ANALYSIS AND ASSESSMENT OF SOFTWARE ENGINEERING EDUCATION AND TRAINING

By

MASSOUD MASSOUDI

Roll No.: 2k18/Ph.D./CO/27

Under the guidance of

Prof. Ruchika Malhotra

Professor, Department of Software Engineering,

Prof. Rajni Jindal

Professor, Department of Computer Science & Engineering

Submitted in fulfillment of the requirements of the degree of Doctor of Philosophy to the

DELHI TECHNOLOGICAL UNIVERSITY

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SHAHBAD DAULATPUR, MAIN BAWANA ROAD, DELHI 110042

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Declaration

”I, **Massoud Massoudi**, Ph.D scholar bearing Roll No. 2k18/Ph.D./CO/27, solemnly affirm that the research work presented in the thesis titled **”Analysis and Assessment of Software Engineering Education and Training”** submitted for the conferment of the Doctor of Philosophy degree in Software Engineering, reflects my authentic scholarly endeavors conducted within the Department of Software Engineering at Delhi Technological University. Furthermore, I certify that the content outlined in the synopsis has not been previously submitted for any academic degree or diploma to any other educational institution or university.

Date :

Place : Delhi

Massoud Massoudi

Roll No.: 2k16/Ph.D./CO/07

Department of Software Engineering,

Delhi Technological University,

Delhi-110042

CERTIFICATE

DELHI TECHNOLOGICAL UNIVERSITY

(Govt. of National Capital Territory of Delhi)

BAWANA ROAD, DELHI-110042

Date: ___________________

This certificate confirms that **Mr. Massoud Massoudi**, bearing Roll No. 2k18/Ph.D/CO/27, has successfully conducted the research outlined in the thesis titled **"Analysis and Assessment of Software Engineering Education and Training"** under the supervision of **Prof. Ruchika Malhotra** and **Prof. Rajni Jindal**, in pursuit of the Doctor of Philosophy degree at Delhi Technological University, Delhi. The work presented here is a product of original research and has not been previously submitted, either in its entirety or partially, for any other academic diploma or degree from any university.

Supervisor

Prof. Ruchika Malhotra

Department of Software Engineering

Prof. Rajni Jindal

Department of Computer Science & Engineering

Delhi Technological University, Delhi-110042

Dedication

I dedicate this thesis to the pillars of my life, my parents, my loving wife, my precious children, my supportive brothers, my invaluable guides, and my dearest friend, Ramin Habibi.

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Abstract

In the fast-changing world of technology, software is the driving force behind significant advances in diverse disciplines including education, agriculture, medicine, engineering, and more. This thesis examines the imperative need to cultivate highly capable software engineers by addressing a number of important issues in software engineering education. The study concentrates on the difficulties of teaching software testing, the need for curriculum improvement, the influence of COVID-19 on education, the advantages of competency-based education (CBE), and the significance of industry-academia collaboration.

This study begins with a systematic review of the literature on software testing education. The findings demonstrate the need for a more hands-on approach that includes practical sessions, educational activities, and tools. This discovery paves the way for the investigation of innovative teaching methods to improve student engagement and learning experiences. Consequently, the second section investigates the incorporation of Project-Based Learning (PBL) and gamification into software engineering instruction. PBL-gamification arises as a promising strategy, motivating students and bridging the gap between industry and academia left by conventional teaching methods.

The third section explores the paradigm transition towards competency-based education (CBE) in Science, Technology, Engineering, and Mathematics (STEM) fields. CBE, which is centred on outcome-based learning, promotes lifelong learning, inclusiveness, and clear expectations. To demonstrate the efficacy of CBE, a comparison is made with traditional educational approaches, using a software engineering competency checklist as a criterion for evaluation. The results

demonstrate the importance of engineering education that focuses on equipping students with practical skills for their future professions.

The fourth segment investigates the impact of the global COVID-19 pandemic on education, focusing on the strain it places on existing educational systems, particularly in regions with limited access to digital technology and internet connectivity.

Fifthly, the study proposes a collaborative strategy to strengthen industry-academic collaboration. This strategy promotes effective communication and provides students and staff with valuable internship opportunities, recruitment channels, and enhanced academic research output by leveraging the influence of alumni. Academia and industry can foster innovation and the applicability of research by leveraging the strengths of alumni.

The dissertation concludes with a comprehensive analysis of the software engineering curriculum at Delhi Technological University (DTU) in India. A survey of students in software engineering exposes both the benefits and drawbacks of the current approach. The findings pave the way for improvements to the SE programme, particularly in refining the teaching manner in order to produce highly qualified and professional software developers who can meet the industry's growing demands.

This comprehensive thesis concludes with a research roadmap for software engineering education, emphasising the importance of industry-academia collaboration and competency-based approaches in preparing students to flourish in the dynamic technology industry. By addressing identified challenges and embracing collaborative efforts, educational institutions can equip future software engineers with the skills and knowledge necessary for success in a technological landscape that is constantly advancing. The study highlights the importance of software engineering education in spurring innovation and development across multiple industries, thereby having a lasting impact on the advancement of society as a whole.

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Papers Accepted/Published in International Journals

1. R. Malhotra, M. Massoudi, and R. Jindal, ”An alumni-based collaborative model to strengthen academia and industry partnership: The current challenges and strengths,” Education Information Technologies, 2022. DOI:https://doi.org/10.10 07/s10639-022-11276-1 (SSCI) (Impact factor: 3.666).

2. R. Malhotra, M. Massoudi, and R. Jindal, ”Shifting from traditional engineering education towards competency-based approach: The most recommended approach-review,” Education Information Technologies, 2023. DOI: https://doi.org/10.1007/s10639-022-11568-6 (SSCI) (Impact factor: 3.666).

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1. R. Malhotra, M. Massoudi and R. Jindal, ”An Innovative Approach: Coupling Project- Based Learning and Game-Based Learning Approach in Teaching Software Engineering Course,” 2020 *IEEE International Conference on Technology, Engineering, Management for Societal impact using Marketing, Entrepreneurship and Talent (TEMSMET)*, Bengaluru, India, 2020, pp. 1-5, DOI: 10.1109/TEMSMET51618.2020.9557522.

2. R. Malhotra, M. Massoudi and R. Jindal, ” Software Engineering Education And Training In Afghanistan: Status, Issues And Comparative Study

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Abbreviations

CIS	**Computer Information Systems**
CS	**Computer Science**
SDLC	**Software Development Life Cycle**
CBE	**Competency-based education**
DTU	**Delhi Technological University**
SE	**Software Engineering**
CWS	**Couse Works**
PRS	**Practicals**
MTE	**Mid Term Exam**
ETE	**End Term Exam**
PRE	**Practical Exam**
F/OSS	**Free Open-Source Software's**
UG	**Under Graduate**
PG	**Post Graduate**
ST	**Software Testing**
ACM	**Association for Computing Machinery**
IEEE	**Institute of Electrical and Electronics Engineers**
ASEE	**American Society for Engineering Education**
JCSC	**Journal of Computer Science and Control**
JiTT	**Just-in-Time Teaching**
CBL	**Case-Based Learning**
TDD	**Test Driven Development**
Web-CAT	**Web-Based Center for Automated Testing**

TDL	**Test-Driven Learning**
WReSTT	**Web-Based Repository of Software Testing Tutorials**
CDIO	**Conceive, Design, Implement and Operate**
QDTM	**Question Driven Teaching Method**
UPM	**Universiti Putra Malaysia**
API	**Application Programming Interface**
IBT	**Inquiry-Based Teaching**
TST	**Teaching Software Testing**
EMT	**Education Modules and Tools**
A&F	**Adaptive and Flexible Method**
ITM	**Innovation in Testing Modules**
TTS	**Self Interest Towards Software Testing**
AES	**Adequacy And Evaluated Strategy**
PSTK	**Practical skills and theoretical knowledge**
MEST	**Managing and executing software testing**
BUTT	**Better Understanding Of Tools And Techniques**
ABT	**Acquire Better Testing Skills**
RWISS	**Opportunity Of Working With Real-World Industrial Software Systems**
GBS	**Game-Based Software Testing**
AICTE	**All-India Council for Technical Education**
UNDSCO	**United Nations Educational, Scientific and Cultural Organization**
ABET	**Accreditation Board for Engineering and Technology**
IIT	**Indian Institute of Technology**
FMS	**Faculty of Management Studies**
SwE	**Software Engineering**
SPSU	**Southern Polytechnic State University**
MOOC	**Massive Open Online Course**
NAAC	**National Assessment and Accreditation Council**
RQ	**Research Question**

WHO	**World Health Organization**
SR	**Systimatic Review**
LMS	**Learning Management Systems**
STEM	**Science, Technology, Engineering, and Mathematics**
S.D	**Standard Deviation**
CI	**Confidence Interval**
UNICEF	**United Nations International Children's Emergency Fund**
ERT	**Emergency Remote Teaching**
NVDA	**Non-Visual Desktop Access**
OCR	**Optical Character Recognition**
ICT	**Information and Communication Technology**
KBL	**Knowledge Based Learning**
KSD	**Knowledge, Skill, Disposition**
PBL	**Project Based Learning**

Chapter 1

Introduction

1.1 Overview of Basic Concepts

The main purpose of software engineering education and training is to train and educate students about industry oriented software engineering related courses such as: Object oriented software engineering, Software testing, Empirical software engineering and so on [1]. Software engineering is a systematic approach that is not referred to single culture as well as customer desired, the development team requires to consider who the client is and what the customer requires. In addition to this, while planning to teach principles of software engineering, variations amongst customers must be considered carefully. The globalization of thought directly connected with the improvement and enhancement of ideas, to the development of ideas and arbitration that can account accurately for multiculturalism. To get use of multiculturalism within software engineering field, the software development companies and students need to understand, when planning a product the designing team may keep the scope of the project in mind. Since most of the products effect worldwide and planning the product requires to take into account the desires, needs and cultural mores of the societies that will be impacted [2].This concept has three main goals: to argue for making Computer Science (CS) and Computer Information Systems (CIS) programs mandatory (rather than elective), to propose an approach that combines practical project-based learning with theoretical aspects of program development, and to outline a method for using semester projects to assess team skills [3].

1.2 Software Engineering Education

Software engineering education prepares students to design, build, and maintain high quality software systems, that are developed within given time and budget. It covers topics such as programming, algorithms, data structures, software design, database systems, software testing and debugging, and software project management. It also teaches critical thinking and problem-solving skills. Software testing is one of the most significant quality confirmation exercises. Be that as it may, it is viewed as a test while instructing in under graduation projects and post graduation projects. One of the inferred difficulties is the means by which to incorporate this theme in processing undergrad projects and in which level of detail. The business has perceived the importance of this more profound and progressively strong arrangement. In any case, in most cases, encouraging software testing is dispersed in controls and with various degrees of detail. Each showing strategy for software testing has its own points of interest and hindrances [4]. Software testing is a procedure to distinguish all bugs that exist in a software item. It is the way toward assessing every one of the segments of a framework checks that it fulfills determined prerequisites or to group contrasts among expected and genuine outcomes. Software testing is additionally performed to accomplishing quality by utilizing the software with relevant experiments. Testing can be incorporated at different focuses in the development procedure relying on the devices and approach utilized. Software Testing for the most part begins after necessities. At a unit level stage, it begins simultaneously with coding; though at coordination level, it begins when coding is finished. Testing procedure can be performed by two different ways that are manual and robotization [5]. Understanding this situation is significant for the recommendation of enhancements and innovations in the method for encouraging software testing. It is one of the most critical stage in Software Development Life Cycle (SDLC). Notwithstanding, Software testing isn't educated as a different course in a large portion of the college settings and there is a lack of compelling instructing and learning systems in this space. Seeing the necessities of the present period, the conventional talk based learning approach isn't adequate and there is a need of dynamic learning strategies in software testing training. Consolidating testing prior into the educational program of undergrad and postgraduate levels, has demonstrated to challenge. Since a few teachers driving this coordination procedure, have identified several general difficulties [6].

Competency-based education, often referred to as CBE, is an educational approach that centers on a learner's mastery of specific subject matter [7]. In CBE, learners advance by assessing their own competencies, demonstrating their proficiency in the necessary skills and knowledge to excel in the subject [8]. This educational model, alternatively called mastery-based, performance-based, or proficiency-based education, is gaining increasing popularity. Many school districts and universities have recently adopted competency-based curricula. Institutions of education embrace CBE for various reasons, including nurturing globally competitive students, designing schools that prioritize effective learning strategies, promoting equity, fostering continuous quality improvement, and enhancing teaching effectiveness [9].

Currently, engineering education faces numerous challenges that require upgrading. The student demographic in higher education institutions in the United States is becoming increasingly diverse, with non-traditional students accounting for over 90 percent of the student body [10]. In the past decade, there has been a shift toward competency-based teaching in STEM (science, technology, engineering, and math) education, particularly in engineering. CBE emphasizes outcome-based, student-centered learning, where students progress to more advanced work once they have mastered the fundamental content and skills [11]. A competent individual possesses the knowledge and abilities to perform assigned tasks at a specified level of proficiency.

1.3 Software Engineering Curriculum at DTU

Delhi Technological University (DTU) is a renowned engineering institution in India with a more than decade-long history in the region, offering numerous graduate degrees in all engineering disciplines, including doctoral, postgraduate, and undergraduate. Since industry demand for highly qualified and professional Software Engineering (SE) graduates is currently outpacing supply. With this in mind, educational institutions can be considered a primary source of professional software developers for the technology industry. On the other hand, the standard of graduates in SE is deemed inadequate and doubtful. Educational institutions must be more cognizant of business needs, develop world-class curricula, and implement viable teaching and learning practices. As a result, these challenges have been identified as vital to DTU's sustainability in order to be addressed more effectively. To that end, we conducted a survey of students in the DTU's software engineering department using a well-designed questionnaire and live interviews to ascertain the difficulties and strengths of the SE curriculum and course, as well as students' perspectives and accomplishments during their academic years. The aim of this paper is to find

shortcomings and strengths in the current approach of the SE course and to enhance the current program, most notably the teaching style used in the SE department. In a nutshell, our sample included 138 students out of 150 in the department. With effect from 2015-2016, DTU's software engineering curriculum is designed for B.Tech (Software Engineering) students. The curriculum covers a variety of courses over four academic years, including core subjects, departmental electives, and university electives. The curriculum spans two academic periods within a single year, referred to as Group A and Group B of freshman year. This should be noted; the time of the practical and theory exams is three hours, and the proportional weights assigned to each subject are as follows: CWS, PRS, MTE, ETE, and PRE. The following table summarizes the cumulative semester-by-semester course load for the entire academic years.
To maintain the commitment to excellence and maintain competitive edge in the rapidly-evolving software industry, there is need to enhance the curriculum in the department of Software Engineering. This includes updating and modifying the course such as: software testing, software engineering, software quality, and empirical software engineering courses on a regular basis to ensure they adhere to the highest international standards. In order to provide students with the most cutting-edge education possible, there is need to enrich the collaborations between industry and academia too.

1.4 Challenges for Industries and Academia

Collaboration between academia and industry holds significant importance in addressing challenges and fostering innovation, even within the realm of software testing. The industry faces constant market pressures, while academia seeks to conduct thorough research. Despite their distinct needs and objectives, both sides mutually benefit from each other's contributions. However, there are instances when their approaches may not align [12]. In all forms of engineering, the ultimate objective remains consistent: delivering artifacts, which can be products or commercial entities, that effectively cater to the requirements of end-users. Additionally, engineering operates at the intersection of various factors, including people, technology, domain expertise, and opportunities. Software engineering, in particular, grapples with its own unique set of challenges. Consequently, software, as a medium within engineering, occupies a space that bridges the fluidity of digital content, which it shares a representation with, and the characteristics of machinery, where software exhibits flexibility and repeatability in application [13].

1.4.1 Motivation

In order to learn and teach effectively the software engineering courses as well as make it more interesting and valuable so that to educate talented and fruitful software engineers whom they contribute longer and better in software companies. Hence, As per number of studies and surveys the interests of students are limited in the field of software engineering, for this, we are planning to apply different tools and techniques such as gamification of learning process and Project based learning and so on, Since, to increase students interest in this field.

Figure 1.1: Motivation

1.5 Objectives of the Thesis

1.5.1 Vision

The objective of the thesis is to assess and analyse the current state of software engineering education and training, identify the gaps and challenges, and propose effective approaches to enhance the quality and relevance of software engineering education and training.

1.5.2 Focus

My dissertation focuses on analysing and evaluating the current status of software engineering education and training. To achieve these objectives. This study explicitly addresses the following perspectives:

1. Analyzing and assessing the current state of software engineering education and training in Delhi Technological University (DTU).

2. Proposing a new methodology of teaching to enhance students' learning experience and improve their practical skills.

3. Developing a model to bridge the gap between academia and industry, enabling students to gain more hands-on experience and increase their employability.

4. Improving the quality of software engineering education and training at DTU through changes to the current curriculum content.

5. Aligning the curriculum content with industry needs to provide students with the necessary skills and knowledge to succeed in their careers.

6. The ultimate goal is to improve the quality of education at DTU, benefitting students, industry partners, and the university as a whole.

7. This research will contribute to the field of software engineering education and training, providing insights into effective teaching methodologies and industry-academia partnerships.

8. Future research could explore the impact of these proposed changes on student outcomes and the effectiveness of the model for industry-academia collaboration.

1.5.3 Goals

The primary goal of this thesis is to enhance teaching methodologies in engineering education. This study will focus on achieving the following objectives:

1. Analyze and assess Software Engineering undergraduate curriculum at Delhi Technological University.

2. To understand and evaluate the Software Engineering Curriculum at Delhi Technological University for post-graduate students.

3. To understand and promote academia-industry education collaboration.

4. To identify the learning objectives, curriculum instruction, and evaluate the quality of instruction.

1.5.4 Summary of Research Objectives

5. To Conduct a Systematic Literature Review of Software Testing Education Courses.
   - Software Engineering
   - Object Oriented Software Engineering
   - Software Testing
   - Empirical Software Engineering
6. To analyse and evaluate the results of the questionnaire:
   - For enhancing the teaching-learning process
   - For introducing new practises and teaching methods
   - For proposing new teaching methods for these courses
7. Revise existing curriculum
   - Acquired insights
   - International curriculum
8. To develop a new/revised teaching strategy for various Software Engineering courses

1.6 Structure of the Thesis

In this section, we delve into the organization of the thesis, providing an overview of each chapter's content and purpose. Chapter 1 introduces the thesis's foundational work and its underlying motivations. Chapter 2 conducts a systematic literature review focused on software testing and identifies research gaps in the field. In Chapter 3, we present a survey pertaining to software engineering education at DTU. Chapter 4 is dedicated to a systematic literature review that explores the global impact of COVID-19 on education. Chapter 5 addresses competency-based education and the revised teaching approach implemented across various courses within the Software Engineering curriculum. Chapter 6 explores the integration of project-based learning and gamification. In Chapter 7, we propose a framework designed to foster collaboration in education between industry and academia. Finally, Chapter 8 concludes the thesis and outlines potential avenues for future research and work in this field.

Chapter 1: This chapter states the basic concepts of software engineering education and training. The motivation behind various approaches of software engineering education and training is explained.

Chapter 2: This chapter provides the detailed systematic literature review on software testing in under graduate and post graduate levels

Chapter 3: This chapter of the dissertation reviews the software engineering education in DTU.

Chapter 4: This chapter provides detailed systematic review on the global impact of COVID-19 on education and its strengths and negative impacts.

Chapter 5: This chapter discusses in detail the competency based education and revising new approach for software engineering courses.

Chapter 6: This chapter provides details on coupling of project based learning and gamification in software engineering education and training.

Chapter 7: This chapter proposes an effective model to enrich the partnerships between industry and academia. This chapter will pinpoint the main role of alumni in enriching the partnership between the two organization.

Chapter 8 This chapter summarizes the conclusion of the work performed and lists few directions for future work.

Chapter 2

Systematic Literature Review on Software Testing and Research Gaps

2.1 Introduction

In the current fast-moving technological age, the market for software systems is of extreme importance. How to educate students in software testing is a question for education experts across the globe [14] [15]. The word software testing method is not used to state that there are no errors in the software. A thorough and prolonged testing process also finds all the bugs in the system. Also, testing itself is not an act but a mechanism used for maintaining a low-risk software base without much testing effort [16] [17]. At present, software testing has become the norm for identifying software glitches [18] . The lack of software-testing industry experts is the main barrier to the industry's progress. Often, it can cause project delays and force developers to get overwhelmed [19]. Furthermore, there is a lack of software testing professionals, although reports and polls suggest that this is already a pressing issue for the software industry [20].

Many software engineering teachers also claim that software testing should be put at the beginning stage of the instructional plan to profit understudies during their software designing activities in later courses [21] . The software testing course is gruelling and monotonous for undergraduate students and unrewarding for postgraduate students. This vital aspect of software engineering is frequently overlooked or disregarded. There is a need to train software testing skills to software engineering students since program verification courses are critical and leading methods for producing software with outstanding quality and improved reliability [22]. We report that almost half (50 percent) of the annual cost for software development is spent on research. Testing is so necessary that it continues to be the most common tool used to guarantee quality applications [23]. In the education market, individual universities lack the opportunity to match theory with practice, contributing to instability. On the one hand, there are problem-based learning methods and other technologically-advanced instructional tactics introduced by [24] [25]. This motivates the understudies to learn individually. One way of promoting the target is educating understudies to feel the positive outcomes of different testing methods and the negative aspects [26]. Thus, ensuring formal testing education is of paramount importance. Software testing impacts how students acquire programming skills [27]. A. Bertolino in [28] claimed, ”Education must continue to keep the pace with the advances in analyzing technology”. There are many automated testing and adaptive design approaches, such as cluster testing, random testing, and similarity-based testing [14]. Despite the various goals they hope to achieve, the suggested alternate measuring methods have many of the same features, such as a good number of experiments. In evidence, a source of evidence provides no new information in software testing. The paper has undergone research using many conventional techniques, including domain testing, coverage testing, and so forth. Testing with various feasible testing methods relies on retaining varied programming requirements [29].

Of course, in many universities, testing is not a core subject but is optional for students [30] . Several colleges instruct students on the essential components of testing. We collaborated closely with industry and academics and have conducted several app testing competitions and industry [31] [32]. Garousi claimed in [33] that Software testing instruction is mostly offered in two settings: (1) the scholarly world (i.e., college courses) and (2) industry. Additionally, Sowe and Kennedy claimed in [34] [35] The software testing course instructors are always trying to find out the relevant materials and pedagogies that will provide long-lasting learning experiences, proposed F/OSS (Free Open-Source Software’s) the framework to improve the condition of students learning outcomes. Some researchers in this field suffering from a lack of a high-quality tool to support a proposed testing approach [36]. A survey performed by a global tech provider of large-scale software systems showed that 75 per cent of them involve failures that are not utilized and do not satisfy the customers’ specifications. High failure rate, product consistency remains a significant challenge in software research and development [37]. We performed this systematic literature review on the latest studies on software testing education to develop the primary studies and answer the addressed research questions. 1) Which exercises and tools are being used for software testing at U.G. and P.G. level? 2) What are the problems faced by teachers and students in the software testing course? 3) What kind of skill sets are required for students to learn software testing? 4) What are the evaluation and remarks of the software testing course? 5) What are the learning outcomes of teaching software testing? We also conclude that our study highlights the value of studying software testing and boosts students ' interest in this main course in software engineering.

2.2 Research Methodology

We conducted a systematic literature review to collect and synthesize the data surrounding teaching program testing at the undergraduate and postgraduate levels. The accepted systematic review methodology in this topic follows the guidelines [38] and [39]. Considering the objective of our research, we followed the Kitchenham and Charters guidelines. This guideline is structured into three key categories: 1) Planning the review, 2) Executing the review, and 3) Documenting the review process. As depicted in Figure 2.1, this framework outlines the systematic literature review process. In the initial planning phase, we crafted a review protocol that encompassed the following steps: formulating research inquiries, devising a search strategy, establishing selection criteria, outlining the quality assessment procedure, delineating the data extraction process, and defining the data analysis methodology, as detailed by [40].

