A Case Study on Teaching Requirements Engineering Concepts using Case-Based Learning

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ABSTRACT

Requirements Engineering (RE) is known to be critical for the success of software projects and for the education of students learning Software Engineering. The traditional way of teaching RE concepts only by the use of problem specifications may not be efficacious and may not lead to enhancement of students' learning to the maximum extent possible. In this paper, we report the results of an experimental study conducted to assess the effectiveness of Case-Based Learning (CBL) methodology to facilitate several concepts of RE. The evaluation was made on the basis of students' responses collected, after CBL execution, to cultivate decision-making skills and a self-learning environment. The authors investigate the difference in students' learning based on case study difference, gender diversity, and team size. Additionally, we collected TAs (Teaching Assistants) opinion about the CBL session. The outcome of this CBL exercise was positive as maximum students were able to achieve all the five stated objectives of CBL.

KEYWORDS

Case-based learning, experience report, experimental study, requirements engineering, software engineering education, teaching methodology

1 INTRODUCTION

Requirements are the first artifact that needs to be generated in order to start with the software development process. Gathering, understanding, and analyzing the set of requirements require some systematic and engineered approaches. RE techniques emphasize the use of systematic and repeatable techniques that ensure completeness, consistency, and relevance of the software requirements [6]. RE is not an exact science and multiple alternative approaches and solutions are possible [5]. RE analysis can be best done through discussion, brainstorming, critical thinking and analyzing problem domain in multiple perspectives [18][22].

Addressing the gap between software industry and academia, the RE is traditionally taught, in academia, using an RE process which starts from a well-defined problem [13][18]. RE course relies on an approach to convey RE related concepts to the students such that it triggers them to analyze the problem statement with multiple perspectives and search for the best suitable solution. It is well known that educators face obstacles in teaching RE concepts due to its multidisciplinary nature which deals with both computer science and social sciences concepts [12][13]. The use of non-traditional learning approaches has gained a lot of interest of the educators in teaching RE concepts [8][25] as it involves discussions, teamwork, decision-making tasks, brainstorming, engagements, and critical thinking. The Case-based Learning (CBL) methodology [7][15][20] also committed to achieving the similar objectives, and can be used to teach some of the RE concepts.

The existing literature on various teaching methodology reflects that CBL has been used since long in the fields of Health Science education [23], Law education, and Business education [9]. However, the application of CBL in teaching concepts of RE is unexplored. Looking at the importance of CBL [15] and the issues of requirements engineering education, we intend to introduce case-based learning for teaching various concepts of RE in Software Engineering course. The main objective of this study is to examine the effectiveness of CBL in teaching RE discipline. We plan to develop RE cases, write experience report, and share them publicly through Software Engineering Case-Based Learning Database (SEABED)[1] with the Software Engineering (SE) community. This is the first case study execution and experience of CBL in RE.

In this paper, we report the results of an experimental study conducted to assess the effectiveness of the CBL teaching methodology to facilitate several concepts of Requirements Engineering. CBL exercise was conducted for post-graduate MSc (IT) students of Dhirubhai Ambani Institute of Information and Communication Technology (DA-IICT)[2], Gandhinagar (India) to cultivate the decision-making skills and self-learning environment. After CBL execution we collected students' responses and did statistical significance test and hypothesis testing. Specifically, we examine the impact of CBL on the students' learning based on case study difference, gender diversity, and size of the team. We have also evaluated the Teaching Assistants (TAs) responses for the data collected about CBL sessions. Our results of the study suggested that CBL is an

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[1] http://seabed.in/
[2] http://www.daiict.ac.in/

effective teaching methodology to teach RE concepts and process to the software practitioners for better understanding and motivation.

The paper is organized as follows. Section 2 presents related literature review and accordingly, outlines our research contributions. Section 3 presents the details of experimental study along with the research questions. Subsequently, we describe CBL execution and data collection in Section 4. Section 5 presents the study results and data analysis. Section 6 discusses implications of our findings, experiences and recommendations on implementing CBL. Section 7 concludes and suggests future work.

2 RELATED WORK AND CONTRIBUTIONS

In this section, we present the works related to our study and highlight our research contributions.

2.1 Case-based Learning for SE Education

Garg et al. [3] developed a case related to software architecture and introduced a Case-Oriented Learning Environment (COSEEd) for teaching Software Engineering concepts to undergraduate and graduate students. The authors found that the COSEEd help students to learn software engineering principles more efficiently. Saini et al. [20] proposed an open source web-based Software Engineering case-based learning platform. They have conducted an experimental study to show the effectiveness of CBL methodology on students' learning, and also provided guidelines to write cases that can be uploaded to the repository for implementing CBL in SE domain.

Kundra et al. [7] used CBL for teaching the concepts of Compiler Design. The authors reported their experience in implementing a Case-based and Project-based Learning for teaching Compiler design concepts. Their results suggested that the case-based teaching enhance students skills of learning, critical thinking, engagement, communication skills and teamwork. Peplow et al. [16] compared responses of female and male medical students to CBL program. They observed that the female students benefited more than the male students from initial discussions and group activities, and developed better communication skills.

