Impact of CBL on Student's Learning and Performance: An Experience Report

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ABSTRACT

Case-Based Learning (CBL) is a well-known teaching methodology adopted across several disciplines for understanding problem domain from multiple perspectives. The CBL is also utilized in the Software Engineering domain to teach various concepts like Requirements Engineering (RE), Software Design and Testing. In this paper, we report the results of a replicated study conducted to assess the effectiveness of CBL methodology in facilitating the learning of several RE concepts. The evaluation was made based on postgraduate students' responses to a set of questions representing five learning principles and a set of case questions for the given case. We found that the use of CBL teaching methodology helps in improving students' learning and performance.

CCS CONCEPTS

• **Social and professional topic** → Software engineering education; • **General and reference** → *Empirical studies*;

KEYWORDS

Software engineering education, case-based learning, requirements elicitation and prioritization, teaching methodology, empirical study

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1 BACKGROUND, MOTIVATION AND AIM

CBL is a teaching methodology primarily used in medical, law, and business domains for introducing multiple perspectives of the scenarios [3][7]. CBL explores different viewpoints of the problem, enhances intrinsic and extrinsic motivation, encourages self-evaluation, critical thinking, and development of learning skills [7]. Software Engineering (SE) is also similar to other domains such as medical, law, and business domains where the information needs to be gathered, designed and analyzed by resolving conflicts among various users involved in the process. Typically, SE is taught in academia using a RE process, which starts with a well-defined problem from where the students undertake the projects and develop other related artifacts. However, the complexity lies in understanding the problem and identify a RE technique which is best suited for the specific scenario. CBL methodology helps to deal with such complexities by complementing lecture-based learning with the real-world open-ended cases and their implementation [6][8][9].

Teaching RE concepts using a non-traditional approach has gained a lot of interest in the literature (e.g., [1][5][11]). The main challenge is providing students with a logical understanding of the RE phase and how the concepts they learned have been applied in real projects. CBL is a well-known teaching methodology that facilitates students with an understanding of real complex scenarios, testing their critical thinking and decision-making skills [3][7]. Related to the SE domain, Garg et al. [2] developed a case for teaching software architecture concepts to undergraduate and graduate students. Their results revealed that CBL helps in improving their learning. Saini et al. [6] developed a case for teaching design principles and provided guidelines to write cases for CBL. Tiwari et al. [9] developed the cases for teaching software testing concepts along with the study to show the effectiveness of CBL.

In this paper, we applied a CBL methodology for teaching RE concepts to the postgraduate students, and assess whether CBL has an impact on students' performance. The cases and CBL execution procedures used in the study are borrowed from the literature [8]. The evaluation criteria are also modified to assess students' performance besides the learning objectives. The results of the study highlighted that the use of CBL methodology in teaching RE concepts motivates them to refer multiple resources and improves their learning and performance.

2 STUDY ELEMENTS

Figure 1 shows an overview of the study conducted for assessing the impact of CBL in students learning and performance, and this section presents various elements related to the study.

2.1 Students Participated in the Study

Nineteen postgraduate students enrolled in the core course on IT561 Advanced Software Engineering in Autumn 2019 at DA-IICT Gandhinagar, India has participated in the study. All the students belong to a similar background in their graduate. However, their earlier experience with a specific RE concept can be a threat and taken care of in the training and execution stage.

2.2 Cases

In this study, we have used two RE cases [8] – Metro Ticket Distributor System (Case A) and LIC Market Driven System (Case B) – to

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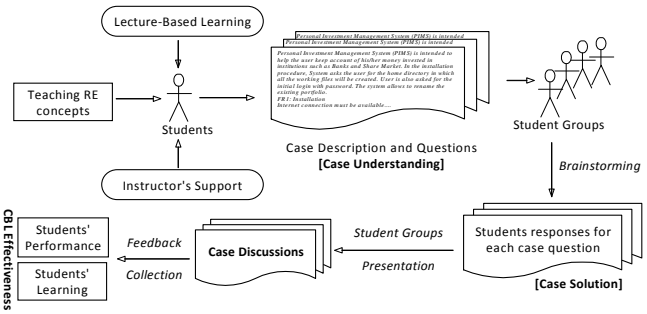

Figure 1: Overview of the study for evaluating the effectiveness of CBL in students learning and performance

assess the impact of CBL on students' performance. Each case consists of a set of questions to be answered during the CBL sessions. Both these cases covered the RE concepts: requirement elicitation, requirement analysis, requirement prioritization, concept mapping, use cases, and user stories.