Subsequently, after finalizing the review protocol, several steps were undertaken within the review. The first step involved the formulation of research questions, which encapsulated the fundamental issues to be addressed in the systematic literature review. Following this, a search strategy was meticulously devised, encompassing search criteria, source selection, and primary study retrieval. The third step involved identifying pertinent studies related to the research questions, concurrently establishing inclusion and exclusion criteria for each primary study. The quality assessment process played a pivotal role, entailing the formulation of quality assessment questions to evaluate the significance and rigor of the identified studies. Following the quality assessment questions, the data extraction process was designed to answer our research questions. At the same time, the subsequent steps concluded with the methods for data synthesis. In the upcoming sub-sections, the following research questions and measures while conducting a systematic literature review are described.

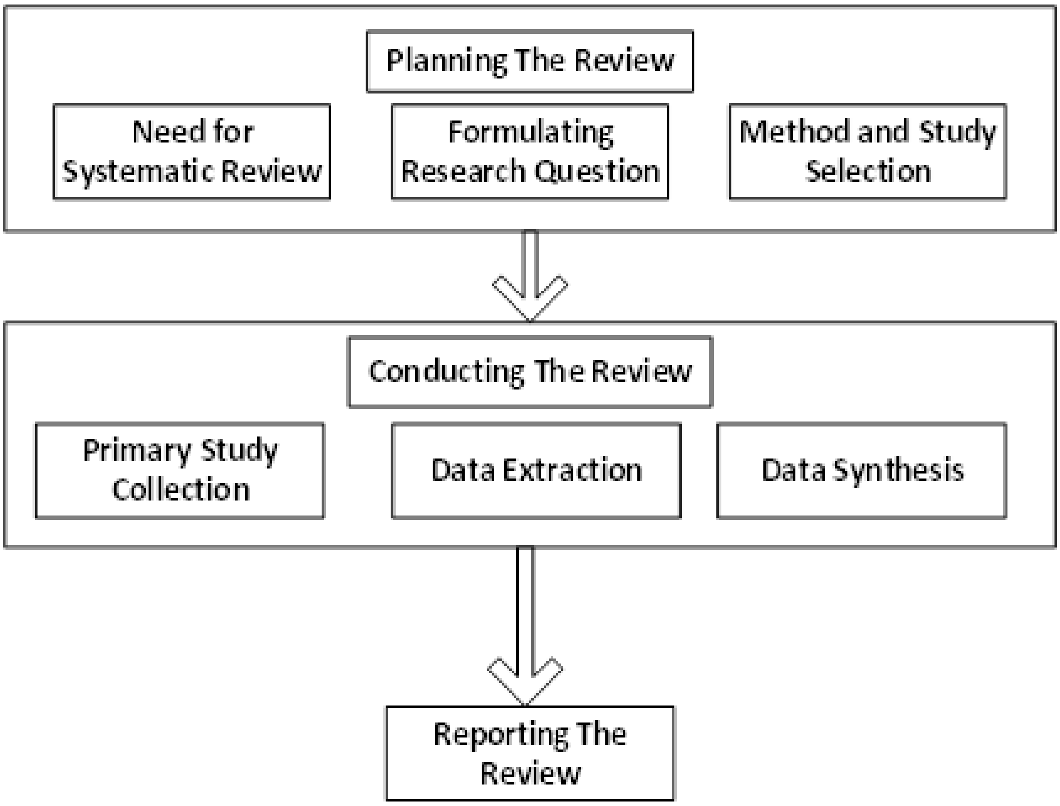

Figure 2.1: Systematic Literature Review Process

2.3 Planning the Review

Considering the guidelines listed in [38], we go through the systematic review planning by presenting research aims and research questions. By following this procedure, we set up the search strategy and parameters.

2.4 Research Questions

This study identifies software testing tools, techniques, procedures, outcomes, and approaches for the undergraduate and postgraduate stages. Table 2.1 summarizes the six research questions and their motivations.

2.5 Search Process

The method used in this systematic literature review has been chosen as the basis for this survey [38]. The search action started with manual searching on the journals related to software testing

Table 2.1: The list of research questions and their motivations

R.Q. #	Research Questions	Motivations
RQ1	Which exercises and tools are being used for teaching software testing course at U.G. and P.G. level?	Identifies and summarizes the exercises and tools used at U.G. and P.G. level
RQ2	What are the problems faced by teachers and students in the software testing course?	Summarizes the problems where teachers and students encountered in S.T. course.
RQ3	What kind of skill sets are required for students to learn software testing?	It summarizes the skill sets for students to learn and implement the testing process easily
RQ4	What are the evaluation and remarks of the software testing course?	It identifies the needs for course curriculum to have appropriate evaluation and feedback
RQ5	What are the learning outcomes of teaching software testing?	Identifies learning outcomes that are appropriately understood and revealed
RQ6	How do different types of exercise affect cardiovascular health?	To compare the effects of various types of physical activity on heart health

and education, such as ACM, IEEE, Elsevier, and other computer-related journals, for review and analysis. This was supplemented using an automatic search of scientific databases. Keywords like software training, testing, undergraduate and postgraduate, education, faculty were used to extract the relevant papers. Hence, journals used for the automatic search were IEEE Xplore Digital Library, Springer Link, ACM Digital Library, and ASEE. Furthermore, the programmed quest string was utilized for approving the diaries of IEEE and ACM. The acceptance criteria were used for selecting the primary study. Thus, table 2.2 summarizes the number of studies on each round of evaluation.

Table 2.2: Evaluation round of primary studies.

Database	Retrieved	Included	Excluded	Included	Excluded
IEEE Xplore	130	50	80	31	19
ACM Digital Library	70	30	40	22	8
Springer Link	20	10	10	1	9
ASEE	5	4	1	3	1
Elsevier	20	5	15	2	3
Others	5	4	2	4	0
Total	250	103	148	63	40

We used two types of search strings at the primary level, and then we narrowed down the search, and we formed the search terms by combining the Boolean expressions ’OR’ and combining the actual search term using ’AND’. And search terms for the identification of relevant studies performed are given below. Testing AND (education OR training OR software OR undergraduate OR graduate) AND Software (testing OR education OR training). On one side, we used OR operator to combine software testing education and software, on the other side, we used AND to join software testing education and training.

2.6 Inclusion and Exclusion Criteria

We reviewed the studies selected based on inclusive and exclusive requirements to ensure their inclusion in the study. Because of this, we have multiple results from research that were filtered by evaluating their abstracts, keywords, introduction, and conclusion.

2.6.1 Inclusion Criteria

Several inclusion criteria were considered to help us gather the relevant studies for this systematic review. This is a paragraph with nested numbering:

1 (a) Review papers included in this work are publications in conferences, journals, or as books

(b) Papers selected for this review were from 1996 to 2019

(c) Articles included in this review were relevant to teaching and learning testing courses at the undergraduate and postgraduate levels.

(d) The language of articles is English

(e) Articles included were peer-reviewed

2 2.6.2 Exclusion Criteria

3 We excluded those studies that did not meet our requirements and not strengthened our search
4 process while screening each article. Papers excluded if:

(a) Journals did not address research questions

(b) The journals did not have precise details

(c) Journals that were published do not have quality

(d) Journals had data repetition

(e) Articles did not address software testing education

There were many papers retrieved in searching. First using keywords, title, and abstract. Hence, the journals were shortlisted. Then, they analyzed to avoid duplicity in work. The inclusion and exclusion of the research papers were done carefully.

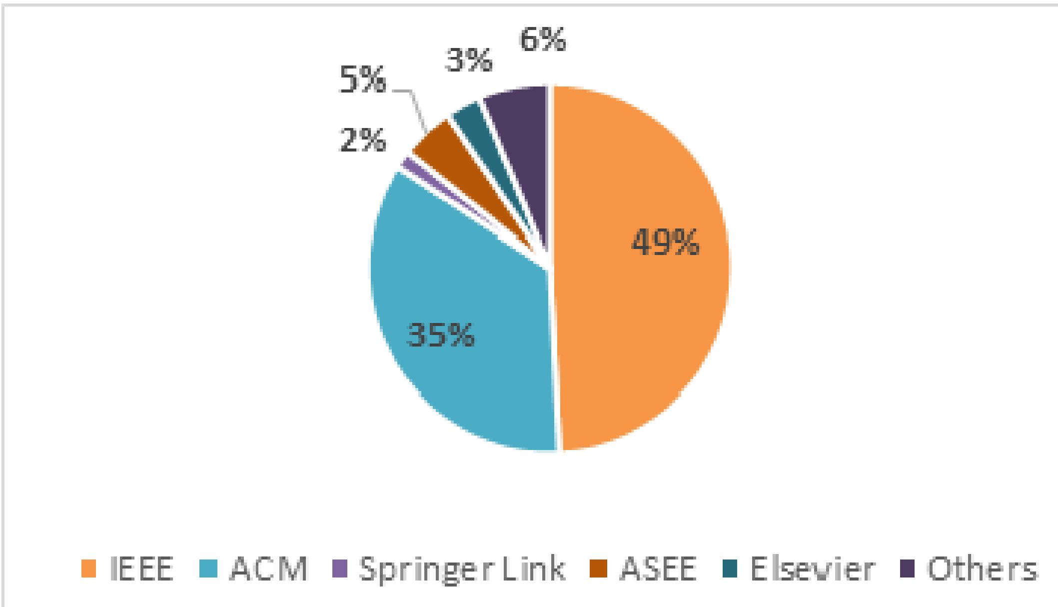

Figure 2.2: Primary Studies

Figure 2.2 illustrates the total number of primary studies with the different classification of journals such as IEEE, ACM, ASEE, etc. The highest number of papers are published in IEEE and ACM, where 31 articles are published in IEEE and 22 are published in ACM. The remaining numbers are issued in ASEE, Springer Link, and Elsevier accordingly.

2.7 Quality Assessment Criteria

For the quality assessment, we developed the questionnaire and the scores were given after the identification of the eligible documents, 1 for Yes, and 0.5 for partially answering the Q.A. Criteria and 0 for No, which did not answer the issues of quality assessment. Hence, the nature of each chosen papers selected against criteria that are derived from Kitchenham and Charters' rules [38]. The questions of the quality assessments are shown in Table 2.3 below.

Similarly, the below figure shows the outcome of our quality assessment approach:

Table 2.3: The quality assessment and evaluation questions

Q #	Quality Assessment Questions	Yes	Partially	No
Q1	Are the goals of the research stated clearly?			
Q2	Does the paper provide answers to the exploration questions?			
Q3	Are the chosen papers expressing different strategies?			
Q4	Is the information accumulation method characterized?			
Q5	Do the papers reference at least ten articles?			
Q6	Are the procedures well-defined?			
Q7	Are the outcomes and findings clearly stated?			
Q8	Are the limitations of the investigation indicated?			
Q10	Does the investigation contribute to the existing literature?			
Q12	Are there guidelines for future research scope?			

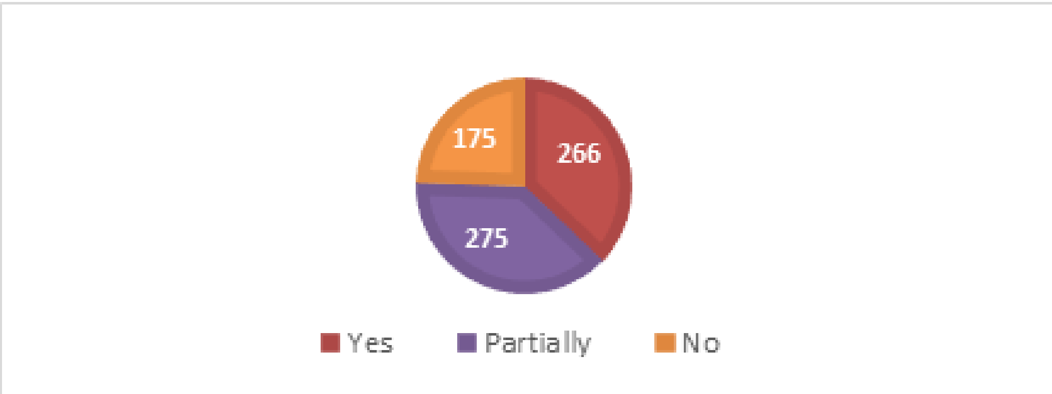

Figure 2.3: Quality Assessment Result

Out of various journals reviewed, 266 were directly answering the quality assessment questions, 275 were partially meeting the quality assessment criteria, and 175 were not addressing the quality assessment questions.

2.8 Data Extraction

Data extraction has been done from various kinds of literature and recordings in a spreadsheet and covering the following rows:

(a) Method of Searching (Manual or Automatic)

(b) Reference Details (Journal Name, Author and Title, Keywords, Name of Publication, Venue, and Type)

(c) Objective

(d) Research Methodology

(e) Conclusive Summary

(f) Research Questions and their implied answers

The reviewer evaluated the data based on the parameters and recorded it in an excel sheet. Two reviewers did the analysis, and they sorted out some misunderstandings with each other. The research questions were answered based on an inductive approach, beginning from the basics. Keywords and phrases were eliminated to prevent over-usage. The grouping was conducted from related questions designed to address the research question. Specifically providing an introduction and discussion of findings. Conceptual reasoning was a vital process in the literature selection. The data were confirmed for consistency by a peer review.

Year-wise publication of primary studies:

Figure 2.4: Publication Year

Based on the figure 2.4 mentioned above, software testing has been researched from the 90s onwards. There were at least four papers published in the year 2003. The number of publications concerning data processing and information analytics has been consistently increasing since 2011 up to 2017. Many such publications addressing the research questions were seen from 2003 to 2019. Academically focused on software testing is one of the main subjects in the second decade of this century.

Table 2.4: Top Publication Summary

Table 2.4: Journal Statistics

Journal Names	Type	Number	Percentage
IEEE/ACM/Springer/Elsevier/JCSC	Journal	6	9.5
ACM Conference on Computer Science and Education	Conference	19	30.2
IEEE Conference on Software education and training	Conference	30	47.6
Others	Popular	8	12.7

2.8.1 Publication Source

Table 2.4 specifies the top publications published in leading journals and conferences of IEEE, ACM, and other prominent journals along with their journal type, number of papers, and their percentages for each publication in related journals. Moreover, most publications are in IEEE Transaction of Software Engineering, ACM Conference on Computer Science and Education and IEEE Conference on Software Education and Training, and so on. More than 9 per cent of the findings were conducted in journals, and about 91 per cent were at conferences. Hence, the number of papers published in journals is less than the papers presented in conferences. Therefore, it requires practitioners to work and publish their findings in this regard in journals. Similarly, the following figure summarized all our top publications along with their percentages.

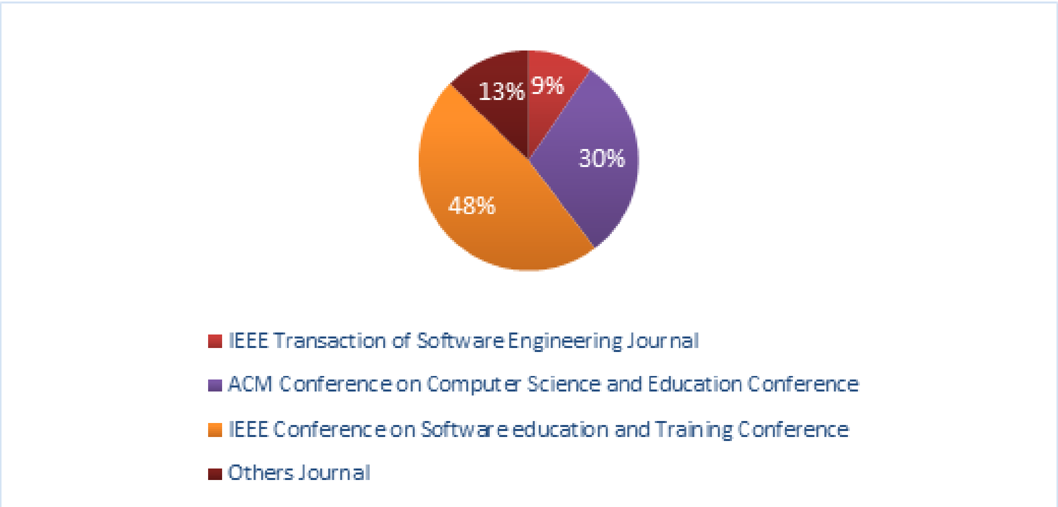

Figure 2.5: Top Publication Summary

Table 2.5 Selected Primary Study gives a novel identifier (R) to each selected primary study along with references; these identifiers will be utilized in the rest of the resulting segments to allude to their comparing chosen related studies.

Table 2.5: Selected Primary Studies

Study No	Paper	Ref No	Study No	Paper	Ref No
R1	Mao (2008)	[1]	R33	Clarke(2014)	[33]
R2	Paschoal(2018)	[2]	R34	Edwards(2003)	[34]
R3	Paschoal (2019)	[3]	R35	Elbaum(2007)	[35]
R4	Silvis-Cividjian (2018)	[4]	R36	Aniche(2019)	[36]
R5	Xie (2011)	[5]	R37	Hynninen(2018)	[37]
R6	Hang (2011)	[6]	R38	Jones(2001)	[38]
R7	Rajlich (2013)	[7]	R39	Krutz(2014)	[39]
R8	Black (2007)	[8]	R40	Lazzarini(2015)	[40]
R9	Garousi (2016)	[9]	R41	Lopez(2015)	[41]
R10	Harrison (2010)	[10]	R42	Lopez(2014)	[42]
R11	Henrique(2015)	[11]	R43	Rebecca(2017)	[43]
R12	Michaeli(2017)	[12]	R44	Shepard(2001)	[44]
R13	Oliveira (2015).	[13]	R45	Garousi(2011)	[45]
R14	Repasi (2009)	[14]	R46	Cheiran(2017)	[46]
R15	Barbosa (2017)	[15]	R47	Padmanabhan(2007)	[47]
R16	Wang (2011)	[16]	R48	Saurabh(2018)	[48]
R17	Timoney (2008)	[17]	R49	Smith(2012)	[49]
R18	Garousi(2010)	[18]	R50	Talon(2009)	[50]
R19	Joshi(2016)	[19]	R51	Yinnan(2011)	[51]
R20	Scatalon(2019)	[20]	R52	Martinez(2018)	[52]
R21	Adams(2000)	[21]	R53	Carrington(1998)	[53]
R22	Agarwal(2006)	[22]	R54	Chen(2014)	[54]
R23	Allison(2015)	[23]	R55	Chen(2011)	[56]
R24	Chan(2005)	[24]	R56	Dias(2017)	[58]
R25	Clegg(2017)	[25]	R57	Bhattacherjee(2009)	[59]
R26	Cowling(2012)	[26]	R58	Eric(2018)	[60]
R27	Earle(2014)	[27]	R59	Masuda(2017)	[61]
R28	Edwards(2003)	[28]	R60	Sowe(2006)	[62]
R29	Frezza(2002)	[29]	R61	Kennedy(1996)	[63]
R30	Jones(2011)	[30]	R62	Ostrand(2010)	[64]
R31	Towey(2015)	[31]	R63	Sarkar(2013)	[65]
R32	Bertolino(2011)	[32]	R64	Güldali(2010)	[66]

This table gives a novel identifier (R) to each selected primary study along with references; these identifiers will be utilized in the rest of the resulting segments to allude to their comparing chosen related studies.

2.8.2 Publication Source

Table 4 specifies the top publications published in leading journals and conferences of IEEE, ACM, and other prominent journals along with their journal type, number of papers, and their percentages for each publication in related journals. Moreover, most publications are in IEEE Transaction of Software Engineering, ACM Conference on Computer Science and Education and IEEE Conference on Software Education and Training, and so on. More than 9 per cent of the findings were conducted in journals, and about 91 per cent were at conferences. Hence, the number of papers published in journals is less than the papers presented in conferences. Therefore, it requires practitioners to work and publish their findings in this regard in journals. Similarly, the following figure summarized all our top publications along with their percentages.

2.8.3 Limitations to Study

The review done here may have a limitation, which is typical for the systematic review. This includes length and depth of search and unreasonable search. Bias can be in selection, implementing inclusion and exclusion criteria, data extraction, and quality assessment. However, efforts are taken by combining the search through the manual and automatic method. Hence, we pinpoint the following threats to this review.

(a) Lack of literature review in teaching software testing course at undergraduate and postgraduate level by practitioners in the field

(b) Limitation in answering review questions due to fewer publications in these areas

(c) To accurately address each study question, a survey would be expected primarily of professionals and academics.

(d) Limitation anticipated in answering review questions has been done subjectively, and no specific metrics and researches are available to make the research objective.

However, we analyzed and reviewed the latest articles for teaching software testing courses at undergraduate and postgraduate levels. Therefore, this review's findings require further expansion by researchers and practitioners to identify the most used practices for teaching the mentioned course.

2.9 Results

The research questions are reviewed and discussed below. Table 2.6 describes the studies used to answer a particular research question.

Table 2.6: Research questions with selected references.

Research Questions	Selected References
Which exercises and tools are being used for teaching software testing courses at U.G. and P.G. level?	R53, R27, R60, R58, R29, R7, R32, R24, R52, R1, R56, R31, R55, R10, R25, R28, R40, R33, R42, R15, R11, R18, R64, R13, R17, R51, R63, R46
What are the problems faced by teachers and students in software testing courses?	R31, R55, R10, R25, R32, R28, R56, R36, R61, R48, R57, R9, R22, R53, R49, R52, R1
What kind of skill sets are required for students to learn software testing?	R27, R10, R42, R17, R47, R32, R31, R56, R30, R12, R43, R19, R54, R51, R24, R26
What are the evaluation and remarks of the software testing course?	R52, R27, R37, R39, R4, R59, R20, R15, R25

RQ1) Which exercises and tools are being used for teaching software testing courses at U.G. and P.G. level? The research question is trying to figure out the exercises and tools used in the university to teach the software testing courses. The number of practices, resources, and tools is being arranged for the same in table 2.7. The total number of studies and the figures for the types of teaching approaches used in the study of software testing courses.

