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Reflections and Pattern Recognition in Problem Based Learning

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***Abstract*—Problem based learning, being student-centered, has been widely used in education programs to enhance the learning process. Self-directed learning and critical thinking are major aspects of the pedagogy among several others. Reflections are generally used to capture the student's understanding during problem-solving. While problems can be designed and solved with supporting learning styles and strategies, computational thinking can aid in the process. Pattern recognition being one of the components of the model can assist in writing reflections. This work proposes to combine pattern recognition into reflection element. The designed case study model was qualitatively and quantitatively analyzed on 37 student's data. Descriptive and In vivo coding was used for round one, which was used to analyze the student reflections on the provided case study. Focus coding was used for round two to identify the evaluation parameters. The parameters were then used for the quantitative analysis. The work presents the themes and codes that were identified in the process. With pattern recognition in the reflections, students were able to relate to the principles studied in the past and arrive at better applicative thought process. Using pattern recognition promises to be an effective strategy to guide towards meaningful reflections.**

***Keywords*—Computational Thinking; Patterns; Pattern Recognition; Problem Based learning; Reflections.**

***JEET Category*—Research**

I. INTRODUCTION

IN the ever-evolving structure of modern education, it is of chief importance to provide students with the necessary skills accompanied with knowledge to solve the real-world challenges and train them with practical applications. Engineering education aims to provide a supportive and well-organized way of learning, enabling students to effectively apply their knowledge and insights in solving complex real-world problems (Masek & Yamin, 2012). One of the recent-popular approaches that meets the demand of improving students' learning by facilitating knowledge acquisition and strengthening the capacity to apply the acquired knowledge in solving real-life scenarios is using Problem-Based Learning (PBL) (Yadav et al., 2011). PBL helps to develop a variety of problem-solving skills and contribute to society and professional endeavors (Boelt et al., 2022).

The problems are usually identified, unpredictably, while solving real-life issues demanding cognition level thinking, collaborative teamwork, and various ways of approaching the problems. These aspects are typically not addressed in traditional classroom problem-solving exercises. Aligned with the prevailing research trends, assessing the effectiveness of PBL often focuses on knowledge gained as a key. Concepts, principles, and procedures are defined as methods to evaluate students' acquired knowledge patterns (Sugrue, 1995). Students' learning must reach to depth of three levels of knowledge structure, which helps them to organize this knowledge within their mind. Throughout the instructional process, it is necessary to encompass concepts, grasp principles, and reflect on the prior information to apply to the real-world conditions (Gijbels et al., 2005).

Reflecting on thoughts holds great weight in professional and personal contexts. It unveils the cognitive processes during the inquiry as the saying goes 'thinking arises in situations of uncertainty, doubt or complexity' (Dewey, 1916). Reflection has to make an effective strategy in teaching so that more stress is given to the quality of thinking rather than only learning (Zeichner & Liston, 1996). In academics, students often encounter a wealth of information but they are found to be eager to engage with real-time scenarios (Barrows, 1996). Providing complex questions helps students to revisit the knowledge they were trained, in order to solve new problems. Not always there is a single solution, complex issues can be solved in many ways but students need to come up with a thought process that is taught using Computational Thinking (CT) elements. CT skills do not solely focus on programming or coding education (Bers et al., 2013) but provide enhancement in students' problem-solving, abstract thinking, similar abilities, and decomposing problems.

One of the major components of using PBL as pedagogy is writing reflections which can strengthen the critical thinking and self-directed learning. Pattern recognition is one of the components of CT that can help to identify the common recurring themes and design better systems. This work explores combining both and measures the effectiveness in problem-solving. Metaphors have been used to explore the pattern recognition using story telling methods (Hegade et al., 2023).

The paper is further divided into the 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 the conclusion in section VII.

II. Literature Survey

This section reviews the literature in the fronts of PBL, CT, and reflections. Solving complex, real-world problems using interdisciplinary knowledge is part of Problem-based learning. Researchers believe students can improve their knowledge and skills using PBL's collaborative and multi-way learning process. PBL has been explored with one-day many-problems approach (Hegade, 2019). Being a student-centered learning approach, it encourages engagement in the research field, practicing both theoretical and practical applications, and developing an efficient solution using information gained and skills for specified problems (Savery, 2015). The main objective of PBL is to improve students' way of learning by challenging various kinds of questions.

