

# SEABED: An Open-Source Software Engineering Case-Based Learning Database

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**Abstract**—Case-Based Learning (CBL) is a teaching methodology based on discussing and analyzing real world problems and solutions. A case is like a story, related to a real world situation that sources a number of challenging problems, which have no obvious solutions. There have been various applications of CBL in the fields of Medicine, Law, and Business. However, there are a limited number of evidences related to the application of CBL in the field of Software Engineering (SE). In this paper, we present an open source web application called SEABED (Software Engineering Case-Based Learning Database). The feature set supported by SEABED comprises Case Submission, Case Collection, Case Search, Case Review, and Case Evolution. SEABED aims to develop and evolve a rich repository of SE cases that might become a basis for enabling the students, instructors, practitioners, and experts to enhance their SE knowledge in an effective way. Further, we present our approach to build a vibrant SE case-based learning community that triggers enough activity around SEABED, required for the platform to reach a critical and wider mass. We communicated with several SE educators around the world and received positive responses on SEABED. In order to investigate the effectiveness of the CBL methodology followed by SEABED, we conducted an experimental study at an Institute of National Importance in India. We present the empirical analysis results of this study and explore the impact of CBL on students' learning abilities.

**Keywords**—Case-Based Learning (CBL), Software Engineering Education, Case Database, Open-Source Case Database, Learning Methods.

## I. RESEARCH MOTIVATION AND AIM

Case-based learning (CBL) is a student-centric modern learning approach that is capable of effectively assisting traditional learning approaches such as lecture-based, project-based, etc [1]. The cases in a case-based learning database are factually based and involve complex problems written to stimulate classroom discussions and collaborative analysis. CBL provides students with authentic real world situations to explore, and apply a variety of information acquired through multiple learning resources to solve a set of related case problems. Since SE is a theoretical subject, cases involve students in active learning and nurture interpersonal or communication skills [2] [3]. The case-based approach engages students in the discussion of specific scenarios that resemble or typically are real-world examples.

Though the use of CBL is quite common, and has been proven vital for Medicine, Law and Business education, its applications in Computer Science education, including Software Engineering (SE) education, are rare. CBL is well supported by some of the existing online case databases, which can be

considered as the backbone of CBL in those fields. To the best of our knowledge, no such case database exists in the area of SE education. We hence aim to develop a comprehensive case database to support the SE education. Inspired by the existing case databases, we have carefully designed and implemented the first case database, namely SEABED<sup>1</sup> (Software Engineering Case-Based Learning Database), for assisting SE Education. SEABED is an open source web based platform to facilitate SE instructors, students, practitioners, and experts with CBL driven SE education through a multi-faceted case database supported by a set of useful functionalities and features.

## II. RELATED WORK AND RESEARCH CONTRIBUTIONS

Garg et al. exercised a case to teach the various aspects of software architecture and design, which engaged the learners in case solving and case listening activities, and contributed towards their communication skills [2]. Razali et al. conducted a survey to prove the effectiveness of Case Methods in SE domain that helped the students to apply their theoretical knowledge in a realistic environment by putting themselves in the role of a decision maker [3]. Kundra et al. utilized CBL approach for teaching some important concepts of compiler design which aided the scholars to understand and practice "how things actually work in professional world" [1]. Jia et al. presented a case study for software design phase which encouraged the students to think about alternative solutions and played a vital role in increasing their awareness about the topic discussed through the case study [4]. Fuller et al. proposed a new approach to teaching software risk management with case studies based on real projects which enabled the students to gain a practical experience in software development risk assessment [5].

In context of existing works, our paper makes the following research contributions:

- 1) We propose the first multi-featured web based platform for CBL in the field of Software Engineering. (refer Section III-A)
- 2) We propose an approach to build a SEABED community and implement our proposed approach to facilitate enough activity and users around SEABED, for the platform to reach a critical mass. (refer Section III-B)
- 3) We present an experimental study to evaluate the outcomes of applying CBL to the basic Under Graduate (UG) level SE

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<sup>1</sup><http://www.seabed.in>

course at Dr. B. R. Ambedkar National Institute of Technology(NIT)<sup>2</sup>, Jalandhar. (refer Section IV-C).

### III. RESEARCH FRAMEWORK AND SOLUTION APPROACH

SEABED is an open source case-based learning web tool for enabling the students, instructors, practitioners, and experts with the capability to enhance their SE knowledge through the development and evolution of various SE cases.