Table 2.7: A table with all cells containing the number 1

Exercises	Number of Studies	Percentages
Just in time testing (JiTT)	5	23.5
QuviQ	7	17.2
Free/Open Source Software (F/OSS)	9	34.1
Metamorphic Testing (MT)	4	8.3
Case-Based Learning (CBL)	5	12.5
Test Driven Development (TDD)	21	36.5
Web-based Center for automated testing (Web-CAT)	12	25.7
Test-Driven Learning (TDL)	10	18.6
Web-Based Repository of Software Testing Tutorials (WReSTT)	15	21.8
Conceive, Design, Implement and Operate (CDIO)	17	19.9
Question Driven Teaching Method (QDTM)	12	18.3

JiTT is a methodology that bridges in-class and out of class components by tertiary online activities. The idea of the JiTT was as follows: the in-class preparation section consisted of a reading test, which required students to read a chapter of the textbook and then respond to a web-based test accessible on our virtual platform. Tests were offered on the day before the lesson, so the teacher had enough time to change the next session, respectively. Productive learning is part of a more holistic approach to instruction and learning activities. JiTT is part of a more comprehensive teaching, and learning approach called active learning (Martinez, 2018). QuviQ is a research platform used to evaluate radio base stations, data networks, and other telecommunications applications by Ericsson or Autosar software. It is a technique that used in the chemical industry to improve the sensitivity and efficiency of analytical samples. It was also included in a two-year, component-based software engineering course taught at UPM as part of an international master's program. Students were taught how to code-review Java in QuviQ. The library is a state machine based API that can verify your API with no side effects [30]. F/OSS is an open-source software creation strategy that consists of 3 stages: a) Students will partake in actual computer applications, b) F / OSS as a learning tool, and c) a practical approach that encourages students to develop prototypes using code written by others [34]. Metamorphic testing is simple, is a fantastic advantage to identifying defects, and has lately been gaining a lot of coverage. Many of the approaches and strategies that have been developed to address the correct test set may not apply to testing conditions that include an oracle challenge, which may significantly affect the ability of the tester to conduct sufficient testing. For the first time, metamorphic experimentation has been proposed to exacerbate the oracle dilemma and seems to be increasing in importance [41]. We are investigating the use of Case-Based Learning (CBL) for an experimental first time at the university level to teach software testing concepts. This is a case-based research approach. CBL sessions must be regularly scheduled, as this requires a lot of effort and energy. The cases shall obey the framework and arrangement of the layout of this course [42]. Test-Driven Learning (TDL) improved students' programming abilities, ensuring quality designs with low defect density [27]. As a whole, we developed a general-purpose automated grading tool, integrated it into Web-CAT, the Web-based Hub, for automated testing, and made it available for all students to use. To demonstrate that the tests accurately and adequately assess proficiency in a specific skill, the Web-CAT Grader evaluates three dimensions of the test. 1) Running student tests based upon correct models and providing feedback on incorrect tests. 2) Informing the learner which areas of the code have been neglected shall be communicated. 3) Web-Based CAT software is a web-based software created using Apple WebObjects [43]. Apparently, in most undergraduate courses, students receive no guidance about how to test their coding and lack the technical skills required to do so. A new strategy is needed to enhance student success in mathematics by bridging the distance between tutors and students. The central premise of this approach is that learners practice test-first coding in all their core courses. Additionally, Research-Based Production is an optimal teaching approach. It is more effective to learn through immersive instruction than traditional research methods [43]. WReSTT is the statement material that protects a valuable learning site that students can check methods and tools for their learning. Ultimately, the research results affirm the students' understandings regarding WReSTT as individuals allude to the efficacy of WReSTT guidance and engaging teaching practices. The article includes opportunities that facilitate collective learning, such as 1) access to the classroom platform where learners can compare the learning tools created by those participants, 2) the opportunity to accumulate equity based on success in educational activities. For e.g., a group of students earn points for completing online quizzes. 3) Social networking features a) interaction sources showing other users conducting various tasks in real-time, e.g., reading a lesson or solving a quiz, b) real-time updates to their personal information showing the points they earned on WReSTT after accomplishing a task. WReSTT is a peer-tutoring program that offers information about testing and testing techniques. Also, the paper contains instructions on the different testing techniques that were used during the class project. Examples of various testing techniques are often given for students to help illustrate what they learn in the classroom. On the other hand, teachers use WReSTT to generate results showing course access and their progress in quizzes involving a range of topics (Clarke et al., 2014). CDIO model created to be part of an education course on software testing. It is a modern way of teaching that combines classroom teaching with versatile and project-based learning. The Center for Growth Education has advocated the idea of doing-learning and project-oriented teaching [44]. The question-driven teaching method (QDTM) is useful and helpful in real-time training since it is recommended and used. The fundamental principle in a question-driven approach to instructional design is to provide students with a primary task. There would be several unresolved concerns and discrepancies throughout the phase. They will understand the technical concepts inherent in the analysis by practising their inquiries. This method is useful to allow students to understand these theories and to adapt them to issues in experience [15].

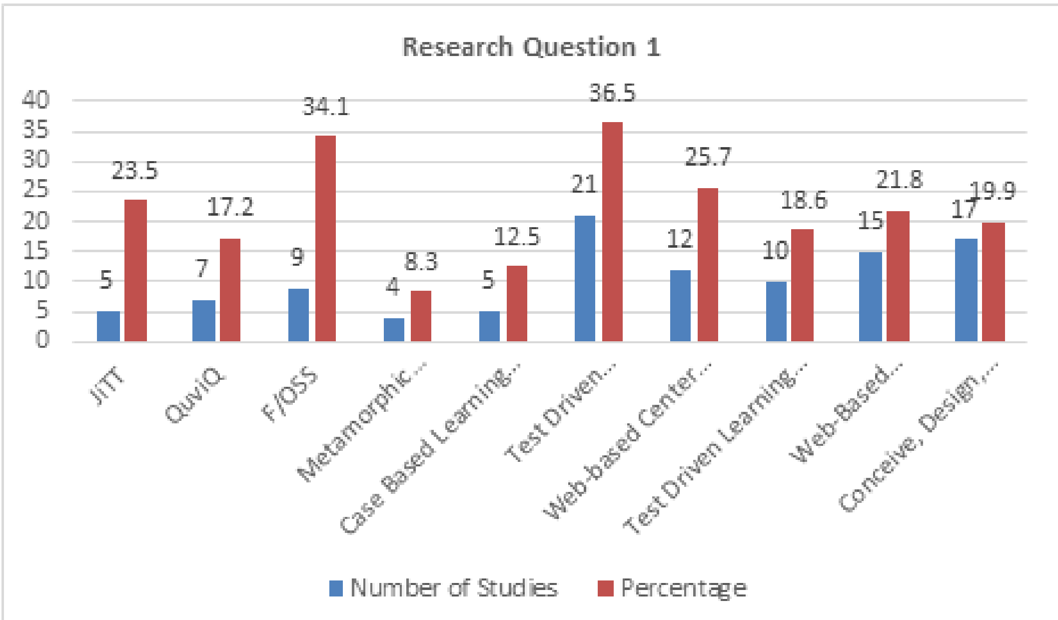

Figure 2.6: Exercises & Tools

This chart shows many software testing exercises and methods that are mainly used in teaching software testing courses to undergraduate and graduate students in various universities; among these exercises and tools, the TDD and F/OSS approach is more familiar with the percentage of 34.1. The lower count is the IBT method; this method used only roughly 8.3

RQ2) What are the problems faced by teachers and students in the software testing course? There are issues that teachers and students encounter with software training. The results presented in table 2.8. All of the difficulties teachers and students face in a software testing course are enumerated in Table 2.8. And due to this fact, software testing practitioners find it to be a heavy-handed topic that lacks creativity.

The related references for RQ2 can be found in table 2.5.

Problems	Number of Studies	Percentages
Teaching Software Testing (TST)	15	31.5
Education Modules and Tools (EMT)	11	21
Adaptive and Flexible Method (A&F)	9	12.6
Innovation in Testing Modules (ITM)	16	24.8

Web-based learning in software testing is still in the stages of development. Many web-based apps have poorly functioned to inspire active learning in understudies. They are viewed as less goal effective due to a lack of alignment with job success [45] [19]. Software testing requires strong technological, learning, and creativity skills [46]. Regretfully, software development is considered dull and uninspired for most undergraduates and postgraduates students [47] [48] [43]. Education tool modules influence learning outcomes and improve the motivation to learn. The lack of necessary academic resources can be a significant problem for students [44]. The course taught in the classroom is not suitable to be taken by students in the business industry. To mitigate the risk factors mentioned above, software testing training and education should be strengthened [18]. The topic of software testing has been ignored in the curriculum, and there is a significant and increasing gap in the knowledge of software engineering graduates [47] [49]. Lecturers understand that the lesson plan and activities require continuous revision when the topic is given so that such a course does not fall into stagnation. An adaptable learning method makes a change in the path to student achievement, using the required increase to meet the learner's specific needs [47] [50] To teach software testing does not require theory much. There are certain types of testing approaches needed and should be conducted carefully. The shortage of software testing experts is one of the most significant hindrances to software industries' development. A reduction in the number of projects will cause a slowdown in the industry [19]. Teaching software testing is difficult for a group of students with little or no interest in a career as a tester [51]. Therefore, mastering the principles and strategies of different testing methods within a short timeframe each semester is another challenge. Moreover, it requires ample time and not be summarized in one semester. On one side, in many colleges, testing is not taught as a fundamental and core subject but rather as a fringe practice for programming [30]. On the other hand, the number of colleges teaches the fundamental concepts of testing to understudies [34].

Figure 2.7: Number and percentages of teachers and students' problems. TST has the highest rates, mostly causing software testing courses to be considered uninteresting, whereas A&F has the lower percentage, 12.6. Regarding the number of studies, the highest count used in this study

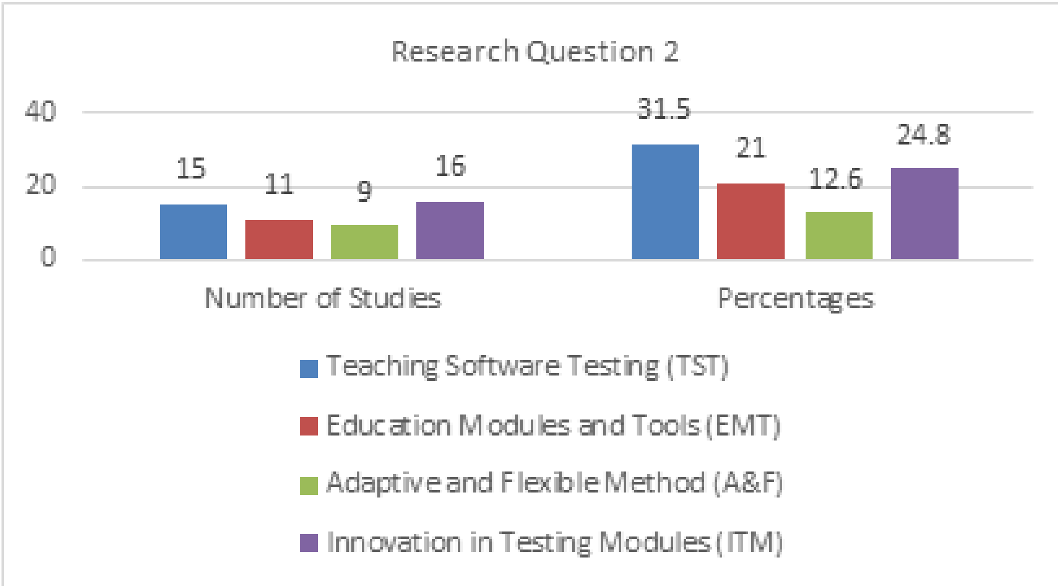

Figure 2.7: Exercises & Tools

is 16 for the ITM Method, and the lower count is A&F.

RQ3) What kind of skill sets are required for students to learn software testing? Programming and software testing require sufficient technological expertise such that students can interpret software testing. Here are several fields of skillsets highlighted in the study:

- Good Programmers and a high level of motivation
- Skills to develop and use Test Driven Development and the ability to use educational games
- Managing and executing software testing process
- Enriched knowledge and learning experience to handle software testing tools and techniques
- Skill to improve in domain testing strategy
- The habit of unit testing the software
- Practical skills and theoretical knowledge
- Adequacy and evaluated strategy
- Extraordinary skills in learning software language
- Sufficiency in skill sets and learning habits

- Self-interest towards software testing
- Unorganized skill development

The corresponding references for RQ3 can be accessed through Table 2.8.

Table 2.8: Answer to research question three

Skillsets	Number of Studies	Percentages
Self Interest Towards Software Testing (TTS)	18	14.9
Adequacy And Evaluated Strategy (AES)	22	28.6
Practical skills and theoretical knowledge (PSTK)	18	18.6
Managing and executing software testing (MEST)	11	11.8
Test-Driven Development (TDD)	16	17.4

Interest in the course is a critical positive point to learn the course systematically [52]. Thus, this triggered enriching skills to develop and use Test Driven Development and use educational games.

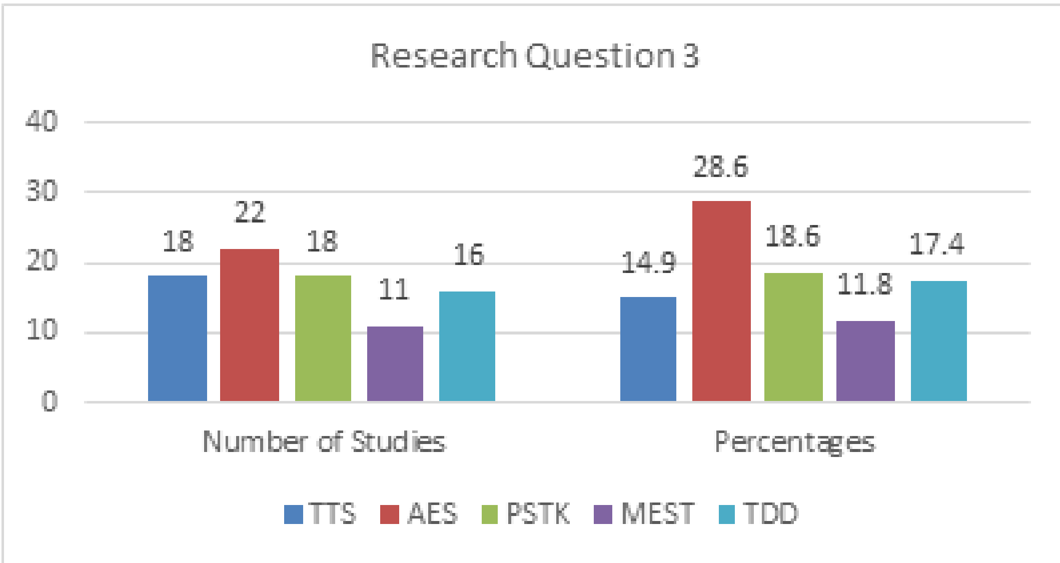

Figure 2.8: Skill Sets

Figure 2.8: Describes the number of studies in blue legend and percentages with the red line; as per the mentioned figure, AES has the highest number of studies and ratios, whereas MEST has the lowest number of studies and percentages accordingly.

RQ4) What are the evaluation and remarks of the software testing course? In a learning curriculum, evaluation and feedback are essential. Hence, this question has been taken as a research question wherein software testing remarks are reviewed and listed. The references for RQ4 can be found in Table 2.9.

Having the right teaching outcome in any course assessment process benefits us further in this regard because any course we teach needs a structured evaluation process. In Table 2.9, various methods are used for the proper evaluation of the software testing course with the number of studies and percentages, respectively.

Table 2.9: Evaluation and Remarks of the Software Testing Course

Evaluation & Remarks	Number of Studies	Percentages
Just in Time Testing (JiTT)	17	19.4
Test-Driven Development (TDD)	21	20.6
MAETIC	15	16.6

The following methods and techniques are used to evaluate and assess students in the learning process.

a. MAETIC is a pedagogical approach to come out with an integrated work environment with a collaborative project management system and project environment

b. Collaboration between industry and academia to enable improved software testing skills

c. JiTT right teaching strategy

d. Property-based testing helps in stimulating intellectual proving it to be a promising career option

e. Aligning software testing with real-time industry needs

f. Evaluation by a tightly controlled evaluation board required for fulfilling the commitment of course curriculum

g. Software testing should unique and engaging test experience

h. TDD proved to be engaging students to develop all practical skills

i. Introducing software testing as the introductory course

The above figure 2.8 presents several along with their number of studies and percentages. As

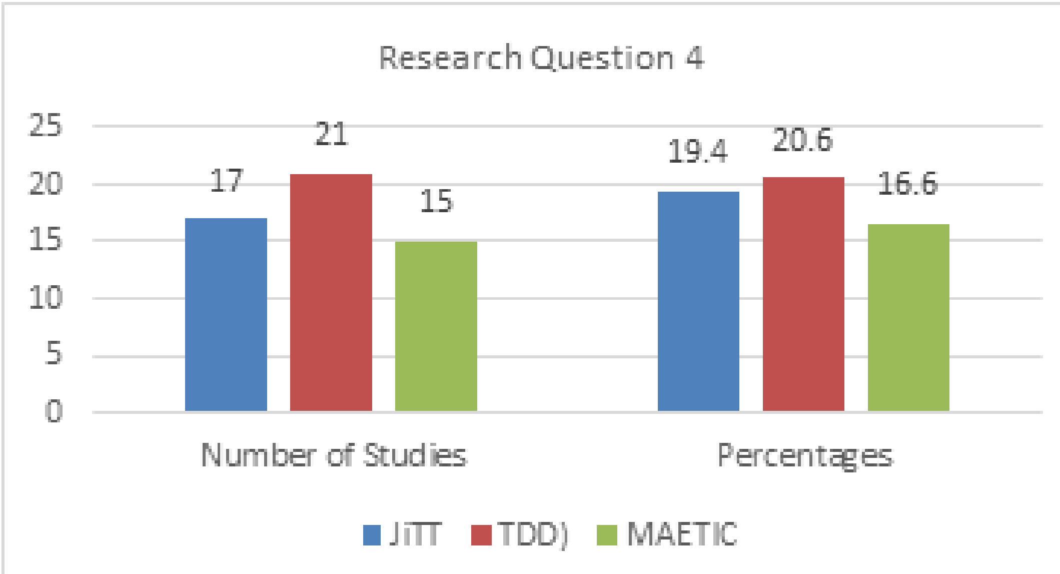

Figure 2.9: Evaluations

per the figure, the highest number of studies are on TDD and the lowest number of studies.

RQ5) What are the learning outcomes of teaching software testing? No course can be satisfactorily completed before learning results are determined. This is the first step toward earning course credit.

a) A better understanding of tools and techniques relating to real-world application.

b) Acquire better testing skills and, in the long term, will become better software engineers.

c) The opportunity of working with real-world industrial software systems .

d) Adaptability to software testing environment and real-time applications .

e) Game-based software testing has a positive impact .

The corresponding references for RQ5 can be accessed through table 2.5. The below table lists some of the software testing course's learning outcomes, where these learning outcomes are appropriately understood. Hence, the highest number of studies is a better understanding of tools and techniques with the 18.4 percentages. The lowest learning outcomes as per the table are Acquire Better Testing skills with the number of studies as 11 and per centages 14.6.

Testing is an exercise that aims to generate quality software products. This is an enormous challenge for this profession because of the scarcity of experience. The most frequent factor is the ineffective teaching of software testing. To stop breakdowns during software testing, students

Table 2.10: A 3-column and 4-row table

Learning Outcomes	Number of Studies	Percentages
Better Understanding Of Tools And Techniques (BUTT)	19	18.4
Acquire Better Testing Skills (ABT)	11	14.6
Opportunity Of Working With Real-World Industrial Software Systems (RWISS)	16	15.6
Game-Based Software Testing (GBS)	17	16.8

must know the software testing methods [44]. This unambitious linked to several factors: i) the incompatibility between conceptual and practical contents that diminish students' motivation towards the course. ii) The topics taught in the classroom are not identical to those needed in the industry; iii) the methods and phases of tests are challenging for students to understand; IV) lack of software development experience in students. To address these problems, specific approaches to inspire teachers were used based on a systematic mapping by Valle, Barbosa, and Maldonado [18]. There is a range of educational tools, Educational Games, Test Driven Development (TDD), and Integrated Teaching of Software Testing and Programming, aiming to support software testing education. Also, Educational games can be handy in software testing. Several research [48] [18] [53] and our conclusions have shown that a software testing course needs more realistic interactions than just theory. Considering educational games are identified as the most effective pedagogical approaches. While other studies [31] [33] [] [51] [32] emphasized the effectiveness of involving real-time industry projects into the current curriculum to enrich students testing ability.

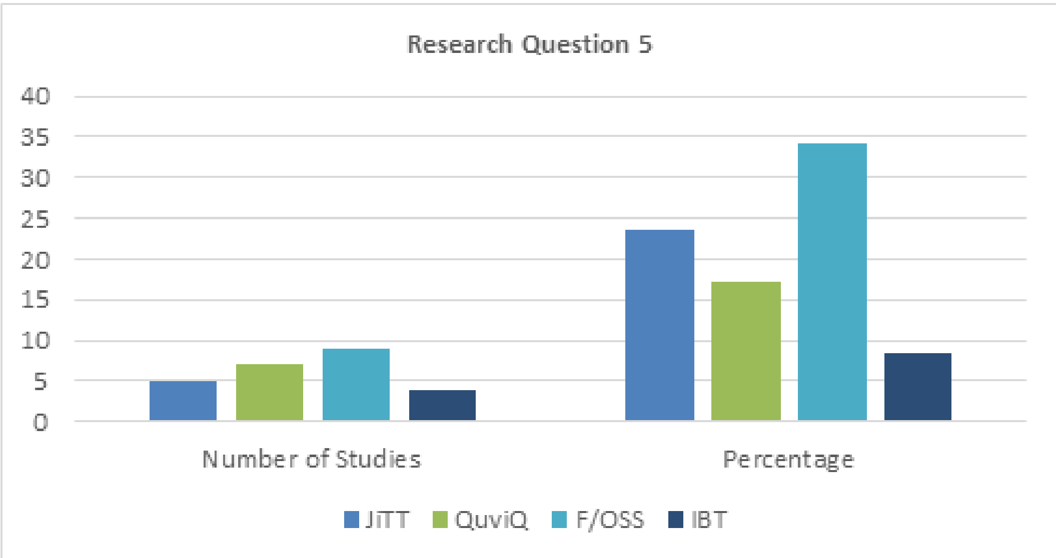

Figure 2.10: Learning Outcomes

From figure 2.10, we conclude that some learning outcomes are enlisted where BUTT has the highest number of studies compared to other teaching software testing courses. In contrast, ABT has the lowest number of studies and percentages consequently.

2.10 Discussion and Future Work

This section details the studies related to software testing education undertaken for undergraduate and postgraduate levels. Owing to the lack of current literature, this is the initial research on teaching software testing courses at the undergraduate and postgraduate levels. We collected and reviewed 63 primary studies to determine the best possible answers to the study issue. In our research, we found a positive effect on the learning process for software testing courses and courses related to software engineering. We hope that our results will help students gain essential knowledge and proficiency in applying different research approaches. It allows students to refine their skill sets in studying the course and leaves them with an incredible feeling of accomplishment. From the findings noted on RQ4, it was found that employee morale was inadequate for the test, and no one was very pleased with the test. This means that real-time industries are having more impact on preparation. However, the learning outcomes(RQ5) providing a structured training program seems to be motivating and may give impetus to integrated professionally managed software testing curriculum for teaching at undergraduate and postgraduate level. Therefore, there is more potential to address our research questions by surveying the students, professors, and industry experts using a standardized questionnaire and arrive at an adequate response for our research questions. We will concentrate on gathering data through surveys and questionnaires from business leaders and related industries for our next project. These methods will enable us to recognize the most ideal and current practical alternatives to the concerned path. We also intend to sustain industry-academia cooperation and create practical projects from scratch and applies all the available methodologies hereafter. To represent the existing state of education in this field and to uncover potential areas for improvement, further analysis must be done [33]

2.11 Conclusion

The research explored the teaching and learning of software testing courses in an educational environment. The paper identifies the necessary expertise, skills and abilities for various software testing courses at the undergraduate and postgraduate levels. We reviewed the literature using the systematic literature analysis of [54] to address our study questions. Furthermore, we find 63 papers matching our primary research to determine the feasibility of the testing course. The survey was conducted on articles published in late 2013 and early 2014, which focused on testing education and preparation. We also reviewed all the related data to address all our analysis questions (section 4.3). As the result of our systematic literature review, we find that despite the proven curriculum for software testing by leading academics and university experts, there is a lack of adequacy in teaching software testing skills that makes students not suited to industry needs. From the study, educating app testers needs more hands-on learning opportunities rather than just theoretical workshops. Therefore, researchers are expected to contribute to refining and enhancing testing activities to encourage greater student engagement.

Chapter 3

Survey on Software Engineering Education in DTU

3.1 Introduction

Software Engineering is impractical by its nature. This is especially valid for software engineering education. Thus, SE in general, and its dynamic contents in particular, should be taught problem-based, as this enables the teaching of abstract concepts by real-world applications, making them more understandable [1]. At the moment, software developers are taught in the conventional manner. This has not resulted in the sufficient availability and quality of developers to meet the increasing demand. Traditional education provides scant provisions for assisting students in maintaining their skills. Due to the lack of distinction between separate programming positions in the software industry, education for software engineers is often confused with education for programmers and other non-engineers [2]. Software engineering education is the critical and basic foundation for developing high-quality software using appropriate methodologies and approaches. The more we employ best practices and high-quality instruction in teaching and practicing software engineering, the more high-quality outcomes we will achieve. The All-India Council for Technical Education (AICTE) has done an excellent job of preparing, developing, and disseminating technical education in India. It has taken some constructive measures over the years to advance engineering education, maintain standards, and keep curricula current and appropriate. Though much has been achieved, the constantly evolving demands of industry, society, and the global stakeholder environment as a result of technological innovation, globalization, and shifting student preferences necessitate a study of engineering education in India. AICTE has established a Committee for preparing a short and medium-term perspective plan for engineering education in India to assist in this effort [3]. According to a UNESCO report [4], which highlighted many important issues concerning engineering education in India.

