Teaching Requirements Engineering Concepts using Case-Based Learning

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Dedicated to

Dr. Ashish Sureka (Author 4)

Our friend, collaborator, mentor, and a lovely human being!

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Researcher, Educator, Programmer and Writer

Table of Contents

Table of Contents

Case-Based Learning in Requirements Engineering

Software Requirements Engineering

- Software requirements engineering encapsulates an important set of activities that are required to express the purpose and functionality of a software system.
- RE is not an exact science and multiple alternative approaches and solutions are possible [5].
- RE analysis can be best performed through discussion, brainstorming, critical thinking and analyzing problem domain from multiple perspectives [14][17].

Case-Based Learning in Requirements Engineering

What is a Case?

A case is like a story, related to a real world situation that sources a number of challenging problems, which have no obvious solutions.

What is Case-Based Learning?

Case-based learning (CBL) is a teaching methodology based on discussing and analyzing real world situations. The CBL methodology [6][11][15] is committed to achieving discussions, teamwork, decision-making tasks, brainstorming, engagements, and critical thinking [7][19].

Research Gap & Unique Challenges

No evidence of teaching Requirements Engineering using CBL

- Paucity of effective teaching and learning techniques for Requirements Engineering (RE) discipline.
- Traditional lecture-based learning approach is not sufficient.
- Need for interactive learning pedagogy.
- Case-based learning drives active learning sessions as proved in previous literature.
- The application of CBL in teaching concepts of RE is still unexplored.

Table of Contents

Experience Reports on Teaching Requirements Engineering

Portugal et al. [13]

Portugal et al. [13] presented challenges faced while teaching RE to undergraduate students.They suggested various RE concepts such as project planning, quality control, client involvement, and budgeting can be taught using Project-Based Learning (PBL).

Zowghi et al. [19]

Zowghi et al. [19] conducted a study to teach RE through role-playing. The authors focused on various RE tasks like elicitation, analysis, modeling, validation, specification, and management.

Case-based Learning for SE Education

Saini et al. [15]

Saini et al. proposed an open source web-based software engineering case-based learning platform called SEABED. They provided a case repository along with a case template, that provides guidelines for case writing.

Garg et al. [3]

Garg et al. created a case related to software architecture and introduced a Case-Oriented Learning Environment. This helped students to learn better software engineering skills.

Case-based Learning in other Domains

Kundra et al. [6]

Kundra et al. used CBL for teaching the concepts of Compiler Design. They observed improvement in the learning, critical thinking, engagement, communication skills, and team work of students.

Peplow et al. [12]

Peplow et al. compared the responses of female and male medical students towards a CBL program. They observed that the female students benefited more than the male students from initial discussions and group activities.

Case-based Learning in other Domains

Fraser et al. [1]

Fraser et al. made software testing education enjoyable by mapping core software testing concepts to the categories of puzzles in the framework of a game. With each level progress in the game, students grasped better testing skills.

Garousi et al. [4]

Garousi et al. used industrial tools and projects for undergraduate software testing labs to demonstrate the real world testing scenario to the students.

Table of Contents

Novel Research Contributions

1. First implementation of CBL for teaching and practicing the concepts of RE discipline for a large class of 112 students at DA-IICT, Gandhinagar (India)[a].
2. Empirical analysis based on case difference, gender diversity, team size, and engagement between the organizing team with the students during CBL sessions.

[a] http://www.daiict.ac.in/

Novel Research Contributions

1. A set of challenges and recommendations derived from the experiences gained while implementing two CBL sessions, and strengthened by the experiences shared by the authors from three different universities collaborating and teaching SE for several years.
2. Two original RE cases, *Metro Ticket Distributor System*[a] and *LIC Market-Driven System*[b], available on SEABED.

