance student's problem solving abilities, critical thinking skills, self-directed learning skills, and domain knowledge. Moreover, PBL cultivates student's motivation, interest, and overall satisfaction with the learning process (Hung et al., 2008). PBL can be implemented in different ways depending on the specific context, goals, and preferences of educators and learners. However, there are common components that define PBL. These include having a real–world problem, a facilitator who guides a student centered approach, the collaboration of students in working towards a common problem, self-directed learning, etc. (Perrenet et al., 2000). Several approaches like one day many problems in PBL have been explored (Hegade, 2019).

Problem based learning (PBL) has proven to be an approach to teaching and learning computational thinking (CT) across different fields and educational levels. Effectiveness of PBL and CT has been studied (Hegade et al., 2023). PBL has been implemented in instructing neuroscience students on experiment design and data interpretation through computer simulations (Barrows & Mitchell, 1975). PBL has been adopted to teach college students programming language concepts and skills by employing real world problem scenarios (Chen, 2017).

PBL has been utlilized to teach high school students sorting algorithms with the aid of visualization tools (Cetin & Larson, 2016). One of the elements that makes PBL effective in improving critical thinking is the process of reflection. Reflections and scaffolding in PBL have been studied and discussed (Patil et al., 2023).

Reflection involves analyzing and evaluating one's thoughts, actions, feedback from others, and outcomes to enhance understanding and performance. Through reflection, learners can identify their strengths and weaknesses, track their progress, adjust their strategies, and apply what they've learned in different situations. Additionally, reflection aids in the development of skills like planning, monitoring, evaluating, and regulating one's own learning (Chang, 2019). There are ways to incorporate reflection into PBL. For instance, learners can be requested to maintain journals or write reports about their problem solving process and the outcomes they achieved.

Another approach is to have learners present their solutions and gather feedback from their peers or instructors. Engaging in dialogues with group members or facilitators about challenges and insights is also an effective method. To support reflection, educators can utilize tools or frameworks that assist learners in organizing their thoughts and actions. The framework of abstraction to help learners develop abstract concepts from concrete experiences while learning CT has been studied (Cetin & Dubinsky, 2017). On the other hand, the framework of reflective creative computational thinking to guide learners in balancing different modes of thinking during game development have been studied as well (Weitze, 2017). Knowledge construction in PBL (Netekal et al., 2023) and abstraction in PBL knowledge construction have been researched (Hegade et al., 2023). Abstraction has been used in problem solving and learning (Unruh & Rosenbloom, 1989). The concept of abstraction has also been used in PBL (Hmelo-Silver, 2004). A more effective way of using case-based learning is problem based learning (Eshach & Bitterman, 2003).

Literature presents an opportunity to combine reflections with abstraction problems and examine its effects on student learning and cognitive skills.

III. Research Design

This section presents the employed research design for the proposed work.

A. Interpretive Framework

The ontological beliefs are that reflections are useful, and evaluating their effectiveness can be beneficial. For the reflections, we stick to abstraction as the underlying conceptual framework. An inductive approach will be used for knowledge construction—epistemology. The data sampling method used is purposive sampling. This work will reflect the researcher and participant's perspectives, both together creating a reality. The reality is not single and is multiple, a combined perspective of all. The work uses multi method approach for data analysis, where there is a blend of qualitative and quantitative methods helping in the process of analysis. Our interpretive framework is pragmatism.

B. Research Question

We construct the research question as presented below, grounded in the roots of problem based learning and computational thinking. Inferences are borrowed from the literature survey in constructing the question of study.

RQ: How are reflections different when computational thinking's abstraction is integrated with problem based learning case studies?

We explore this by designing case studies that explicitly asks to abstract or generalize and reflect, and the other which

only asks to reflect.

C. Model

Based on the gaps in literature survey and the elements of study under consideration, a model was designed to guide the case study design. This model is presented in Figure 1.

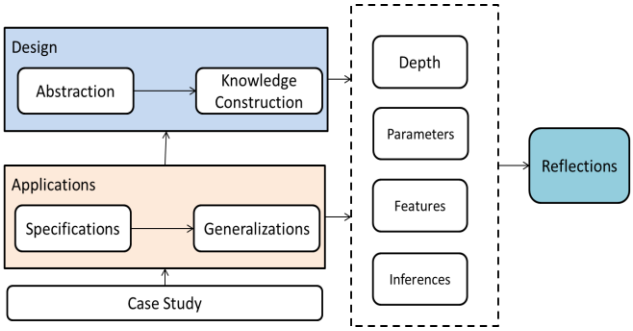

Fig. 1: Model for case study design

The case studies are designed in such a way that they have abstractions that can lead to knowledge construction and further adaptations. These lead to the depth, parameters, features, and inferences that lead to various applications extended to other domains. Further questions are designed to reflect on these elements.