1. Staff dissatisfaction with the skills of engineering graduates and postgraduates.
2. Engineering education is, by all means, a drain on the majority of students.
3. Engineering education has failed to attract talented students who are genuinely needed to contribute to social growth.
4. Due to its reputed difficulty, it is rarely chosen by students.
5. Multidisciplinary expertise and work experience are needed in engineering.
6. The program is deficient in the majority of application-oriented skills and approaches.
7. Project-Based Learning is a viable instructional strategy that can be applied in any semester.
8. Using appropriate technical technologies will increase students' interest in the learning process.

Engineering accreditation bodies such as the Washington Accord and ABET must play a critical role in persuading engineering institutions to upgrade their services, partnerships with students, academic personnel roles, infrastructure facilities for students and employees, appraisal of methodologies, and measurement approaches to enhance the program's efficacy [5]. Taking into account the above, we have decided to take the next step in improving the consistency of the DTU software engineering program, as well as the problems and difficulties associated with the teaching and learning methodology for software engineering courses. To achieve the desired results, we formulated the following research questions: (1) What are the primary obstacles faced by students enrolled in the software engineering course at the SE department? (2) Do faculty members in the Department of Software Engineering need teaching skill training in order to impart high-quality expertise to software engineering students? (3) Does the department foster cooperation between academia and industry in order to produce high-quality programs with the assistance of student labor? (4) Does the department offer an up-to-date, globally recognized curriculum in the field of SE? Are appropriately addressed in this study.

3.2 Delhi Technological University

Formerly known as Delhi College of Engineering, the Delhi Technological University(DTU) is one of the city's oldest autonomous public universities, offering advanced engineering courses as well as a variety of other management-related courses. Founded in 1941 as Delhi Polytechnic. As a result, the college came under the jurisdiction of the Delhi Government in the year and was affiliated with the University of Delhi until 2009. Following that, the college was elevated to university status and renamed Delhi Technical University. The university serves as the mother institution for many renowned colleges in Delhi, including the Indian Institute of Technology, Delhi (IIT, Delhi), the Faculty of Management Studies (FMS, Delhi), and many others. DTU is situated in Shahbad Daulatpur on the Main Bawana Road in Delhi. Khera Kalan railway station is 9.5 kilometers away. The closest subway stations are Samaypur Badli and Rithala. Indira Gandhi International Airport is 37.7 kilometers away. Rohini Depot 4 is the nearest bus depot at a distance of 2.5 km.

3.3 Software Engineering Curriculum in DTU

With effect from 2015-2016, DTU's software engineering curriculum is designed for B.Tech students. The curriculum covers a variety of courses over four academic years, including core subjects, departmental electives, and university electives. The curriculum spans two academic periods within a single year, referred to as Group A and Group B of freshman year. This should be noted; the time of the practical and theory exams is three hours, and the proportional weights assigned to each subject are as follows: CWS, PRS, MTE, ETE, and PRE. The following table summarizes the cumulative semester-by-semester course load for the entire academic years.

Table 3.1: elective courses.

1st Sem	**2nd Sem**	**3rd Sem**	**4th Sem**	**5th Sem**	**6th Sem**	**7th Sem**	**8th Sem**
Mathematics - I	Mathematics - II	Analog Electronics	Digital Electronics	Object Oriented SE	Software Testing	B.Tech. Project-I	B.Tech. Project-II
Physics - I	Physics - II	Data Structures	Software Engineering	Algorithm Design & Analysis	Operating System	Training Seminar	Empirical SE
Chemistry	Basic Electrical Eng.	Object Oriented Programming	Comp. Organization & Arch.	Dept. Elective - 1	Compiler Design	Software Project Mgmt.	Dept. Elective - 7
Basic Mech. Eng.	Programming Fundamentals	Web Technology	Database Mgmt. Systems	Dept. Elective - 2	Dept. Elective	Computer Networks	Dept. Elective - 8
Workshop Practice	Engineering Graphics	Eng. Analysis and Design	Discrete Structures	University Elective	Dept. Elective - 4	Dept. Elective - 5	
Communication Skills	Env. Science Intro.	Engineering Economics	Fundamentals of Mgmt.	Professional Ethics	Technical Communication	Dept. Elective - 6	

3.3.1 List of Departmental Elective Courses

The following table 3.0 details the elective courses offered by the department:

No	Subject	No	Subject
1	Software Requirement Engineering	19	Soft Computing
2	Computer Graphics	20	Artificial Intelligence
3	Information Theory and coding	21	Theory of Computation
4	Digital Signal Processing	22	Software Reliability
5	Advanced Data Structures	23	Multimedia Systems
6	Microprocessor & Interfacing	24	Parallel Computer Architecture
7	Distributed Systems	25	Bio-Informatics
8	Parallel Algorithms	26	Natural Language Processing
9	Software Maintenance	27	Advanced Database Management Systems
10	Software Quality & Metrics	28	Data Compression
11	Grid & Cluster Computing	29	Real Time Systems
12	Pattern Recognition	30	Information & Network Security
13	Data Warehousing & Data Mining	31	Swarm & Evolutionary Computing
14	Cyber-Forensics	32	Semantic Web and Web Mining
15	Robotics	33	Cloud Computing
16	Machine Learning	34	Big Data Analytics
17	Intellectual Property Rights & Cyber Laws	35	Wireless and Mobile Computing
18	Advances in Software Engineering	36	Agile Software Process

3.3.2 University Elective Courses

Table 3.2: elective courses.

1st Sem	2nd Sem	3rd Sem	4th Sem	5th Sem	6th Sem	7th Sem	8th Sem
Mathematics - I	Mathematics - II	Analog Electronics	Digital Electronics	Object Oriented Software Engineering	Software Testing	B.Tech. Project-I	B.Tech. Project-II
Physics - I	Physics - II	Data Structures	Software Engineering	Algorithm Design & Analysis	Operating System	Training Seminar	Empirical Software Engineering

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1st Sem	**2nd Sem**	**3rd Sem**	**4th Sem**	**5th Sem**	**6th Sem**	**7th Sem**	**8th Sem**
Chemistry	Basic Electrical Engineering	Object Oriented Programming	Computer Organization & Architecture	Departmental Elective Course -1	Compiler Design	Software Project Management	Departmental Elective Course-7
Basic Mechanical Engineering	Programming Fundamentals	Web Technology	Database Management Systems	Departmental Elective Course -2	Departmental Elective Course	Computer Networks	Departmental Elective Course-8

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1st Sem	**2nd Sem**	**3rd Sem**	**4th Sem**	**5th Sem**	**6th Sem**	**7th Sem**	**8th Sem**
Workshop Practice	Engineering Graphics	Engineering Analysis and Design (Modelling and Simulation)	Discrete Structures	University Elective Course	Departmental Elective Course -4	Departmental Elective Course -5	

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1st Sem	**2nd Sem**	**3rd Sem**	**4th Sem**	**5th Sem**	**6th Sem**	**7th Sem**	**8th Sem**
Communication Skills	Introduction to Environmental Science	Engineering Economics	Fundamentals of Management	Professional Ethics & Values	Technical Communication	Departmental Elective Course-6	

To conclude, we used the Rose-Hulman Institute of Technology as a model for the IEEE/ACM SE-2014 curriculum guidance in order to determine the strengths and weaknesses of the DTU SE curriculum [6] They addressed the following metrics for each course in the curriculum:

"B.9. Software Testing and Quality Assurance (SPSU) SWE 3643 Software Testing and Quality Assurance Southern Polytechnic State University (to be Kennesaw State Univ. in 2015) Marietta, Georgia Frank Tsui ftsui@spsu.edu http://cse.spsu.edu/ft sui (class notes available when I offer this course)

Catalogue description This course demonstrates how to describe software quality and how to quantify it using a variety of testing techniques. The course covers non-executable program review/inspection methods, executable software black-box and white-box verification techniques, and test interpretation. Specific methods for developing test cases are implemented, including boundary value, equivalence class, control paths, and dataflow paths testing. The definition of configuration management is used to discuss various levels of monitoring, including functional, feature, and system/regression checks.

Expected Outcomes After taking this course, the student will be able to:

1. Explore and understand the notion of quality and the definition of quality

2. Understanding and setting quality goals, measuring techniques, and analyzing product and process quality.

3. Learn how to develop test plan, test process, test scenarios, and test cases to achieve the quality goal.

4. Exploring and mastering techniques to achieve the quality goals for software product through a) inspection/reviews, b) black/white box testing techniques, and c) verification using unit, component, system and regression test.

5. Introduce the students to the notion of and techniques to achieve the quality goals for the software project through QA planning, through configuration management and through software development process improvement

Where does the course fit in your curriculum? This is a three-credit-hour mandatory course for all undergraduate software engineering and game design majors in their second semester or later. This course requires completion of the Introduction to Software Engineering course.

In recent years, this course has had a class size of about 30 to 35 students. Additionally, some students majoring in computer science take this course as an elective.

Table 3.3: Discussion of topics during the course.

No	Topics
1	Definitions, Basic Concept, and Relationships of Quality, Quality Assurance, and Testing
2	Overview of Different Testing Techniques
...	...

3.4 What is the Format of the Course?

The course is taught in the conventional face-to-face classroom format, which includes seminars, student assignments, and student presentations. The course meets twice a week for 1.5 hours over the course of a 16-week semester (including final exam). Outside of class, students also collaborate in small teams. a) to prepare for the in-class inspection/review, b) to prepare for test case creation, test execution, and test result reporting and interpretation, and c) to prepare for a class presentation on product quality focused on an analysis of the test objective, test team status, and test results.

3.5 What Methods are used to Evaluate Students?

Individual students are evaluated by two closed-book class-room tests. Students are often evaluated in teams on the basis of their individual effort, participation, and attitude toward their team projects. Assessment of team assignments also requires students' evaluations of one another.

Course textbooks and materials: There is one textbook: Software Testing, A Craftsman's Approach, by Paul C. Jorgensen, Auerbach Publications, 2008 ISBN: 0-8493-7475-8 Additional readings are sometimes used for some topics (for example: "Advances in Software Inspections" by M. Fagan, "What is Software Testing and Why Is It So Hard" by J. Whittaker, "How to Design Practical Test Cases" by T. Yamaura, "Clearing a Career Path for Software Testers" by E. Weyuker , et al, etc.)

Pedagogical Advice: Students also get fixated on various testing techniques and lose sight of the purpose with which these tasks are being performed. As a result, they must be reminded of why and how much diverse testing is needed in relation to multiple quality objectives.

Table 3.4: Pedagogical advice.

KA	**Knowledge Unit**	**Hours**
QUA.pda	Basic definitions, concepts, and relationships among quality, quality assurance (product and process), and testing.	3.0
QUA.pca		
VAV.fnd		

3.6 DTU's Curriculum for Software Engineering

On the other hand, the curriculum specifications for the Department of Software Engineering at Delhi Technological University are as follows: They discussed the following points for each course in the curriculum.

1. Subject Code: SE202 Course
2. Title: Software Engineering
3. Contact Hours: L: 3 T: 0 P: 2
4. Examination Duration (ETE) (Hrs.): Theory 3 Hrs Practical 0
5. Relative Weightage: CWS 15 PRS 15 MTE 30 ETE 40 PR 0
6. Credits: 4
7. Semester: IV
8. Subject Area: DCC
9. Pre-requisite: Nil
10. Objective: To introduce fundamentals of software engineering including requirement specifications, software design, testing and maintenance.

Table 3.5: Course details.

S.No	Contents	Hours
1	Introduction: Introduction to Software Engineering, Software characteristics, Software components, Software applications, Software Engineering Principles, Software metrics and measurement, monitoring and control. Software development life-cycle, Waterfall model, prototyping model, Incremental model, Iterative enhancement Model, Spiral model.	8

Table 3.6: List of Software Engineering Books

S.No	Name of Books/Authors/Publishers	Year of Publication/Reprint
1	R. S. Pressman, "Software Engineering – A practitioner's approach", 3rd ed., McGraw Hill Int. Ed.	1992
2	K. K. Aggarwal & Yogesh Singh, "Software Engineering", 2nd Ed., New Age International	2005
3	Sommerville, "Software Engineering", Addison Wesley	2001

3.6.1 Software Engineering Curriculum Issues and Challenges

Taking into account the curricula at Rose-Hulman Institute of Technology and Delhi Technological University, the following points might be seen as challenges to the existing curriculum of DTU's software engineering department.

1. Each subject lacks a specified level of cognitive ability.
2. The curriculum lacks an overview of the program.
3. The program has no specified objectives or anticipated outcomes.
4. There is no explanation of the course in the catalogue.
5. No summary of the course's outcomes
6. No fit of course in the curriculum.

3.6.2 Software Engineering Curriculum Strengths

In accordance with the SE-2014 ACM/IEEE curriculum standards, the SE department curriculum at Delhi Technological University possesses the following strengths.

1. The major factors which influence the decision has been considered in the design of the software engineering curriculum at Delhi Technological University
   (a) The Stakeholders
   (b) The curriculum material
   (c) Quality issues
2. Alternate teaching environment such MOOC is considered
3. Alternate institutional models are considered and included
4. The three specific elements which cause the success of educational program is considered
   (a) Faculty
   (b) Student
   (c) Infrastructure

3.6.3 Facilities at SE Department

The Department of Software Engineering at DTU is a rigorous, doctoral-granting department accredited by NAAC. Additionally, this department offers the following services to undergraduate, graduate, and doctoral students. The department has the following facilities:

a) Well-equipped Labs

b) 24/7 internet access

c) Access to prominent journals such as: IEEE, ACM. SpringerLink and so on.

d) Research facilities

e) Industrial visits

3.7 Industry Collaboration in DTU

Industry-academia collaborations are like earth and water, they live in harmony. They cannot exist apart from one another. Collaborative effort between industry and academia promotes improvement and innovation in technology and enables university to be more relevant to industry [7]. DTU promotes the industrial collaboration and interaction of faculty with industry for mutual benefits in alignment to the research and quality policy of the university. The goal of the university is to provide exposure to the faculty to the world's best industrial experiences and to establish industry-academia and industry-research relationship as expounded in the mission of education and research [8].

3.8 Research Questions

Our research questions are intended to elicit information about the problems and strengths of the software engineering program and courses offered by the department of software engineering, as well as to propose strategies and methodologies for improving the consistency of teaching and students' skills over time.

Table 3.7: Research questions and motivations.

No	Research Question	Motivation
1	What are the primary obstacles faced by students enrolled in the software engineering course at the SE department?	It identifies problems and proposes solutions.
2	Do faculty members in the Department of Software Engineering need teaching skill training in order to impart high-quality expertise to software engineering students?	It assesses faculty capacity and the department's teaching quality.
3	Does the department foster cooperation between academia and industry in order to produce high-quality programs with the assistance of student labor?	This RQ seeks to ascertain the department's relationship with industry in order to develop real-world programs through industry engagement.
4	Does the department offer an up-to-date, globally recognized curriculum in the field of SE?	It provides an overview of the department's curriculum and its consistency in comparison to international benchmarks.

The preceding table shows our research questions in relation to the current state of software engineering education in software engineering departments and provides solutions and responses based on our survey conducted through well-defined questionnaires and interviews.

3.9 Data Collection

The respondents expressed their willingness to participate in the survey and willingly completed the questionnaire. All the participants' identities were anonymous and they decided to participate in the study's survey in order to gather data. The survey was conducted at Delhi Technological University's software engineering department. We clarified the survey's secrecy during the online survey's administration. There were no questions that requested sensitive information, and respondents completed the survey privately. As a result, respondents gave their consent and their personal information and views were kept private, so they did not address any confidential topics [9]. The study, which took place in September 2020, aimed at students in the department of software engineering who are interested in pursuing careers in the field of software engineering. To ensure the questionnaires were authentic, we verified that students who replied had taken additional classes during the semester. Additionally, to ensure the questionnaires' reliability, we used comfort sampling and snowball sampling, distributing the questionnaires to departmental teachers via a WhatsApp group and email IDs, who then distributed them to students enrolled in their courses. The students completed the questionnaires voluntarily and they were then collected and analyzed.

3.9.1 Survey Results and Procedure

We began our study by recognizing the issues, challenges, and abilities associated with the department of software engineering's software engineering course. Then, using the gathered data, we developed the four research questions outlined above. As shown in the figure below, there are 119 male respondents (85.5 percent) and 20 female respondents (14.5 percent). A sizable proportion of respondents are already enrolled in their second or fourth year of studies. Our goal with this survey was to gather data from more than 80% of the department's students in order to solicit accurate input and ascertain the department's challenges, barriers, and opportunities.

	Frequency	Percent (%)	Measure	Value
Male	119	85.5	Mean	1.14
Female	20	14.5	Median	1.00
Total	139	100	Mode	1
			Std.Deviation	0.352

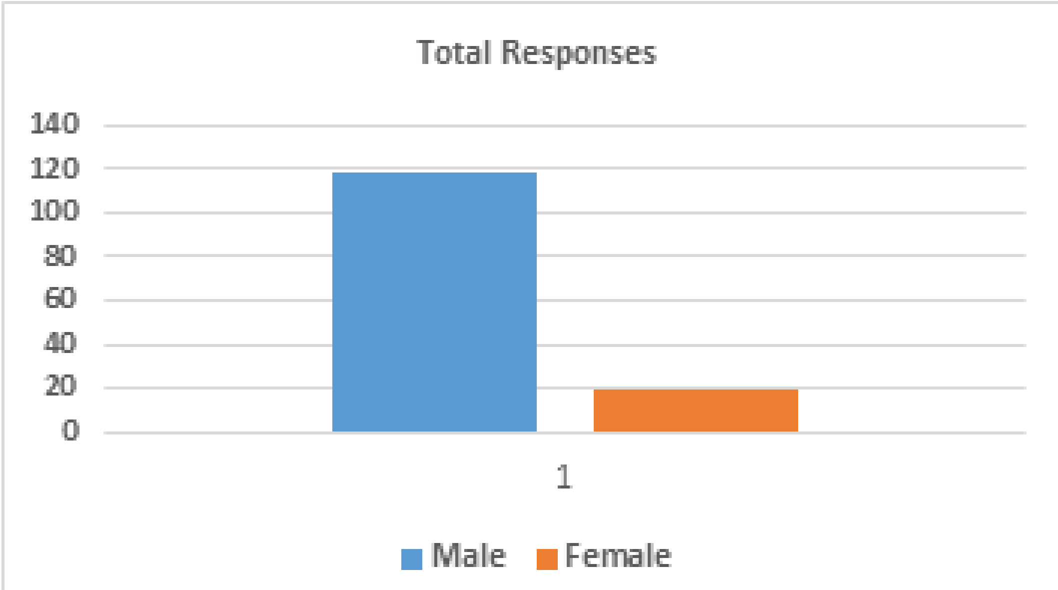

Figure 3.1: Total Responses

3.10 Research Question 1

Our first research question focused on the problems and concerns faced by students in the department; our survey results specifically addressed this research question in a detailed and understandable way. The following table summarizes the issues and challenges faced by software engineering students in relation to the software engineering course.

a) Developing real-world projects

b) Investing less time and resources

c) Collaborating with industry

d) Methodology of teaching

e) Undergraduate exchange programs with foreign universities.

f) Program revision

g) Labs should be staffed by qualified instructors rather than M.Tech students

h) more practical and collaborative

The preceding are student interests and challenges, with the majority of students concentrating on industrial collaboration and real-world projects.

3.11 Research Question 2

Our second RQ focused on the teaching skills and pedagogical methods associated with software engineering courses. Additionally, we asked students to share their perspectives on teaching methodologies and their concerns in this area. As shown below, 41 students out of 138 strongly agree and agree with the department's current teaching methodology, while 32.4 percent of students provided a neutral response to the questions. Simultaneously, nearly 52 students out of 138 disagree firmly and strongly with the existing teaching methodologies used in the software engineering course.

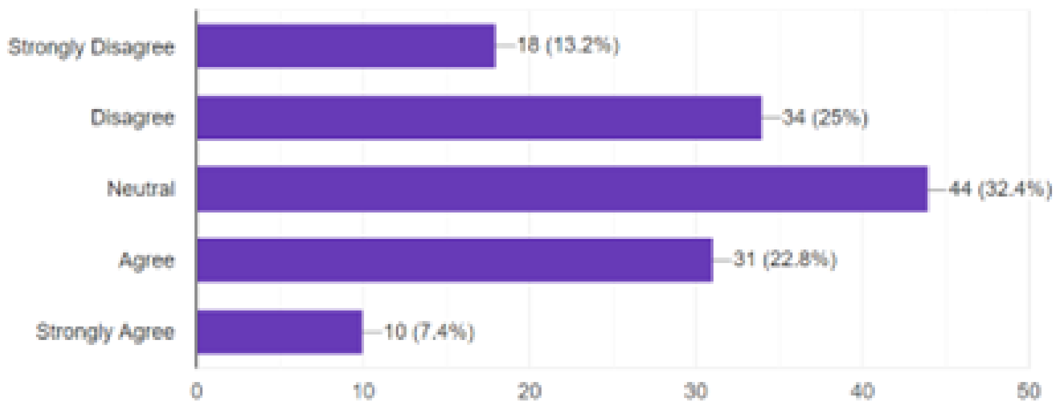

Figure 3.2: teaching approach

On the other hand, in response to our next question about faculty training for teaching software engineering courses at the department, we received the following response: 97 out of 138 students agreed that faculty development programs and training are essential for faculty in the department of software engineering to cover the courses effectively.

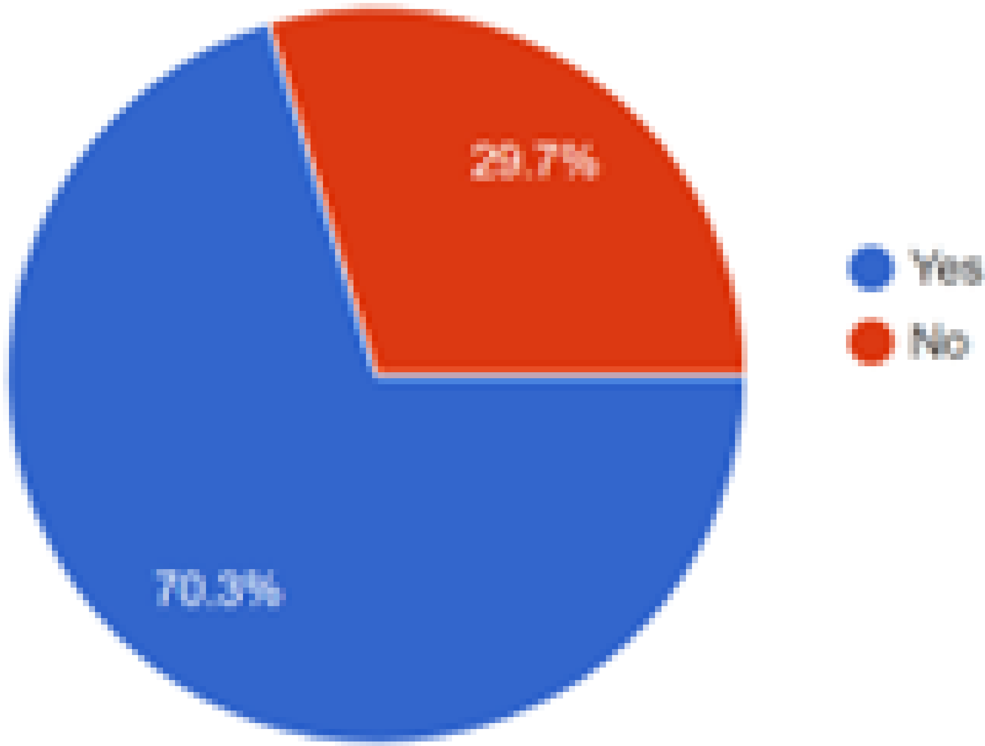

Figure 3.3: Faculty training

3.12 Research Question 3

Our third RQ is inquiring about academic-industry collaboration. Additionally, it is attempting to ascertain how the department facilitates such collaboration with industry for the purpose of developing real-world projects using students' capacity and force. According to our review of the poll, more than 62% of students want the department to facilitate collaboration between academia and industry in order to partake in real-world initiatives led by industry experts.

