A Preliminary Study on Case-Based Learning Teaching Pedagogy: Scope in SE Education

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ABSTRACT

Case-Based Learning (CBL) is an established teaching methodology approach used across several disciplines where students apply their theoretical knowledge to real-world scenarios. Application of CBL in several disciplines raises questions regarding writing cases followed by effectively executing the learning based on them. In this paper, we report the results of a preliminary review study performed in understanding the history behind adoption of CBL in different domains such as law, science/medical, business, engineering, and software engineering through targeted literature survey. Consequently, we report various challenges and guidelines recommended by the existing literature on CBL across such disciplines.

KEYWORDS

Case-Based Learning (CBL), Case, Software Engineering (SE), Thematic analysis, Preliminary study

1 INTRODUCTION

Teaching methodologies across disciplines have evolved and move towards adopting the real-world scenarios. These methodologies facilitate collaborative learning, develop students’ motivation to learn, encourage learner self-reflection, allow for scientific inquiry, integrate theoretical knowledge and practice, and support the development of a variety of learning skills [1].

Several popular teaching methodologies (e.g., lecture method, discussion method, problem-based learning, role plays, flipped classroom, gamification, etc.) have been developed to provide a framework for defining characteristics, roles, and responsibilities, including versatility, storytelling power, and efficient self-guided learning [2][3][4]. Case-Based Learning (CBL) teaching methodology adopted across several disciplines aims to facilitate active learning by applying the students’ theoretical knowledge to real-world scenarios [2][5]. In CBL methodology, the students typically work in groups on cases targeting some real-world problems. A case is unique, complex, and open-ended in terms of highlighting multiple perspectives of the problem [6].

CBL has a long history of successful adoption in various domains such as science (i.e., medical), law, business, health, education, and engineering disciplines. All these domains involve the analysis of the problem from different perspectives to reach an inevitable conclusion to apply a theory (or solution) for that problem. Hence, the CBL methodology involves guided inquiry, rigorous discussions, and knowledge about the problem. The problem defined in CBL could be a story that includes multiple scenarios and termed as the case or the case study. Although many claims were made for CBL as an active learning and teaching method, very little evidence was quoted or generated to support these claims [5][7].

Software Engineering (SE) is a flexible domain with uncertainties and multiple interpretations, which involves an understanding of the theoretical concepts by analyzing the relevant related problem [2]. Looking into other domains where CBL is successfully implemented, and likely the complexity of teaching the concepts are similar, we aim to identify a conceptual framework for writing cases and implementing them in the SE domain to illustrate various concepts. For this, we have reviewed other domains where CBL is typically used for improved learning and engagements, and have drawn a set of guidelines for writing compelling CBL cases for SE education and effectively executing them. Specifically, the study questions are as follows:

- **SQ1** What is a Case in CBL?
- **SQ2** How to write the Case in CBL?
- **SQ3** What is the importance of the case?
- **SQ4** What is CBL Teaching Methodology?
- **SQ5** How to execute CBL sessions?
- **SQ6** What is the importance of CBL?

This paper reports the results of an initial review study on CBL to determine its significance in terms of improving student’s learning and performance across various domains (such as law, medical/science/health, CS/Engineering/Education, business, SE). A total of 28 papers were analyzed based on themes to answer the six SQs. The outcomes of the study highlighted the effectiveness and significance of CBL, and consequently, we answer the SQs and also discussed how the CBL can be applied in the SE domain as well.

The rest of the paper is: Section 2 presents the research methodology adopted along with the search and selection process. Section 3 describes the data extraction based on the specific themes articulated in the SQs. Section 4 enumerates our analysis findings. Section 5 discusses the implications of our study, while Section 6 highlight recommendations for adopting the CBL teaching methodology. Section 7 concludes and suggests future work.

2 RESEARCH METHODOLOGY

In this study, we followed the research methodology for conducting review studies suggested by [8][9][10]. The overview of the phases involved in the CBL study is shown in Figure 1. The research methodology starts with the identification of study questions (SQs). The SQs are primarily focused on the knowledge-base
Exclusion Criteria: Papers not published in the English language; Papers that do not relate to the SQs; Papers without bibliographic information and with inadequate information about cases and CBL.

The third phase deals with the data extraction and analysis process followed by reporting the results of formulated six study questions.

3 DATA EXTRACTION AND SYNTHESIS

The search and selection process identified a total of 28 studies, as primary studies, shown in Appendix Section (Table 4). We developed a Data Extraction Form to collect the data extracted from the selected primary studies. A template for the data extraction is shown in Table 1. Based on the fields defined in the data extraction form we further analyzed whether for every recognized paper the required themes were present, partially present or not present. The results of the data synthesis of six SQs with reference to the primary studies are present in Table 2. The data extraction procedure was performed by the first author, cross-checked by the second author, and in case of any conflicts resolved by the third author. After data extraction and re-validation of the same, the synthesis of data was done by applying thematic analysis techniques [12]. The process for applying thematic analysis for each of the SQs – each SQs can be considered a theme for synthesis – is shown in Table 3. Based on the thematic analysis, the identified literature information related to each of the SQs is shown in the followed sections.

3.1 What is a ‘Case’?

Science/Medical Domain: Cases are written as problems which provide background details of a patient or clinical situation. The context or situation placed by cases promotes authentic learning supported by related articles, artifacts, clinical signs and laboratory results [1].