2.3 Case Description

Here, we briefly describe the two cases, along with a few questions. In actual, both cases consist of eight questions each. These two cases can be downloaded from the link[1] & [2].

Case A: Metro Ticket Distributor System

Bangalore Metro station wants to establish a TicketDistributor machine that issues tickets for passengers travelling in metro rails. Travelers have options of selecting a ticket for a single trip, round trips or for multiple trips. They can also issue a metro pass for regular passengers or a time card for a day, a week or a month according to their requirements. The discounts on tickets will be provided to frequent travelling passengers. The machine is also supposed to read the metro pass and time cards issued by the metro counters or machine. The ticket rates differ based on whether the traveller is a child or an adult. The machine is also required to recognize original as well as fake currency notes. The typical transaction consists of a user using the display interface to select the type and quantity of tickets and then choosing a payment method of either cash, credit/debit or smartcard.

The ticket or tickets are printed and dispensed to the user. Also the messaging facilities after every transaction are required on the registered number. The system can also be operated comfortably by a touch-screen. A large number of heavy components are to be used. We do not want our system to slow down, and also usability of the machine. The TicketDistributor must be able to handle several exceptions, such as aborting the transaction for incomplete transactions, insufficient amount given by the travellers to the machine, money return in case of aborted transaction, change return after successful transaction, showing insufficient balance in the card, updated information printed on the tickets e.g. departure time, date, time, price, valid from, valid till, validity duration, ticket issued from and destination station. In case of exceptions, an error message is to be displayed. We do not want user feedback after every development stage but after every two stages to save time. The machine is required to work in a heavy load environment such that in the morning and evening times on weekdays or weekends performance and efficiency would not get affected.

Questions:

Q1. Enlist all functionalities of the TicketDistributor system in the form of user stories. Can you prioritize them (using the requirement prioritization techniques, e.g., AHP, Numerical Assessment, MoSCoW method, etc.), keeping priorities of non-functional aspects into consideration? Provide details.
Q2. List all possible features and components. But we need a highly responsive system for the quick issue of the tickets so we need to neglect some. Which features and components could be neglected without affecting the system's performance?
Q3. Identify three different use cases where conflicts between the requirements occur? Do you think that conflicts can be resolved?

Case B: LIC Market-Driven System

LIC, an insurance company wants to digitize a range of business processes and provide a complete solution that addresses all aspects of the agent-insurer relationship. Consider yourself as a part of Requirement Analyst team at Retinodes Software Company, and your job is to gather and prioritize the set of requirements. In this new requirement of the project, there are no existing systems that can be analyzed for the development. Requirements have to be gathered, negotiated, validated and prioritized through multiple stakeholders which is a complex process because all stakeholders have different perspectives, requirements and priorities. Therefore, Retinodes want to have a requirements engineering framework that can be used in market-facing projects.

To start with, you need to identify the set of stakeholders associated with the system, the domain information about the insurance market, and possible features. The first product LIC wanted you to develop consolidated insurance packages which can compete with the packages provided by other insurance companies. Another product is based on the customer priority, based on the insurance policies available the customer can create his/her own package and send a request for the review. The system have to automatically analyze the package, provide suggestions (if any), and at last give a competing price for the package. To understand the problem domain, existing packages have to be analyzed and the demands and restrictions from the insurance policy and agents have to be understood completely. The requirements and feasibility report generated by you, will further be used by the development team for implementation.

Questions:

Q1. Identify all the stakeholders and users of the systems. Enlist all features of the LIC Market-Driven system by each user of the system, in the form of user stories. Can you prioritize them using the requirement prioritization techniques? How? Provide details.
Q2. Suggest an effective requirement engineering framework that can be used in market-facing projects because there are no existing systems that can be analyzed for the development so we need to consider all requirements from the core.
Q3. Let us assume that the customized package developed by the customer (using your second product) is similar as the package available in your pre-defined package. What is the possible reason behind this defect? How it can be ensured that this would not happen?