2.2 Experience Reports on Teaching RE

Teaching RE concepts using a non-traditional approach has gain lot of relatively recent interest in requirements engineering domain [1, 8, 14, 25]. The main challenge is providing students with a logical understanding of what they may face, and how the concepts they learned have been applied, in real projects.

Portugal et al. [17] presented an experience report on facing challenges while teaching Requirements Engineering to undergraduate students. The study was conducted in three consecutive semesters with a total of 57 students by taking traditional lectures, applying project-based learning methodology, and collecting feedbacks. They suggested that the RE concepts such as project planning, quality control, company structure, client involvement, and budgeting can be taught using project-based learning methodology with a systematic approach improves students understanding.

Zowghi et al. [25] conducted study to teach requirements engineering through role-playing. The authors focused on various RE tasks like elicitation, analysis, modeling, validation, specification, and management. The role-playing tool for teaching RE through problem-solving gives a better understanding of multiple perspectives of RE and the techniques to apply for each task of RE. Peng et al. [8] also applied role-playing tool for teaching RE concepts. Specifically, they worked with a wiki to construct requirements specifications during classes and collaboratively. The suggested approach is useful to incorporate the bidding of projects such that the interest or commitment of the developers with the project gets increased, and help clients to bring their creativity in proposing a feasible set of requirements.

Our work is different from the existing work and based on CBL methodology to teach requirements engineering. A case in CBL is a unique, complex, and uncertain narrative structure of some contemporary interest arousing event or problem. In order to answer the case questions, students need to investigate the problem thoroughly and apply the RE concepts that they learned during the lecture sessions. Apart from CBL implementation in a Software Engineering course, our goal is to examine the impact of gender diversity, change in case problem, and impact of team size on students' responses.

2.3 Research Contributions

In contrast to the existing work, this paper reports makes three novel research contributions:

(1) First implementation of CBL for teaching and practicing the concepts of Requirements Engineering discipline for a large class of 112 students.
(2) Empirical analysis (including gender-based, team size-based, students and facilitator engagement) of CBL execution at DA-IICT, Gandhinagar (India).
(3) Suggesting recommendation and challenges based on the experience shared by 3 professors and 1 TA (authors from 3 different university collaborating and teaching SE for several years) on implementing CBL methodology.
(4) Writing two original requirements engineering cases, *Metro Ticket Distributor System case*[3] and *LIC Market-Driven System Case*[4] and submitting them to existing software engineering case repository (SEABED).

3 EXPERIMENTAL SETUP

In this section, we present various elements of our CBL implementation in Software Engineering course.

3.1 Research Questions (RQs)

In this work, we aim to investigate the effectiveness of CBL methodology by examining the students' responses to their learning, critical thinking, and engagement with the RE concepts taught using CBL sessions. Specifically, we intend to assess whether the use of CBL help to enhance several teaching objectives such as students' learning, critical thinking, engagement, communication skills and teamwork. Accordingly, we frame four research questions for investigation and analysis that are as follows.

RQ1 Do CBL results differ on the basis of case study differences among students groups?

[3] http://seabed.in/case-study/Metro_Case.pdf
[4] http://seabed.in/case-study/LIC_Case.pdf

RQ2 Do CBL results differ on the basis of gender diversity among students groups?

RQ3 Do the students who opted for or ended up working in smaller groups show different responses to the students who opted for or worked in larger groups?

RQ4 Does CBL results in an increased/better engagement between TAs and students?

3.2 Subjects

The subjects were 112 senior-undergraduate students undergoing a compulsory (or core) course on *IT 632 Software Engineering* in Autumn 2017 at DA-IICT, Gandhinagar (India). The CBL exercise was conducted as a graded exercise for the course. The students were familiar with problem-solving exercises studied in their object-oriented analysis and design course.

3.3 Cases

We created two requirement engineering cases along with two sets of questions to assist planned CBL sessions related to requirements engineering. Both the cases intend to facilitate the concepts of understanding the problem domain, requirement elicitation, and prioritization through the real-world case. Specifically, the topics RE concepts covered in the cases are requirement elicitation techniques, requirement analysis, requirement prioritization techniques, concept mapping, use cases and user stories.

3.4 Experimental Design

We used a single-factor incomplete block design during the experiment [24], where every student groups has not worked on all the cases, and students experiences is considered as a blocking factor. The class size of 112 students was divided into 14 groups – 8 groups of 6 students, 4 groups of 11 students and 2 groups of 10 students. The students were divided into a total of 14 different groups based on their Cumulative Percentage Index (CPI), and gender. The details of the student's groups created for CBL sessions are shown in Table 1.