Law: Cases are factually-based, complex problems written to stimulate classroom discussion and collaborative analysis. Case teaching involves the interactive, student-centered exploration of realistic and specific situations [14].

Business: ‘A case is a description of an actual situation, involving a decision, a challenge, an opportunity, a problem or an issue faced by a person/community in an organization’ [15]. Cases in business tend to be in print form, although video and hypermedia are beginning to gain in popularity.

CS/Engineering: Breuner et al. defines cases as tools that are widely used in graduate and undergraduate education [16].

In general: By reviewing the definition of cases for all the domains, we can now define a case in general. The cases must have the following characteristics [17]:

- Represent specific knowledge tied to a context
- May consume small or large chunks of time
- Record experience that might differ from what was expected
- Posses useful lessons to help problem solver achieve some goal or warns about potential failures.

3.2 How to write case for CBL?

Science/Medical Domain: In health professional education, cases are mainly designed on the real-patients. These patients can be physically present in the hospitals, can be stimulated patients or

Figure 1: Overview of the phases involved in our CBL study
virtual (online patients) [18]. According to guidelines given by National Centre for Case Study Teaching in Science [18], the case must be based on real patient stories, must tell a story, authentic, should be designed in such a manner that they align with the learning outcomes, stimulates interest and eagerness for finding the solutions, and with generalized applicability throughout the domain. The clinical sciences are studied utilizing the patient cases and henceacimiento data; structured ways of thinking; considering various aspects of situations, understanding the what and why of given situations, reality of the cases; preparation for future encounters; relevance to practice, advancing involvement in decisions of patient care, emphasis on thinking of the actions for patient care, schematic representation of the cases, and (iii) Reflection (Increased responsibility (self and others): resourcefulness and consumers of research, more confident in the role as educator, holistic approach to patient care, transforming attitude toward effective patient care, professional attribute of caring, emphasis on holistic approach to patient care, increased understanding of patient’s culture/beliefs, group dynamics/collaboration/leading, professional attribute of caring, increased interaction in and among groups).

**Law:** Designing cases for law is tricky because it involves much more than the common sense recognition of factual similarities and differences. Even the best students, graduates of excellent universities and professionals are required to put their maximum efforts to master case designing. Cases must be developed in relation to questions of sound policy, social fact background, and non-legal disciplines [22]. Despite the fact that the students in the American law schools were less in number, CBL was adopted from the very beginning and case books were compiled as a supporting material [22]. The cases must focus on the following objectives [22]: (i) introduce students briefly to any branch of law, (ii) impart information, (iii) provide preliminary insight into certain ideas and (iv) organize the knowledge of a concept.

**Business:** Many cases are best developed from scratch. For requirements gathering and interviews, cases in business may take over a years’ time along with a huge investment [23]. Johnson et al. [24] classifies cases into three categories: (i) Decision/dilemma cases consisting of a short introductory paragraph setting up the problem of consideration, (ii) Issue/ appraisal cases used to teach the skills of analysis to students, and (iii) Case histories are finished stories of illustrative models of topics in action. An effective and efficient case discussion strategy meets the following objectives [25]: meets the learning objectives, creates an engaging and dynamic conversation about the case with clarity, flow and purpose, permits

### Table 1: Data extraction form

<table>
<thead>
<tr>
<th>Paper ID</th>
<th>SQ1</th>
<th>SQ2</th>
<th>SQ3</th>
<th>SQ4</th>
<th>SQ5</th>
<th>SQ6</th>
</tr>
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<tr>
<td>S1</td>
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<td>P</td>
<td>Y</td>
<td>Y</td>
<td>P</td>
<td>Y</td>
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<tr>
<td>S2</td>
<td>P</td>
<td>N</td>
<td>P</td>
<td>N</td>
<td>P</td>
<td>Y</td>
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<tr>
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<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>P</td>
<td>Y</td>
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<tr>
<td>S4</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>S5</td>
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<td>Y</td>
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</tbody>
</table>

### Table 2: Results of the information present in the primary studies for six SQs [Y: Available, N: Not available, P: Partially available]

- Limitations/threats to validity/Constraints
- Observations
- Findings and conclusions
- Applied Settings
- Relevance
- Aim of the study/Study focus
- Context
- Title
Table 3: Data Synthesis [12][13]