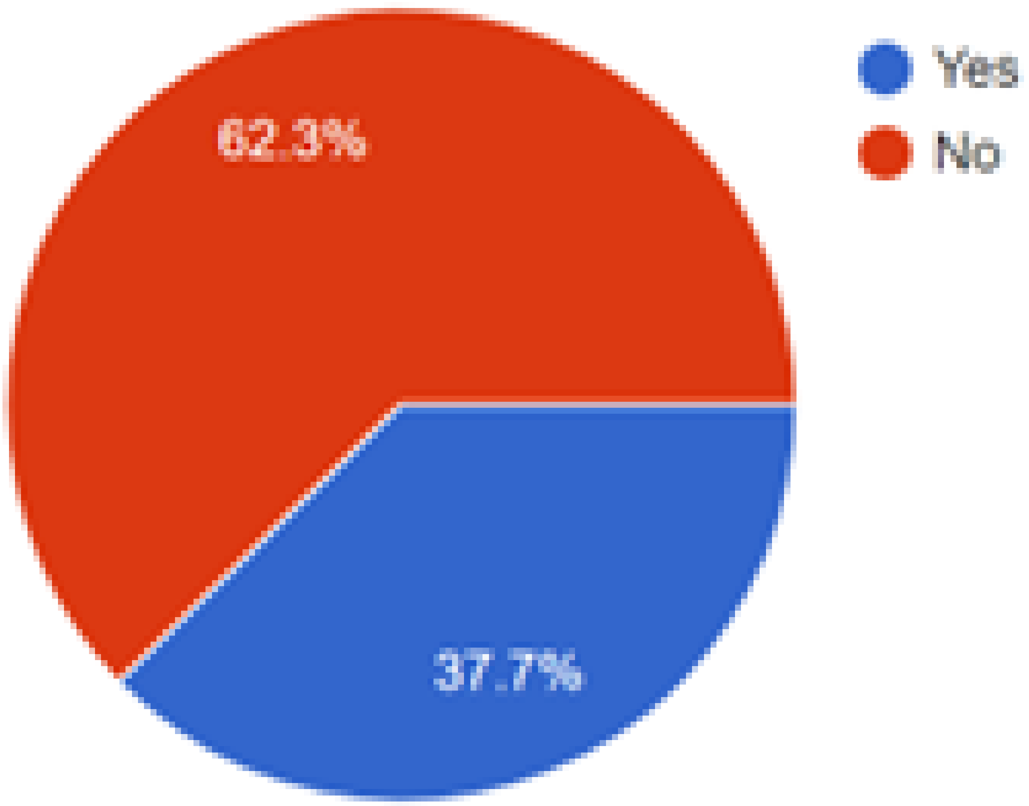

Figure 3.4: Academy-Industry collaboration

Additionally, the following survey question emphasized the importance of students focusing on real-world projects prior to entering a real-world job environment; the outcome, as shown in Figure 3.4, is staggering and must be addressed immediately.

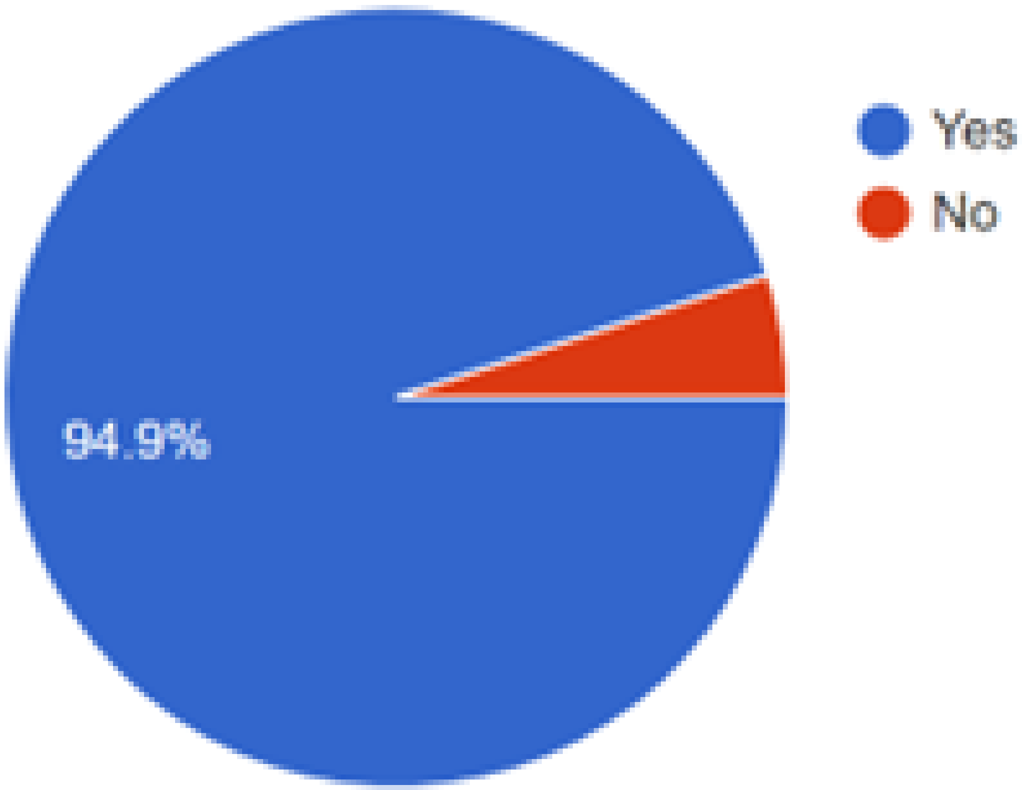

Figure 3.5: Real world project concern

The above statistics reveal that nearly 95 percent of students are faced with a real-world working environment upon graduation from software engineering disciplines. As a result, we must establish cooperation between academia and industry in order to address this problem and produce our students to the market with real-world project completions. According to [10], teaching theoretical concepts with no connection to their practical applications or examples in the student's context can discourage learning, which explains why teaching and learning are major challenges in higher education. According to [2,] one of the most difficult challenges in higher education, especially when teaching highly theoretical subjects like requirements engineering, is keeping students' attention and enthusiasm while presenting the key principles required for students to work in industry after graduation. It has long been proven that experience-based learning will facilitate any of these activities: On the one hand, presenting students with industrial case studies as opposed to "dry" academic assignments will help boost student engagement and motivation. On the other hand, a classroom approach centred on case examples will result in a rich learning atmosphere that promotes teamwork, engagement, and self-directed analysis of the taught concepts.

3.13 Research Question 4

Our previous research questions addressed the quality of the curriculum in the department of software engineering and student concerns. Additionally, we shared our questions about the components and strengths of the department curriculum through our questionnaire. As shown below, 52.2 percent of students strongly agree or agree with the current curriculum, while 24.6 percent disagree. Given that 23.2 percent of responses are neutral, we may infer that the department's new program complies with international standards but needs updating to ensure that it complies with all international standards and ”updates the laboratories' computer systems to industry expectations.” Increase industrial training in the curriculum” in order to increase student satisfaction and produce conclusive results.

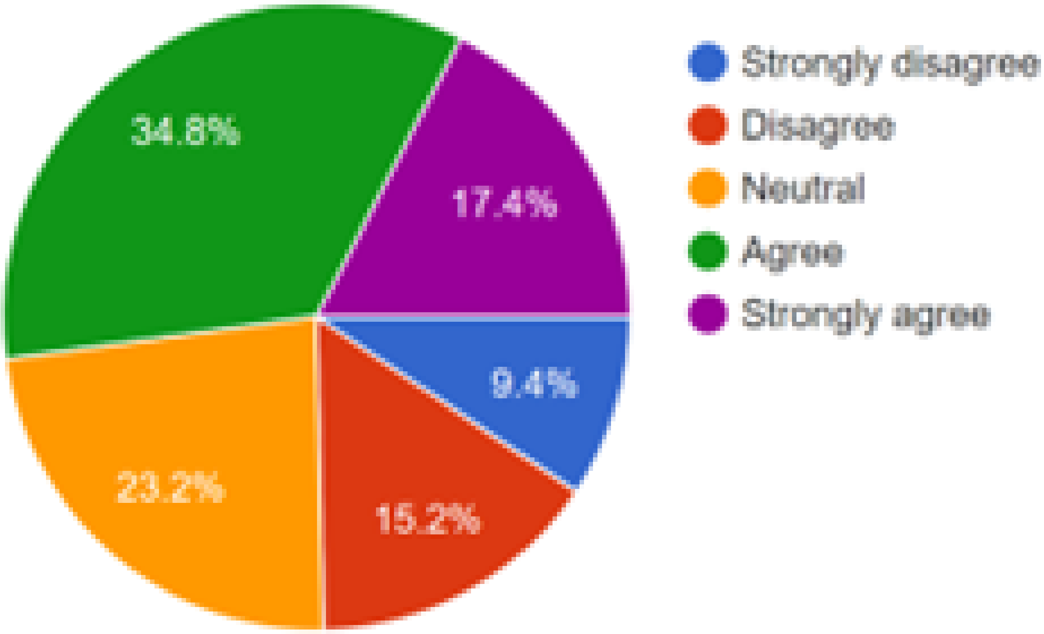

Figure 3.6: curriculum concern

3.14 Conclusion

So far, we have discussed the software engineering curriculum and course offerings at Delhi Technological University. We have compared the current SE curriculum at DTU to the SE-2014 curriculum guidelines of ACM/IEEE, identified the strengths and weaknesses of the DTU's SE curriculum, and briefly discussed the state of engineering in India. This paper also discussed the strengths and weaknesses of the new curriculum for the SE department; we discovered that the curriculum's greatest asset, additionally, the primary factors that contribute to the performance of the SE educational program are considered, including teachers, students, and the department's facilities. On the other hand, several problems with the current curriculum are raised.

Chapter 4

Systematic Literature Review on The Global Impact of COVID-19 on Education

4.1 Introduction

The COVID-19 pandemic has spread internationally, infecting practically every nation worldwide. The infection was discovered in December 2019 in Wuhan city, China. Nations throughout the globe warned individuals to take precautions. Hand sanitizer, face masks, safe distancing, and avoidance of large crowds and rallies have all been included in public care procedures. To flatten the curve and prevent disease spread, lockdown and stay-at-home have been implemented [55]. Hence, lockdown and safe distance practices were implemented due to the outbreak of COVID-19 in several nations and resulted in the suspension of colleges, learning centers, and higher education institutions. The way instructors convey quality education is experiencing a major shift, with instructors now delivering through many online methods. Despite the obstacles encountered by both teachers and students, online, remote, digital, and progressive education have proven to be effective in combating this unexpected global pandemic. Switching from traditional on-campus to digital learning can be a different experience for instructors and learners; they must tweak the lack of alternative systems. The institutions and instructors embraced ”Education in an Emergency” using several platforms and are now being pushed to adjust to an unfamiliar system [56]. The transition from on-campus education to online learning in the educational context poses a unique challenge for instructors in all educational settings. The unanticipated pandemic affected almost 98 percent of the region’s learners and academicians [57]. Today, with the COVID-19 and the lockdown period, digital learning has remained a necessary component of education's continuity and growth. The most successful educational systems incorporate this notion throughout the many stages of learning, from basic to higher education, to provide a greater amount of learning with quality and by utilizing various technologies available to complete learning activities in the optimal conditions [58]. The spread of this infection results in digital education. Students require appropriate ideological coaching to defeat the obstacles set by COVID-19. As a result, employing digital learning to assist students in resisting COVID-19 and mitigating its educational consequence has become a trendy new research area [59]. Closures of educational institutions affect around 600 million school-aged children worldwide. Nearly 320 million students in India are affected, with over 34 million enrolled in post secondary education. The outbreak of COVID-19 culminates in a digital revolution in higher education through online learning, video conferencing, digital books, online examinations, and interactivity in virtual worlds. Additionally, COVID-19 had a tremendous consequence on learning efficiency and performance when applied to online learning approaches. Online education is frequently skewed in favor of low-income and marginalized learners. It is well recognized that deaf and hard-of-hearing learners struggle with digital learning [60]. Another significant problem students face due to this pandemic is preserving psychological well-being. According to the United Nations Educational, Scientific, and Cultural Organization (UNESCO), both primary and elementary schools were closed worldwide in April 2020, and more than one billion educators did not attend college, causing an unanticipated problem in the field of education and raising concerns about its detrimental consequences on psychological disorders [61] [62]. Although mind statics is a critical sign of psychological well-being, individuals frequently overlook it. Numerous suicides have been reported during the COVID-19 era due to depression. As a result, early detection and treatment help avoid these occurrences. According to research finding conducted in Nepal, 38 percent of doctors suffer from anxiety and depression. It was dumbfounding that the lockout during the COVID-19 outbreak harmed the public's psychological well-being. According to the World Health Organization (WHO), psychological well-being encompasses ”abstract affluence, saw self-sufficiency, self-governance, capability, intergenerational dependence, and self-fulfillment of one's intellectual and passionate potential, among others” [63]. Historically, psychological health has been an unaddressed health concern, which the COVID-19 has surprisingly increased. Consequently, it is vital to increase rates of access to psychological well-being treatment services [61].

Hence, this research aims to systematically review and characterize the state-of-the-art

COVID-19 global consequence on education and address the proceeding research questions:

a) What are the positive and negative impacts of COVID-19 on the educational system?

b) What significant changes could occur in the educational system and institutional processes due to COVID-19?

c) What percentage of students can follow digital learning during the COVID-19 pandemic, and their satisfaction and concerns from digital learning?

d) How did technology play a vital role in educational institutions during COVID19?

e) Do faculties and Ph.D. students' research activities impact during COVID19?

f) How does the COVID-19 affect students' psychological and mental health?

g) How effectively did educational institutions manage the move from on-campus to digital learning during the pandemic?

4.2 Methodology

The main purpose of this research is to systematically review and characterize the state-of-the-art of the COVID-19 influence on education. This SR adheres to the guidelines established by [38] and [64]. The SR process is divided into three stages: 1) Planning the review, 2) Conducting the review, and 3) Reporting the results of the review. The first phase of SR is divided into three sub-sections: a) The need for SR; b) Formulating research questions, and c) Method and study selection. The second phase consists of three sub-sections: a) Data gathering for primary studies; b) Data extraction; and c) Data synthesis. Finally, the third part of SR is the overall review's reporting. The method of conducting SR is outlined in figure 4.1. In the first stage, we conceived and developed a review protocol that included the following steps: a) topic identification, b) development of a search strategy, c) selection criteria, d) quality assessment process, e) data extraction process, and f) data analysis process [40]. After the process was completed, the review proceeded in steps. The first step was to formulate research questions that incorporated the essential issues that needed to be addressed throughout the SR of the literature. Following the first step, a search strategy was created, search criteria, and a list of recognized sources from which primary studies were retrieved. The third phase finds relevant articles that address the research questions; we also determined each primary study's inclusion and exclusion criteria during this phase. By designing specific quality assessment questions to evaluate critical and relevant studies, the critical component of the quality assessment process is recognized. The data extraction process was designed to fulfill our research questions while meeting the quality assessment criteria. Simultaneously, the other steps completed the methodologies for data synthesis. The next subsections describe the research topics and methods utilized to conduct an SR of the literature.

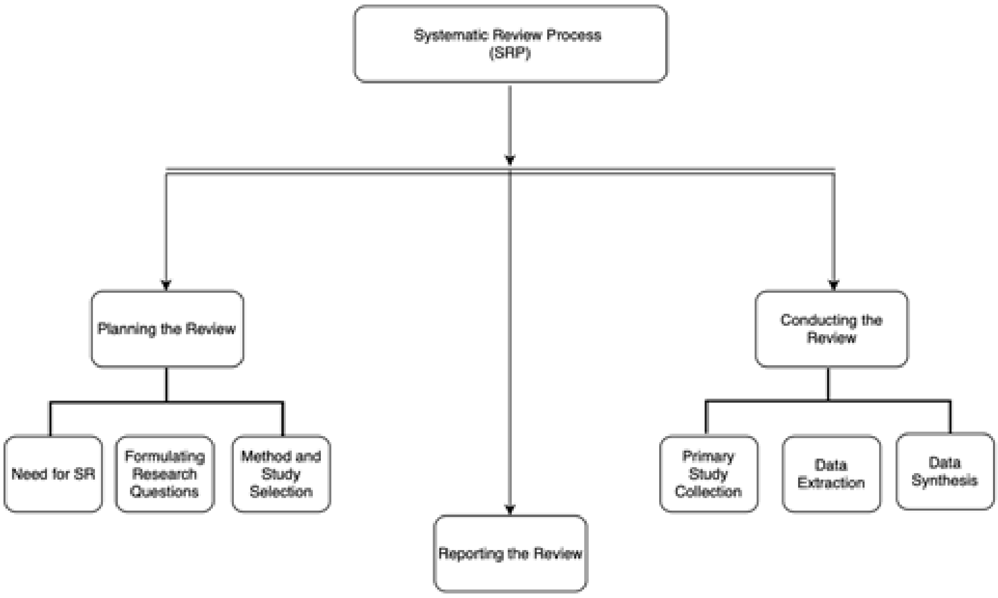

Figure 4.1: The complete systematic literature review process

4.2.1 Planning the Review

Considering the guidelines listed in [38], we go through the systematic review planning by pre-senting research aims and research questions. By following this procedure, we set up the search strategy and parameters.

4.2.2 Research Questions

This SR aims to determine the global consequence of COVID-19 on education worldwide. We formulated the research questions (RQs) by searching and reading multiple articles and resources related to COVID-19 effect on education and other sec-tors. The first author developed approximately 20 RQs and shared them with the second and third authors for filtering. We formulated seven RQs for this SR after filtering the RQs. Table 4.1 summarizes all the formulated RQs and their motivations.

Table 4.1: Total number of research questions.

RQs	Research Questions
RQ1	What are the positive and negative impacts of COVID-19 on the educational system?
RQ2	What significant changes could occur in the educational system and institutional processes due to COVID-19?
RQ3	What percentage of students can follow digital learning during the COVID-19 Pandemic, and their satisfaction and concerns about digital learning?
RQ4	How did technology play a vital role in educational institutions during COVID19?
RQ5	Do faculties and Ph.D. students' research activities impact during COVID19?
RQ6	How does the COVID-19 affect students' psychological and mental health?
RQ7	How effectively did educational institutions manage the move from on-campus to digital learning during the pandemic?

4.2.3 Search Process

In this work, the SR approach was used in compliance with [38]. The search began with a man-ual search of the journal for publications addressing COVID-19's impact on education. For instance, ACM, IEEE, ScienceDirect, Taylor & Francis, and other special issue journals linked to COVID-19 were consulted and researched. An automated search of scientific databases supported the process. The keywords like COVID-19 and education, COVID-19 and psychological well-being, COVID-19 and research, COVID-19 and distance education, COVID-19 and e-learning, COVID-19 and students, COVID-19 and faculty, and COVID-19 and assessment process were used to extract relevant publications. Thus, the automatic search was conducted using the IEEE Xplore Digital Library, Elsevier, ACM Digital Library, Taylor & Francis, SAGE, MDPI and Wiley. The primary study was chosen under the inclusion criteria. As a result, figure 4.2 depicts the number of primary studies obtained during each evaluation session.

4.2.4 Inclusion and Exclusion Criteria

We evaluated the selected studies using both inclusive and exclusive criteria to ensure they met the study's inclusion criteria. Consequently, we filtered the number of studies by title, abstract,

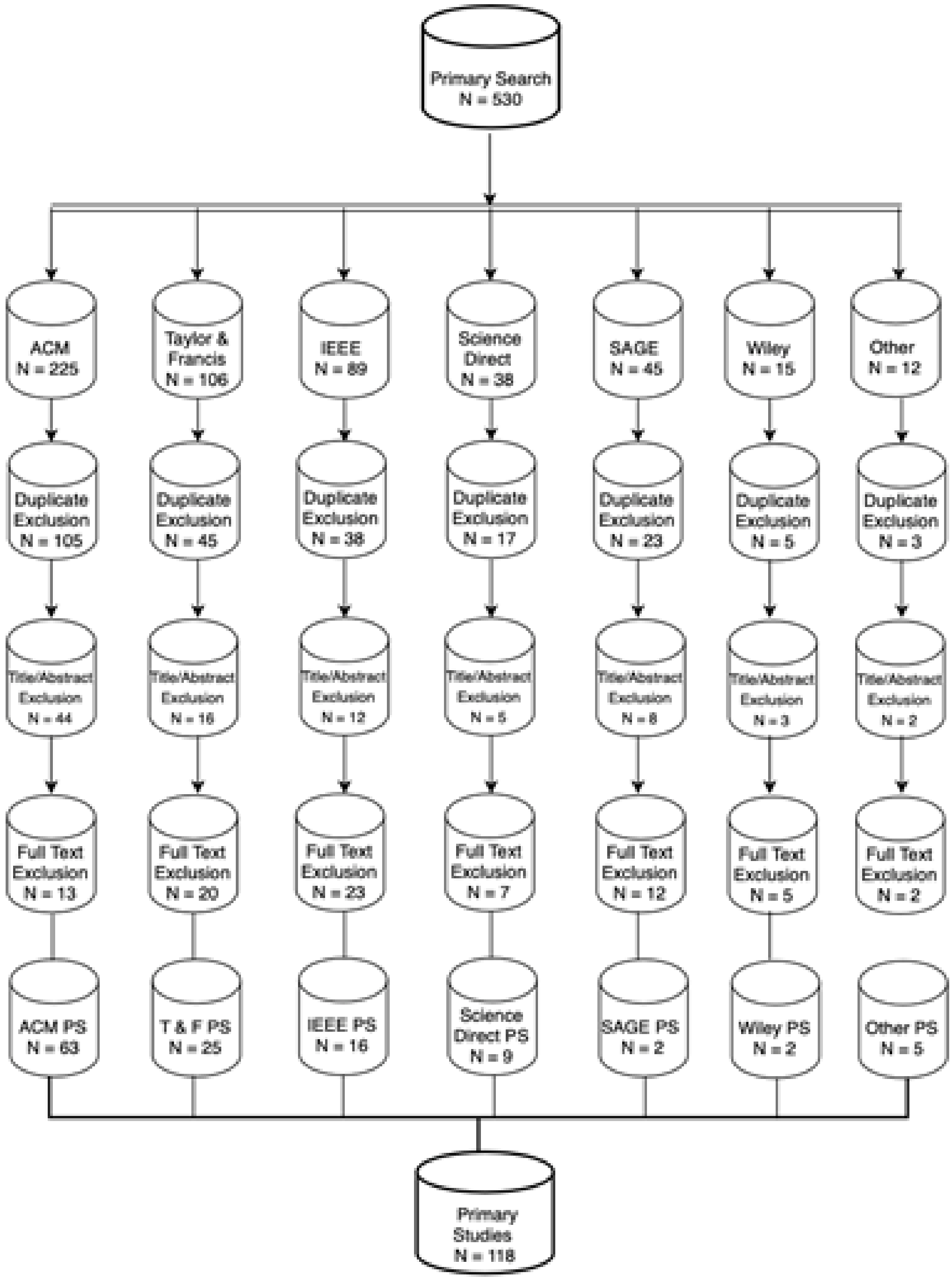

Figure 4.2: The search process for gathering the primary studies

full text, and duplicates.