D. Sampling

This work is carried out by obtaining consent from all the participants and adhering to the research ethics as mandated by the KLE Technological University, Hubli. Participants were informed that the collected data would be used for research purposes. Data was collected from 37 students who were undergoing a course on Model Thinking from the School of Computer Science and Engineering department. The students have completed their second year of engineering. The sampling technique used was total population sampling, which is a subset of purposive sampling. In total population sampling, we choose to examine the entire population (Sharma, 2017). The data collection included survey forms to be completed and written case study solution sheets in the form of documents to be submitted.

IV. METHOD

This section describes the objective and the case study design for the data collection.

A. Objectives

The objectives of the work are as listed below in Table 1 formulated on the basis of the research question design.

TABLE I
OBJECTIVES

ID.	Objective
OBT_1	To understand the abstractions present in the system
OBT_2	To reflect on the abstractions critically relating to the real-world applications
OBT_3	To identify the conceptual themes in the reflections

The objectives were used as a guide to formulate the case study and questions for reflection.

B. Case Study Design

In order to bring out the abstraction from the problems, the cases selected for the study were model problems. The models selected are applicable in more than one domain so that students can generalize and discuss their applications. Below are questions 1 and 2 accordingly.

Question 1: Write your reflections on Natural Order (nature has its own way of balancing out the events). What are the essential features of this model? And Question 2: Generalize the producer-consumer problem. What are the parameters that define this problem? What are the essential features of this model? What are the domains that you can apply this problem on? Write your reflections. While the first question was generic, second one asked to abstract and list the applications. Though not explicitly asked, even for the first one, it is expected that students do the same.

V. RESULTS AND DATA ANALYSIS

This section presents the results and the data analysis of the carried out work. The submissions made by students were evaluated qualitatively and then quantitatively. For qualitative analysis, the coding was performed in two rounds. First, a combination of descriptive and vivo coding was used. In descriptive coding, passages were coded according to the topic (Linneberg & Korsgaard, 2019). There was an influence of research question in this process. As we were also looking for exact words from the reflections, we used Vivo coding as well (Smith & Firth, 2011). Vivo captures the exact experiences and perspectives from the reflections. Focused coding was employed for the second round, where we categorized the related themes and merged them (Benaquisto & Given, 2008). The paper presents a summary and analysis of the coding methods.

A. First Round Coding

In order to understand the ideas expressed by students, their responses are carefully examined and are identified into different themes that represent the overall reflections. During the coding phase we used suitable coding methods to identify various thematic elements from the provided statements. Both descriptive coding and, in vivo coding was used during this round of analysis.

Descriptive coding is a technique used to summarize data using concise labels or codes. It involves assigning phrases or terms to segments of data in order to capture their content and meaning. (Saldaña, 2021) These codes serve as a way to express the essence of the data. For instance, when examining interview responses regarding experiences with an educational program, descriptive codes such as "positive feedback," "challenges encountered," or "impact on learning" may be created. Each code aims to represent the main idea or concept

found within the statement "Participants consistently expressed satisfaction with the interactive teaching methods, citing increased engagement and a positive shift in their attitude toward learning". In this research we discovered themes that emerged from the reflections, on the case study of Natural Order. Some of the themes we observed through coding were the 'domino effect' 'feedback mechanism' and 'mutual understanding'. These themes provide an understanding of the content discussed in a more abstract manner. A few of the samples from student's reflections that was coded using descriptive coding that were mapped using Computer Science and Engineering (CSE) conceptual understanding are: "Guidance provided by one and remaining follows the same rule", is coded as LEADERSHIP because it clearly demonstrates adherence to rules. The student's reflection, "What happens to one thing can affect other things, even if they are far apart", this is coded as DOMINO EFFECT since it illustrates the cascading effect to falling dominos. The student's reflection, "To prevent the resource to get leaked for accessed by others locks must be applied", is coded as RESOURCE MANAGEMENT, as it aligns with the concept of managing resources in CSE theories. And the statement, "Multiple clients generate requests (produce) processed by server threads" is coded as DIVIDE AND MERGE TASK, since it represents a key concept, in CSE theory. Another student reflected, "Everything is interrelated in the ecosystem", this reflection was classified as INTERDEPENDENCY since it emphasizes the interconnected nature of everything within an ecosystem. Lastly a statement by a student mentioned "Balance should be maintained everywhere, extinct and overpopulations" and this is coded as STABILITY CHANCES due to the focus of their reflection on equilibrium maintenance, and etc.