<table>
<thead>
<tr>
<th>SQs (Themes of study)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQ1: What is a Case in CBL?</td>
<td>We identify the definition of ‘case’ from the domains (Science/Medical, Law, Business, CS/Engineering, SE) chosen for the study. The case definitions are present in all the primary studies except S2 and S20 where the answer of SQ1 can be extracted partially.</td>
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<tr>
<td>SQ2: How to write the Case in CBL?</td>
<td>We identify the papers with guidelines, suggestions, recommendations and procedures to write a case. We have also searched for the example cases on the primary studies. All the papers except S2 explains the theme, and studies S1, S9, S11, S16 and S20 defines the theme partially</td>
</tr>
<tr>
<td>SQ3: What is the importance of the case?</td>
<td>To answer SQ3, we identify the set of studies that shows the importance of using a case in different settings by conducting the empirical study using students as subjects. All the papers explain SQ3 except S2, S6 and S20 which defines the theme partially</td>
</tr>
<tr>
<td>SQ4: What is CBL Teaching Methodology?</td>
<td>We identify the papers with explanation about CBL teaching methodology All the papers except S2 defines the theme and SQ6 defines the theme partially</td>
</tr>
<tr>
<td>SQ5: How to execute CBL sessions?</td>
<td>For SQ5, we identify studies with suggestions, recommendations, and explanation about how to conduct CBL sessions The settings in which the technique is applied/evaluated/observed (students, professionals, practitioners). The observations are drawn out by analyzing each primary study The papers S1, S2, S3, S4, S6 and S21 explains our theme partially</td>
</tr>
<tr>
<td>SQ6: What is the importance of CBL?</td>
<td>We identify the studies highlighting the importance/significance of CBL teaching methodology All the papers explains the theme</td>
</tr>
</tbody>
</table>

students and instructors to plan their participation without sacrificing the discussion quality and stick to the deadlines. To prepare a new generation of finance exemplars, Bruner et al. [7] talks about the guidelines about how to write/select a case:  
- write cases in such a way that employ, exercise, or explore a tool/concept  
- highlight the dilemmas of decision makers: good case discussion should dwell on the nature of the problem  
- critique the cases: students should lead the search, make the knowledge discovery and recommend improvements  
- embrace uncertainty: instructor should encourage students to test the sensitivity of their findings to variations in assumptions  
- demand the action recommendations arising from analysis and look for unintended consequences

**CS/Engineering**: As engineering is a huge field, [23] talks about writing a case by simply collecting a series of articles from magazines focusing around a single topic. They suggest to use preexisting articles because they come from recognized sources and immediately in their use. [14] used a pre-existing material to design real cases in the field of decision support systems. They chose real-life case studies that were discussed in the referenced book with more expansion.

**In general**: In CBL execution, two most important questions faced by the experimenters are: (i) how to write a case, and (ii) how to teach the case. The amount of work and time required for the preparation depends upon the type of materials to be provided to the students. [23] talks about how to write a case in 100-word paragraph format supported by evaluation based on the questionnaires like: What is the problem being investigated?, What specific conclusions can be drawn from this study? supported by some more detailed questions. Many experts argue that a typical class size should be in between 20 to 60 students to involve the diversity of opinion. And if it is too large, then the participation of the students might fall [23]. He further recommends to follow moot court competition procedure for debate style case discussion with 3-5 members per team. In all the methods of case teaching, as a common approach, the instructor must have clearly defined objective, correctly structure the presentation to develop the analytical skills and must be sure that the participation is maximized [23]. Cases can be designed with complete information to quickly understand the case, or incomplete information may be provided through which students must engage in conversation and considerable reasoning to reach an informed decision [14].

### 3.3 Importance of the Case

**Science/Medical Domain**: In health professional education domain, the learning pattern depends on the patient cases which is further utilized in studying basic, social and clinical sciences [18]. Furthermore, many other related topics are studied in relation to these cases with an integration of clinical presentations and learning. Therefore, the students learning is associated with real-life stories.

**Law**: Christopher Columbus Langdell, in 1871 when he joined Harvard as a professor of Law, was the first to implement case method to the study of Law. His biggest achievement was to introduce the case method into university legal education in eighteenth century [26]. Majority of law students are anxious to gain the advantage of critical thinking and practical knowledge in law, cases must be used to train them [27]. Every university, at least once, should implement cases in teaching the concepts of law to students [26].

**Business**: Benton E. Gap uses ‘Business live cases’ for implementing CBL [7], where he defines live cases as the study of financial issue using current, publicly available information to resolve those issues, like determining the intrinsic value of a firm, making asset/liability management decisions for a bank, and making investment portfolio decisions. In a case discussion, the business instructor serves as a leader or facilitator and the participants are encouraged to identify the issues confronting the company, suggest several possible alternatives, make recommendations, and extend
A Preliminary Study on Case-Based Learning Teaching Pedagogy: Scope in SE Education  

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the findings to other companies or contexts [15]. [24] used cases from sub-disciplines including decision sciences and managerial economics, finance, international business, management and marketing.

**CS/Engineering**: [14] talks about the advantages of using a case: the real context of the problem through case provides a concrete framework of the problem and therefore, is more motivational to the students/learners. Through cases, complex concepts in the decision support process can be more easily understood. Learning through cases reduces the potential for “inert” knowledge. Exploring story like, real life cases, increases interaction learning among students.

**In general**: Well designed case induces a deeper level of learning by inducing critical thinking and reverse engineering process in mind[28]. Case allows one to brainstorm a topic and search different sources to get the solutions[6].

### 3.4 What is CBL?

CBL is defined in a number of ways depending on the discipline and the type of case employed. It is often contrasted with Project-Based Learning (PBL), as both are separated by a very thin boundary [29]. CBL uses a guided inquiry mechanism with defined learning outcomes which makes it more structured than PBL. The definition of CBL can be categorized according to the underlying themes which are hallmarks of inquiry-based learning and the raw material for inquiry is the case itself [18].