[a] http://seabed.in/case-study/Metro_Case.pdf
[b] http://seabed.in/case-study/LIC_Case.pdf

Table of Contents

Study Objectives and AIMs

Study Objectives

To investigate the effectiveness of CBL methodology in teaching/learning various RE concepts as a part of a SE course by examining the achievement of a set of five learning objectives through empirically analyzing students' responses to CBL execution.

Five Learning Objectives

Five learning objectives include students' learning, critical thinking, engagement, communication skills and teamwork.

Study Objectives and AIMs

AIMs

AIM1: *Is CBL method effective in achieving various learning objectives?*

AIM2: *Do students who worked in smaller groups show different responses to those who worked in larger groups?*

AIM3: *Does CBL effectiveness in teaching RE concepts differ across two RE cases?*

AIM4: *Is CBL effectiveness in teaching RE concepts influenced by gender diversity?*

AIM5: *Does CBL result in a better engagement between TAs and students?*

Table of Contents

Subject:

112, 2nd year postgraduate students of Msc (Information Technology) studying a compulsory course on IT 632 Software Engineering at DAIICT Gandhinagar (India).

Cases

- **Metro Ticket Distributor System Case**
- **LIC Market-Driven System Case**
  Both the cases intend to facilitate the concepts of understanding the problem domain, requirement elicitation and prioritization through real world scenarios.

Table of Contents

Table: Characteristics of the Pilot Study Design

Session	Case	Count	Subjects Group		
I	A	S1-S56	G1-2-6-7 (6 student)	G3-G5 (11 student)	G4 (10 student)
II	B	S57-S112	G8-11-13-14 (6 student)	G9-G10 (11 student)	G12 (10 student)

Elements of our study

1. Factor (Independent Variable): RE case
2. Alternatives: Case A (Metro Ticket Distributor System) and Case B (LIC Market-Driven System)
3. Response (Dependent) Variables: Students responses with reference to case difference, gender diversity, team size
4. Study Design Method: Single-factor incomplete block design [18].

Table of Contents

Preparation and Subject Training

1. Seven lecture sessions were organized to familiarize the students with the RE concepts.
2. Two-hour lab session was conducted to introduce them to the concepts of CBL through a class presentation, learning videos and demos.
3. Additionally, The course instructor planned to demonstrate CBL to TAs (two master students, one doctoral student, and one research fellow) such that the team (educators and TAs) could help students groups more efficiently in understanding the concepts.

Table of Contents

Metro Ticket Distributor Case

Case A

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 etc.....

Metro Ticket Distributor Case

Questions:

Q.1 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.

Q.2 List top five parameters on which the performance of the system can be achieved. List out all the possible use cases?

LIC Market-Driven System Case

Case B

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 etc.....

LIC Market-Driven System Case

Questions:

Q.1 Prepare a list of market-facing technologies helpful for this project. According to you, would market-facing technologies be helpful in the proper deployment of the product? Why?

Q.2 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.