In vivo coding method involves utilizing the actual words and phrases used by participants in their data to label and categorize specific segments of information. The original meaning of "in vivo" relates to something that exists within a living organism. (Saldaña, 2021) When applying In Vivo coding the objective is to faithfully represent the language used by participants capturing the essence of their experiences or perspectives without imposing external interpretations. This approach ensures that the data remains authentic and allows for an understanding of how participants view things. For instance, when examining interview responses regarding experiences with new fitness program: "I feel like I'm conquering new challenges every session, pushing my limits and discovering what my body is capable of." This is coded as "conquering new challenges" using participant's own words. Using in vivo coding proves highly effective in staying aligned with the students' responses, preventing the introduction of biases, and ensuring adherence to the context. Here are a few samples of student reflections that have been coded using In Vivo coding: "The nature keeps changing now and then, and it is inevitable", this was coded as CHANGE AND INEVITABILITY given that the term changing and inevitable itself serves as a code. Another student's reflection states, "Recovering from damages and overflow of the buffer", is coded as RECOVERY AND MITIGATION since it is directly denoted in their reflection. The reflection, "Efficient scheduling strategies ensure optimal resource utilization and task completion" is coded as EFFICIENT PLANNING preserving the exact meaning from the student's reflection. The student's reflection, "adaptation helps maintain balance in the ecosystem and adjust to their environment" is coded as OPEN FOR ADAPTABILITY, by taking the exact words from reflection into consideration. Another reflection of a student states, "Sequential order of producing and consuming of resources", is coded as SEQUENTIAL ORDER and "Positive or Negative feedback helps in maintaining state of equilibrium" is coded as FEEDBACK MECHANISM and etc.

Answers were analyzed to identify the themes. A sample of few themes assigned is presented in Table 2 below. Several such themes were classified from the case studies. 28 such reflections were identified from the case studies.

TABLE II
SAMPLE THEMES AND CODES

Student Reflection	Theme	Code
Working in team helps to perform various task simultaneously	Coordination	Task Division and Efficiency
The nature keeps changing now and then and it is inevitable	Stability	Change and inevitability
Positive or Negative feedback helps in maintaining state of equilibrium.	Team abilities	Feedback mechanism
Every organism has its role and if one fails coordination becomes difficult	Mutual understanding	Mutual understanding

The summary of themes identified is presented in Table 3 below, which contains the set of 28 identified reflections. All others were saturated into one of the 28 identified reflections. There were also certain common ones that were merged to make the list boil down to a list of 20.

TABLE III
THEMES CATEGORIES

Themes	Codes
Coordination	Resource management Task division and efficiency Collaboratively working Recovery and mitigation Harmony through cooperation
Mutual understanding	Modularity and abstraction Efficient planning
Optimal approach	Divide and do task Divide and merge Collaborative task-decomposition
Stability	Stability chances Sequential order Change and inevitability

	Natural Instincts
	Domino effect
	Cyclic consequences
Team abilities	Open for adaptability
	Leadership roles
	Data integrity and efficiency
	Feedback mechanism

B. Second Round Coding

The coding process exhibits a cyclical nature. Additional coding iterations are usually done to emphasize aspects aiding in the creation of ideas, understanding of meaning, and/or the formation of theories. (Saldaña, 2021). In second round of coding, focus coding is used, because it aids in recognizing patterns and layers of significance by examining variations and connections, among sub themes. This approach helps narrow down the code and organize the coded data by identifying conceptual similarities leading to the formation of major categories or themes derived from the collected information (Saldaña, 2021). The codes derived from the first round of coding are organized into relevant groups, as illustrated in Table 3. From the sample code mentioned in first round of coding, "recovery and mitigation" and "resource management" are grouped under COORDINATION with other codes like "task division and efficiency", "collaboratively working" and etc. since these codes represents the coordination among themselves. Similarly, "divide and do task" and "divide and merge" are categorized as OPTIMAL APPROACH since they represent the problem solving in an optimal way. STABILITY includes codes such as "change and inevitability" and "domino effect". Lastly, "open for adaptability", "leadership role" and "feedback mechanism" are grouped under TEAM ABILITIES category. These are mapped based on computer science and engineering conceptual understanding. As focused coding was used, they were merged to form decision questions, understanding the problem, the features, the parameters that decide the model, and the depth of abstraction and application, that helped us to identify the evaluation patterns led by the coding process.

C. Case Study Scores

Table 4 presents the evaluation of 37 answers based on the identified parameters of second round coding process.