#### A. Creation of SEABED Platform

The basic framework of SEABED is designed keeping in mind the intuitiveness and simplicity of the tool. SEABED is designed using HTML, JavaScript, AJAX and PHP technologies. In addition to being a repository for the cases related to SE, SEABED has a variety of useful features. One can easily access all these features from anywhere as SEABED is a web based platform. Fig. 1 gives a quick overview of the major features of SEABED. All these features are easy to understand and interact with. Some of the important features of SEABED are described below:

**1) Case Submission:** The primary feature of SEABED is *Case Submission*. It can be used to submit the cases related to Software Engineering by filling the required details in the fields mentioned. After a thorough review of submitted case, if the case is found to be correct and useful, it is uploaded to the SEABED database. Otherwise, authors are informed about the relevant issues by email.

**2) Case Collection:** This section provides a quick view of the cases that exist in the case database. Cases can be accessed by clicking on any of these cases. The categories in Fig. 1 represent various phases of software development life cycle. To maintain the organization, the cases are placed under respective categories in the SEABED database.

**3) Case Search:** One of the core features of SEABED is *Case Search*. It is quite interactive and user friendly as it provides a faceted search. One can search the database by mentioning the *Term 1*, *Term 2* and the category in which they lie, respectively. The advanced search operators, namely *AND* and *OR*, are provided which enhance the capability of this section. SEABED maintains an open source case database and aims to provide the results based on the query.

**4) Case Evolution:** It is also one of the main features of SEABED. Under this section, user can find a root case as well as all the revised versions for a particular case. This section consists of two work flows:

**4.1) Case Revision:** This feature provides a provision to the authors to revise any case present in the SEABED database. A *case revision document* must be accompanied with a document justifying it. The *justification document* explains the rationale behind the amendments committed to the previous case version.

**4.2) Experience Report:** This field gives a facility for an instructor to submit an *experience report* regarding the execution of CBL session in the classroom, involving a case already existing in the SEABED database. The *experience report* is

one comprehensive document that includes the experiences, empirical analysis, recommendations, comments, and also the analysis and summary of student solutions to the case questions, specific to one CBL session.

**5) Views and Opinions:** This section brings the viewpoints and inferences of the experienced and skillful researchers about SEABED. This is to motivate the idea of the methodology followed in the development of SEABED.

**6) Publications and Presentations:** This section exhibits some of the publications and presentations in the field of SE case-based education and research. Hence a compilation of the research publications and presentation related to practicing SE CBL in classrooms can be accessed from here.

#### B. Building up SEABED Community

We reached out to several SE educators all over the world through emails to create awareness about SEABED and requested them to submit cases. We have used social media channels, such as Twitter<sup>3</sup>, to make people aware of our platform. We have received several positive responses and we expect the number of cases in the repository to grow gradually. Table-I provides statistics related to email responses we have received from educators from various countries such as India, Netherlands, Australia, Germany, Canada, Malaysia, etc. Total 154 mails were delivered during Jan 1, 2017 to Jan 15, 2017. These recipients include 147 Professors and 7 Post-Doctoral Fellows.

TABLE I: EMAIL RESPONSE SHEET

Response	Instructor	Post-Doctoral Fellow	Total
Number of Positive Feedback	19	2	21
Ready for Case Submission	3	1	4
Ready for Case Revision	1	1	2
Will implement cases in their classrooms	4	0	4

Community creation procedure for SEABED is outlined below:

**1) Quality Control:** Instead of accepting large quantity of low quality cases, our attention is to target cases with high quality, so that our value adding users will not vacate the community. For instance Quora<sup>4</sup> has employed the similar concept and became successful. We implement a moderation-based and review-based process to ensure quality.

**2) User Interaction:** Since the platform is in its early stages, so we have been able to gain only a small segment of critical mass i.e. few instructors from different geographical locations. Until we get a full-fledged set of users, we will be working very closely with the initial set of instructors. We are surveying them to understand their needs and challenges, they are facing

<sup>2</sup><http://www.nitj.ac.in>

<sup>3</sup><https://twitter.com/>

<sup>4</sup><https://www.quora.com>

while implementing CBL pedagogy. We are providing full support to these instructors through emails, so that they can assimilate and practice the concepts easily. By knowing their course structures, we are creating cases that address the needs of their respective course objectives and curricula.

**3) Testimonials:** We have approached a group of niche users such as professors from institutes of national importance. They have expressed their willingness to participate in the community. We will collect testimonials from such faculty members which will help in creating a good prestige of the platform. This will motivate other educators to teach SE concepts using CBL.