[1] http://www.seabed.in/case-study/Metro_Case.pdf
[2] http://www.seabed.in/case-study/LIC_Case.pdf

2.4 Study Design

In our study, each student group has worked only in one case, and hence the design is incomplete, and the blocking factor is students' experience. Therefore, the chosen design is single-factor incomplete block design [10]. A total of 16 students had participated in the final execution of the study, 3 of them have missed the training session hence not included. The students' groups were formed randomly, and each group consists of four students. And, then the cases were randomly assigned to the group of students. Two groups (G1, G3) had worked on the Metro case, and the other two groups (G2, G4) worked on the LIC case. Both the cases were linked to eight questions, and each team member was given the responsibility of two questions. The various elements of the study design are:
Factor (Independent Variable): RE case
Alternatives: Case A (Metro Ticket Distributor System) and Case B (LIC Market-Driven System)
Response (Dependent) Variables: Students feedback on CBL Sessions; Students performance
Blocking Factor: Student's experience

2.5 Evaluation Criteria

The effectiveness of the CBL method in achieving five different learning objectives (such as learning, critical thinking, engagement, teamwork, and communication skills) was judged by collecting students' responses for the survey questions. The students' responses for each of the learning outcomes were collected on a four-point scale (Strongly Agree (SA), Agree (A), Disagree (DA), and Strongly Disagree (SD)). The list of survey questions grouped by the learning objectives is shown in Table 1. We used the same CBL survey questions as utilized by various researchers (e.g., Saini et al. [6], Kundra et al. [4], Tiwari et al. [9], Tiwari et al. [8]) for assessing the impact/effectiveness of CBL teaching methodology.

Another criterion for evaluation is the impact of CBL on students' performance. The assessment is done by collecting students' responses to the given set of comprehensive questionnaires (case questions) in different stages (during case solving and after CBL conclusions) related to each of the cases.

3 TRAINING & CBL EXECUTION

The overview of the empirical study is shown in Figure 1, and here, we describe details about the student's training, lecture and feedback sessions, and actual execution of the CBL sessions.

3.1 Preparation & Training

Before performing the execution of CBL sessions, ten lecture sessions were organized to introduce students with the RE concepts (e.g., requirement elicitation, requirement analysis, requirement prioritization, user stories, use cases, etc.). Additionally, a lab session of two hours was also conducted to introduce them with the idea of CBL and what steps need to be undertaken while performing the study. An examination was also conducted to know whether the students can able to learn the taught RE concepts. Based on their performance in the exam, the feedback was given to each of the students by the course instructor. This exercise would help in limiting the blocking factor.

Table 1: Survey questions grouped by the objectives

Objectives	Q.No.	Questions
Learning	Q1	I feel the use of case was relevant in learning about RE concepts
Learning	Q2	The case allowed for a deeper understanding of RE concepts
Learning	Q3	The case will help me to retain the different aspects of Requirements Engineering better
Critical Thinking	Q4	The case allowed me to view an issue from multiple perspectives
Critical Thinking	Q5	The case was helpful in synthesizing ideas and information presented in course
Critical Thinking	Q6	The case added a lot of realism to class
Engagement	Q7	I was more engaged in class when using the case
Engagement	Q8	The case discussion increased my interest in learning about Requirements Engineering concepts
Communication skills	Q9	The case discussion strengthened my communication skills to speak in front of the audience
Team work	Q10	The case discussion increased my confidence to work in a team
Learning of RE concepts	Q11	Choose RE concepts that can be better understood while solving the case Requirement Elicitation Technique **OR** Requirement Documentation (Use Cases & User Stories) **OR** Requirement Prioritisation Techniques **OR** Understanding Problem Domain **OR** Understanding Multiple Perspective of the Problem **OR** Feasibility Analysis **OR** Conflict Detection

3.2 Execution

The CBL methodology sessions are carried our in three stages: *Case Understanding*, *Case Solving*, *Case Discussion/Conclusion* [7][8]. The execution of the CBL methodology was performed in two sessions each of two hours. In the first session, eight students of G1 and G3 were called and demonstrated how the case can be solved. The student's groups were then asked to start working on the case in the lab session itself *[a.k.a Case Understanding]*. The course instructor was available in the session to help them in analysing the case and the procedure if needed. The case consists of eight questions, and hence each student in the group has assigned the responsibility of two questions such that their performance can be graded after the CBL exercise. The grading was done only based on their performance on the assigned case questions.