Table of Contents

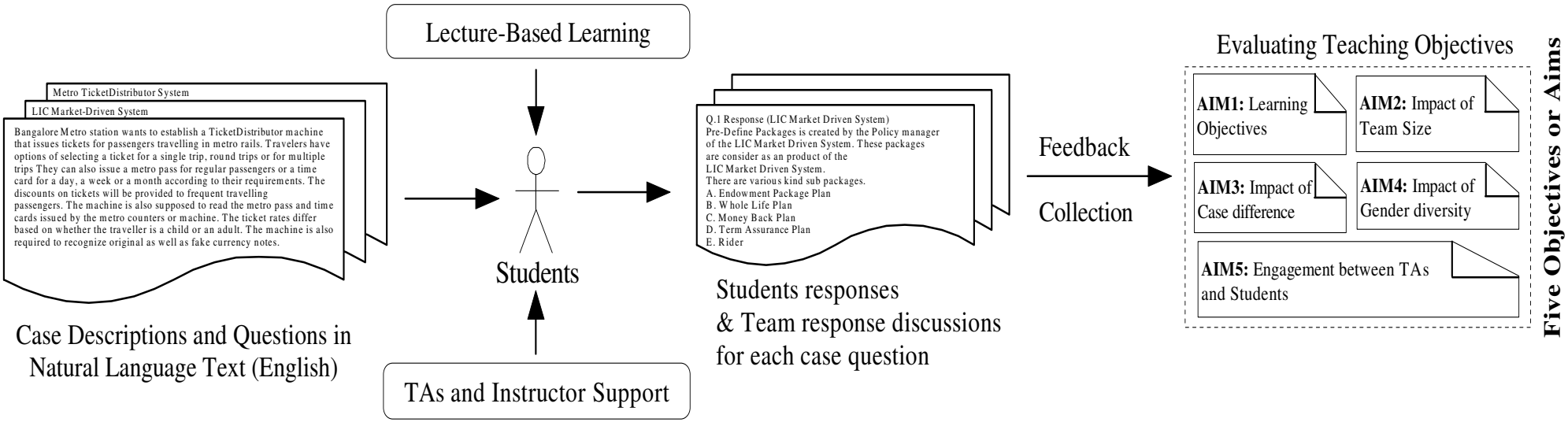

Figure: Overview of the study for evaluating the effectiveness of CBL in students' learning

CBL Execution

- **Case Understanding Phase**
- **Case Solving Phase**
- **Case Discussion Phase**

Rationale behind question distribution

- Group size of 11 students, each student was responsible for one question and two students were responsible for Q1 and Q3. And, one student was responsible (team leader) for the additional question.
- Group size of 10 students, each student was responsible for one question and two students were responsible for solving Q1 and Q3. All students had to answer the additional question.

Rationale behind question distribution

- Group size of 6 students, each student was responsible for one question, and remaining three questions were assigned among six team members such that each additional question was assigned to different pairs of students in the group.

Table: Survey questions grouped by the respective teaching objective (Part 1)

Teaching Objectives	**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.

Table: Survey questions grouped by the respective teaching objective (Part 2)

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.

Table: Survey questions grouped by the respective teaching objective (Part 3)

Engagement	Q7: I was more engaged in class when using the case.
Engagement	Q8: The case discussion increased my interests in learning about Requirements Engineering.
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.

AIM1: Analysis on Learning Objectives

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

Questions	**SA**	**A**	**DA**	**SD**
Q.1 I feel the use of case was relevant in learning about RE concepts.	44.50%	53.60%	1.80%	0
Q.2 The case allowed for a deeper understanding of RE concepts.	47.30%	48.20%	4.50%	0
Q.3 The case will help me to retain the different aspects of Requirements Engineering better.	47.30%	49.10%	3.60%	0

AIM1: Analysis on Learning Objectives

Questions	**SA**	**A**	**DA**	**SD**
Q4 The case allowed me to view an issue from multiple perspectives.	**5**5.50%	**4**2.70%	**1**.80%	0
Q5 The case was helpful in synthesizing ideas and information presented in course.	**3**2.70%	**5**6.40%	**1**0.90%	**0**
Q6 The class added a lot of realism to class.	**3**2.10%	**5**7.80%	**1**0.10%	**0**

AIM1: Analysis on Learning Objectives

Questions	SA	A	DA	SD
Q7 I was more engaged in class when using the case.	**3**2.70%	**5**2.70%	**1**4.50%	**0**
Q8 The case discussion increased my interest in learning about Requirements Engineering.	**4**2.70%	**4**9.10%	**8**.20%	**0**
Q9 The case discussion strengthened my communication skills to speak in front of the audience.	**5**3.60%	**4**2.80%	**3**.60%	**0**
Q10 The case discussion increased my confidence to work in a team.	**6**3.60%	**3**3.60%	**2**.70%	**0**

Statistical Analysis on Learning Objectives

- 98.1% of total number of students agreed (SA+A) that the cases were relevant in learning various RE concepts (Q1), and 95.5% of the students suggested that the cases allowed for a deeper understanding of case concepts (Q2).
- Almost 14% of total students don't think that they were more engaged in class when working with the cases (Q7).