Table 1: Percentage of male and female students in each group, and group average CPI

Group	# of Members	%Male	%Female	Average CPI
G1	6	63.64	36.36	7.436
G2	6	72.73	27.27	7.478
G3	11	60	40	7.257
G4	10	72.73	27.27	7.061
G5	11	66.67	33.33	7.058
G6	6	66.67	33.33	7.06
G7	6	60	40	7.166
G8	6	66.67	33.33	7.116
G9	11	63.64	36.36	7.068
G10	11	63.64	36.36	7.064
G11	6	72.73	27.27	7.366
G12	10	66.67	33.33	7.062
G13	6	63.64	36.36	7.064
G14	6	72.73	27.27	7.257

The experimental design can be inferred from Table 2 for both the cases. In our study design, we have chosen different size of students group in order to analyze the impact of group size on the student learning, critical thinking and engagement of the concepts. Out of 112 students, 76(68%) were boys and 36(32%) were girls. While assigning students to each team, we ensure that the group must be balanced with respect to gender, and their CPI attained in their previous academic sessions. We have evaluated students solution for each of the case from their case presentations, and case reports. We have identified best group for each case and rewarded with 10 marks in final grading. A total of seven days of time were given to all groups for solving the case. The various experimental elements of the study design are as follows.

Table 2: Design of the Experiment

Case-based Learning					
Session	**Case**	**Subject**	**Group**		
I	A	S1-S56	G1-G4 (6 student)	G5-G6 (11 student)	G7 (10 student)
II	B	S57-S112	G1-G4 (6 student)	G5-G6 (11 student)	G7 (10 student)

- *Factor (Independent Variable)*: requirements engineering case
- *Alternatives*: Case A (Metro Ticket Distributor System) and Case B (LIC Market-Driven System)
- *Response (Dependent) Variables*: students response with reference to case difference, gender diversity, impact of team size
- *Experimental Design*: Single-factor incomplete block design

4 CBL EXECUTION AND DATA COLLECTION

In this section, we provide details about the preparations done for CBL including students training, case descriptions, and CBL execution.

4.1 Preparation and subject training

Before commencing the CBL exercise, ten lecture sessions were taken to familiarize students with the RE concepts, using traditional lectures sessions, covered in the two cases. Additionally, two hours lab session was conducted to introduce them with the concepts of CBL for the better understanding through presentation, learning videos and demos. We have four TAs (two master's students, one doctoral student, and one research fellow) who would get familiar with CBL. The course instructor planned to demonstrate TAs with the CBL such that we can help us students more efficiently.

4.2 Case Description

This section briefly describes the two cases along with few questions. The detailed cases can be downloaded from footnotes 3, 4.

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 card 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 at the morning and evening time in weekdays, and in 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 the possible features and components. But we need a high 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 systems performance?
Q3. Identify three different use cases where the conflicts between the requirements occur? Do you think that the conflicts can be resolved? How?
Q4. Let us assume that there is a passenger who issued the ticket but he lost it somewhere. No authority would believe him as he lacks the proof. What safety features, according to you, should be incorporated as a proof against lost tickets?

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 has 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 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? (e.g., AHP, Numerical Assessment, MoSCoW method, etc.) 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? In which requirements engineering activity, this defect can be handled? Please provide a scenario to justify.
Q4. Can there be 'Open Issues' – issues those are identified but not taken care of? If yes, what are they? Is there some alternative ways for their resolution, such that no requirements conflict will happen?

4.3 Execution

The implementation of CBL was done in two different sessions each of two hours. In first session, 56 students (7 groups) were assigned Case A (Metro Ticket Distributor System), and demonstrated how the case has to be exercised. The students groups were asked to start working on the case in the lab session itself, where TAs and the instructor is available to help them to analyze and understand the requirements specified in the case. The students were given one week time to solve the case (takeaway, not as a classroom exercise) such that students get sufficient time to analyze by assessing multiple resources. After the case solving exercise was completed, four hours session was conducted for case discussions and analysis. Similarly, for Case B (LIC Market-Driven System) the aforementioned process is followed for remaining 56 students.

Specifically, the study was carried out in three different phases, 'Case Understanding', 'Case Solving', 'Case Discussions'. In the *Understanding Phase*, the case study was allotted to each team and asked them to understand the case study. In the *Case Solving Phase*, each student was asked to take the responsibility of one or more questions depending on the team size. However, the response to each question had to be finalized through team work. In our study, both RE cases consists of eight questions, and Q1 and 3 are more complex than the other six. The questions were randomly assigned to the students group and details of each group type are as follows.

(1) For the group size of 11 students, each student was responsible for one question and two students are responsible for solving Q1 and Q3. And, one student is responsible (who is a team leader) for the additional question.
(2) For the group size of 10 students, each student was responsible for one question and two students are responsible for solving Q1 and Q3. Also, all students in the team are responsible for answering the additional question.
(3) For the group size of 6 students, each student was responsible for one question, and remaining three questions (two case questions (Q1, Q3) and one additional question) were assigned among six team members such that the group of two students has got the responsibility of one question each.

One can see that each student, in groups of 6, has more responsibility than their classmates in the groups of 10 or 11. However, before conducting the session we ask students to come forward if they are willing to undertake this exercise in the group of 6. The rationale behind choosing different group types was explained to students in CBL session, and they were also introduced to the results, benefits or limitations for choosing different group types.

Finally, in the *Case Discussions Phase*, each student team was asked to submit their responses on the response sheet for all the eight questions, and then present their responses to the case questions. The students were allowed to use any kind of material for reference like internet, textbooks, etc. A targeted *discussion* was carried out after each team's presentation for their responses to the case questions. All responses to the questions and survey questions were collected using Google Forms.