**4) Recommendation System:** We will use personalized recommendations to suggest cases based on user's interests. For instance if a user submits a case or an *experience report* on a particular case then she will receive an automatic notification from SEABED recommending other cases that she may want to consider.

**5) Promotion and Dissemination:** We will conduct workshops on case-based learning for increasing awareness about SEABED. We will create video tutorials explaining the Case-Submission and Evolution process. We will upload them on YouTube<sup>5</sup>.

**6) Guidelines and Templates:** We provide guidelines for case creation in the form of a template as depicted in Table-II. Writing a case is a time consuming task but the learning it imparts is rewarding. Case writing requires creativity and experience. A case is slightly different from a case study. A case study is a fact based representation of past phenomenon with some analysis that provides learning for upcoming events whereas a case may represent a particular scenario described in the case study. Table-II describes a template created by us and to the best of our knowledge no such template exists which provides step-by-step guidelines and directions to the case creator.

Reaching out to a critical mass, involving and engaging the practitioners for contribution are two of the major challenges, we are facing. The system will become self-sustaining, once a critical mass is achieved [6].

#### IV. EMPIRICAL DATASET, ANALYSIS, AND VALIDATION

This section briefly explains the experimental setup used by us, case exercised and empirical analysis conducted by us to support the SE case-based learning.

##### A. Experimental Setup

The experimental study presented in this paper was carried out on a total of 89 B.Tech (UG) 3<sup>rd</sup> year (2014 batch) students from Computer Science and Engineering (CSE) branch of Dr. B. R. Ambedkar National Institute of Technology (NIT), Jalandhar<sup>7</sup>. A SE case covering the basic architecture and design concepts of software development was carefully designed along with a set of four questions to be answered. 22 teams of four students each (with an exception of one five-member

TABLE II: SEABED CASE TEMPLATE

Steps and Components	Description
Objectives and Goals	First and foremost identify the purpose of writing a case. What skills the facilitator want to foster through this case i.e learning outcome? Present a goal based scenario and try to cover one or two concepts at a time.
Scope	The case must adhere to the curriculum structure while opening multiple gateways of learning for the students.
Domain	What domain knowledge is essential for solving a particular case? This will guide the facilitator to conduct few introductory lectures. Students should have at least a basic understanding of the case. Otherwise they will lose their interest.
level	Identify your target audience. For instance if the case is designed for 2nd year UG students to facilitate the Requirement Gathering Process through a practical situation. It is always better to have a common background between reader and writer.
Size	It is hard to grab user's attention for long pages. A case is a comprehensive document that requires 400-500 words maximum.
Relevance	The case should be of a relevant topic related to SE. Keep a track on case leads and case needs [7].
Development	What are the elements of the problem that lead the students towards the learning goals [8]? Develop a case from scratch. A case can present a fact based real world problem or sometimes introduces an entirely new situation.
Didactic Design	A case can be designed in two ways: 1) Structured manner. 2) Ill-structured manner: which requires brainstorming and creativity. [9]
Tell a story	Use place, time, actors, description, and sequence of events in a narrative flow. A case slightly differs from a story as the learner has to put himself in the role of one or more players portrayed in the case [7].
Data	Split the data so that readers have to look at multiple resources in order to investigate the problem [9]. Create dilemma that requires the learner to think from various perspectives. Make sure data should be sufficient to solve the problem.
Strategies	A case should lay stress on strategies and procedures than solutions.
Focus	A case should outline a problem which has no obvious answer. It emphasizes interest arousing controversial affairs that leads the learner to the expedition of discovery and prompts to make a decision.
Create surprise	Try to create surprises. For instance suddenly ask the students to assume themselves in a different role than the one featured centrally in the case [7].
Affirmation	The case should present sufficient evidences that show the need of addressing the problem. E.g. Twitter had lot of outages especially during popular events such as 2008 Macworld conference keynote address. [ref. Twitter Case <sup>6</sup> ]
Legal Issues	All judicial, ethical, and professional standards must be respected by the case [10].