Statistical Analysis on Learning Objectives

- Collectively, more than 90% of the students felt that the cases allowed them to view the problems from multiple perspectives (Q4), helped in synthesizing ideas (Q5), and added realism in the class (Q6).
- A significant 97.2% students agreed that the case discussions increased their confidence to work in teams, while 96.4% believed that it strengthened their communication skills.

AIM 2:Impact of Team Size on Learning

Table: Percentage of SA, A, D, SD sliced by team size

Q.No.	Small Group (5-6)				Large Group (10-11)			
	SA%	A%	DA%	SD%	SA%	A%	DA%	SD%
Q1	40.0	57.8	2.2	0	47.0	51.5	1.5	0
Q2	42.2	48.9	8.9	0	50.0	48.5	1.5	0
Q3	35.6	60.0	4.4	0	53.0	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	53.0	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	51.5	45.5	0	3
Q10	60.0	35.6	4.4	0	65.2	33.3	1.5	0

AIM 2:Impact of Team Size on Learning

Table: Evaluation marks of students sliced by Case A & B

Q.No.	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

Statistical Analysis of Impact of Team Size on Learning

- Null hypothesis says there is no relationship between the team size and the student learning during CBL execution. The alternate hypothesis says the team size influences student learning.
- The t-test results show a p-value of 0.2291 at a significance level $\alpha = 0.05$.
- We fail to reject the null hypothesis, and conclude that the size of the team does not have any effect on student learning.

AIM 3:Case Difference

Table: Percentage of SA, A, D, SD sliced by Case

	Case A				Case B			
Q.No	**SA%**	**A%**	**DA%**	**SD%**	**SA%**	**A%**	**DA%**	**SD%**
Q1	51.8	48.2	0	0	37.0	59.3	3.7	0
Q2	46.4	53.6	0	0	48.1	42.6	9.3	0
Q3	57.1	41.1	1.8	0	35.2	57.4	7.4	0
Q4	60.7	37.5	1.8	0	51.9	46.3	1.9	0
Q5	35.7	57.1	7.1	0	29.6	57.4	13.0	0
Q6	30.4	58.9	10.7	0	33.3	57.4	9.3	0
Q7	35.7	44.6	19.6	0	29.6	61.1	9.3	0
Q8	42.9	48.2	8.9	0	42.6	50.0	7.4	0
Q9	51.8	41.1	7.1	0	55.6	40.7	0	3.7
Q10	69.6	26.8	3.6	0	57.4	40.7	1.9	0

Statistical Analysis of impact of Case Difference on Learning

- Null hypothesis says that there is no relationship between the case differences and the student learning during CBL execution. The alternate hypothesis says that the cases influence students' learning.
- T-test for both agree and disagree percentages, we get a p-value of 0.8455, at a significance level $\alpha = 0.05$.
- We fail to reject the null hypothesis, and conclude that the two cases are perceived as equally effective.

AIM 4: Gender Diversity

Table: Percentage of SA, A, D, and SD for the 10 questions sliced by Gender

	Male				Female			
Q.No.	**SA%**	**A%**	**DA%**	**SD%**	**SA%**	**A%**	**DA%**	**SD%**
Q1	48.6	50.0	1.4	0	36.1	61.1	2.8	0
Q2	48.6	51.4	0	0	44.4	41.7	13.9	0
Q3	47.3	47.3	5.4	0	47.2	52.8	0	0
Q4	56.8	41.9	1.4	0	52.8	44.4	2.8	0
Q5	31.1	59.5	9.5	0	36.1	50.0	13.9	0
Q6	33.8	54.0	12.2	0	30.6	63.9	5.6	0
Q7	35.1	46.0	18.9	0	27.8	66.7	5.6	0
Q8	39.2	51.4	9.5	0	50.0	44.4	5.6	0
Q9	59.5	33.8	4.1	2.7	41.7	55.6	2.8	0
Q10	63.5	35.1	1.4	0	63.9	30.6	5.6	0