**Science/Medical Domain**: For pre-hospital education, [1] defines CBL as an education paradigm that closely relates to andragogical PBL but differs in strategic execution. It is learner-centric method with an intense interaction between the participants. CBL is defined as teaching and learning approach that aims to prepare students for clinical practices. The clinical cases link theory to practice and encourages inquiry-based learning methods [18]. According to a survey performed at Queen’s university– CBL strives students to resolve those questions having no single right answer [18]. Harvard Business School (HBS) is one of the biggest and earliest (1920) institutions to adopt case based method for its curriculum. Its website states “when students are presented with a case they place themselves in the role of decision maker, followed by analysis, discussion about their findings with other groups. CBL helps students to probe underlying issues, find alternatives, and suggest courses of action in light of the organization’s objectives” [18].

**Law**: Case-based learning (CBL) was first introduced in law schools in late 1800’s and since early 1900’s, it has also been popular in business schools [14]. [22] describes CBL as a collaboration in the kind of thinking as a legal scholar studying cases relevant to the solution of a given problem. The participants are in a teacher-student relationship. The students are not told the answers rather depends on the potentialities to recognize the clue, the connecting link, and thus to form a judgement. Case based learning reaches into the dynamics of the judicial process, the adaptations of generalizations to varying facts and social problems.

**Business**: The case method is a common pedagogical technique to teach fundamentals of business and management. The instructors assign a business case, a narrative description of a real management dilemma, and then ask students to assume the role of a case protagonist, analyzing the situation further supported by proposing a plan of action [30]. These learning sessions are built on the premise that group discussions, conversations and social dialogue constitute a critical aspect of learning [25].

**CS/Engineering**: CBL is also a powerful technique in the field of marketing using artificial intelligence, and has been successfully employed in advanced systems like Intelligent tutoring systems [14]. [5] takes about CPLC (Case-based and Project-based Learning) environment for teaching Compiler design concepts to students at university level. **In general**: Two pedagogical principles lie under CBL architecture: Active learning and learning from cases. This demands that the students be actively engaged in a meaningful task. The learning is further augmented by just-in-time teaching through relevant cases. In practice, CBL is both, an art and a science [31]. CBL consists of two interdependent components: a task environment which provides an engaging task by posing open-ended and thought provoking questions, and a storyteller which monitors the learners’ interaction with the task environment [31].

### 3.5 How to execute CBL? (Is there some guidelines, advice/implications, lessons learned, evaluations highlighted by the study?)

Different authors have given different thematic CBL execution guidelines. The guidelines for CBL execution given by [32] focus on evaluator/tutor selection for study. An important issue in CBL execution is the use of expert and non-expert evaluators/tutor [1]. The most common area of enquiry roams around whether the evaluator/tutor must be an expert in the subject under study. [32] argues that students led by experts have higher test score but at the expense of student learning because the tutor preparation time detracts from the overall classroom time.

**Science/Medical Domain**: [33] conducted a study to compare CBL learning with structured cases and learning with unstructured cases with 79 medical students. Their study revealed that, as a preliminary evidence, medical students preferred an unstructured approach to the cases for CBL execution. Gender based studies performed by [34] shows that female candidates performed and viewed better CBL constructs than male candidates. Creanimate is a case-based teaching system based on three primary goals: engaging interaction, understanding of the conceptual relations about the animal adaptation, and motivates to make own case libraries to be used to reason about other animals [31]. It involves recognizing the particulars of clinical situations, making sense of patient data, information decisions and reflection of the results [19]. CBL takes place in small face-to-face groups but can take place online and bigger groups [18].

**Law**: According to suggestions given by [22], case based method for learning in law should not get postponed to second or third year of study. It must be implemented in the first year itself to secure the immediate benefits of learning. **Jerome et al.** recommends to conduct training sessions before conducting CBL activities. The preliminary objective may be aided by having the students read cases, which will provide the necessary minimal understanding of the law cases. Professor Hall, with his team, developed cases which in turn were overwhelming but costly in comparison with its advantages [22]. In the law case study performed by [14] students were asked probing
questions, they analyzed the problem depicted in the story to find answers of the questions. Starting from the first case and going to the last one, the CBL passed through several stages. At the end of the first stage, students divided their responsibilities for searching the required information. In the second stage, students demonstrated their findings and shared opinions. [14] says 'the power of this method is its interactive approach between thinking, discussion, and searching for more information'.

Business: Keith Rollag highlights some most effective ways and design strategies to teach business cases online, specifically in asynchronous electronic discussion boards for MBA programme at Babson College, USA [30]. The guidelines given by [24] are based on the lessons learnt by [35]. To evaluate the benefits of case discussions, [15], uses the questionnaires which are analyzed on a 5-point scale. These questionnaires include evaluation on leadership skills, conflict resolution techniques, communication and persuasion skills, beliefs and values, confidence, communication skills, and team work. Most of the students said that CBL activities motivates for quest for the right answer rather than going for the correct answer. [14] employed discussion format as a way for teaching the cases. The objective was to structure the discussion to develop the analytical skills of the students, and to make sure that student participation is maximized. [24] highlights an investigation of case-based teaching and learning in the business faculty at a bilingual (Chinese-English) university in Hong Kong. The work reports of an ethnographic investigation that examined the experiences and perceptions of the business professors who were using cases for teaching.