The CBL exercise was assigned a weightage of 10% across all different assignments for the Software Engineering course. The best team in a session was allotted 10 extra marks that would be added in their end-semester examination marks. This was done to incentivize and further increase engagement. The overall exercise was evaluated and graded by one faculty member, two M.Tech research scholars, one research follow, and one PhD scholar from SE domain. Also, the students' responses were evaluated and graded both at the student level and group level in the class-session itself. When one student team was giving presentation, other groups were asked to assign them marks on the scale of 1-5 based on their understanding of the problem and responses to each question. Since peer-evaluation [21] is an active learning technique that causes students to think, ask questions and respond, we adopt this strategy to increase reliability and validity of the results [19].

5 DATA ANALYSIS AND RESULTS

This section presents the analysis of the data collected during the CBL sessions, to evaluate the impact of CBL on students understanding the RE concepts.

5.1 Data Validation

The collected data was analyzed to identify discrepancies in the students' responses. As it turned out, one subject from group G1 has submitted two different responses for the survey feedback questions and one student from group G8 has not attended the CBL implementation sessions. So we have not considered these two male students survey and evaluation data for our analysis, hence a total of 110 data points (i.e., 74 (66%) males and 36 (34%) females) were analyzed to draw conclusions. In the following, we present the results of each research question by analyzing the data collected during CBL sessions.

5.2 Overall Analysis

Table 3 shows the list of survey questions and students' responses to the CBL learning outcomes with regard to their learning, critical thinking, engagement, teamwork and communication skills. The responses were collected for each of the CBL learning outcomes in terms of Strongly Agree (SA), Agree (A), Disagree (DA), and Strongly Disagree (SD). We have used the same CBL survey questions that were utilized by Saini et al. [20] and Kundra et al. [7] for assessing the efficacy of CBL. From the Table 3, it can be inferred that 98.1% of a total number of students agreed (SA + A) that the case was relevant in learning about RE concepts (Q1) and 95.5% of the students thought that the case allowed for a deeper understanding of case concepts (Q2). Another observation is, almost 14% of total students don't think that they were more engaged in class when using the case (Q7). We believe that this may be due to the CBL session conducted as a takeaway session. More than, 90% of the students felt that the case allowed them to view the problem in multiple perspectives (Q4), helpful in synthesizing ideas (Q5), and added realism in the class (Q6). A significant 97.2% students agreed that the case discussion increased their confidence to work in a team and 96.4% strengthen their communication skills. These strong agreements give positive indications about the CBL exercises.

5.3 RQ1: Case difference

Table 4 shows the percentage of SA, A, D, SD for the teaching objectives to investigate the case difference on students learning. To further investigate, we framed a research question as "Is there any significant difference between the students' responses for Case A and Case B?", and performed the t-test for both agree% and disagree%. Here, the null hypotheses (H_{01}) assume that there are no significant differences, and the alternative hypotheses (H_{11}) suggest the existence of significant differences between the student's responses for both cases.

After performing the t-test for both agree% and disagree%, we get a t-value of 2.262 and p-value of 0.8455 at a significance level of $p<0.05$. Thus, we fail to reject the null hypotheses. Therefore, our result suggests that the two cases are equally effective and help students to achieve the learning objectives.

5.4 RQ2: Gender diversity

Though the strength of female in computing domain is fewer, their participation and contribution are important for the society to have a more balanced and equal representation [4][11]. For this, we did gender-specific analysis [2] and our research question for the same is, "Is there any significant difference between the responses from male and female students?". The overall results of Table 3 is represented in the form of male and female responses for both the cases. Table 5 shows the percentage of male and female responses in the form of SA, A, D, SD for ten questions. Here, we perform

Table 3: Survey questions grouped by the respective learning principles [SA: Strongly Agree, A: Agree, DA: Disagree, SD: Strongly Disagree]

Teaching Objectives	Q.No.	Questions	SA	A	DA	SD
Learning	Q1	I feel the use of case was relevant in learning about RE concepts.	44.50%	53.60%	1.80%	0
Learning	Q2	The case allowed for a deeper understanding of RE concepts.	47.30%	48.20%	4.50%	0
Learning	Q3	The case will help me to retain the different aspects of Requirements Engineering better.	47.30%	49.10%	3.60%	0
Critical Thinking	Q4	The case allowed me to view an issue from multiple perspectives.	55.50%	42.70%	1.80%	0
Critical Thinking	Q5	The case was helpful in synthesizing ideas and information presented in course.	32.70%	56.40%	10.90%	0
Critical Thinking	Q6	The class added a lot of realism to class.	32.10%	57.80%	10.10%	0
Engagement	Q7	I was more engaged in class when using the case.	32.70%	52.70%	14.50%	0
Engagement	Q8	The case discussion increased my interest in learning about Requirements Engineering.	42.70%	49.10%	8.20%	0
Communication skills	Q9	The case discussion strengthened my communication skills to speak in front of the audience.	53.60%	42.80%	3.60%	0
Team work	Q10	The case discussion increased my confidence to work in a team.	63.60%	33.60%	2.70%	0

Table 4: Percentage of SA, A, D, SD for the 10 questions sliced by Case (to investigate if case influences the satisfaction level)