After the session, the groups (G1 and G3) were given one week to solve the case, as a home assignment, such that students get sufficient time to refer the resources and analyze the case *[a.k.a Case Solving]*. Similarly, the same process was followed for the other two remaining student groups (G2 and G4). After the case-solving exercise was completed, a three-hour session was conducted for presentation and discussions *[a.k.a Case Conclusion]*. Each student groups were given 20 minutes to present their case solutions. These presentations were followed by rigorous discussions to reach conclusions. This phase help students to understand a specific RE

Table 2: Students' responses to the questionnaires on the five teaching objectives [SA: Strongly Agree, A: Agree, DA: Disagree, SD: Strongly Disagree]

Teaching Objectives	Q.No.	SA	A	DA	SD
Learning	Q1	68.75%	31.25%	0	0
Learning	Q2	43.75%	50%	6.25%	0
Learning	Q3	56.25%	37.5%	6.25%	0
Critical Thinking	Q4	43.75%	56.25%	0	0
Critical Thinking	Q5	87.5%	12.5%	0	0
Critical Thinking	Q6	25%	75%	0	0
Engagement	Q7	31.25%	68.75%	0	0
Engagement	Q8	56.25	37.5%	6.25%	0
Communication skills	Q9	75%	18.75%	6.25%	0
Team work	Q10	87.5%	12.5%	0	0

technique well-suited in a specific scenario by hearing different views of the student groups.

4 ANALYSIS AND RESULTS

In this section, we present a detailed analysis of the data obtained by the students' responses on a four-point scale. Additionally, we have analysed the students' answers for the case questions (during and after the case sessions) to assess the effectiveness of CBL on their performance.

4.1 Overall Analysis for Learning Objectives

Table 2 shows the students' responses to the survey questions on a four-point scale. It can be clearly seen from the table that the students feel that (1) the use of case was relevant in learning about the RE concepts; (2) the case allowed them to view scenarios from multiple perspectives; (3) the case bring better realism to the class; (3) they feel that they are more engaged when using the case; and (4) the case discussions helped them to work in a team. However, there are few objectives in which the students have some disagreements as well. Though, this count is very small but can be incorporated in the later stages to achieve those objectives.

One student (6.25%) felt that the case is not sufficient enough to help him/her for a deeper understanding of the RE concepts. The same student had also felt that the case doesn't help him/her to retain different aspects of RE. Again, the disagreement is also showed for Q8 related to engagement. Another disagreement showed by a student on communication skills objectives that the case discussion doesn't help in strengthened his/her communication skills. As the student groups had worked on two different cases, it would be interesting to see whether the disagreements for four questions spread across both the cases or limited to only one case. This analysis is shown in the next section. On average, it can be seen that the use of CBL for teaching RE concepts has a positive impact on achieving the five different learning objectives.

4.2 Case Analysis for Learning Objectives

Table 3 shows the case-based analysis for the five learning objectives to investigate the impact of case difference on student's learning. One can see from the table that the student's agreement for both the cases is more than 87%. Hence, it can be inferred that both are cases are effective and helped students in improving their learning towards the objectives. However, few students (#2, belong to the G3 group) who had worked on Case A have disagreements over Q2, Q3, Q8 and Q9. To further analyze the student's performance, the case solutions submitted by the students are evaluated and analysed by the course instructor (shown in the next section).