<sup>5</sup><https://www.youtube.com>

<sup>6</sup><http://seabed.in/case-study/Twitter-Case.pdf>

<sup>7</sup><http://www.nitj.ac.in/>

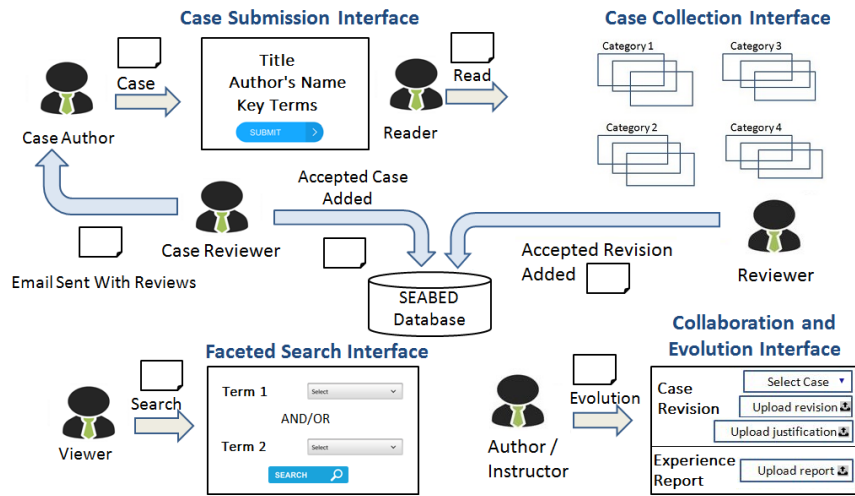


Fig. 1: SEABED Architecture and Framework

team) were formed and the same case was allotted to each team. To enhance the honest participation of each student in a team, each student was asked to take the responsibility for one of the four case questions. However, the response to each question had to be finalized through team work. A set of three introductory lectures were conducted to enable students with the basic knowledge about CBL as well as specific SE concepts related to the case presented. Each student team was given four days to work on the case and related questions. Each 4-member team was asked to submit a joint case response report carrying the responses for all four questions. Each team was then required to present their responses to the case questions. A targeted discussion over the responses to the questions, was carried out after each team's presentation.

To further motivate the whole hearted student participation, two methods were introduced. Firstly, this CBL exercise was assigned a weight-age of 6 out of 10 assignment marks for the SE course. Normally there are five mandatory student assignments each carrying 2 marks for a UG course. Secondly, three Best Team Work awards and three Best Individual Awards were conferred to the selected students. As recommended by previous studies [1], the overall exercise was conducted by a group comprising two faculty members, two Ph.D. research scholars and one M.Tech research scholar from the SE domain. Also, grading of responses to case questions was performed at both student as well as group levels to determine contribution of each team member. This exercise was conducted in order to evaluate the impact of SE CBL exercise. We provided the students with a survey questionnaire targeted to identify whether they gained in various learning credentials including learning, critical thinking, engagement, communication skills, and team work [1]. Each question has four options: Strongly Agree (SA), Agree (A), Disagree (D), and Strongly Disagree (SD); out of which a student could choose only one. The survey questions along with the related learning principles are listed in Table-III. The information about SE case, questions, student responses, awards and survey responses, are available at SEABED.

### B. Sample Case

This subsection presents the example case and related questions used in the experimental study. The All Is Well (AIW) Case<sup>8</sup> is about choosing the right technology stack during the design phase of an online medicine store application. Following is a brief description of the SE case used in our experiment. Due to the page limit for the paper, we have omitted certain parts of the case to highlight the more important ones.

*You are part of the Software Engineering team at All Is Well (AIW) Pharmacy Incorporation. AIW wants to set-up an online medical store to sell a wide range of medicines. You and your team need to select the technology stack for developing the online store. Selecting the right technology stack for the given requirements is critical as it naturally has several serious consequences on the business. A choice of the wrong technology can have an adverse impact on the business. You need to decide the server and client side frameworks to use. You also need to make decisions on the programming language, database, web-server and server operating system to use. For example, should you use Ruby, Python, C# or PHP programming language? Should you use Ruby on Rails, Django or .NET framework? All Is Well want their website to be responsive and expect it to be accessed by their customers using a variety of devices such as tablets, desktops, laptops and mobile phones. They expect that 50%-60% of their traffic will come from mobile devices. AIW is looking for a solution which makes it easy for them to scale and grow gradually.*

*The user base of the website is wide: young and old, rural as well as urban. The company does not want to own any IT infrastructure and wants to use an external cloud computing platform. An important requirement is to support all the popular browsers like Internet Explorer, Mozilla Firefox and Google Chrome. The application will receive both structured and unstructured data. The application should have its own login/authentication mechanism as well as single sign-in using social media platforms like Google+ and Facebook.*

<sup>8</sup><http://www.seabed.in/case-study/Design-All-is-Well-Case.pdf>

Since AIW is in the domain of healthcare, data security and sensitivity is vital. Also, they intend to provide a wide variety of online payment options for their customers including credit cards, debit cards, net banking, etc., but not cash on delivery. Figuring out the best technology option for the payment system is another vital decision. AIW has the prime focus toward customer satisfaction. Hence, they require an efficient and prominent customer feedback and help feature enabled through both email and telecommunication assistance. As fast medicine delivery is critical to the health of the customer, providing a feature to track the medicine delivery status is much desired, which will require a decent API that can interact with the courier services portal.