Case A					Case B				
	SA%	A%	DA%	SD%		SA%	A%	DA%	SD%
Q1	51.8	48.2	0	0	**Q1**	37	59.3	3.7	0
Q2	46.4	53.6	0	0	**Q2**	48.1	42.6	9.3	0
Q3	57.1	41.1	1.8	0	**Q3**	35.2	57.4	7.4	0
Q4	60.7	37.5	1.8	0	**Q4**	51.9	46.3	1.9	0
Q5	35.7	57.1	7.1	0	**Q5**	29.6	57.4	13	0
Q6	30.4	58.9	10.7	0	**Q6**	33.3	57.4	9.3	0
Q7	35.7	44.6	19.6	0	**Q7**	29.6	61.1	9.3	0
Q8	42.9	48.2	8.9	0	**Q8**	42.6	50	7.4	0
Q9	51.8	41.1	7.1	0	**Q9**	55.6	40.7	0	3.7
Q10	69.6	26.8	3.6	0	**Q10**	57.4	40.7	1.9	0

t-test and found t-value for agree% is 2.262, the p-value is 0.710 at a significance level of $p<0.05$. Therefore, we fail to reject the null hypotheses. This means that there is no significant difference in the responses from male and female students. Based on this results, we conclude that the difference in gender has no effect in the CBL and help both male and female students to achieve learning objectives.

5.5 RQ3: Impact of team size on students learning

The relationship between team size and productivity in a specific environment is a question of investigation in SE domain. However, no theoretical arguments and empirical evidence are available in favor of either larger or smaller teams, hence it is hard to generalize an effective team size [10]. CBL exercise involves team and their collaboration by sharing their varied skills in complementary roles to solve the case, we intend to investigate the impact of two different team size on students learning. Table 6 shows the percentage of SA, A, D, SD for the teaching objectives to investigate the impact of team size on students learning.

In order to analyze the table data, we framed a research question as “Is there any significant difference between the students' responses of smaller and larger groups?”, and performed the t-test

Table 5: Percentage of SA, A, D, SD for the 10 questions sliced by Gender (to investigate if there is any gender differences). NOTE: Overall Strength of the class: 112 (36 Female, 76 Male). # of students participated in the study: 110 (# of female: 36, # of male: 74)

	Male					Female			
	SA%	A%	DA%	SD%		SA%	A%	DA%	SD%
Q1	48.6	50	1.4	0	**Q1**	36.1	61	2.8	0
Q2	48.6	51	0	0	**Q2**	44.4	42	13.9	0
Q3	47.3	47	5.4	0	**Q3**	47.2	53	0	0
Q4	56.8	42	1.4	0	**Q4**	52.8	44	2.8	0
Q5	31.1	60	9.5	0	**Q5**	36.1	50	13.9	0
Q6	33.8	54	12.2	0	**Q6**	30.6	64	5.6	0
Q7	35.1	46	18.9	0	**Q7**	27.8	67	5.6	0
Q8	39.2	51	9.5	0	**Q8**	50	44	5.6	0
Q9	59.5	34	4.1	2.7	**Q9**	41.7	56	2.8	0
Q10	63.5	35	1.4	0	**Q10**	63.9	31	5.6	0

for both agree% and disagree%. The t-test results reveal t-value of 2.2621 and p-value of 0.2291 at a significance level of $p<0.05$. Based on this, we fail to reject the null hypothesis and conclude that the size of the team does not have any effect on students learning.

Table 6: Percentage of SA, A, D, SD for the 10 questions sliced by team size (to investigate if there is any impact of team size on students learning)

Q.No	Small Group (#5-6)				Large Group (#10-11)			
	SA%	A%	DA%	SD%	SA%	A%	DA%	SD%
Q1	40	57.8	2.2	0	47	51.5	1.5	0
Q2	42.2	48.9	8.9	0	50	48.5	1.5	0
Q3	35.6	60	4.4	0	53	40.9	6.1	0
Q4	57.8	37.8	4.4	0	45.4	54.5	0	0
Q5	35.6	55.6	8.9	0	30.3	59.1	10.6	0
Q6	31.1	57.8	11.1	0	31.8	59.1	9.1	0
Q7	33.3	53.3	13.3	0	31.8	53	15.1	0
Q8	46.7	46.7	6.7	0	42.4	48.5	9.1	0
Q9	57.8	35.6	6.7	0	50	45.5	0	3
Q10	60	35.6	4.4	0	65.2	33.3	1.5	0

In order to further investigate the impact of team size on students learning, each of eight case questions solved by the students for each case was analyzed and represented in Table 7. The marks shown in the table was evaluated in 10 points and was the average of the marks given by 4 TAs, instructor and students groups. 4 small groups (G1, G2, G6, G7) and 3 large groups (G3, G4, G5) were assigned Case A and 4 small groups (G8, G11, G13, G14) and 3 large groups (G9, G10, G12) were assigned Case B. The students from each group were evaluated and graded on the basis of 9 questions (8 main +1 additional) and every question carried 10 marks. So, the answers have evaluated in a total of 90 marks. The group who scored the highest marks for Case A was a larger group (G3) with a total of 70 marks and the group who scored the highest marks for Case B was again a larger group (G9) with a total of 80 marks. So, for both cases, best groups were the larger groups.