CS/Engineering: While analyzing the technical case, the students must focus upon 10 steps [36]:

- Identify the problem
- Determine the nature of problem
- Understand the importance and urgency of the situation
- Analyse the situation, both qualitatively and quantitatively
- Generate alternative, if possible
- Establish decision criteria
- Select the preferred alternative and predict outcome
- Outline the implementation plan
- Identify the missing information (relevant)
- List out all assumptions during analysing the case

Selecting group size for CBL execution is a challenge. There are interrelated theoretical perspectives on how smaller groups impacts the learning in an academic setting. Some of the factors are motivational perspective, individual accountability, cognitive perspective and enhanced student-centric learning. The study performed by [36] explains the role of small discussion groups and suggests guidelines based on their experience for the small groups into CBL execution:

- All students must attend the discussion fully prepared
- Each member should actively participate
- It is not necessary to have group leader or a spokes-person
- Everyone should take responsibility
- Stick to deadlines
- Stick to time limits

Again, the selection of objects play an important role in the success of CBL studies. Novice students are less likely to participate in case studies on a full time basis because they may lack real-life working experience to contribute to fruitful discussions. On the other hand, full-time employed students are easier to engage with such activities because age and work experience makes them more mature and confident [37]. Talking about the barriers, [37] says that Asian students might face problems in class discussions, like language barrier, fear of losing face, reliance on others and passive habits from school.

In general: The evaluation of CBL activities depends on the nature of CBL execution and types of cases used. [38] talks about evaluating the students responses through a survey rating score, known as Case-Rating assessment. Respondents are prompted to rate each of the questions using a 1-5 Likert scale (1= not at all to 5= extremely). For evaluation of knowledge gains and attitudinal changes [38] suggests to use a comparison between pre and post-test experimental design having same survey questions. After the overall responses, some interesting patterns emerge which can be further analyzed to answer the questions [14] suggests to evaluate a case on the basis of two key factors: case-content and what is learnt from the case.

3.6 Importance of the CBL

CBL engages students in discussing the situations related to real-world problems [18]. Some authors used the following objectives to capture the nature of learning such as self-directed [39][40], self-motivational [41], cooperative, active and interactive, and efficacy and valuable [42].

Science/Medical Domain: Thistlethwaite et al. concludes that CBL is helpful in enhancing intrinsic and extrinsic motivation, encourages self evaluation, critical thinking, and development of learning skills [43] for prehospital education. These case enhances the relevance as they are written on real life examples and actual performance of the health professionals. The case-based learning format requires the students to recall previously covered material and concepts to solve the clinical cases [1]. It serves a purpose of learning other than specific learning outcomes - the students are exposed to authentic and realistic cases before clinical attachments. This prepares them for clinical practices and provides opportunities to formulate diagnosis and management plans [44]. This further helps to address integral image of the whole patient rather than separate views of the affected organs [42]. It involves recognizing the particulars of clinical situations, making sense of patient data, information decisions and reflection of the results [19]. The linking of theory to practice is emphasized [45][46]. It functions as a bridge between knowledge and working life [47]. Students involve themselves in group work, cooperative learning and problem-solving with the help of their friends, groups and mentors [48]. CBL takes place in small face-to-face groups but can take place online and bigger groups [18]. It blends the aspects of cognitive and social constructive models by emphasizing on different components of learning process [49]. It provides a direct relevance of the information to be learnt. CBL helps in developing reflective thinking and deeper conceptual thinking [50]. For Bachelor of Dentistry, despite of long preparation time for CBL activities to be conducted [51] believes that CBL must be incorporated into the curriculum as it develops better problem skills as compared to some other learning
paradigms. The majority of the evidence outlined in the literature review for medical domain shows that CBL was enjoyed by both students and tutors [1]. The study done by [52] using an example case to access the effectiveness of learning through erroneous example versus non-erroneous example in undergraduate medical education (arterial hypertension; hyperthyroidism) shows that prior knowledge combined with cases helps students in understanding the clinical domain in detail. [18] shows a survey on applications of CBL in medicine, dentistry, veterinary science, nursery, midwifery, physiotherapy and related domains. CBL encourages attitude of students towards medical education [53].

Some researchers like (e.g., [54][51][3] and [55]) highlights the importance of CBL in medical sciences using student evaluations at University level through a combination of Likert Scales and questionnaires. They captured the students responses and majority of the students embraced qualities of CBL. The results shows that their learning was improved logically, CBL was helpful in improving clinical reasoning and diagnostic interpretations. Williams et al. show that CBL activities are helpful in providing dynamic curriculum and helps students to work in collaboration by enhancing team work, group understanding and active participation of students. Techniques of CBL helps in vertical and horizontal integration of the syllabus and hence introduces a dynamism in curriculum. Majority of studies documenting students’ better performance in CBL have been conducted in the United States, Europe and Australia at the graduation level [56]. Psychology can be learnt and applied more effectively when lectures are supplemented with clinical cases [56]. Students commented on the degree of creativity, challenge, interest and enjoyment afforded through the case-study method [49]. According to students reviews CBL stimulated academic challenge, offered a sharply realistic perspective from which to apply course content [49]. Students gave a high score to CBL for understanding of clinical problems. Student attendance and involvement also comes under process evaluation; implementation of the intervention rather than its impact [18]. At evaluation level 2, when post-intervention test was compared with pre-intervention test the results showed an increase in knowledge of psychology [57]. Students, tutors and experimenters responded positively towards CBL experiments [18].