Students can solve complex problems by developing multiple solutions, as a goal for problem-solving involves exploring questions. Identifying the main cause of the problem, and the necessary conditions required to solve the question, is possible when students work collaboratively in groups and determine the kind of information required, that helps them to become self-contented, self-evaluated, and engaged problem-solvers (Beringer, 2007). The reason for stating PBL as self-centered is that teachers cannot instruct insights and learning, it's the student who must be disciplined to explore learning issues and reflect on them by self-evaluation and peer feedback. Instead of going through the traditional approaches of teaching by following a hierarchical list of chapters, students should engage in contemplation of their thought process and oversee and adapt their strategy.

John Dewey, a philosopher, and educator, recommended the cultivation of reflective thinking skills as a significant educational goal, which helps to attempt an action and experience a noticeable response (Dewey, 1956). Reflection, which involves introspection and turning one's focus on self (Steier, 1995), serves as a foundation for encouraging students to thoughtfully approach complex problem-solving and consider real-world applications. Exercising in creating, building, and programming improves knowledge construction as it involves the fundamental idea of experiential learning that relates to design and learning (Harel & Papert, 1991; Kafai & Resnick, 1996). Reflection has proven to be beneficial for practitioners as part of educational literature (Gould & Taylor, 1996; Johns & Freshwater, 1998; Mayes, 2001; Smith 1992). Dewey's idea contemplates examining the proposed ideas by testing and interventions (Dewey, 1910).

Computational thinking emerged with the idea of cognitive techniques and resolving mathematical problems (Guzdial, 2008), the notion of thinking akin to the computer which was termed procedural thinking, as computational thinking emerged as a valuable element of cognitive skills (Sondakh, 2018). In many ways, computational thinking has been defined (Voogt et al., 2015), as the thought process employed to frame a problem and articulate its solution in a manner that a computer can effectively utilize (Wing, 2014). The cognitive approach of abstracting problems and devising solutions that can be automated (Yadav et al., 2014). Incorporating computational thinking into classroom instruction and integrating it into teaching practices can be the most effective approach. Effectiveness of PBL and CT has been studied (Hegade et al., 2023) Developing computational thinking does not inherently demand the utilization of computers or programming. Computational thinking has 4 sub-categories (Voogt et al., 2015; Wing, 2008) namely - decomposition, pattern recognition, abstraction, and algorithms. To effectively draw insights by reflecting on complex applications or problems using problem-solving processes by utilizing computational thinking paradigms can be enhanced by devising solutions that can be replicated to address analogous problems. While computational thinking as a comprehensive approach may not be replicated for every situation, pattern recognition can aid in identifying specific components that may be addressed by integrating elements from prior situations.

The literature presents an opportunity to combine the reflections with pattern recognition problems and examine their 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. To construct the knowledge this work uses the inductive approach. Considering the sampling method used, this work has its own limitations. The work reflects the researcher's and participants perspectives. The work uses multi method approach for data analysis. Both qualitative and quantitative methods are used for analysis. Hence our interpretive framework is pragmatism.

B. Research Question

Considering the gaps and fields of study interest, which are PBL and CT, we construct the research question as

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

We explore this by designing a case study that explicitly asks to pattern recognize and reflect and another that only asks to reflect.

C. Model

Based on the gaps in the literature survey and the elements of the study under consideration, a model was designed to guide the case study design. This model is presented in Figure1.

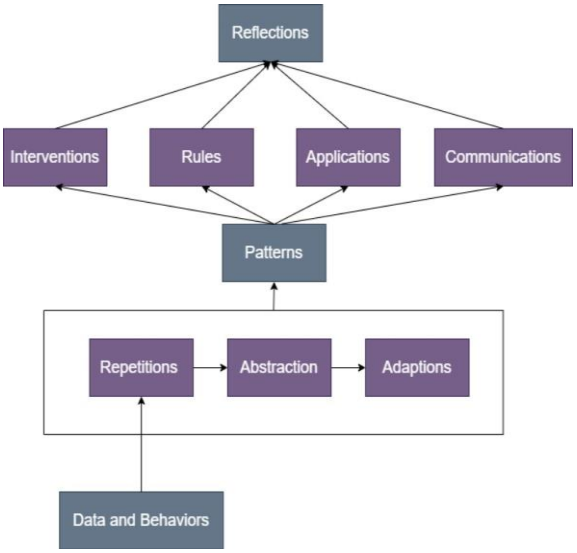

Fig. 1: Model for case study design

The case studies are designed in such a way that once the data has been collected it can be analyzed to identify patterns using repetitions. Information can be used to understand abstractions and adaptions generalized by students to know what influenced them to have such interventions using guidelines that govern student behavior in the form of rules. Applications are how interventions and rules are applied using communication with guides or peers. Further questions are designed to reflect on these elements.