Initial interpretation of the data shows that the team size has a huge impact on students learning. However, the close observation of the data shows that the difference of the total marks between the large group and small group for both the cases is negligible. For instance, G7-smaller group of Case A is 68 which is closer to the total marks of G3 (best group of Case A), and average marks of smaller (66.7) and larger (71.8) groups is not significant. Arguably, we can say that in one hand, each student of a larger group has the responsibility of a single question and due to this utilized time in researching and identifying the best solution, for that question only. On the other hand, the student of smaller group was responsible for answering multiple case questions, and this may result in scoring less mark as he/she could not devote equal time to those questions.

Overall, the results of both types of analysis suggested that the size of the team does not affect the students learning. Hence it can be inferred that we can choose any group size (5-6 members or 10-11 members) for CBL practices.

5.6 RQ4: TAs perception on CBL

Table 8 shows TAs questionnaire and their responses for capturing TAs perceptions on CBL. All the four TAs have responded that they don't have any prior experience with CBL as a student and as a TA. Before the implementation of CBL session, TAs were gone through the research papers from SEABED, solved few cases, discussed among themselves and with the instructor too. When the TAs were asked that which group type they found easy to manage or facilitate. The two TAs found that smaller groups are easier to manage; one TA stated that both group types are manageable, whereas one TA responded that facilitating larger group easier than smaller groups.

When the TAs were asked whether they found CBL for RE more useful than the traditional lecture-based learning, for the students to grasp the underlying RE concepts. All TAs agreed that CBL is more useful than the lecture-based learning for certain topics like RE. They also stated that the total number of TAs participated in the CBL exercise was sufficient for the class of 112 students. As the CBL exercise involve self-evaluation and assessment which demands new ideas and strategy varies from groups to groups, but they are overall satisfied with the students' responses to the case questions. After the CBL exercise, TAs have experienced the first time, were feeling confident about assisting in another CBL session. With regard to the time allocation, time spent, and participation between member between members of a group, the TAs responded that (1) they have spend equal time on each group, (2) the time allocated to each group for solving the case is sufficient, and (3) they have found balanced participation between members of the group in different group types.

Another interesting aspect of this CBL exercise is assessing the impact of team size on CBL, hence asked the TAs to suggest what should be the better group size based on the TAs experiences with CBL session and facilitating difference students' group size. Two TAs admitted that smaller groups could be a better option, one TA suggested that any group size can be chosen, and one TA stated that larger groups can be chosen. Overall, the TAs responses and their stated experiences showed that the CBL results in an increased engagement between them and students.

6 DISCUSSIONS

In this section, the authors share their recommendations and practical challenges encountered while exercising the CBL methodology. At last, we describe the possible threats to validity and our efforts to deal each of them.

6.1 Experiences, Challenges and Recommendations

This paper reports the findings and the author's experiences with CBL for teaching RE. The authors involved in the study who are experienced educators in SE and coming from 3 different universities share their recommendations to other educators, and practical challenges encountered while implementing CBL methodology in RE.

The organization and implementation of CBL sessions in a course require a significant amount of planning and focused efforts. Implementation of the CBL session starts with the development of the case. While defining a case several points must be kept in mind: (1) a case must not be too complex and should be understandable to the students (2) writing a case would demand a sort of "reverse" engineering approach, i.e., how should we define the case so that it takes the students to multiple resources, and (3) the questions attached to a case must take the students to a variety of resources including books, websites, blogs, discussion forums (both developer and general), and not be found at a single place. One of the major aims of CBL is to send the students on a quest for the best (or the most appropriate) solutions. The "solutions" means that each question can lead to multiple solutions from different student groups. This scenario then should trigger a discussion following the students' presentations.

Another aspect of the CBL is teaching the concepts modeled in the cases. CBL is a non-traditional teaching methodology, and the concepts have to be taught using traditional lecture-based teaching (i.e., classroom teaching). All the topics that can be taught using traditional lecture-based sessions, cannot be taught using CBL. Hence, it is important to identify that what are the concepts modeled in the cases and has to be specified in the case descriptions. This would help students to concentrate and focus on only those concepts to solve the case. Both the TAs and students were new to the CBL methodology. As the TAs were the facilitator of the group of students to understand CBL, it is important to illustrate them with

Table 7: Evaluation marks of the students responses submitted for case questions sliced by case A and case B

	Small Group								Large Group					
	Case A				Case B				Case A			Case B		
	G1	**G2**	**G6**	**G7**	**G8**	**G11**	**G13**	**G14**	**G3**	**G4**	**G5**	**G9**	**G10**	**G12**
Q1	6	7	7	8	7	10	8	10	9	10	7	10	9	7
Q2	6	10	9	7	6	9	7	10	7	8	10	9	10	10
Q3	5	6	7	8	7	9	7	7	8	7	6	8	8	10
Q4	6	7	6	8	6	8	7	6	6	7	6	10	8	6
Q5	7	7	6	7	7	7	7	6	8	6	7	9	10	7
Q6	8	6	6	8	7	7	6	6	7	6	7	9	9	7
Q7	8	8	8	6	9	8	7	7	8	8	7	7	8	8
Q8	8	8	8	8	7	9	8	7	8	7	7	9	8	9
AQ	8	8	8	8	8	8	8	8	9	8	8	9	8	7
Total	62	67	65	68	64	75	65	67	**70**	67	65	**80**	78	71

CBL concepts, motivation and implementation process prior to the execution. All the TAs were instructed and guided by the whole execution plan, by the course instructor. They have also asked to refer several resources like YouTube links about CBL, research papers and cases available in SEABED platform.