**Law:** The impersonal objective quality of case method analysis develops a searching, critical attitude, which is a perennial need of the law profession. Professor Gerhart Hassler, supporting CBL, said that he had taught in both, Germany and the United States and had no doubt that the cases if applied properly, stands far better than the teaching methods used in continental Europe [22]. The pre-eminent merit is that CBL provides intellectual drill, and helps them with a legal tone of mind and forensic habits of reasoning [58]. It helps the law people familiar with the law through incessant practice in the analysis of law cases, where the concepts and principles of Anglo-American laws are recorded [58].

**Business:** University of Alabama uses two live cases - corporate financial policies and bank administration for MA/MBA courses [7]. They further explains why learning through cases should be used in business subjects: (i) cases provide the opportunity to apply finance theory to practical situations using the real world data, (ii) the hands-on approach keeps them updated with the current affairs, (iii) the students are free to choose the firm of their interest to analyze, and (iv) student learn to use judgement in dealing with issues rather than seeking a single ‘right answer’. [25], based on their experience, lists out the advantages of conducting CBL online for business domain. Firstly quality and effectiveness of the case discussion is better as compared to face-to-face discussions because students get more time to understand and edit their responses. Also it removes some biasing decisions as they get sufficient time to formulate a response with an interesting insight on the case.

**CS/Engineering:** To test the emotional engagement factor in cognitive sciences, Nkhoma et al. conducted an experiment with the undergraduate students. A research framework was established to study multidimensional relationship through cases. The study found that the case discussion improved emotional engagement, which in turn positively influenced positive group interaction supported by individual learning performance [37]. [5] used CBL for teaching the concepts of Compiler Design course where the authors reported their experiences in implementing case-based and project-based learning for teaching various Compiler Design concepts. Their results suggested that the case-based teaching enhances students skills of learning, critical thinking, engagement, communication skills and teamwork.

**In general:** The case method cannot overcome all the ills in the teaching pattern, however it is considered the best method for developing higher order reasoning skills with learning objectives like critical thinking, brainstorming, co-ordination, team work and establishes good relationship with the instructors. It helps students develop appropriate indexes for the cases in their memories to be used with future incidents. Kolodner suggests problem situation topic indexes and appropriate solution indexes as an overview for case execution [17].

In experimental studies on CBL performed by [59][60][61][62], the students’ feedback was very positive. The students’ feedback were captures using the set of questionnaires. The collected feedback consists of the keywords like satisfied, motivational, challenging, strongly agreed, confidence gained, enhanced learning for different type of feedback questions. For instance, the experiments conducted by [58] shows that the participants who worked in groups liked CBL significantly better than those who worked alone with the cases, and expressed a preference for working in a group in future experiments. However, in few studies the experimenters received a mixed response post execution of CBL. Some authors were not sure of the applicability of CBL in summative assessment [63][64]. From the academic schedule point of view, work load on students and adverse amount of time required for the activities were the primary cause of dissatisfaction among the students [64][65][66].

### 4 ANALYSIS: SCOPE IN SE EDUCATION

Based on the data collected and synthesized from the identified studies, we can now highlight the scope of adopting CBL for teaching Software Engineering concepts. In this section, we try to answer our study questions with respect to Software engineering context. Some authors have already applied CBL successfully for teaching SE concepts namely, requirements engineering, software testing, software architecture [2][5][6]. Now the question arises: *Is it worth to apply CBL pedagogy for teaching other concepts of Software Engineering too?*
What is a case? Many authors have defined cases based on their experiment objectives. Here we extracted all definitions of a case w.r.t SE context. Cases are known to promote think forward from first principles. As an instructional method, cases can bring both theory and practice to learning by engaging students in contextualized learning environment [67]. Cases are versatile tools of learning and can be used in didactic as well as an active learning environment in Software engineering [67]. A case in CBL is a unique, complex, and uncertain narrative structure of some contemporary interest arousing event or problem [4]. Cases motivates students to read, understand, and discuss complex real-life scenarios, testing their analytical thinking and decision-making skills [6].

How to write a case? A thorough analysis requires some key points to be followed: understanding the project in context using SE domain and knowledge, identifying the constraints, identifying implicit problems and factors impacting the explicit challenges, identifying various stakeholders, their roles and considering different stakeholder perspectives [67]. In order to answer the case questions, students need to investigate the problem thoroughly and apply the concepts [6]. Their work also highlights the impact of gender diversity and change in case problem on students’ responses. Garousi et al. used industrial tools and projects for undergraduate software testing labs to demonstrate the real world testing scenario to the students [6]. They used two cases, the first case intends to facilitate the concepts of responsiveness testing and performance testing (in terms of speed or response time), and the second case facilitates the concepts of security testing and functionality testing in software engineering.

Saini et al. proposed SEABED platform, which 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 [2]. Its features include:

- Case submission
- Case collection
- Case search
- Case evolution
- Views and opinions

Their cases before getting published are evaluated by the team, then they are released, further can be used by other practitioners for CBL experiments and studies. But they have very limited number of SE cases.