4.2.5 Inclusion Criteria

Multiple inclusion criteria were explored in this SR to support us in collecting relevant studies. The following criteria were used to select papers for this study:

(a) Papers included in this work were published in conferences and journals

(b) Papers chosen for this review were published between 2020 and 2022.

(c) The articles covered in this evaluation dealt with the COVID-19's global consequences on education.

(d) Articles are written in the English language.

(e) The articles included in this collection have been peer-reviewed and have appeared in reputable journals and databases such as ACM, IEEE, Taylor & Francis, ScienceDirect, and others.

4.2.6 Exclusion Criteria

We began excluding articles that did not meet our criteria and did not improve our approach to searching for each article. Articles were excluded from this SR based on the following criteria:

(a) Journals did not answer the research questions we formulated.

(b) The articles lacked detailed information about the instructional impact of COVID-19.

(c) The articles were published in low-quality journals; and d. The articles had duplication.

(d) The articles made no mention of the impact of COVID-19 on learners or instructors.

We extracted about 530 articles in the first attempt. We began our search with keywords mentioned in sub-section 2.3, the manu-script's title, and the abstract. As a result, the articles have been shortened. We then analyzed to verify there was no duplication of work. We carefully selected the research publications for inclusion and exclusion, and we removed those articles that did not cov-er our objectives in this SR.

Figure 4.3 depicts the overall number of primary studies chosen for this SR. The statistic indicates that ACM conference pa-pers cover the most primary studies compared to other publications, that is 50 percent. Additionally, Taylor & Francis has the second-highest articles selected as primary studies for this SR, accounting for 20 percent of total primary studies. The remainder of the primary studies in this SR is eight percent of IEEE conference papers and five percent of IEEE journal papers. ScienceDi-rect covers about seven percent of primary studies, while the remaining six percent are from other publications and databases such as SAGE and Wiley.

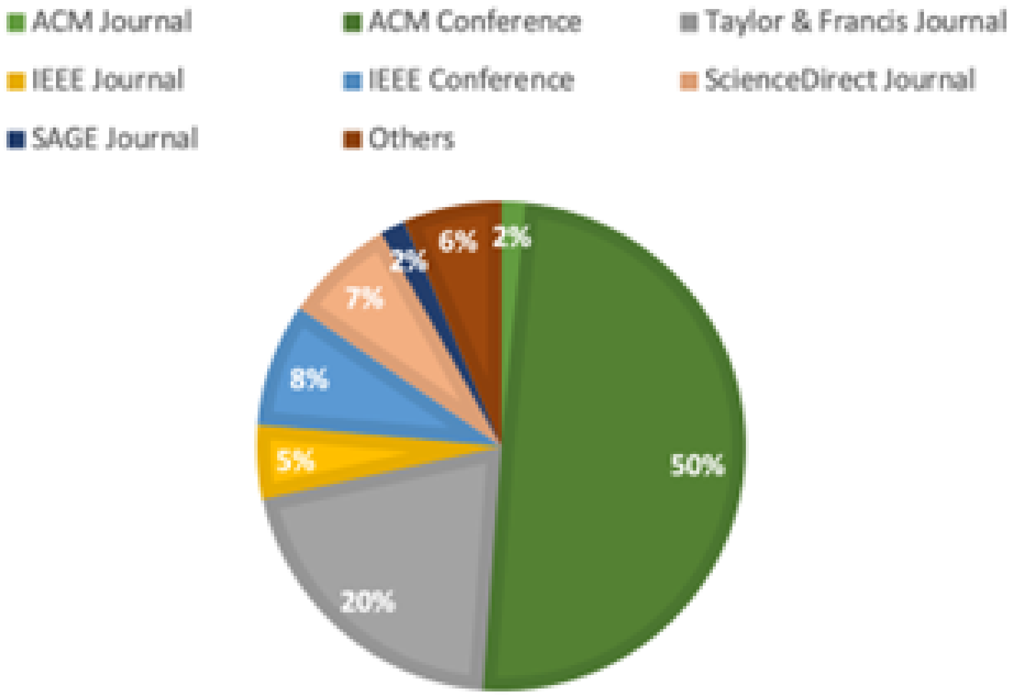

Figure 4.3: Total number of primary studies

4.3 Quality Assessment Criteria

We developed ten questions to assess the quality of each primary study included in this SR. In addition, we created an ex-cel sheet for quality assessment. After identifying high-quality articles, we assigned scores of 1 to those that explicitly addressed the quality assessment questions, 0.5 to those that addressed the quality assessment questions in part, and 0 to those that did not explicitly address the quality assessment questions. As a result, the nature of each selected paper is defined by the [38] criterion. Table 4.2 below contains the quality assessment questions.

Table 4.2: Quality assessment questions.

Q#	Quality Assessment Questions
Q1	Is the research objective expressed straightforwardly?
Q2	Is the paper directly answerable to the exploration's questions?
Q3	Are the selected papers exemplifying distinct approaches?
Q4	Is the method for accumulating information described?
Q5	Do the papers have at least ten citations?
Q6	Are the techniques definable?
Q7	Are the conclusions and scientific discoveries clearly illustrated?
Q8	Is the study add useful/additional contribution to the writing?
Q9	Is the audit able to identify flaws and gaps in the existing study?
Q10	Do the articles establish guidelines for future research?

The following figure 4.4 outlined the overall quality assessment of the primary studies for this SR

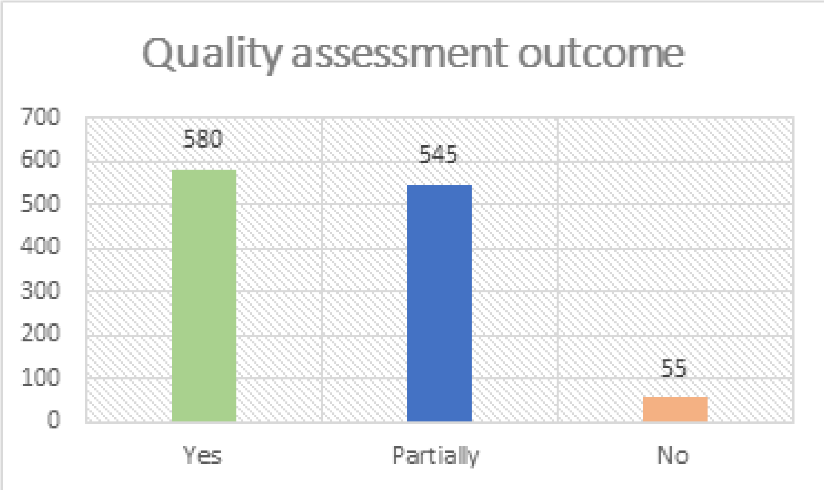

Figure 4.4: The quality assessment questions outcome

The preceding figure 4.4 illustrates that, of the numerous journals assessed, 580 specifically addressed quality assessment questions with a score of 1, while 545 marginally addressed quality assessment criteria with a score of 0.5. Finally, 55 manuscripts did not address the quality assessment questions.

4.4 Data Extraction

For this SR, the following criteria were taken from a range of publications and recordings to perform the data extraction process:

(a) Search methods (manual or automatic)

(b) Bibliography (Journal name, Author, Title, Keywords, Publication Name, Location, and Type)

(c) Primary goal

(d) Research methods

(e) Closing remarks

(f) Research questions and the consequences of their Answers analysis, and we resolved various misunderstandings among ourselves. Inductive reasoning addressed the research questions, beginning with the fundamental notions. They were deleted to avoid the overuse of keywords and phrases. The questions are grouped according to the research topic, addressing a concise overview of the findings. A peer-review process was performed to confirm the consistency of the data.

Table 4.3: List of publications.

Database Names	Type of Articles	Number of Journals	Number of Conferences	Percentage
ACM	Journal/Conference	2	61	53.3
Taylor & Francis	Journal	25	0	21.18
IEEE	Journal/Conference	6	10	13.55
ScienceDirect	Journal	9	0	7.62
SAGE	Journal	2	0	1.69
Others	Journal	7	0	5.93

The overall number of high-impact publications in major journals and conferences from ACM, IEEE, Taylor and Francis, ScienceDirect, and others included in this SR is shown in Table 4.3, along with the journal type, number of papers, and proportion of each publication in related journals. Additionally, most publications are at ACM conferences, whereas most journal articles are published by Taylor and Francis.

4.4.1 Results

The outcome of our SR to outlined in this section. The seven research questions established to be addressed in this SR are included in Table 4.4 and the specific primary study (PS).

Table 4.4: The research questions and the selected primary studies for each RQ.

Research Questions	Selected primary studies	Conference Papers	Journal Papers
What are the positive and negative impacts of COVID-19 on the educational system?	[60] [65] [55] [66] [67] [68] [69] [59] [58] [70]	9	11
What significant changes could occur in the educational system and institutional processes due to COVID-19?	[71] [72] [73] [74] [75] [76] [77] [78] [79]	14	7
What percentage of students are able to follow online learning during the COVID-19 Pandemic, and their satisfaction and concerns from digital learning?	[80] [81] [82] [83] [84] [85] [86] [87] [88] [89] [90] [91] [92] [93] [94]	22	9
How did technology play a vital role in educational institutions during COVID19?	[95] ,[96] [97] [98] [99] [100] [101] [102] [103] [104] [105] [106][107] [108] [109] [110] [111] [112] [113]	15	5
Do faculties and Ph.D. students' research activities impact during COVID19?	[91] [114] [115] [116] [117] [118]	1	5
How does the COVID-19 affect students' psychological and mental health?	[119] [120] [121] [122] [123] [124][125] [126] [127] [128] [63]	2	10
How effectively did educational institutions manage the move from on-campus to digital learning during the pandemic?	[70] [129] [100] [130] [131][89] [132] [79] [91] [92] [133] [134] [135][136]	18	14

Table 4.4 categorizes each research question according to the number of PS selected. Hence, the selected PS is classified according to the frequency of conference and journal papers for each RQ.

4.4.2 Research Question 1

COVID-19's spread has hugely impacted educational systems worldwide, influencing roughly millions of learners in more than 200 nations worldwide. The shutdown of training centers, educational institutions, and other learning platforms impacted over 90 percent of the world's learners, which significantly impacted every part of human-being lives. Policies promoting safe distancing and restricted movement have detrimental effects on long-established instructional practices. Reopening schools fol-lowing limitation easing adds another layer of difficulty since several new standard operating procedures must be implemented [137]. The first RQ examines the COVID-19's negative and positive effects on the educational system. RQ1 aims to ascertain the primary consequence of COVID-19 on education. Numerous studies have been published relevant to RQ1. We di-vided the impacts into two categories. The first section analyzes the COVID-19's negative effects on education systems in table 4.5, while the second section discusses the COVID-19's positive effects on education systems in table 4.14. Transitioning from traditional on-campus education to digital education can be a completely different experience for learners and instructors. They must adjust if they do not have other alternatives. Throughout the outbreak, digital learning platforms enabled training centers, schools, and colleges to promote learning while all educational institutions were physically shut down [56]. Numerous scholars have found and emphasized the following challenges [55][138].

Table 4.5: The COVID-19 negative impacts on education systems.

Negative challenges	Description
Accessibility	Access to online classes was a significant barrier for those living in remote areas without access to technology. Most learners lack access to smartphones and televisions at home and have inadequate web connectivity. x of businesses and offices have been forced to close, leaving a big percentage of the population with no or little income. Most pupils in Bhutan's digital education system come from remote regions where most parents are illiterate farmers. Learners assist their families on the farm with agricultural tasks and household chores. Learners demanded their tests be rescheduled for midday due to their requirement to work in the crops in the early morning hours.

Table 4.6: Negative challenges and solutions for freshers in higher education during COVID-19.

Negative challenges	Description
Freshers	COVID-19's global spread has posed significant problems to old-fashioned higher education, particularly for first-year students without a major; many are unsure about their true abilities. As a result, it is challenging for individuals to make sound judgments based on their abilities. Generally, current approaches focus exclusively on isomorphic data, neglecting relationships between heterogeneous data. In addition, Xia et al. (2021) provides a novel framework for making appropriate suggestions to first-year students based on the analysis of heterogeneous educational data. This framework enables first-year students to determine their skills and recommend appropriate majors and learning materials.

Table 4.7: Negative challenges related to adaptability to digital technologies.

Negative challenges	Description
Adaptability to digital technologies	The COVID-19 outbreak and the subsequent social isolation have impacted all sectors of society, including education. To remain viable, educational institutions have had to adjust to changing circumstances quickly. As a result, an extraordinary push toward online education has occurred. Numerous organizations, including commercial providers of digital education platforms, have hastened to offer their support and solutions, often for free [113]. According to [68], distance learning and remote lesson systems have forced instructors and learners to adapt to digital technology and digital learning. They enable the progression of teaching processes based on teacher-prepared teaching resources and a calendar that has been adapted to the current pandemic.

Table 4.8: Negative challenges related to pedagogy of learning.

Negative challenges	Description
Pedagogy of learning	The COVID-19 outbreak caused a paradigm shift in the educational system's teaching, learning, and assessment approach. Around the world, educational institutions are changing away from traditional or on-campus instruction toward digital learning [104]. Another significant shift in educational methodology occurred because of the COVID-19 outbreak, with an increase in the number of overseas learners studying in Malaysia. International students may be unable to participate in virtual live classes in synchronization with Malaysian time due to the time zone difference between Malaysia and their home country.

Table 4.9: Negative challenges related to investment in creating smart classes.

Negative challenges	Description
Investment in creating smart classes	Because of the COVID-19 outbreak, many instructional institutions have been obliged to transition to digital learning, whether or not they have enough technology resources. Educational institutions must encourage learning via online platforms to preserve the flow of education and generate revenue. Additionally, most institutions invest adequately in developing digital platforms and smart classrooms to close the gap left by the pandemic [69].

Table 4.10: Negative challenges related to institutional financial loss.

Negative challenges	Description
Institutional financial loss	The nationwide closure impacts over 60 percent of the world's learners. The largest educational institutions in the UK, USA, Canada, and Australia depend heavily on the influx of Chinese and Indian learners. Both cross-border and internal movement restrictions hurt financial operations, administrative activity, and educational delivery. Moreover, many parents may be hesitant to send their children abroad for further education in the coming years due to the significant danger of viral infection [69].

Table 4.11: Negative challenges related to student assessments and examination.

Negative challenges	Description
Student assessments and examination	Online assessments of learners are conducted with considerable trial and error, doubt, and ambiguity among instructors, learners, and guardians. The strategy used to take digital examinations differs according to the instructors' flexibility and the students' compatibility. Appropriate procedures to prevent plagiarism have yet to be implemented in many learning centers and institutions, owing to the large student population. An internal assessment and tests for primary public qualifications have been suspended. However, in the United Kingdom, A levels have been canceled for the entire cohort.
state-level board exams cancellation	Recruitment exams, university-level exams, and entrance exams are canceled.

Table 4.12: Negative challenges related to entrance examinations cancellation.

Negative challenges	Description
Entrance examinations cancellation	In most countries, the internal examinations have been postponed and canceled due to the COVID-19 pandemic [55].

Table 4.13: Negative challenges related to disruption of education systems.

Negative challenges	Description
Disruption of education systems	Due to the COVID-19 pandemic, the transition from on-campus instruction to digital learning in most of the world's education systems was a crucial challenge for instructors at all educational levels. Similarly, most educational institutions globally dealt with the crisis somehow, allowing students to continue learning using digital platforms and minimizing the gap imposed by the COVID-19 outbreak. However, educational activities in the least developed nations have been postponed without digital learning due to a lack of internet resources and digital technology facilities [66].

Table 4.14: The COVID-19 positive impacts on education systems: Change in Quality of Digital Learning

Positive impacts	Description
Change in quality of digital learning	The COVID-19 outbreak has impacted the education system and slowed economic growth. The lockdown declared in March 2019 caused an unexpected halt in teaching and assessment. To compensate, educational institutions have offered free online courses and discounts on digital learning sessions. This change in teaching and learning methodologies has been facilitated by ever-growing technologies, propelling the younger population towards digitalization [58, 139]. The shutdown of educational institutions has also affected students' education. One immediate solution is necessary to ensure the continuity of institutes and universities. To ensure a smooth class, an online teaching style is used. Educational institutions use learning management systems and open-source digital learning tools to run digital classes in quality [65]. According to [60], COVID-19 positively influenced learning efficiency and performance through online learning methodologies.

Table 4.15: The COVID-19 positive impacts on education systems: Change in Research Work

Positive impacts	Description
Change in research work	COVID prompted a significant increase in virology research, now potentially accounting for 10-20 percent of all biomedical studies. Sharing study findings and data has become more efficient than ever before. The COVID-19 crisis resulted in an unprecedented surge in publication. Specialty journals are being overwhelmed with submissions, including many COVID-related studies. Since December 2019, almost 20,000 articles on COVID have been published, many in reputable publications. COVID publications are being submitted to preprint servers for quicker dissemination before peer review. Virology research before COVID accounted for less than 2 percent of biomedical studies. COVID has highlighted the importance of virology research. The research community's extraordinary adaptability in the face of the pandemic has been demonstrated [116].

Table 4.16: The COVID-19 positive impacts on education systems: Educational Innovation

Positive impacts	Description
Educational innovation	COVID-19's impact on social, economic, educational, and cultural activities will define 2020. This effect has manifested itself in a slew of changes to the way procedures and services are carried out. Numerous educational innovation projects were undertaken by various researchers at the international conference's Educational Innovation track. The accepted works in Track-6 emphasize information management and cooperative work and models adapted to the pandemic situation pioneered by COVID-19, game-based learning, projects, motivational features, competencies, and mobile technologies [129]. The majority of educational institutions pioneered creativity in the digital learning processes, utilizing various methods to convey knowledge to their learners worldwide. Through digital lectures, digital resources, online tests and assessments, and interactivity in a virtual atmosphere, the outbreak of COVID-19 culminates in a digital revolution in higher education [60, 77].

Table 4.17: The COVID-19 positive impacts on education systems: Student Engagement

Positive impacts	Description
Student engagement	Learner involvement is defined as an engagement in educationally successful methods both in and out of academia. Learner attachment is frequently affiliated with high-impact activities, which refer to various curricular and co-curricular activities such as research works, internships, learning communities, and collaborative projects, which have improved learner learning, determination, and engagement [60]. Learners' attachment in higher education, both in and out of the classroom, has long been a critical component of learner progress and achievement. Maintaining a high level of student participation throughout COVID-19 may be especially critical for students from underrepresented groups in computing. Learner attachment is stated as involvement in educationally successful methods both in and out of the classroom [75].

4.4.3 Research Question 2

Lecturers have spent several months resolving the numerous challenges due to pre-service instructors' career planning inter-ruptions globally. The emphasis has been on escalating existing concerns in certain instances, while the concentration has been on the new issues posed by the pandemic situation in others. Numerous educators and institutions worldwide have taken advantage of the current crisis to experiment with new modes of operation, adopt novel pedagogical approaches, and reconsider the nature of their learning preparation programs. Another article emphasizing substantial changes in education curricula is from The National University of Malaysia, which addresses introducing a technological pedagogical content knowledge framework [140]. The COVID-19 outbreak had a variety of consequences on education at all levels. Institutions and teacher educators were compelled to react rapidly to an unexpected and forced shift away from on-campus instruction toward digital education. Hence, the necessary modifications that educational institutions must make are to create learning environments that are compatible with the goals of instructor education programs and the conditions under which colleges and universities operate [141]. A list of changes that educational systems and the institutional process will witness due to COVID-19 is enlisted in table 4.18 [141] [142].

Table 4.18: Significant factors and descriptions

Significant factors	**Descriptions**
Pedagogical approach	• Teacher as facilitator • Learners at the center • Knowledge integration • Remote learning (Asynchronous and Synchronous)
Learning design	• Flexible • Personalized • Contextualized • Social • Formative • Use of appropriate tools and technology
Facilitation	• Internet facilities • Assessment facilities • Examination facilities

Significant factors	Descriptions
Technological innovation and integration	• Learning management systems (LMS) • The autonomous digital learning hub • Supporting teaching and learning
Sustaining Co-Curricular Connections	Support for extracurricular student activities was another way departments encouraged students to engage in equity-focused activities while participating in distant learning. The administrators and instructors of the Computing Alliance of Hispanic-Serving Institutions assisted student leaders in contacting peers for club meetings and designing online courses to continue providing competent development opportunities such as remote interviewing advice. While the COVID-19 controversy harmed some students' attempts to develop a community, it created possibilities to improvise and accommodate children who would not have been permitted to participate in activities otherwise [75].

Significant factors	Descriptions
Creating a virtual learning environment	Due to the COVID-19 outbreak, several educational institutions moved the learning process from on-campus to a virtual learning environment. COVID-19 mandated that the university and two school districts transfer all students to virtual learning by late March 2020. This marked a significant shift in the project's delivery mechanism for elementary teacher professional development, prompting our team to add two new objectives to the summer institute: assisting teachers in using online technologies and creating an engaging and collaborative virtual environment. The team was inspired by the organizers of the 2020 RESPECT conference and pre-conference seminars, who transformed the event into an interactive online format in a matter of days. The project's key takeaways are as follows: (a) elementary teachers' technology adoption barriers must be addressed; (b) shared physical experiences and a combination of individual and group activities result in active online involvement; and (c) computational thinking is an effective tool for designing and developing a successful virtual professional development experience for elementary teachers [73].

Additionally, the study addresses the significance of a systematic approach to digital education pedagogy that incorporates tech-nology to help the learning process. This study demonstrates that practical education domains such as instructional design require further attention. Additionally, more emphasis should be paid to pedagogical difficulties relating to teaching and learning. Another significant change occurring in educational institutions such as schools, colleges, and universities is improved digital literacy [72]. Our students must have the skills to assess and solve complicated challenges in today's technology-driven era. STEM (Science, Technology, Engineering, and Mathematics) classes provide these abilities. These classes engage students and enhance their ability to think critically, solve problems, be creative, and collaborate. This strategy aims to lay a solid basis for engineering and science literacy, boost diversity, equity, and inclusion in the STEM field, and prepare the workforce for the future [71].

4.4.4 Research Question 3

Educational institutions throughout the globe in the spring of 2020 suddenly transitioned to digital instruction as campuses shut down and the states issued stay-at-home orders in response to the COVID-19 outbreak. Students at several colleges world-wide may have encountered difficulties and inconveniences during the spring 2020 campus closures. Students encountered tech-nical difficulties as courses migrated online [85]. More than 70 percent of students reported having inconsistent wi-fi, while over 10 percent reported having no wi-fi. As a result, over half of the students encountered internet connectivity chal-lenges, making remote studying difficult. Additionally, approximately 20 percent of students possessed outdated computers, im-peding their ability to participate completely in remote learning. The following are some of the difficulties cited by students:

Table 4.19: Student challenges and outcomes

Student challenges	Outcome
I lacked adequate internet connectivity. Due to the financial situation, I was forced to cancel my internet service. Although most of my lessons are virtually conducted, what we are expected to do is unclear.	
Challenges of Taking examinations and quizzes at home	Taking examinations and quizzes was a challenging part of digital learning during the assessment and quizzes time. When a family member is distracting you and your Wi-Fi connection is inconsistent. We constantly worried about not finishing on the due date when my Wi-Fi goes off.
Rural students with low internet facilities	It also resulted from the substandard internet speed at my residency. It's proven challenging to maintain a strong connection during live lectures. The speed challenge caused us to lose Zoom meetings and sessions.
Reliable internet access	We frequently get behind in class and have difficulty understanding what is said.
Student's sense of belongings	Nearly half of learners assessed ”Covid-related stress and anxiety” as ”very” or ”extremely” problematic. Given recent developments surrounding COVID-19, it is vital to underline that these temporary online/hybrid learning environments will undoubtedly put many learners' sense of belonging to the test, particularly entering freshers [143].