Teaching RE concepts using a non-traditional methodology requires the course instructor to motivate students with the benefits of it. CBL is a different kind of teaching methodology and students are experiencing it the first time, hence sessions on CBL needs to be conducted in order to illustrate them with CBL. The demonstration of CBL should consist of CBL videos, case examples, implementation of CBL, and its practical relevance. While conducting this kind of sessions, we found that the students are enthusiastic about the new teaching methodology. The performance of the students was evaluated individually as well as group-wise. We found that several groups come-up with a different solution, and we believe this may be due to their understanding of the problem domain and implementation of RE concepts in real projects. For instances, in Case A, G1 showed a good understanding of the case, a wide list of performance parameters and detailed explanation of each of them. G4 had a good explanation of user stories. They involved new concepts and good approaches for answering the questions and showed creativity by explaining usability of the system for blind users. In Case B, G9 had good user stories with diagrammatic representation, G12 had the best RE Framework with the detailed explanation of the concepts. After that, a target discussions on each of the group solutions has to be done in order to identify best possible solution among the arrived ones. This help the students to analyze their solutions such that they can mend their ways of understanding the problem specification in different perspectives.

GrammaticaBased on the feedbacks submitted by the students, it can be clearly interpreted that they found CBL an innovative and interesting technique in education and asked to conduct more CBL sessions in other topics of SE. They have explicitly mentioned that this exercise helped them to think from different perspectives by conducting brainstorming sessions and thereby improved their critical thinking skills, and understanding of the concepts of RE more effectively. The students found themselves engaged in research activity and they accessed several resources to serve the questions. Some of the students found problems in understanding the scenario modeled in the case, i.e., ambiguous requirements with respect to the cases. The questionnaires involved taking assumptions into consideration and every group had a different set of assumptions so this approach was less acceptable by few students. Some students suggested extending the time duration given to solve the case so that they could understand the cases well and can find better solutions.

From a very long time, the students are taught using traditional lecture-based learning environment where they are primarily dependent on the course instructor for understanding the concepts and related problems. Such environment provides a total dependency on instructor's assumptions, thoughts, and understanding of the topics taught to them. Now during CBL experiment, they were exposed to an unfamiliar environment where each of them was responsible for presenting their own thoughts, understanding, critical thinking, and decision making to solve case questions. The motivation of the students to converge towards the best solution in CBL is a challenging task as it involves the equal participation of team members, team management and discussions within the groups. Therefore, it is recommended that the time duration for solving and discussing the case is to be shorter (not like a project implementation of one academic semester), otherwise, the students may lose interest in the case.

We experienced CBL with both group types, larger and smaller. As each student in the group was responsible identifying the best possible solution, it is recommended that the number of questions in the case would be equal to the number of team members in a group. This would help students to take responsibility of at least one question and he gets sufficient time for the research. We have not imposed any time limit for the presentation and discussion, so some groups took 15-20 minutes and some groups took 45 minutes. Thus, we recommend limiting the discussion time, otherwise, presentations would become less interesting. Every group should have a direct interaction with all the involved members to involve them better in a self-learning environment. After the presentation, a discussion session of about 10-15 minutes of the team with other teams should be involved.

The authors recommend that the CBL sessions can be conducted as the lab exercise because designing and implementing CBL sessions was time consuming. It involves arranging extra sessions, apart from their regular schedule, for introducing them with CBL concepts, understanding the cases and discussion on the solutions.