While defining a case several points must be kept in mind [6]: (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 invoke students into exploring a variety of resources including books, websites, blogs, discussion forums (both developer and general). One of the major aims of CBL is to send the students on a quest for the best (or the most appropriate) solutions. These solutions originated from different student groups form a common multi-perspective representation against each case question. This scenario should then trigger a discussion following the students’ presentations.

Importance of a case: Software engineering cases intend to facilitate the concepts of understanding the problem domain, requirement elicitation and prioritization through the real-world scenarios. Through the cases developed from real world software, students understand and practice how things work in the real world. Cases help to build skills like confidence and critical thinking [5].

What is CBL? [68] defines learning through cases as an active and student-centric learning method which enables students to relate their experiences to the learning process and improve their learning through problem solving activities. It provides a means for acquiring concepts, skills, tools and techniques in the presence of a context where the instructor and students are engaged in a meaningful manner. One of the most important elements is the case itself. It is either self-developed by the instructor or academic team, or retrieved from a case-repository. [5] differentiates CBL from traditional learning in the manner that it places students the center of the education process.

How to execute CBL? [67] introduces COSEEd - a learning environment for SE with contextualized case enquiry at its heart. It consists of learning objectives, pedagogy and assessment in tight integration to help students learn SE and engineering skills expected from a software professional through cases. This framework was used by them to teach four software engineering courses at IIIT-H in India. Through an experiment using Twitter-case with 320 students, their results revealed that a case study oriented approach, with well-designed case studies, is suitable for teaching and learning of software engineering concepts. The observations/suggestions drawn from the study includes the authenticity of the case makes the learning activity realistic, interesting and hence motivating for students, scaffolding helped to build student skills and confidence, pre-presentation discussions allowed students to design well reasoned quality solutions and avoid tangents. Experience with Software architecture and design in COSEEd clearly suggests that instructors should set their expectations after due consideration of student profile, nature of topic and time available [67].

In order to address the gaps between existing university-level software testing education and the training standards used in industry, [6] experiments with CBL to facilitate the training of selected software testing concepts at tertiary-level for undergraduate students to cultivate the decision making skills in a self-learning environment. [6] used a single-factor incomplete block design for the experiment where, block size is small as reduced block size decreases chances of experimental error. To prepare the students for experiment, they conducted four lecture sessions before the final experiment to teach the students about the topics related to the two cases, and to enable them with the basic idea of CBL. After the training, the study was carried out in three phases, ‘Case Understanding’, ‘Response Gathering’, followed by ‘Discussions’. Each student team was asked to submit their responses on the response sheet for all the questions, and then present their responses to the case questions through presentations. The survey questions used to investigate CBL outcomes in a four-point scale (strongly agree, agree, disagree, and strongly disagree) were further utilized by Kundra et al [5] and Saini et al [2] for assessing the efficacy of CBL.

The challenges faced by [6] in executing CBL are - cases need to be designed carefully and should not deviate from the scope of
course structure, selecting appropriate software testing topics to be covered by CBL sessions and managing large groups of students having different capabilities was a challenge.

Tiwari et al. [6] report the results of an exploratory pilot study conducted to assess the effectiveness of CBL methodology in facilitating the learning of several RE concepts. The evaluation was made on the basis of students’ responses to a set of survey questions from various key learning principles, collected after the execution of two CBL sessions. For the study design, [6] choose different sizes of students groups in order to analyze the impact of group size on student learning, critical thinking, and engagement of the concepts. Before commencing the CBL exercise, traditional lecture sessions were organized to familiarize students with the RE concepts. For each case, the study was formally carried out in three different phases, ‘Case Understanding’, ‘Case Solving’, ‘Case Discussions’. The objective was to analyze the students responses on five aims: analyzing the impact of CBL on learning objectives, impact of team size on learning, case difference, gender diversity and TAs perception with CBL [6]. Based on the feedback submitted by the students, it can be clearly interpreted that they found CBL an innovative and interesting technique in SE education, and asked to conduct more CBL sessions in other topics of SE too.

Importance of CBL: The Case based learning Method has long been used effectively in education. Its potential use in applied science such as SE however has yet to be further explored. SE is an engineering discipline that concerns the principles, methods and tools used throughout the software development life cycle [68]. In the effort to provide the necessary knowledge to software engineers in both technical and non-technical aspects, SE courses tend to be overly theoretical and unidirectional in terms of instructor-student interaction. The normal teaching methods that are used to present SE topics tend to rely on whiteboard and projector. As a result students merely listen, absorb and memorise lessons in order to regurgitate them in the examinations and they become less creative and innovative in generating solutions [68]. In order to create an effective learning environment that blends both theoretical and practical elements, the case teaching and learning method is seen as a viable solution. It is generally accepted among SE students for teaching and learning the subject matter. There are four major factors that influence the successful use of the method namely, environment, case, instructor and student [68]. CBL focuses on the best solutions and helps students to get a feel of how the concepts can be applied in real projects. The students were advised to look for the ‘best possible solutions’ relevant to the case [6]. Evaluations performed by [2] showed that the case was helpful for synthesizing ideas and information presented in the course.