- 1) What are the various parameters that will form the basis for the selection of appropriate technologies or frameworks?
- 2) Identify various requirement conflicts and ambiguities, along with assumptions and major constraints that may potentially impact the selection of a technology stack.
- 3) Enlist the pros and cons of good and bad technology selection decisions with respect to the selection parameters.
- 4) Justify the selection of a particular technology stack with respect to the basic SE design principles.

TABLE III: SURVEY QUESTIONS GROUPED BY THE RESPECTIVE LEARNING PRINCIPLES

learning Technique	Questions
learning	Q1: I feel the use of case was relevant in learning about course concepts.
learning	Q2: The case allowed for a deeper understanding of course concepts.
learning	Q3: The case will help me to retain the different aspects of Software 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 interests in learning about Software 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.

### C. Empirical Analysis and Evaluation

An empirical analysis is conducted on the responses to the survey questionnaire, as recorded by the students. The number (N) and percentage (%) of SA, A, D, and SD selections against each survey question are presented in Table-IV. It can be observed from Table-IV that the percentage of students agreeing to each of the survey questions range from 75% to 97%, which

TABLE IV: FREQUENCY SCORES FOR EACH SURVEY QUESTION [LT: learning Technique, Q: Question, SA: Strongly Agree, A: Agree, DA: Disagree, SD: Strongly Disagree, VR: No. of Valid Responses]

LT	Q	SA(%)	A(%)	DA(%)	SD(%)	VR
LN	Q1	18 (20.2)	60 (67.4)	9 (10.1)	2 (2.2)	89
	Q2	11 (12.5)	67 (76.1)	9 (10.2)	1 (1.1)	88
	Q3	29 (32.5)	55 (61.7)	4 (4.4)	1 (1.1)	89
CT	Q4	10 (11.6)	45 (52.3)	30 (34.8)	1 (1.1)	86
	Q5	24 (27.5)	42 (48.2)	17 (19.5)	4 (4.5)	87
	Q6	18 (20.4)	49 (55.6)	19 (21.5)	2 (2.2)	88
EG	Q7	15 (17.0)	51 (57.9)	17 (19.3)	5 (5.6)	88
	Q8	31 (34.8)	55 (61.7)	3 (3.3)	0 (0)	89
CS	Q9	28 (31.4)	50 (56.1)	9 (10.1)	2 (2.2)	89
TW	Q10	9 (10.2)	67 (76.1)	12 (13.6)	0 (0)	88

indicates a positive general opinion of students towards SE case-based learning. For Q1, 87.6% of students agreed (SA and A) that case discussions are relevant in learning about various SE concepts, which implies that the example case was fruitful in transferring knowledge about important SE concepts to the students. 88.6% of students agreed to Q2 showing that case presentations and discussions inculcated deeper understanding of various SE concepts involved, including software design principles, software architecture, etc. A staggering 94.2% were of the opinion that CBL would assist them in retaining at-least some features of Software Engineering (Q3). A relatively lesser number of students felt that practising this CBL exercise enhanced their critical thinking. For Q4, a significant 63.9% of students suggested that case discussions provided them with a good practice to view an issue from multiple perspectives.

About 75.7% were of the opinion that case was helpful in synthesizing ideas and information presented in the course (Q5). A significant 76.1% of the students believed that the given exercise resulted in additional realism in the class (Q6) because of the real world nature of the case. The Q7 and Q8 covering engagement principle showed maximum variation in agreement percentages. Where 75% felt more engaged in class during case discussions, a high 96.5% of students reported that case discussions did increase their interest in learning about Software Engineering. A large number of students (87.5% and 86.3% respectively) also thought that case discussions boosted their communication skills (Q9) and enhanced their team work skills (Q10) which shows that case discussions helped in development of personal and interpersonal skills. Summarizing the empirical results, it is observed that the students found the CBL exercise interesting and thought provoking. Fig. 2 shows the mean percentage of the number of students (taken over each group of survey questions representing a learning principle) endorsing the ability of CBL exercise to practice all five learning principles. Overall 19.33% strongly agreed (SA) and 55.20% simply agreed (A) that they were able to grasp all the learning principles during the complete CBL exercise, which means a significant 74.53% of students at-least agreed