TABLE IV
SCORES ON IDENTIFIED PARAMETERS

Section	Natural Order	Producer-Consumer
Decision question	0.927	1
Understanding of the problem	4.013	4.24
Features listed out	2.837	3
Parameters defining problem	2. 621	3.70
How well abstraction is done	3.73	3.86
Application	1.7	2.83

Table 5 below presents the overall scores of two case studies designed.

TABLE V
OVERALL SCORE

Section	Natural Order	Producer-Consumer
Average	23.05	24.32
Variance	5.77	4.78
Standard Deviation	2.40	2.18

The two studies were validated using the ttest in the spreadsheet application. The hypothesis were written as

Null: two group means are equal.

Alternative: two group means are not equal.

The results obtained can be seen in Table 6 below.

TABLE VI
TTEST RESULTS

T-Statistic	Scores
P(T<=t) two-tail	0.034758366
T Critical two-tail	1.994437086

As the p value is smaller than the value of significance (two tailed test), we hence reject the null hypothesis and accept the alternative hypothesis. We can thus conclude that the two group means are not equal.

D. Student Feedback

Feedback was collected from the students on two questions. The first feedback was collected on overall course effectiveness, and second was on learning effectiveness of the case study of the model problems. The two feedbacks are presented in Figures 3 and 4, respectively, below

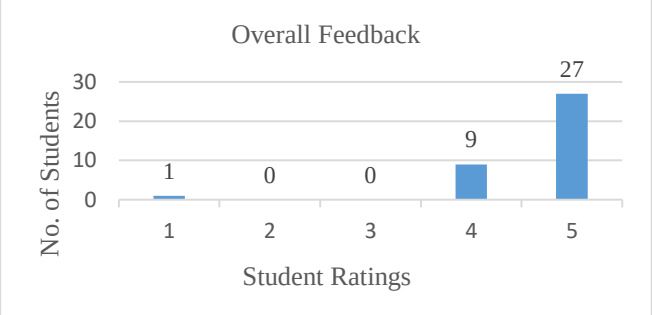

Fig. 3: Overall course feedback

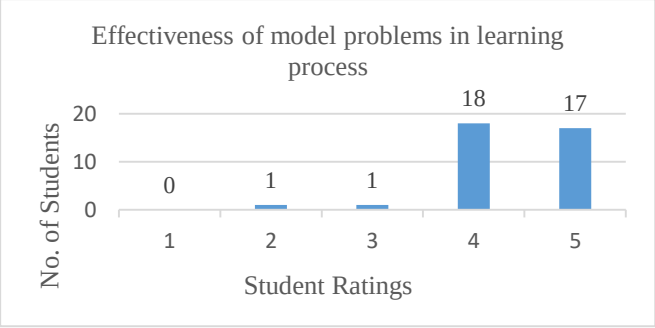

Fig. 4: Learning effectiveness of case study

We can see from the feedback given by 37 students that the learning process has been satisfactory, and 35 students are positive about the process.

VI. Discussion

Though the mean values are almost the same, we have concluded using a t test that the two group means are not equal. In order to explore this further, the themes generated were revisited to analyze each of the case studies. Table 6 below presents the number of themes that originated from each case study, including natural order and of producer-consumer.

TABLE VI
THEMES FROM EACH CASE STUDY

Type	Number of Themes
Natural Order	9
Producer-Consumer	14
Common to Both	3

The numbers clearly show that when generalization is explicitly asked in the reflection, the number of themes generated is 17 (14 + 3). This indicates that when abstraction is specially used, it can help students connect with the real-world applications in a better way.

If we closely observe the themes that are generated, for example: Feedback, divide and merge, Domino effect, etc., they all originated from the second case study. Abstraction can provide a channel that can help students think of a system in holistic way, extract principles and general ideas, and then apply them to other applications. Reflections are insightful, with same mean scores and the same variation, but still lead to better knowledge accumulation.

The students' feedback has been positive, indicating that the process has been effective in their learning. 35 of 37 students were satisfied with the case study learning.

VII. Conclusion

Abstraction can help in writing better reflections as compared to general reflective statements. If a faculty member can generalize the problem, it can bring a holistic essence to the problem and help students connect with real-world in a deeper way. This addresses the self-directed learning component of the PBL. The objective of this work was three-fold and it has been achieved. The abstractions present in the system have been understood. Reflect on the abstractions critically relating to real-world applications achieved through a well-crafted case study. To identify the conceptual themes in the reflections, we coded the data and identified that abstraction can provide meaningful themes and help to connect with varying solution space depth.

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