5 DISCUSSIONS
We performed a review study of CBL to investigate its effectiveness in law, business, medical, engineering, software engineering and in general, based on our theme-based study questions. Further, with the help of data synthesis and analysis we highlighted the importance of CBL in the existing software engineering literature. SE encapsulates an important set of activities that are required to develop a software system. Further analyzing a set of software requirements require systematic, quantifiable, and repeatable techniques that ensure completeness, consistency, and relevance of requirement, consisting of the huge number of SE concepts. Our study shows that CBL has been successfully implemented in limited concepts of SE. We further analyzed the existing literature to know whether CBL can be used to teach other concepts of software engineering based on the observations from other domains.

Limitations of the study: Our study is limited to accessing the effectiveness of CBL in five domains (law, medical, business, software engineering and in general). Again we have not used DLs for searching papers of interest. In future, we wish to extend this study to other domains and use DLs for effective search strategy.

Case vs case study: The ‘case’ and ‘case study’ in CBL methodology are used as synonyms. However, there is a specific way of writing a case for the CBL methodology. A case study involves a detailed intensive study of a unit. The purpose of a case study is to generalize learned information from one study to another. An effective case tells a real-engaging story, raises a thought-provoking issue, has elements of conflict, lacks an obvious or right answer, encourages students to think and take a position, provides plenty of data about character, location, context, actions.

6 RECOMMENDATIONS FOR PREPARING A CASE AND EXECUTING CBL
By absorbing the definition of case and guidelines for writing a case, we can now identify basic criteria for selecting a good case, that must have: a clear problem statement; focus on the problem; and alignment with the program objectives. Besides, cases must be based on meaningful realistic situations which do not contain ideal and clear-cut solutions [68]. Further we recommend some guidelines to write and execute case efficiently based on our analysis [1][2][5][6][7][18]:

- first identify the goals and purpose of writing a case
- the scope must be clear; if it targets the curriculum then it must adhere to the curriculum structure
- identify the domain knowledge required to execute the case; this helps facilitator to conduct training sessions
- identify your targeted audience
- make case a comprehensive document (400-500 words)
- be relevant while putting the information
- should lay stress on strategies and procedures than solutions.
- should outline a problem which has no obvious answer.
- 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 [69]
- should present sufficient evidences that show the need of addressing the problem
- All judicial, ethical, and professional standards must be respected by the case [70]

Based on the analysis results, we present our recommendations for implementing CBL in the classroom sessions. The CBL methodology can be implemented in six different stages:

1) Traditional Lecture-based Learning: Before conducting CBL sessions, it is recommended to conduct traditional learning sessions for the students to teach them SE concepts for which
CBL is to be conducted. It is also suggested to introduce them with CBL concepts (several videos are available online\(^2\)).

(2) **Case formation**: Next stage is the formulation of a case for the concepts to be covered in the CBL sessions. The specific guidelines for creating the case are given above. The example cases can be found online\(^1\).

(3) **Case Understanding**: After the preparation and training, the students can form groups. Each group can be allotted a different case for analyses and understanding. Here, in this stage, it is recommended that the students must be allowed to use literature resources to better understand the problem domain. But this stage consists of numerous threats such as copying the solutions, lack of team participation, and lack of support. Hence, it is recommended to conduct these sessions in the lab/classroom environment (as the course instructor is available for any help).

(4) **Case Solution**: Each case consists of some case questions, and each student group has to answer these case questions collectively by referring to multiple resources. The groups are then asked to submit their case solutions and then move to the next stage for discussions.

(5) **Case Discussion**: Soon after the completion of the previous stage, the students’ group must be asked to present their solutions. Based on each groups’ solutions, a discussion session must be arranged.

(6) **Conclusions**: The above discussion exercise helps the students to analyze the best suitable practice that could be adopted in SE to find the best solution. It also helps them in brainstorming and thinking critically.

Through our study, we identify that the “concept” behind implementing CBL through cases is common among all the domains. Again the logic behind designing the case too remains the same along with all the domains. All the concepts in SE are interrelated, possibly directly or indirectly, and with related underlying theory. With minor changes and modifications in the existing CBL execution, based on our analysis, we infer that if CBL is successfully implemented in some concepts of SE, then the similar guidelines with no or little modifications can be used in implementing other related concepts of SE, required the guidelines are followed systematically. Our study may work as a supporting document for all the researchers who in the future wish to implement CBL for teaching concepts of SE.

### 7 CONCLUSIONS AND FUTURE SCOPE

This paper reports a preliminary review study on CBL, a teaching methodology, to determine its significance in adopting CBL practices in different domains. The study formulates a strong theoretical basis for transferring knowledge information from other domains to the Software Engineering domain. While analyzing the set of studies, we tried to investigate whether it is worth to apply CBL pedagogy for teaching other concepts of Software Engineering. Our work also highlights the guidelines which are used to assess the effectiveness of CBL practices in different domains. Consequently, the study presents the guidelines for defining cases, case execution and case procedures for CBL sessions.

The major publication venues for publishing CBL related studies are known in numerous domains, hence, the present study can be extended and reported in the form of systematic literature reviews or mapping study.

### APPENDIX

The list of primary studies included in the review study is shown in Table 4.

### REFERENCES


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\(^1\)https://www.youtube.com/watch?v=JQDalr1r7ox

\(^2\)https://sites.google.com/site/saurabhiiitdmj/resources/Case.pdf
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<th>S.No.</th>
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<td>S3</td>
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