D. Sampling

Data was collected from 37 students who were undergoing a course on Model Thinking from the School of Computer Science and Engineering department who completed their second year at KLE Technological University. The sampling technique used was purposive sampling. It is the process of choosing many people such that the selected together produce as close as the totality (Rai & Thapa, 2015). In this total population was chosen to examine, to avoid bias in the results. A consent form was shared with all the students stating that the data would be used for research purposes. With their signed consent and permission, as per university guidelines, data was collected for the research work. The data collection included survey forms to be completed and written case study solution sheets 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 listed below in Table 1 formulated based on the research question design.

TABLE I
OBJECTIVES

ID.	Objective
OBJT_1	To understand the patterns present in the system
OBJT_2	To reflect on the patterns critically relating to the real-world applications
OBJT_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

As patterns were the major emphasis of the case study design, two problems were selected from NetLogo: Moths and Ants.

In the moths' case study, students had to understand how moths are attracted to light and the different patterns that exist in the system. After exploring the model students were asked to 'Write the reflections for the model'. In the ants' case study, they search for food. The pheromone trail leads to more ants following the paths and hence the patterns. Students were asked to explore the mode and students were explicitly asked 'What patterns do you observe in the system and how can you relate them to other practical applications?' Though both the case studies exhibit patterns, the difference between the two case studies was that the second one explicitly stated patterns and asked to relate to real-world applications. The links for the case study are Moths (https://ccl.northwestern.edu/netlogo/models/Moths) and Ants (https://ccl.northwestern.edu/netlogo/models/Ants)

V. RESULTS AND DATA ANALYSIS

This section presents the results and the data analysis. The solutions presented by the students were graded for the quantitative study. The results are presented in the following sub-sections. Two rounds of coding were carried out on the case study data for qualitative analysis. In the first round of coding a mixture of descriptive and In vivo coding was used. In descriptive coding, we code the passages according to the topic of interest (Holton, 2007) to get a word capitalized code. In vivo coding, we use the exact phrases and words collected from the case study experiences and perspectives (Saldana, 2021).

Codifying is the process that allows segregating, grouping, relinking, and reapplying the code on data to achieve relative patterns and to get consolidated meaning (Grbich, 2014). For the second round of coding, Focused coding was employed where we categorized the related themes and merged them (Benaquisto & Given, 2008).

A. First Round Coding

Answers were analyzed to identify the themes that are broad categories, that capture the main idea of students' reflection. In the initial coding phase, various thematic elements were identified from the given statements based on suitable coding methods. Both Descriptive and In vivo coding was used in first round. Descriptive coding involves assigning labels to segments of text that represent specific themes or concepts. These labels act as shorthand summaries. In this research work identified themes from the reflections for question on Moths and Ants simulation, the themes observed under descriptive

coding include 'dynamic approach', 'leadership roles', 'feedback mechanism', 'Divide and solve' etc. These themes help to get the content of the reflection in abstract way. 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: "Local interactions leading to global patterns." This was coded as a DYNAMIC APPROACH as the definition of dynamic method of solving problems defines larger problem can be solved using smaller once. The student's reflection "Based on number of people visited an area it provides valuable insight whether to choose" tells a way of passing information to others that can be called as feedback giving so is coded as FEEDBACK MECHANISM. Similarly, "Collecting food bit by bit makes a complete bite" was coded as INCREMENTAL ACCUMULATION as aligning with the reflection's emphasis on the accumulation of food pieces. Reflection "climate is key factor for growth of organism" and "living in a community allows for situations to be handled in a way that everyone lives in harmony, even when someone is in a bad situation" is coded as REAL WORLD because the code summaries the reflection's important aspects of the natural world and ecosystem dynamics. "Without having target random behavior is observed" it presents more of sense like trying all possible action and is coded as BRUTEFORCE etc.