Table 3: Case-based Analysis of ten question on five learning objectives (SA, A, D, SD in percentage)

	Case A				Case B			
Q.No	**SA%**	**A%**	**DA%**	**SD%**	**SA%**	**A%**	**DA%**	**SD%**
Q1	87.5	12.5	0	0	50	50	0	0
Q2	75	12.5	12.5	0	75	25	0	0
Q3	62.5	25	12.5	0	50	50	0	0
Q4	50	50	0	0	37.5	62.5	0	0
Q5	75	25	0	0	100	0	0	0
Q6	25	75	0	0	25	75	0	0
Q7	62.5	37.5	0	0	0	100	0	0
Q8	62.5	25	12.5	0	50	50	0	0
Q9	50	37.5	12.5	0	100	0	0	0
Q10	62.5	37.5	0	0	100	0	0	0

Table 4: Distribution of responses based on student feedbacks for RE concepts they understood

RE Concepts	%age of Agreement
Requirement Elicitation Technique	68.75%
Requirement Documentation (Use Cases & User Stories)	93.75%
Requirement Prioritisation Techniques	81.25%
Understanding Problem Domain	93.75%
Understanding Multiple Perspective of the Problem	81.25%
Feasibility Analysis	37.5%
Conflict Detection	87.5%

Additionally, we have asked the students to choose RE concepts that they understood better while solving the case. A total of seven concepts have been highlighted, taught using the traditional lecture-based sessions, and asked them to choose the concepts based on their learning. Table 4 shows the students' response to Q11, and it can be clearly seen that the cases help them in understanding all RE concepts (e.g., requirement elicitation, requirement documentation (use cases and user stories), requirement prioritization, understanding problem domain, understanding multiple perspectives, conflict detection) framed in both the cases except 'feasibility analysis' (only with 37.5% agreement).

4.3 Analysis based on Student's Performance

At the time of *case solving* stage, the students (each student had assigned the responsibility of two questions) were asked to submit their responses for the case questions. Hence, these questions were evaluated by the course instructor for the correctness. Table 5 shows the evaluation of the submitted responses in the following scale *(0 represent incorrect; 1 represent correct; 0.5 represent partially correct)*. The complied solutions to the case questions were taken from the previous study conducted by the authors in 2018 [8], and act as a basis for the evaluation.

After this analysis of the student case solutions, we have identified the set of case questions for which student groups come up with trivial/incorrect/ambiguous solutions. Based on the analysis shown in Table 5, for Case A, we have identified 6 questions (CQ1

Table 5: Analysis of case questions *(case solving stage)*

	Case A								Case B							
Q.No.	G1				G3				G2				G4			
	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8
CQ1	-	-	-	1	1	-	-	-	0.5	-	-	-	1	-	-	-
CQ2	-	-	-	0.5	1	-	-	-	1	-	-	-	1	-	-	-
CQ3	0.5	-	-	-	-	0.5	-	-	-	1	-	-	-	0.5	-	-
CQ4	0.5	-	-	-	-	0.5	-	-	-	0.5	-	-	-	0.5	-	-
CQ5	-	1	-	-	-	-	1	-	-	-	0.5	-	-	-	1	-
CQ6	-	0.5	-	-	-	-	0.5	-	-	-	0.5	-	-	-	0.5	-
CQ7	-	-	1	-	-	-	-	0.5	-	-	-	0.5	-	-	-	0.5
CQ8	-	-	0	-	-	-	-	0.5	-	-	-	0.5	-	-	-	0.5

and CQ5 are not considered), and for Case B, we have identified 7 questions (CQ2 is not considered) for further analysis.

Next, in the *case discussion* stage, the student's groups have presented their case solutions. A session of two hours was organised soon after the presentation of all groups completed. In this session, the identified set of case questions – specific to the case – were given to the students and asked them to submit their responses based on their understanding of the case after the case discussion stage. The responses submitted by the students were then again analysed by the course instructor and found that the CBL methodology has a positive impact on the student's performance as well. The specifications and related RE concepts are now better understood by the students.

Overall, the results of our empirical study revealed that the use of CBL methodology complements traditional lecture-based teaching and improves students learning and performance. The students enjoyed working on the cases and also help in achieving teaching objectives such as critical thinking, engagement, teamwork, and learning of concepts.