Statistical Analysis of Gender Diversity on Learning

- Null hypothesis says that there is no relationship between the gender and the student learning during CBL execution.
- From t-test we find that p-value for agree% is 0.710, at a significance level $\alpha = 0.05$.
- We fail to reject the null hypothesis, and conclude that there is no significant difference in the responses from male and female students.

AIM 5: TAs perceptions with CBL

Questions	TA Response #1	TA Response #2
Q1.What prior experience did you have 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
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.
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
Q4.Did you spend equal time on each group? On a scale of 1 to 5 in which 1 is unequal and 5 is equal. 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)

TAs Questionnaire and their responses

Questions	TA Response #3	TA Response #4
Q1.What prior experience did you have with case-based learning 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?	First I myself had gone through the concept of case based learning, and then gone through the cases provided by instructor	I went through 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	4
Q4.Did you spend equal time on each group? On a scale of 1 to 5 in which 1 is unequal and 5 is equal. 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.	5 (smaller groups)	4 (smaller groups)

TAs Questionnaire and their responses

Questions	TA Response #1	TA Response #2
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
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
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
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.	4	5

TAs Questionnaire and their responses

Questions	TA Response #3	TA Response #4
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	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.	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
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.	4	4

TAs Questionnaire and their responses

Questions	TA Response #1	TA Response #2
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
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
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

TAs Questionnaire and their responses

Questions	TA Response #3	TA Response #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.	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.	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.	5-6 members	5-6 members

Analysis on TAs perceptions with CBL

- Overall TAs responses and their stated experiences showed that the CBL results in an increased TA involvement and satisfaction, along with high engagement between the organizing team (mainly TAs in this case) and students.

Challenges and Recommendations

Challenges

- The case must not be too complex and should be understandable to the students.
- The cases need to be designed carefully and should not deviate from the scope of course structure.
- 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.

Challenges and Recommendations

Challenges

- The questions attached to a case must invoke students into exploring a variety of resources.
- Separate cases may be framed for each concept or group of concepts as one case designed for some selected RE concepts may not work for other articulated concepts.
- As the case questions involved forming assumptions and each group had its own unique set of assumptions, so this approach was less acceptable to some of the students.

Challenges and Recommendations

Recommendations

- The authors suggests to conduct introductory sessions on CBL before performing the exercise to acquaint them with this approach.
- CBL sessions can be conducted as the lab exercise(designing and implementing CBL sessions is time consuming and extra sessions are needed)
- The authors suggest that the training of TAs through a well-designed execution plan before the CBL sessions is very important as this builds up a relationship of trust between TAs and instructors.

Challenges and Recommendations

Recommendations

- Students must be encouraged to find best solutions rather than searching for right solutions.
- Number of questions in the case should be equal to the number of team members in a group.
- Limiting the discussion time is recommended.

Threats to validity

- Students may have discussed the case problem with other groups prior to their own session.
- The study was done only with two groups of students of different sizes.
- Several components is based on qualitative data and perceptions which is not generalizable as opposed to experimental studies [16].
- Inaccuracy in students' perceptions of their own learning may compromise measurement validity.

Conclusion and External Validity

- Response bias, inflation of answers and the responses or outcome can be based on perceptions.

Conclusion

- We proposed CBL for Software Requirements Engineering in education with the aim to impart in-depth and practical knowledge through a self-learning environment.
- Students approved the importance of CBL with an overall agreement on all five stated objectives: learning, critical thinking,engagement, communication skills and team work .
- The statistical analysis revealed that there is no significant effect observed on quality of solutions based on case difference, group size and gender diversity.

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