Table 8: TAs Questionnaire and their responses

Questions	TAs Response			
	#1	#2	#3	#4
Q1. What prior experience you had with case-based learning as a student and as a TA?	No prior experience	First experience with CBL as a student and as a TA	No, first experience	No. This is first time I went through case-based learning.
Q2. How much and what kind of preparation did you do before the case-based learning sessions?	visited CBL research papers from SEABED, discussed about the topic with my colleagues, studied the cases provided	Studied research papers and reports from SEABED, gone through the cases and try to solve them, followed by discussions	First I myself had gone through the concept of case based learning, and then gone through the cases provided by instructor	I went through what is case based learning and discussed cases with the instructor and other TAs
Q3. Did you spend equal time on each group? On a scale of 1 to 5 in which 1 is unequal and 5 is equal.	3	5	3	4
Q4. Did you find facilitating/managing smaller groups (#5-6) easier than large groups (#10-11)? On a scale of 1 to 5 in which 1 is hard and 5 is easy.	Smaller groups (2/5) & Larger groups (4/5)	5 (both group types were manageable)	5 (smaller groups)	4 (smaller groups)
Q5. Did you find the time allocated to each group for solving the case sufficient? On a scale of 1 to 5 in which 1 is less and 5 is sufficient	4	5	5	5 (larger group), 4 (smaller groups)
Q6. Did you find imbalanced participation or a balanced participation among members of a group? On a scale of 1 to 5 in which 1 is imbalance (not everyone equally participating) and 5 is balance.	3	5	5	3 (larger group), 4 (smaller groups)
Q7. Do you find case-based learning for requirements engineering more useful than the traditional lecture-based learning, for the students to grasp the underlying RE concepts? On a scale of 1 to 5, where 5 is most useful and 1 is not useful at all.	5	5	5	5
Q8. Do you find the total number of TAs appropriate for the class size that participated in this CBL exercise? 5 for most appropriate and 1 for inappropriate.	5	5	4	4
Q9. Are you satisfied with your responses to the student queries during the CBL exercises? 5 for most satisfied and 1 for not satisfied at all.	5	5	3 (the given CBL exercise itself demands for new ideas which varies from groups to groups, and therefore more focused towards discussing on there ideas and less on query solving)	4
Q10. How confident do you feel about assisting in another CBL session for teaching requirements engineering? 5 for most confident and 1 for not at all confident.	4	5	3 (because its requires more in-depth knowledge of the scenario which we have not exercised practically)	4
Q11. Based on your experiences with CBL session and facilitating difference students' group size, can you suggest what should be the better group size? 5-6 members or 10-11 members.	10-11 members	Both can be considered equal	5-6 members	5-6 members

CBL focuses on the best solutions and helped students to get a feel how the concepts can be applied in real projects. Though the students were instructed that the when they identify solution for the case questions search for the 'best solution' suited for the case, many of them seemed to search for the "right answers" instead of concentrating on the "best answers". Overall, based on our experiences with CBL, the authors recommend that the educators can choose CBL for teaching certain topics of RE or other software engineering concepts to achieve certain learning objectives.

6.2 Threats to Validity

Here, we present possible threats [24] related to our CBL study.

Construct validity: In our study, we have considered two RE cases for evaluating the effectiveness of CBL methodology. The idea of the two cases was proposed by the two primary authors and then reviewed by the other two authors in order to fill gaps between academia and industry. The other two authors of the paper have a significant amount of experience in the industry. A total of 14 groups of different group sizes were created, specifically, to analyze the impact of team size on students learning. Each student team was created based on the CPI such that the average CPI among the student's group was same (see Table 1).

Before choosing the group type, the students were informed about the rationale behind this kind of assignment. Based on the student willingness to participate in the group, the team was formed by maintaining average CPI among all the groups. Another threat may be the questions assignment among the members of smaller and larger group. In our study, the questions were randomly assigned to the students by following the procedure mentioned in execution section and also ensured that one student in the group would not get the responsibility of multiple questions.

The students were selected for the study from the number of students registered for the course, thus removing the possibility of self-selection. The subjects were given sufficient amount of teaching on RE concepts and rationale behind CBL methodology. Subjects were allotted sufficient time (i.e., one week) to analyze the case so that they do not feel pressurized.

Internal Validity: Prior to the CBL execution, the subjects were informed with the marking scheme. Since this exercise was conducted as a takeaway assignment, and we have suggested them to discuss the case questions among the team members, and also informed that the best team (come with quality solutions) will be rewarded with extra marks in their grade points. So, the possibility of accessing other groups documents was taken care of.

One of the major potential threat may be the marking (or evaluation) of the student's case submissions. The evaluation of the students' responses was done by the instructor and 4 TAs individually. The marking on the scale of 1-5 given by other students groups was also considered for evaluation. All the evaluation data were collated and finalized in collaboration with 4 TAs and an instructor. Though this was carefully done, one can argue for a potential bias here.

Conclusion Validity: We have considered all students of the same batch to conduct the exercise such that heterogeneity does not exist. The design of the experiment was incomplete-block design, as it was not feasible to ask students to consider both the cases. Involving students with both the cases may encounter some learning bias and the CBL related responses may get affected.

External Validity: The CBL methodology is a non-traditional way to teach various concepts such that students can understand situations that may arise in handling real projects. This CBL study utilized students as subjects for teaching RE concepts, and we believe that the results can be potentially generalized to software practitioners.

7 CONCLUSIONS AND FUTURE WORK

Case-based learning methodology for teaching requirements engineering education enhance students learning, critical thinking, engagement, and team working through a self-learning environment. Two RE cases were designed and used for implementing the CBL methodology. The execution of the CBL results in the experience report, recommendations, and practical challenges encountered.

The students' responses showed positive indication towards five teaching objectives. More specific analysis of the students' responses revealed that the (1) difference in RE cases, (2) use of group types (small or large), and (3) gender diversity, does not affect the quality of solutions and students involvement in the CBL exercise. Overall, our results revealed that the CBL approach, with a well-designed case, is suitable for teaching and learning of RE concepts. Additionally, the TAs who are the facilitators of CBL sessions shared their experiences, recommendations and suggested that CBL results in an increased engagement between them and students.

In future we plan to target additional topics related to Requirements Engineering curriculum using CBL pedagogy.

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