Table 4.20: Student challenges and outcomes

Student challenges	Outcome
Learners' frustrations, accomplishments, difficulties, and enthusiasm	Learners were divided on whether the change to digital learning was required following the COVID-19 pandemic. Forty percent of students believed the relocation would be somewhat or extremely difficult, compared to 50 percent who believed it would be somewhat or extremely easy, with 10 percent undecided. However, learners agreed that digital learning to comply with the COVID-19 pandemic was less successful than in-person education. On the other hand, approximately 30 percent of learners reported no significant difficulty transitioning from on-campus to digital learning [81].

However, as indicated by the following statement, some departments and individual faculty members took aggressive measures to ensure students received the required tools. Some universities responded to these technological requirements by providing technical support that enabled learners to finish their courses remotely.

According to some students, the most significant assistance they acquired was support for internet facilities, hot spots, laptop sys-tems, and some specific access to the physical campus where they could use the internet. Given the numerous problems learners face during campus shutdown, faculty served as the primary source of support for learners during spring 2020 remote learning. The majority of learners stated that they sought assistance from teachers during digital in-struction. More crucially, 84 percent of learners rated faculty assistance, whether in or out of the classroom, as useful, with 41 percent rating it as very effective [75] [144]. The research work (Ahmad et al., 2020) examined learners' satisfaction with instructional information systems and their in-volvement with courses. Learners' average ratings on the Likert scale were collected, and the standard deviation (S.D) was ana-lyzed to observe dispersion in mean scores. The findings indicate that students' overall satisfaction with educational information systems remained satisfactory, with an average of 3.8 (SD = 1.1) and a confidence interval (CI) of 0.2 at a 95 percent confidence level. Learners also performed better in visual aesthetics, with a mean score of 3.6 (S.D. = 1.2). Additionally, learners expressed their dissatisfaction with how courses are communicated via educational information systems and how they are not effectively increasing their learning as expected. Additionally, they demonstrated ineffective engagement tactics, a lack of assistance during lab work, and online activities that were not carefully developed to maximize their talents. The average mean score in communication and effectiveness of infor-mation systems was 2.3 (S.D = 1.0), which is inconsistent. Students demonstrated considerably greater unhappiness with lab work, scoring an average of 2 (S.D = 1.0) and 2.6 in engaging in online activities (S.D = 1.3). Table 4.21 contains five questions to assess learners' satisfaction following the institution's administration, staff, and students' thorough preparation before the deployment of digital instruction in Vovinam college since the COVID-19 outbreak. The overall agreement percentages are quite dramatic, ranging from 74.02 percent to 91.67 percent. The mean value is 4.16, and the standard deviation is 4.62, indicating a high level of contentment. The incidence of disagreement is relatively low, ranging between 1.96 percent and 10.78 percent. Between 6.37 and 15.2 percent is considered neutral. The question with the maximum average score, 4.62, and the largest percentage of agreeing with learners, 91.67 percent, is about providing learners with prior information about the platforms and applications utilized in online teaching and learning during the COVID-19 crisis [94].

Table 4.21: Satisfaction of learners with Vovinam's preparation for digital learning.

Questions	SD	D	N	A	SA	MV
I acquired assistance on how to learn digital learning during COVID-19.	3.43	2.94	12.75	18.14	62.75	4.34
Throughout the COVID-19 pandemic, I was told about the systems and applications utilized in my classes.	0.49	1.47	6.37	18.63	73.04	4.62
The educator enrolled me in the Vovinam class for us to discuss learning exercises during COVID-19.	6.86	3.92	15.20	14.22	59.80	4.16
I can learn online during COVID-19 with a reliable system and web connection.	0.49	2.94	7.35	17.65	71.57	4.57

Table 4.22: Accommodation for digital learning during mid-COVID-19 pandemic.

My accommodation is peaceful, and there is sufficient room for digital learning in the mid-COVID-19 pandemic.	2.45	8.33	13.24	13.24	62.75	4.25

Similarly, during the pandemic, learners took an average of four online classes compared to one course before the outbreak. 68.7 percent of learners were happy with digital and remote learning, and 41.6 percent would not suggest it to others. Nonetheless, learners expressed satisfaction with the education during digital learning 60.9 percent, and nearly half, 47 percent, expressed satisfaction with the flexibility provided by online learning. 35.2 percent of students expressed dissatisfaction with the time required to obtain learning resources, while 34.4 percent expressed dissatisfaction with teamwork during digital learning, detailed in table 11 [145].

Table 4.23: Learner's satisfaction with digital learning during the COVID-19 pandemic.

Tools	Learners opinions	M	SD	N	SD/D %N	N %N	SA/A %N
	Course assignments were communicated clearly.	3.52	1.06	358	18.4	21.5	60.1
	The assessment, the test, and the feedback were all completed as scheduled.	3.13	1.21	358	32.4	21.8	45.8
Instructor	I was a member of the class and a participant in the online course.	3.58	1.03	358	12.0	29.1	58.9
	I trust the faculty members' accessibility.	2.81	1.12	358	38.8	33.5	27.7

Table 4.24: Content table 2

Tools	Learners opinions	M	SD	N	SD/D %N	N %N	SA/A %N
Technology	I'm content with digital learning platforms.	3.18	1.16	358	27.7	27.4	45.0
	I am content with digital communication, which includes email and notifications.	3.56	1.16	358	17.9	21.2	60.9
	The Blackboard LMS is user-friendly.	3.56	1.11	358	15.4	23.2	61.5
	I'm satisfied with download speeds for educational information.	3.05	1.21	358	31.3	33.5	35.2

Table 4.25: Content table 3

Tools	Learners opinions	M	SD	N	SD/D %N	N %N	SA/A %N
Setup	I am impressed with the quantity of digital learning sessions.	3.27	1.17	358	20.7	32.1	47.2
	Online classes give you greater schedule flexibility.	3.19	1.23	358	29.1	23.5	47.5
	I am content with the self-directed activities I have been handed.	3.01	1.13	358	30.4	37.2	32.4
	I enjoyed collaborating on projects during COVID-19 on my digital learning.	3.19	1.26	358	28.2	29.6	42.2

Table 4.26: Content table 4

Tools	Learners opinions	M	SD	N	SD/D %N	N %N	SA/A %N
Interaction	I am content with the level of engagement between myself, my teachers, and my colleagues.	3.15	1.14	358	28.2	27.9	43.9
	I'm satisfied with interactive tasks in online learning.	3.02	1.13	358	30.7	34.9	34.4
	I am able to compare my level of comprehension to that of other students.	3.33	0.99	358	16.2	42.2	41.6

Table 4.27: Content table 5

Tools	Learners opinions	M	SD	N	SD/D %N	N %N	SA/A %N
Outcome	I am confident in my ability to participate in online courses.	3.16	1.20	358	26.8	31.6	41.6
	I am content with the level of effort needed in digital learning.	3.09	1.33	358	30.7	24.3	45.0
	I am pleased with how I performed in the digital learning during COVID-19.	3.17	1.24	358	29.9	29.3	40.8
	I am happy with my final results from COVID-19.	2.99	1.17	358	31.0	34.6	34.4

Table 4.28: Content table 6

Tools	Learners opinions	M	SD	N	SD/D %N	N %N	SA/A %N
Overall satisfaction	I am capable of using the knowledge I gained in digital learning during COVID-19.	3.08	1.19	358	29.6	28.8	41.6
	I will tell others about the positive impact of digital learning.	2.81	1.29	358	41.6	22.6	35.8
	I prefer online learning to face-to-face education.	3.94	1.14	358	10.9	20.4	68.7

Table 4.29: Content table 7

Tools	Learners opinions	M	SD	N	SD/D %N	N %N	SA/A %N
Online courses	My degree of satisfaction pushes me to enroll in other distance learning.	1.39	2.78	358	26.3	32.7	41.1
	In general, I am pleased with digital learning during COVID-19.	3.04	1.24	358	30.7	27.9	41.3

SD = strongly disagree; D = disagree; N = neutral; A = agree; SA = strongly agree

4.4.5 Research Question 4

The COVID-19 pandemic is still growing. Technology is gaining popularity in a wide range of application domains. In the domain of education, technology aids the distribution of knowledge and information acquisition by enabling the availability of course materials and virtual learning. Online learning has been crucial during the COVID-19 outbreak [95]. The requirement to perform socially and professionally while staying at home and socially isolating has resulted in the widespread acceptance of online meetings and remote working. Digital education is critical, as millions of learners worldwide struggle to complete their studies in these challenging times [146]. Technological components and digital educa-tional platforms are critical components of the education ecology of universities worldwide, serving as an engaging medium for introducing subject content, mediating diverse modes of learning, administering homework assignments, and managing student records. Without a physical classroom, interactions between learners and instructors and access to classroom tools were impossi-ble. Academies responded by adopting various existing digital infrastructure, tools, and applications to enable instructors and families to participate in an online version of education. For instance, each participating institution designated a learning management system. Parents and instructors could access teacher-assigned learning assignments, upload completed assessments, ask questions, and receive feedback from the instructors. Additionally, instructors referred learners to curriculum-aligned technology-based learning platforms such as Mathletics1, Manga High2, Study Ladder3, and Decodable Readers4 to supplement numeracy, literacy, and language instruction. Moreover, pre-produced YouTube videos were used extensively to expose children to various themes, including science, sustainability, health, and physical education [96]. Comparative research among Spain, Italy, and Ecuador focuses on using smartphones and content consumption in digital learning during the COVID-19 pandemic. Learners' use of technological devices has increased throughout the lockdown time. As a result, the analysis demonstrates that the tendency is consistent across the three countries. Spain, with 96.2 percent, and Italy, with 96 percent, have extremely high rates; nevertheless, Ecuador, despite its high rate, has a lesser rate of 85 percent, a characteristic related to the region's socioeconomic status idiosyncrasies. The study confirms a significant increase in technology usage due to the COVID-19 pandemic's containment in the gadgets most frequently used during quarantine. Moreover, the research indicates that the mobile phone and laptop are the two devices that have seen the largest growth during the pandemic [98]. Consequently, the study by [99][112] illustrates in table 4.31 the digital resources utilization during the COVID-19 pandemic in digital learning.

Table 4.30: Technologies used during COVID-19 in education institutions.

Technologies	Usages	Secondary Education	Higher Education
	Yes	42.9 %	97.3 %
Zoom	No	57.1 %	2.7 %
	Yes	47.9 %	6.8 %
Google Classroom	No	51.1 %	93.2 %
	Yes	36.1 %	85.1 %
Microsoft Teams	No	63.9 %	76.8 %
	Yes	23.5 %	52.7 %
Moodle	No	76.5 %	47.3 %
	Yes	39.7 %	34.2 %
WhatsApp	No	60.3 %	65.8 %
	Yes	13.7 %	9.7 %
Facebook	No	86.3 %	90.3 %

The study by [147] discussed the role of technology on students and teachers in the education context and the possibilities for technology use during the pandemic. Learners' perspective is to address current educational difficulties by suggesting novel approaches to teaching-learning, with a demand for increased interaction and a want for more technological tools in their lectures. They asserted that the ICT tools assist their learning because of their diversity. On the other hand, instructors do not share their students' perceptions of the learning process. They feel their learners have only mastered tasks requiring autonomy and collaboration. Another study [3] suggests a blended learning strategy incorporating a MOOC platform, a live broadcast platform, an experimental platform, and other technologies. This digital learning technique incorporates webcast instruction, web-based learning, digital instruction, remote practice, and post-class self-study. The majority of research discuss the beneficial impact of technology during COVID-19, not just in the education sector, but also in other disciplines [101][102][103].

4.4.6 Research Question 5

The COVID-19 outbreak has marred numerous researchers, Ph.D. candidates, and academicians. Due to the reduction of in-person activities at educational institutions. As a result, several Ph.D. candidates have encountered additional obstacles[148]. COVID-19 also inflicted devastation on an unequaled scale in human history, massacring tens of millions of people, ruining economies, closing borders, and wreaking havoc globally. It has strained hospital resources and workers in many areas and will have a long-term impact on medical research, both short and long term. Before the COVID out-break, medical research comprised less than 2 percent of all biomedical research. Nonetheless, the number of laboratories and researchers pivoting to address COVID-19 related research concerns is impres-sive, accounting for approximately 10 to 20 percent of current biomedical inquiry, illustrating the scientific community's remarkable adaptability [116]. Japan used safe distance as one of the approaches for countering COVID-19; it included the 3 C model denoting knowledge of the below: a) Confined spaces with limited ventilation, b) Congested settings, and c) Closed conversations. The campaign against the COVID-19 pandemic has also impacted research at academic institutions, with many scientists forced to halt or curtail their work during the outbreak [13]. Wet-lab experimentation, which involves using experimental equipment and reagents, cannot be recreated in remote working situations; even if investigators can conduct studies in a lab, new coronavirus transmission increases due to the 3 C model occurring in the lab. As a result of the outcome-based system in which researchers worldwide (including in Japan) operate, delays in research may result in increased emotional hardship for biologists [115]. The same authors [115] also conducted a study on the impact of COVID-19 restrictions on 300 researchers. Table 4.32 highlights the variables for which significant variations were identified in response to the following question: "How much effect does COVID-19 have on your research activity?" In the group whose research workplace was disrupted by COVID-19 restrictions, many respondents claimed being tormented and a negative atmosphere pervading their laboratory. On the other hand, the proportion of people who reported a pleasant atmosphere in their laboratory is low among the groups significantly impacted by COVID-19 interventions. COVID-19-affected individuals expressed high levels of worry about upcoming laboratory work and a decline in enthusiasm to do research.

Table 4.31: The consequence of COVID-19 barriers on the research activities in 300 researchers using factor analysis.

Questions	Criterion	Serious	Some	No	P-value
	Strongly	5.9 %	11.8	3.2	
Have you ever felt as though you were being harassed?	Moderately	11.8%	3.2	3.2	0.0208
	Others	82.4 %	85.0	93.5	
	Often	15.7 %	8.0	4.8	
As demonstrated by the question, a pessimistic tone prevailed. Should we perform research in light of this circumstance?	Sometimes	25.5 %	20.3	6.5	
	Neither	27.5 %	25.1	22.6	0.0008
	Not much	19.6 %	26.7	22.6	
	Often	9.8 %	3.2	12.9	
	Sometimes	5.9 %	16.0	16.0	
Constructive research environment amidst a critical condition: conduct research.	Neither	33.3 %	37.4	37.4	0.0053

Table 4.32: Future concerns and motivation changes of 300 researchers during COVID-19.

Questions	Criterion	Serious	Some	No	P-value
	Not much	19.6 %	24.6	9.7	
	Not at all	31.1 %	18.7	32.3	
Do you have concerns regarding the future of your research?	A little	49.0 %	54.5	29.0	0.0001
	Not so much	15.7 %	28.3	46.8	0.0001
	Not any	0.0 %	1.6	21.0	
	Significantly decreased	25.5 %	4.8	0.0	
	Slightly decreased	13.7 %	21.9	8.1	
How much change has occurred in terms of your motivation?	No change	43.1 %	63.6	71.0	0.0001
	Slightly increased	7.8 %	7.5	12.9	
	Significantly increased	9.8 %	2.1	8.1	

The chi-square test determined the P values. *Not significant. To summarize RQ5, the COVID-19 pandemic has presented new difficulties to global academic researchers. There is a need for a deeper understanding of the COVID-19 and its socioeconomic consequences through educational studies. Future re-search will be multidisciplinary and global, fostering a new wave of biological and medical research in general for humankind's health [117].

4.4.7 Research Question 6

The pandemic increased the danger of death from a viral infection, but it also put Chinese citizens and the entire world un-der intolerable psychological strain [149]. The pandemic's continued growth, safe distancing practices, and postponement in re-opening institutions, colleges, and learning centers worldwide are expected to affect college learners' mental well-being. The study by [123] focused on undergraduates at a Chinese medical college. The surveys were completed by 7143 re-spondents, who were considered in the final analysis. They used standardized questionnaires to measure these pupils' psychologi-cal well-being during the outbreak. Table 4.34 outlined the extent to which the pandemic affected the psychological well-being of college students. 75.1 percent of all participants exhibited no anxiety symptoms, whereas 21.3, 2.7, and 0.9 percent of learners had mild, moderate, or severe anxiety.

Table 4.33: The total number of students with various degrees of anxiousness.

Anxiety	Quantity	Ratio (%)
Typical	5367	75.1
Medium	1518	21.3
High	196	2.7
Severe	62	0.9

The association between learner demographic factors and anxiety is depicted in Table 4.35. Residing with families had a ma-jor influence on distress, with learners living alone experiencing increased anxiety (P.05, whereas gender and area had no signifi-cant effect on anxiety (P ¿.05. Additionally, learners from remote regions, 1.02 percent, families with unstable earnings (1.09 percent, learners who did not live with their parents 1.13 percent, and learners who had a relative or acquaintance infected with COVID-19 2.56 percent were significantly more likely to be seriously stressed P.001.

Table 4.34: University Students' Anxiety over the COVID-19 Pandemic: A Univariate Analysis.

P-value	Factors	Total	Anxiety Level				Statistics
			Typical	Medium	High	Severe	
Gender 0.421							-0.805
	Male	30.35%	75.78%	20.66%	2.35%	1.20%	
	Female	69.65%	74.85%	21.51%	2.91%	0.72%	
None 0.864							0.292
	Hubei Province	0.94%	73.13%	23.88%	2.99%	0.00%	
	North	83.85%	75.04%	21.40%	2.72%	0.84%	
	South	15.32%	75.78%	20.29%	2.83%	1.10%	
Residency 0.001							30.550
	Urban	35.98%	78.75%	17.74%	2.68%	0.82%	
	Rural-urban	20.18%	74.97%	21.98%	2.43%	0.62%	
	Rural	43.83%	72.25%	23.79%	2.94%	1.02%	
ParentsIncome 0.001							-7.262
	Yes	47.14%	79.03%	18.15%	2.20%	0.62%	
	No	52.86%	71.66%	24.02%	3.23%	1.09%	
ResideWithParents 0.014							-2.457
	Yes	95.04%	75.40%	24.02%	2.62%	0.85%	
	No	4.96%	70.06%	24.02%	5.08%	1.13%	
FriendsGotCOVID-19 0.001							-3.553
	Yes	0.55%	51.28%	38.46%	7.69%	2.56%	
	No	99.45%	75.27%	21.16%	2.72%	0.86%	

Another study [124] examined 3,707 students and staff, of whom 2,530 were affiliated with the Spanish university of Valladolid and thus comprised the sample for this study. 66.1percentt of the respondents were female, and their ages ranged from 18 to below 75 years (M = 27.9, SD = 12.4). Students made up 76.8 percent of the participants, administrative personnel made up 9.8 percent, and teachers and academic staff 13.4 percent. Table 4.35 describes their characteristics concerning their circumstances at the University of Valladolid.

Table 4.35: Participants' unique features concerning the circumstances at the University of Valladolid.

Institution condition	Quantity %
Team	
learner	76.8%
Managerial personnel	9.8%
Instructors members and academic personal	13.4%
Learner group	
Undergraduate	90.1%
Postgraduate	6.9%
Researcher	2.4%
Other	0.5%
Area of Study	
Arts & Humanities	13.5%
Sciences	10.2%
Health Sciences	17.2%
Social Sciences and Law	37.0%
Engineering and Architecture	22.0%

Table 4.36: Institution Condition and Study Area Distribution

Institution condition	Quantity %
Year (undergraduate students)	
1	22.5%
2	24.1%
3	19.6%
4	26.4%
5	4.5%
6	2.6%
Not willing to say it	0.3%
Study area (Researcher)	
Humanities & Arts	20.9%
Sciences	13.3%
Medical Sciences	15.0%
Social Sciences and Law	24.8%
Engineering and Architecture	26.0%

Master students were compared to Ph.D. students in terms of sadness, anxiety, and stress. Except for the anxiety subscale, E&A learners scored significantly lower than students from other batches on all three subscales. Undergraduate students in their sixth year of study (including only medical learners) had much lower anxiety and stress ratings than fresher students. At the same time, fourth-year students also had significantly lower depression scores than fresher learners. Instructors and academic adminis-trators from the A&H region scored significantly higher on the three subscales than workers from the E&A area. In contrast, la-borers from the HS area scored significantly higher on the anxiety subscales [124]. Another study found that 53.8 percent of those surveyed in 1210 cities across China rated the mental and psychological consequences as moderate and severe. 16.5 percent reported higher levels of emotional symptoms of depression; 28.8 percent reported moderate to severe anxiety and depression, and 8.1 percent reported high to severe anxiety levels. Extended lockdown had several negative consequences for mental health. Participants aged 12–21 years demonstrated a greater psychological effect four weeks after the commencement of COVID-19 in a survey. This age demographic was primarily composed of learners who had been suspended from school for an extended period, necessitating digital education support and creating confusion about assessments and admission procedures. Additionally, individuals with pre-existing psychiatric problems had barriers to receiving mental health support during the quarantine[122]. Another research finding examined Bangladesh pupils' mental well-being during the pandemic. According to the results, 57.05 percent of students had mild to extremely severe stress, comparable to a study of adults in Bangladesh 60 percent. The findings could be compared to another study that found that 28.50 percent of Bangladeshi pupils had moderate to severe stress during the pandemic. Moreover, the study indicates that 26.66 percent of learners experienced typical to high anxiety, which is fewer than the Bangladeshi study's 33.28 percent who expressed moderate to severe worry and higher than the China study's 7.7 percent, but close to another China study's 24.9 percent [125]. Furthermore, a few studies by [150][121] assessed and measured the influence of perceived e-Learning misconduct on psychological distress and mental health experienced by university students during the COVID-19 outbreak. University learners are undergoing psychological distress due to inadequate e-Learning technologies and worrying about wasting an academic year. Consequently, [127] performed a study of 1182 learners of different ages from various educational institutes in Delhi, India. The article discussed the numerous effects of COVID-19 on all modes of instruction, digital classrooms, and learners' mental health. 13.6 percent of respondents across all age groups reported experiencing well-being-related concerns during the period of worldwide travel restrictions. Likewise, when students were asked about their body weight fluctuations throughout this period, 37.1 percent reported a dramatic increase, 17.7 percent reported a decrease, and 45.3 percent revealed no transformation.

4.4.8 Research Question 7

The circulation of the COVID-19 pandemic engulfed the globe, morphing economies, health, and education at all levels and among all people. Elementary, intermediate, and tertiary education had consequences, leaving higher education institutions to deal with it independently. In most countries, traditional classroom instruction has been phased out from on-campus learning to entirely digital learning [151] UNESCO and UNICEF estimate that the global impact of COVID-19 on education in early March affected approximately 295 million learners by 7 June 2020 and about 2 billion students in 193 nations, accounting for 99 percent of the population today (UNESCO, 2020). Today's students and instructors are more digitally adept than previous generations, spending hours watching television, surfing the web, and streaming video, not to mention gaming. These activities will facilitate the development of creative teaching and learning initiatives that will allow schools to evaluate and enhance faculty, student-teacher, and student achievement. Educational institutions were not exempt from this rule. California's and the rest of the United States' higher education systems continued to operate primarily online, with only a few on-campus courses. Due to a surge in several cases in New York and New Jersey and subsequent dissemination of the virus to additional states. They added synchronous and asynchronous virtual teaching to their services. Educational institutions and their teacher preparation programs followed suit. Prospective teachers not only attended classes on campus but also participated in school activities. In partnership with school districts, colleges, and cooperating teachers, educational institutions continued experimental school placements in spring 2020. Faculty members in teacher preparation programs developed alternative plans that included instructional methods, technologies, and tools to ensure that teacher candidates acquired the expected expertise, skills, and cognitions during their teaching experience, as defined by professional licensing agencies. They also included experimental observations and student teaching guidance [151]. Another study (Osman, 2020) examined the effect of the COVID-19 outbreak on the Sultanate of Oman and the educational platform in general. Additionally, they present an analytical assessment of the college experience and the lessons learned from the pandemic's impact on the shifting education and learning landscape and the dissemination and adoption of e-learning in education systems. They implemented a plan for Emergency Remote Teaching (ERT). Before implementing the ERT strategy, the institution prioritized this vulnerable group of learners. The Department of learners with disabilities provides a variety of assistive technologies to these students, including the NVDA screen reader, Index Everest v5, Natiq Reader, Braille display, OCR tool for PDF reading, and text to speech tool. Moreover, the Department established needed instructional changes for disabled learners enrolled in online courses. Another study by [152] examined how early career instructors adjusted to digital learning during the COVID-19 education cuts. Almost all teachers stated maintaining contact with their learners and parents. In addition to assigning tasks and providing feedback, the instructors stated that they had introduced new learning information to their learners. Furthermore, the computer technology accessible at the institution played a vital role. Tutorials were substantially associat-ed with maintaining social interaction, providing online lectures, and task differentiation. The Media Competence Framework was built by six subject areas in Table 4.38, spanning text generation programs to algorithm manipulation.