'In vivo' coding in Latin means 'in the presence or living' emphasizing the importance of using labels directly from participants as it helps to capture richness and nuances of participants. In a general example "I guess the journey is about taking massive amounts of data, and breaking it down. You'll have so many little bits of information everywhere that you can use and re-arrange and tidy up in the end", using In vivo the code would be BITS OF INFORMATION that covers the essence of statement. Utilizing in vivo coding will be highly effective for maintaining alignment with the student's responses, avoiding the introduction of any biases and deviation from context. A few of the samples from student's reflections that was coded using In vivo coding are "To maintain balance there should be movement within the colony so that all ways are explored" was coded as EXPLORATION given that the term 'explored' itself serves as a code, "Planners effectively designing where the crowd should move" was coded as an PLANNING EFFECTIVELY, "individuals with different roles and responsibilities help in efficiently performing various tasks" is coded as INDIVIDUALS WITH DIFFERENT ROLES EFFECIENTLY PERFORM TASK and "Resource collecting allows individuals to survive periods of scarcity or unfavorable conditions" that is coded as RESOURCE COLLECTING etc.

The themes that originated from the study are summarized in Table 2 below. Several such themes were classified from the case studies. 30 such reflections were identified from the case studies.

TABLE II
SAMPLE THEMES AND CODES

Student Reflection	Theme	Code
Complex patterns are produced by basic rules	Divide and solve	Team wise solving
Once all possibilities of solution to a current problem are identified then advance to the next	Optimal approach	Optimal approach
Resource collecting allows individuals to survive periods of scarcity or unfavorable conditions.	Resource collecting	Survival of fittest
To maintain balance there should be movement within the colony so that all ways are explored	Exploration	Design Technique
Collecting resources in one place and using it for later purposes	Merge and Divide	Optimal Approach
Working in a group is more effective than individually, as the evaporation rate of chemical traces will be stronger in group	Collaborative efficiency	Team wise solving
Collecting food bit by bit makes a complete bite	Incremental accumulation	Sequential approach

The summary of themes identified is presented in Table 3 below from the set of 30 identified reflections. The codes presented are the result of first round coding that are categorized into related groups and named under themes as part of second round coding. All others saturated into one of the 30 identified reflections.

TABLE III
THEMES CATEGORIES

Themes	Codes
Design Technique	Brute Force approach Sequential order Exploration Incremental accumulation
Natural Order	Real-world application Convergence and divergence Resource transformation
Optimal approach	Dynamic approach Inheritance approach Efficient selection process Planning effectively Greedy approach Merge and divide
Survival of fittest	Resource collecting Safe state Stability chances Focused actions Marketing Survival competition
Team wise solving	Divide and solve Individuals with different roles efficiently perform task Collaborative efficiency

	Mutual understanding
	Leadership roles
	Indexing and ordering
	Feedback mechanism

B. Second Round Coding

In the second round coding Focus coding is used as it helps in identifying patterns and layers of meaning by determining variations and interconnections between sub-themes and narrow downs the code. Focused Coding involves organizing coded data by identifying thematic or conceptual similarities, leading to the development of major categories or themes derived from the data (Saldana, 2021). From the Codes obtained after round one of coding those are narrowed down under related groups as shown in Table 3. From sample code mentioned above, dynamic approach and planning effectively are grouped under OPTIMAL APPROACH with other codes like Merge and divide, Greedy approach etc as the code represents the way of problem solving in optimal way, similarly, Incremental approach and Brute force approach, exploration etc are merged into the DESIGN TECHNIQUE category because those all codes define design structuring. NATURAL ORDER includes codes related to real world and resource utilizing. Also, codes like Survival competitions, Safe state, Stability chances are grouped under SURVIVAL OF FITTEST. Finally, TEAM WISE SOLVING is theme for codes representing about team like Mutual understanding, Collaborative efficiency, Feedback mechanism etc.

Students used the design techniques, optimizations, survival tactics, balancing, and advantages of teamwork into their reflections. If we closely observe these, they are all interconnected with the decision, communication, path and exploration patterns. Communication can be observed as a means of Team wise solving, identified from the theme, similarly Optimal approach and Natural order for the Trajectory path, and using exploration as a parameter helps to evaluate students' interventions on survival of fittest, Design Technique. This helped us to identify the evaluation patterns as led by the coding process.