5 DISCUSSIONS

The implementation of the CBL involves various challenges like *case development*, *case execution* and *case discussion*. Various SE cases have been available in the web-based open source portal (SEABED[3]), where anyone can contribute, download cases, and implement them in their classroom. All the information related to case execution and discussions is described in detail, and we believe that can be replicated in the future. The empirical study was conducted with the postgraduate students, and the subject's experience with the concepts was tackled by providing essential training and feedback to all the students. As the experimenter and the students don't have any inclination towards the CBL technique; hence, related bias can be ruled out. The evaluation/grading was done only for the student's submitted case solutions (during and after the case sessions), and their feedbacks related to CBL sessions were anonymously collected. Hence, honest feedback from the students can be expected. At the time of execution, one session was organized for G1 and G3 (Case A), and another session for G2 and G4 (Case B), hence the possibility of copying solutions from each other can be ruled out. However, the student groups were also allowed to take the cases outside the lab sessions and instructed that their answers would be checked for plagiarism with the groups.

[3]http://www.seabed.in/

The evaluation criteria used for analyzing the impact of CBL methodology on student's learning and performance is qualitative rather than quantitative. Though we tried to assess the student's performance by evaluating their case solutions, still subjective, hence, new metrics for assessment need to be devised in the future.

6 CONCLUSIONS & FUTURE WORK

CBL methodology for teaching RE education enhance students learning, critical thinking, engagement, and teamwork through a self-learning environment. The students' responses showed a positive indication of all five learning objectives. Our results revealed that the CBL approach, with a well-designed case, is suitable for teaching and learning of RE concepts, and have a positive impact on the students' performance. In future, we plan to target additional topics related to RE curriculum using CBL pedagogy.

REFERENCES

[1] Brian Berenbach. 2005. A hole in the curriculum. In *Proceedings of the 1st International Workshop on Requirements Engineering Education and Training (REET'05)*. IEEE Computer Society, 62–67.

[2] Kirti Garg, Ashish Sureka, and Vasudeva Varma. 2015. A case study on teaching software engineering concepts using a case-based learning environment. In *1st International Workshop on Case Method for Computing Education*. 13.

[3] Lina D Kantar and Angela Massouh. 2015. Case-based learning: What traditional curricula fail to teach. *Nurse education today* 35, 8 (2015), e8–e14.

[4] Divya Kundra and Ashish Sureka. 2016. An experience report on teaching compiler design concepts using case-based and project-based learning approaches. In *Technology for Education (T4E), 2016 IEEE Eighth International Conference on*. IEEE, 216–219.

[5] Peng Liang and O. de Graaf. 2010. Experiences of using role playing and wiki in requirements engineering course projects. In *2010 5th International Workshop on Requirements Engineering Education and Training*. 1–6.

[6] Veena Saini, Paramvir Singh, and Ashish Sureka. 2017. SEABED: An Open-Source Software Engineering Case-Based Learning Database. In *2017 IEEE 41st Annual Computer Software and Applications Conference (COMPSAC)*, Vol. 1. 426–431.

[7] Jill Elizabeth Thistlethwaite, David Davies, Samilia Ekeocha, Jane M Kidd, Colin MacDougall, Paul Matthews, Judith Purkis, and Diane Clay. 2012. The effectiveness of case-based learning in health professional education. A BEME systematic review: BEME Guide No. 23. *Medical teacher* 34, 6 (2012), e421–e444.

[8] Saurabh Tiwari, Deepti Ameta, Paramvir Singh, and Ashish Sureka. 2018. Teaching Requirements Engineering Concepts Using Case-based Learning. In *Proceedings of the 2Nd International Workshop on Software Engineering Education for Millennials (SEEM '18)*. ACM, New York, NY, USA, 8–15.

[9] Saurabh Tiwari, Veena Saini, Paramvir Singh, and Ashish Sureka. 2018. A Case Study on the Application of Case-Based Learning in Software Testing. In *Proceedings of the 11th Innovations in Software Engineering Conference (ISEC '18)*. ACM, New York, NY, USA, Article 11, 5 pages.

[10] Claes Wohlin, Per Runeson, Martin Hst, Magnus C. Ohlsson, Bjrn Regnell, and Anders Wessln. 2012. *Experimentation in Software Engineering*. Springer.

[11] Didar Zowghi and Suresh Paryani. 2003. Teaching Requirements Engineering Through Role Playing: Lessons Learnt. In *Proceedings of the 11th IEEE International Conference on Requirements Engineering (RE '03)*. IEEE Computer Society, Washington, DC, USA, 233–242.