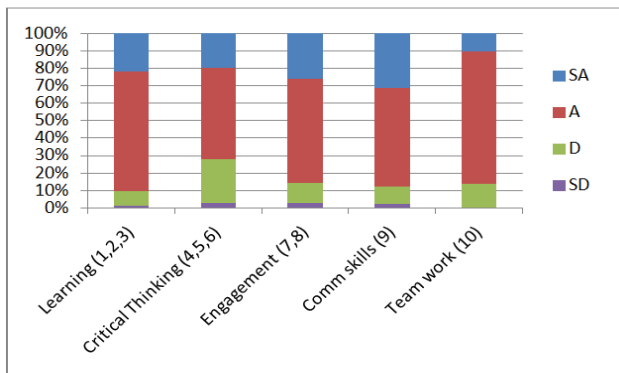


Fig. 2: Frequency Scores for various learning principles

to have achieved the all five learning principles of learning, critical thinking, engagement, communication skills and team work.

On the other hand, on average 13.70% (D = 12.07 and SD = 1.63) disagree to have acquired the learning principles during this exercise.

TABLE V: ACTUAL AND EXPECTED OBSERVATIONS

Actual		Expected	
Agree	Disagree	Agree	Disagree
80	8.66	74.89	13.76
62.66	24.33	73.49	13.50
76	12.5	74.75	13.74
78	11	75.18	13.81
76	12	74.33	13.66

The respective frequencies of individual survey questions are summed up to determine a frequency score for each of the five learning principles. These frequency scores are utilized to perform the chi-square test. Student responses were aggregated into two categories Agree (SA+A) and Disagree (SD+D) as shown in Table-V, and then the expected observations (given by  $\text{row\_total} * \text{col\_total} / \text{grand\_total}$ ) were calculated. Next, considering the Significance Level as 0.05 and degree of freedom as 4, chi square and p values were calculated. From  $\chi^2 = 13.56$ , and  $p\text{-value} = 0.009$ , it can be inferred that CBL impacts the attainment of various learning principles. Furthermore, it is clear from the experimental data that it is a positive effect, i.e. more students agree that CBL enhances the skills of learning, critical thinking, engagement, communication and team work.

#### D. Challenges and Suggestions

We faced a number of challenges during the execution of this SE case-based learning exercise. Although three preparatory lecture sessions were conducted to introduce case-based learning to the students, it was observed that students found it difficult to switch from lecture-based learning to case-based learning. Another challenge is the decent conduct of presentations and discussions which required a day-long session.

Also, sustenance of interest among students during such long sessions is problematic.

We believe motivation towards self-learning among students is the key to the success of CBL. Also, more than one pre-evaluation case-based learning sessions are required to let the students better absorb various aspects of the given case. This study was conducted on 89 students; a large class size which hampers the conduct of discussions. Dividing such a large class into multiple groups of 20 odd students may help, where multiple case-based sessions could be conducted in parallel and the best outcomes of those groups can be merged to have a final discussion. As suggested in [1], we formed a group of four instructors to manage the whole process. In order to evaluate contribution of individual (student) team member, fixing the responsibilities for individual questions was made mandatory. This helped us in understanding contribution of each student towards the work performed by his/her team. To further motivate the students, we gave additional evaluation marks to those students who participated actively and meaningfully in the discussions.

#### V. CONCLUSION AND FUTURE WORK

In this work, we propose a web based open source tool SEABED, based on case-based learning (CBL). Besides maintaining an open source case repository of the SE cases, it contains various features such as Case Submission, Case Collection, Case Search, and Case Evolution. SEABED aims to be beneficial for students, researchers, instructors and practitioners alike and aims to provide the SE cases which are related to the real world complex problems. Based on the experimental study conducted on a set of 89 UG students, CBL is found to be effective with an agreement of 74.53% students who were able to understand all five learning principles of learning, critical thinking, engagement, communication skills, and team work. As SEABED is still in its early days, we intend to extend it in a number of ways. As the cases form the backbone of such a platform, it will be extremely vital to add a variety of SE cases covering problems from different software development life cycle phases to the Case Collection section. In future, we aim to add more features to Case Submission, Case Search, and Case Evolution sections. We also target to conduct the experimental study on school going students and help them to develop critical thinking skills by understanding the course concepts well. A practical evaluation of the effectiveness of our publicly available web based tool will also be planned once the tool is adequately adopted as reflected by the number of active users.

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