C. Case Study Scores

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

TABLE IV
SCORES ON IDENTIFIED PARAMETERS

Section	Moths	Ants
Decision question	0.76	0.889
Trajectory Path	6.722	6.722
Exploration	2.667	2.695
Communication	2. 58833	3.00

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

TABLE V
OVERALL SCORE

Section	Moths	Ants
Average	14.638	15.583
Variance	5.665	6.593
Standard Deviation	2.380	2.5676

The two studies were validated using the ttest using the spreadsheet application. The formula was used to produce the results. 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	0.119311815
T Critical two-tail	1.995468907

As the p value is greater than the value of significance (two-tailed test), we hence accept the null hypothesis and reject the alternative hypothesis. We can thus conclude that the two group means are equal.

D. Student Feedback

Feedback was collected from the students on two questions. One feedback was collected on overall course effectiveness and the second one on the learning effectiveness of the case study. The two feedbacks are presented in Figure 2 and 3 respectively below.

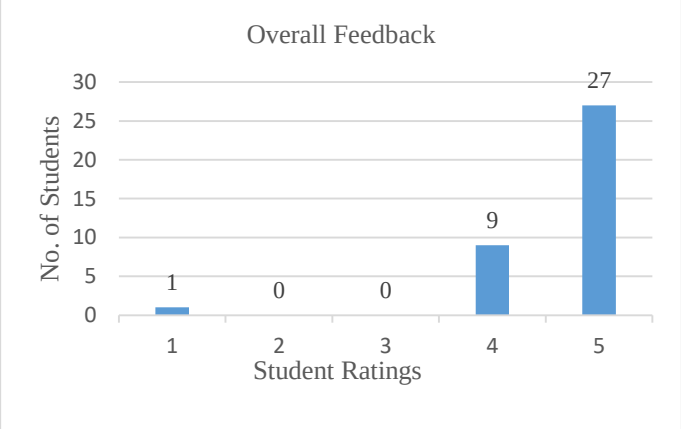

Fig. 2: Overall course feedback

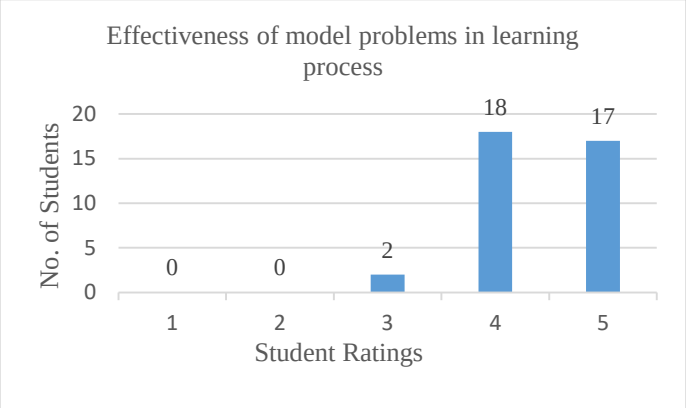

Fig. 3: Learning effectiveness of case study

We can note from the feedback given by 37 students that the learning process has been satisfactory.

VI. Discussion

This case study helps us to arrive at intriguing discussion points. Though the mean values are almost the same, we have concluded that the two group means are equal from ttest results. To explore this further, the themes generated were revisited further to analyze each of the case studies. Table 7 below presents the number of themes that originated from each case study.

TABLE VII
THEMES FROM EACH CASE STUDY

Type	Number of Themes
Moth	7
Ant	20
Common to Both	3

The numbers clearly show that when pattern recognition is explicitly asked in the question of Ant simulation, the number of conceptual themes generated is 20. In-fact, 23. This clearly indicates that the pattern recognition component of computational thinking can help in writing better reflections.

The patterns help students in recollecting the different concepts they have studied in the previous semesters. This can be an ideal way of writing reflections where critical thinking, cognitive skills, and relating to practical applications are expected. This helps to draw our objectives when pattern recognition and reflections, are used in problem-based learning. Also, most themes correlate to the core courses they have studied in the past years. This off-course is one of the objectives of PBL where students play between the known and unknown knowledge.

Student 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. The learning process of NetLogo is found effective in understanding the graphical model of systems. Researchers also find Netogo an interesting way to teach students about knowing nature of the system. (Vattam et al., 2011).

VII. Conclusion

Pattern recognition can help in designing effective case studies. The work stated that one of the objectives was to understand the patterns present in the system. Reflections can help to identify these. If these have to be systematically explored then the question must prompt with the trigger word of pattern rather than generically stating to write the reflections. The concept's themes mostly relate to the past experiences of the students and this might also help them to explore new applications. The process appears to be an effective way to design reflections.

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