Table 4.37: Scale inventory of options for teachers to develop technological competence during their education.

Subscale	Item example	No of items	Alpha %
actuate and deploy	Digital information and data organization, structure, and security (teaching resources and project information)	4	0.62
Educate and research	Undertaking targeted data through internet searches and in online libraries (documents, date, literature)	4	0.80
Collaborate and information exchange	Regulating digital interaction, addressing media-related behavioral issues.	4	0.68
Supply and presentation	The planning, design, and presentation of media goods in an age-appropriate manner for the intended audience (learners), as well as their appropriate distribution	4	0.72
Evaluate and analyze	Analyze media characters' roles and influence on media education: businesses, interest groups, governments, individuals, and news media.	4	0.82

Additionally, a few research [153][154] indicated that most educational in-stitutions and policymakers cultivate, recruit, and retain a robust instructor workforce. For instance:
a. Focus on high learning is considered, including residencies in high-need communities for teachers and leaders.

b. Adapt educator professional development options to meet contemporary needs

c. Assist mentors and new teachers in their roles

d. Establish a time for collaboration

e. On- and offline practicums and practical learning

Consequently, several other studies [155][156] conducted an assessment of the literature on online teaching and learning strategies in teacher education, analyzing 134 empirical papers. In terms of teacher education, it is necessary to explain how institutions and individuals adapted to the new normal created by the COVID-19 pandemic. The findings emphasized the importance of a complete vision of online education pedagogy that incorpo-rates technology to help teaching and learning [157].

4.5 Threats to Validity

This systematic review established that certain research fields demand particular consideration. To begin with, a stronger emphasis on practical learning areas such as instructional design and engineering education should be established. Additionally, greater attention should be paid to the pedagogical issues supporting cognitive enhancements. In the meantime, some research described educational methods that facilitated reflection and knowledge acquisition, but not all of them discussed the pedagogical issues. Additionally, further studies are needed to determine the impact of an integrated digital education and learning pedagogy. Additionally, research should utilize a holistic approach to examine engineering education difficulties and include practical principles in urgent scenarios like the COVID-19 outbreak. Finally, a stronger emphasis should be placed on practical and theoret-ical teaching experiences. While research on practicum experiences in virtual teacher education addresses these concerns, addi-tional research on practicum experiences in other procedural areas such as physical education, music, and visual arts is desirable [141].

4.6 Discussion

To the best of our knowledge, the COVID-19 pandemic and lockdown marred nearly every sector of society, most notably education worldwide; people were forced to relearn how to organize communication and contact. We presented a systematic re-view of the pandemic's global consequence on education to ascertain how the pandemic affects education systems differently and globally. Our research questions focused on the global effect of COVID-19 on the educational systems, learners' contentment and concerns with digital learning, faculties and researchers' research activities, the role of technology in the learning process, changes to educational institutions, student mental health, and overall, the effective transition from on-campus learning to digital learning. The present study provides comprehensive insight on the impact of the pandemic and the innovations in digital learning by most of the educational institutions wordwide. Firstly, in the RQ1, we examined the overall impact of the COVID-19 on the education system globally. We found that the closure of instructional institutions harmed the education system and the teaching-learning process during this lockdown time and caused negative and positive influences. During this crisis, the teaching-learning process is critical to devise appropriate interventions to ensure that teaching and learning continue to operate smoothly [60]. Despite the significant obstacles posed by the COVID-19 outbreak, certain countries China [158], Georgia [70], the United States of America [75], India [60][65], Pakistan [126], Bangladesh [125], Philippines [159], Spain [124], Vietnam [160], Indonesia [77], Morocco [58], United Kingdom, Mexico [66], Oman [161], Brazil [68], Argentina [72], Japan [115], Netherlands [162], Germany [152], and Egypt [76] have implemented processes to mitigate the impact of education cuts via remote education, while others have officially announced the end of the academic year. Since education cuts, governments have addressed the difficulties and complications associated with implementing digital education options. These obstacles center on digital material deployment, teacher assistance, family orientation, and overcoming connectivity issues [58]. Secondly, in the RQ2, we addressed the significant changes that occurred in the educational system and institutional processes due to the COVID-19 pandemic. Numerous publications, such as those from Oman [161], Argentina , [163] and California [164], provide a compelling narrative of what occurred in the subsequent months, instructional shutdowns, the transition to the digital learning environment and the resulting rapid growth of the technological knowledge and skills required of faculty members. The following paper [140] summarizes an empirical investigation that focused on three critical factors in the shift to digital learning in the educational institutions a) connectivity, b) involvement, and c) interaction; it also provides certain valuable clues for how these concerns might be handled as we continue to develop these innovative instructional strategies. The abrupt, unanticipated, and mandated change from on-campus to digital education has caused the creation of different obstacles, limitations, and opportunities that must be explored. Available literature indicates the existence of an emergency electronic education, the challenges associated with inadequate digital teaching facilities, instructors' lack of experience, the communication and information gap, i.e., limited resources and information available to all pupils, and the tight environment at home. Furthermore, a lack of mentoring and support and concerns about instructors' abilities to adopt digital instructional methods have been observed [141]. Subsequently, in RQ3, we investigated the possibility of students' participation in digital learning during the COVID-19 pandemic and their satisfaction and concerns about digital learning. Meanwhile, most students lack control over their time in science and engineering classes. They feel stressed and require direct support from the instructor and adequate access to information communication technology (ICT) facilities such as laptops, personal computers, and the availability of internet signals for each learner. While most learning occurs in a linear fashion, there are still obstacles to boosting learners' capacity to solve issues that need higher-order thinking skills. Additionally, they indicate their interest and satisfaction with the flexibility of study time. They are taught to learn more autonomously, and a larger number of learners grasp ICT equipment and facilities. This enables learners to be more creative when completing tasks and searching for lecture references while also allowing for more efficient storage of the material presented. In other words, the digital imprint left behind enables pupils to review their lectures numerous times [80]. Our RQ4 investigated the vital role of technology in educational institutions during the COVID19 pandemic and lockdown. By serving as the sole platform for instructional design, delivery, and evaluation, technological education has played a critical role in mitigating the impact of this pandemic on educational programs [104]. As researchers from diverse disciplines attempt to develop pandemic prevention and control mechanisms, there is a need to exchange current study findings to foster collaborative inquiry and technological networks to ensure the viability of Covid-19 research. Furthermore, digital education is deeply rooted in the planning and design of course resources using several available theoretical approaches. The migration of universities to digital learning has been challenged due to the low quality and proper planning, design, and development of digital instructional programs during the pandemic [165]. Online schools can benefit children of all ages but are not a suitable substitute for on campus education. Even though many private school instructors in India have the technology and digital infrastructure to educate virtually, this is not the situation for the vast majority of public educators [166]. Technology is gaining popularity in a variety of application areas and contexts. Technology paved the distribution of knowledge in education and information acquisition by enabling the accessibility of educational resources and digital learning. Digital learning was demonstrated to be necessary for COVID-19. Moreover, studies indicate a large increase in technology use in all examined contexts following the pandemic; different variables may have contributed to these increases, depending on the environment. Perceived social isolation, pandemic fears, and tracking have the greatest influence on how people utilize technology during the pandemic and lockdown [95]. The adaptations of the instructors and learners with different technologies had a dramatic increase during the pandemic. Teachers received specialized training in digital learning, either to enable them to use the technological platforms obtained by certain individuals or those open to the public, such as the Digital Class. Google Classroom. Technology aided in education improvement and contextualized the refounding of institutional relationships and the modification of teaching practices and instructional objectives [99]. In the RQ5, we find out about the impact of COVID-19 on faculties and students' research activity. Numerous sectors have seen a dramatic surge in research activity conducted by various researchers and educational institutions. Before the outbreak of COVID-19, medical sciences research accounted for fewer than 2 percent of all scientific research. Nevertheless, the quantity of labs and researchers pivoting to address COVID-19 related research concerns is impressive, perhaps accounting for 10 to 20 percent of current biomedical exploration, demonstrating the scientific community's extraordinary adaptability [116][116]. Additionally, according to a study [115] on 10,557 individuals through a questionnaire, COVID-19 has a deleterious effect on research efforts. Almost (1963), researchers engaged in more research activities and suffered greater intimidation than non-researchers (8572). Additional research on the consequence of COVID-19 restrictions on 300 researchers was carried out. Females were far more likely to report being intimidated than males. Females had a higher overall decline in motivation for research. Restriction of research operations due to COVID-19 outbreak constraints resulted in future anxiety and reduced interest in research. Overall, the increase in the research work is considerable during COVID-19 in non-technical fields. Subsequently, in the RQ6, we explored the COVID-19 impacts on students' psychological and mental health. It is well-established, from a mental health perspective, that school-aged students' socialization influences their learning and behavior, which in turn affects their scholastic, psychosocial, and interpersonal performance [61]. We discovered through multiple studies that the COVID-19 pandemic had impacted learners' physical and mental health since its outbreak. Numerous students, respectively, reported minor to extremely serious anxiety and depression. Nearly 58 percent showed minor to particularly serious levels of stress among Bangladeshi students [125], Chinese students [122][123], Spanish students [124], Indian students [63][127], and Pakistani students [126]. Finally, in RQ7, we have investigated the effective transition of educational institutions from on-campus learning activities to digital learning. Many institutions worldwide have either abandoned or delayed all campus events and other programs in response to concerns. Institutions implemented ex-traordinary efforts to prevent and safeguard all learners, professors, and employees from contracting the extremely contagious disease. As a result, all face-to-face classes were converted to online courses. The COVID-19 pandemic occurred due to the shift from on-campus to a digital platform [167]. Educational institutions experience a profound shift in facilitating learning. Technically, this approach entails several digital learning activities and the implementation of various technology to achieve the provision of skills, leadership, and social consequences. As a result, various colleges redefined their curricula to include the use of technology and critical aspects of technology [130][168]. Furthermore, various institutions worldwide, such as the Philippines [159], Indonesia [89], India [169], the United States (W. Wang et al., 2021) [92], Vietnam [170][167], China [136][158], and Georgia [70] have successfully shifted to digital learning during the COVID-19 outbreak. They are experimenting with a new approach to teaching reform that combines online and offline components. Overall, the transition resulted in substantial changes in how digital learning is used across diverse institutions worldwide amid the COVID-19 pandemic.

4.7 Conclusion

The current SR addresses all seven RQs by systematically reviewing COVID-19's global impact on education worldwide. The RQs addressed most of the COVID-19's potential impacts on educational settings. Students' psychological and mental health, technological advancements, students' concerns and satisfaction with digital learning, significant changes in the educational system, faculty and student research activities, and the effective transition of educational institutions from on-campus to online learning. Apart from its negative consequences, the COVID-19 positively affected global education systems. Switching from traditional on-campus education to online mode was a completely new experience for both learners and instructors, which they were forced to adapt to without other options. The pandemic's major obstacles and detrimental effects on education were the learners' and teachers' access to digital materials. Access to online classes was a significant barrier for those living in distant areas without access to technology. Most pupils lack access to smartphones and computer systems at home, and their Internet connectivity is inadequate. Another significant detrimental effect of the pandemic has been on first-year students, who are uncertain of their true skills. Despite these negative consequences, global education institutions saw remarkable technical advancements during this pandemic by facilitating the availability of course materials and virtual learning, technology dissemination of knowledge, and information in the educational context. During the COVID-19 outbreak, online education was important. Additionally, we detail the pandemic's negative and beneficial effects in Tables 6 and 7 of Section 4. Finally, numerous educators and institutions worldwide have used the current crisis to experiment with new modes of operation, implement unique pedagogical approaches, and rethink the nature of their learning preparation programs.

Chapter 5

Competency Based Education and Teaching Approaches

5.1 Introduction

Competency-oriented learning is a broad concept that focuses on students' mastery of a specific subject matter. [7]. In CBE, students must evaluate their competence and show that they've acquired the essential skills and knowledge required to successfully finish the subject as a way to advance in their learning journey [8]. CBE, also known as mastery-based, performance-based, or proficiency-based education, is on the rise. An increasing number of school zones and academics have introduced competency-based curricula in recent times. Educational institutions embrace this approach for several reasons, such as fostering globally competitive students, creating schools that prioritize effective strategies for student success, promoting greater equity, establishing a pathway for quality improvement and learning, and enhancing the effectiveness of teaching methods [9]. Engineering education currently confronts numerous challenges that require modernization. The diversity of students in US higher education institutions is expanding, with more than 90% of the student body comprising non-traditional students [10]. Over the last ten years, there has been a shift in STEM education, particularly in the field of engineering, towards the adoption of a competency-based instructional approach. CBE is an outcome-focused, learner-centered form of education where students advance to more advanced coursework after mastering the fundamental core content and skills [11]. A competent individual possesses the capability and skills necessary to carry out assigned tasks and perform at a required level of proficiency.

Within the framework of the competency model, knowledge differs from the term ”skill.” Knowledge refers to what one understands, whereas skill pertains to what one can effectively execute. Competencies are the result of integrated learning experiences where abilities, capabilities, and knowledge converge to shape educational and learning frameworks tailored to the specific task they are designed for.

Furthermore, enthusiasm for competencies is growing globally, with competencies and skills being examined from a dynamic perspective focused primarily on meeting the needs of workers. Competency models can also be employed by employers looking to hire. For instance, prospective employees, whether students or workers, are vying for positions to attain job stability. As a result, competency-based approaches strongly align with positive student learning outcomes, shifting the focus from instructional delivery to student achievement [171]. In response, software engineering education needs to extend its focus beyond the acquisition of curriculum knowledge and encompass a broader spectrum of knowledge and skills. This broader concept can be encapsulated by the term ”competence.” Within a competence-centered curriculum, ethical considerations, business and societal relevance are integral components.

Successful software engineering education and training should address not only what individuals know but also how they acquire knowledge and why they engage in learning (ACM/IEEE, 2020). This concept aims to encourage educators who support CBE to explore the integration of game design elements into their courses. In essence, the incorporation of game dynamics is customized to foster competency development. This connection is established at the highest level of abstract learning objectives through the utilization of dynamic strategies [172]. Our research delves into the critical aspects of transitioning towards a competency-based approach in software engineering education and training. Additionally, we highlight the benefits and the role that competency-based learning plays in contrast to knowledge-based learning within the realm of software engineering education. Consequently, we have formulated several research questions, and our aim is to address the following inquiries:

1. What constitutes different competency levels, and how do they impact students who may have limited skills?

2. What types of assessments are utilized in competency-based education for software engineering?

3. What are the strengths and weaknesses linked to competency-based education within the

software engineering domain?

4. What sets competency-based education apart from knowledge-based education, and what incentives drive academia's transition towards a competency-based learning model?

5.2 Background

5.2.1 Competency-Based Education

Indeed, competency term is often used interchangeably in the literature, and their definitions can vary among different scholars. These concepts typically revolve around ”descriptions of the tasks,” which specify what an individual must accomplish in their profession, and ”descriptions of behavior,” which detail how an individual carries out these tasks [173]. Various studies have presented multiple perspectives on competency. In the context of CBE, the primary focus is on a student's capacity to demonstrate what they can do, emphasizing practical skills and abilities, rather than merely assessing their theoretical knowledge [174]. It's important to note that while CBE is a widely used concept, there is no universally standardized and universally accepted definition of the term. According to Weinert, one perspective on competency defines it as ”an inter-individually available collection of prerequisites for successful action in meaningful task domains.” This definition underscores the idea that competencies encompass the necessary prerequisites for effective performance in real-world tasks [175]. The concept of competency, as described by Weinert, encompasses various aspects of an individual, including their potential, skills, cognitive processes, understanding, and the capability to apply self-developed solutions to problems within specific and well-defined contexts. This definition underscores the holistic nature of competency, considering not just what one knows but also how effectively they can apply their knowledge in practical situations [172]. Consequently, when we consider the fundamental principle of CBE, it operates on the premise that courses are not merely channels for transmitting information but are designed to focus on developing comprehensive skills that enable students to tackle complex problems in diverse contexts. In this perspective, imparting knowledge is seen as a more straightforward and straightforward process compared to the transfer of competencies to students. Developing competencies necessitates various teaching approaches and leads to a distinctive perspective on the learning process [176].

1. Learning/education is viewed as an active and participatory endeavor that takes place

within suitable contexts that involve addressing challenges within an expert practice.

2. Learning outcomes are explicitly defined, encompassing not just knowledge but also course-specific methods, social skills, individual abilities, and action-oriented competencies.

3. Learners take responsibility for their own learning and play an active role in the learning environment, while teachers primarily serve as coaches and mentors.

4. Success in competency development relies on being inspired and experiencing emotions as its fundamental pillars.

Additionally,[177] highlighted that, contrary to common belief, the barriers to gaining new cognition in STEM fields are often not due to intellectual limitations but stem from deficiencies in foundational competencies like self-competency, practical skills, cognitive abilities, and social competencies. Based on our experiences, we've developed effective methods to identify and address these competency gaps. Remarkably, students on the verge of failure have shown remarkable improvement in exams after experiencing transformations. This underscores the importance of pinpointing specific foundational competencies as prerequisites for acquiring advanced knowledge, as detailed in [178]. Figure 5.1 illustrates the essential competencies for acquiring technical skills, with self-competency at the core, serving as the foundation for progressively complex abilities. Practical and cognitive competencies encompass essential structured work methods and capabilities that support goal-oriented work.

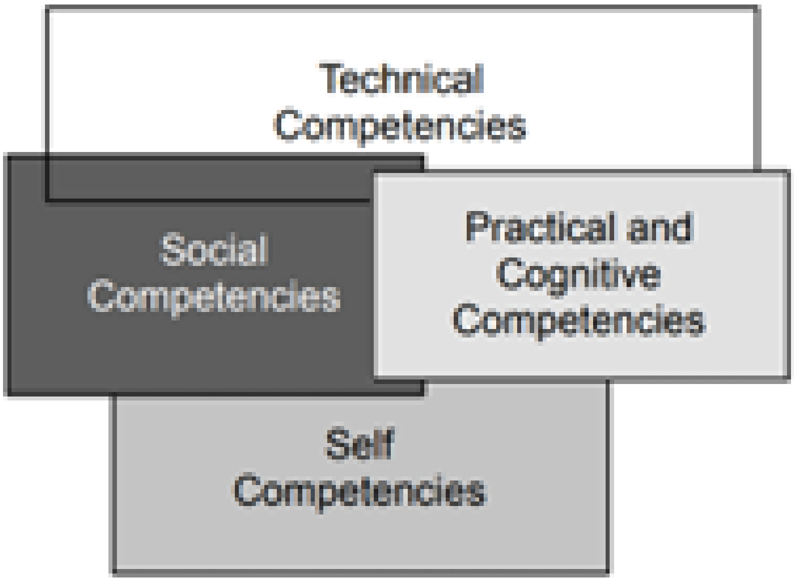

Figure 5.1: Competency call for acquiring technical competencies

In Figure 5.1, it appears that there is a focus on acquiring technical competencies. Additionally, social competencies are highlighted as encompassing the ability to recognize and respect the needs and desires of others, communicate effectively with them, and provide support when necessary [178]. It's worth noting that there are no universally accepted alternatives to competency-based instruction, and the concept itself lacks a well-defined definition. Consequently, the distinction between competency-based and competence-oriented approaches may be considered meaningless. A competency-based curriculum is designed to serve students who are actively engaged in creatively addressing challenges. The perspective gained by emphasizing competencies profoundly influences how learners acquire information and engage in the learning process [172][176]. Competency-Based Education (CBE) places a significant emphasis on ”output” rather than solely on ”learning.” This approach is increasingly prevalent in various education programs and ongoing training initiatives. In CBE, the primary goal is for learners to demonstrate their abilities and competencies in real-world contexts, emphasizing practical application and skill development [179]. The concerns you've raised highlight the importance of ethical considerations and responsible implementation of educational methods, including Competency-Based Education (CBE). It's crucial to ensure that any educational approach, including CBE, is used with the best interests of individuals, society, and humanity as a whole in mind. Education should always prioritize the well-being, personal growth, and ethical development of individuals while fostering a positive impact on the economy and culture. Responsible and ethical practices in education are essential to avoid any potential negative consequences [180].

5.3 Methondology

This study appears to be a comprehensive analysis of CBE and KBL in the context of engineering education and training, particularly in the field of software engineering. The research aims to assess the strengths, impacts, and limitations of these two educational approaches and provide insights into the effectiveness and benefits of CBE. Additionally, it appears that meta-analysis research is employed to compare these approaches, highlighting their respective strengths and weaknesses in the context of STEM education. The ultimate goal is to determine which approach holds the most promise for enhancing engineering education and training and potentially encouraging institutions to transition to a CBE-based system.

5.3.1 Research Questions

The study's primary focus on shifting from knowledge-based learning to competency-based software engineering instruction is clear. It seems that Table 5.0 outlines the research questions (RQs) formulated for the research, along with the motivations behind each question. This structured approach will likely help guide the research and provide a clear framework for addressing key aspects of the transition to competency-based education in the context of software engineering.

RQs	Research Questions	Motivations
1	What do competency levels entail, and how do they impact a learner who possesses limited skills?	RQ 1 seeks to determine the impact of five core competency levels on students with restricted abilities and skills.
2	What forms of assessment are employed in competency-based education?	RQ 2 will investigate the diverse assessment methods utilized within competency-based education and the current state of software engineering competency assessment.
3	What are the pros and cons of applying CBE within the realm of software engineering?	RQ 3 in the field of software engineering education delves into the strengths and weaknesses of CBE.
4	What are the key differences between competency-based and knowledge-based education, and what drives academia's shift towards competency-based learning?	RQ 4 aims to pinpoint the fundamental disparities between competency-based education and knowledge-based education, as well as the motivations behind academia's adoption of the CBE approach.

5.3.2 Search Process

Your research methodology for gathering relevant articles on engineering education and competency-based learning appears rigorous and comprehensive. You've leveraged a variety of reputable resources and scientific databases, including ACM, IEEE, Taylor & Francis, and others, to identify relevant papers. Use of keywords like "competency-based learning in software engineering," "competency-based instruction in engineering education," and related terms demonstrates a systematic approach to the search process.

Furthermore, the inclusion criteria you've established, such as focusing on studies conducted primarily since 2010 and ensuring study independence, enhance the reliability and relevance of the selected publications. Your final sample size of 78 studies suggests a robust dataset for your research.

Table 5.1, summarizing the number of publications from various journals, conferences, and resources, provides a clear overview of your data sources. Overall, your methodology appears well-structured and designed to yield valuable insights into the application of CBE in engineering education.

Table 5.1: Presents an overview of the findings included in this review

Type	Number	Percentages
Journal	44	57%
Conferences	12	15%
Others	22	28%
Total	78	100%

Table 5.1 provides a useful breakdown of the sources of the articles you've gathered for your study. It's notable that a significant portion, 57 percent, comes from reputable journals in the field of education, such as Engineering instruction, the European Journal of Education, and STEM Education. Another 15 percent of the papers were sourced from prominent conferences, including IEEE and ACM events, which are well-regarded in the academic community. The remaining 28 percent of research was collected from diverse sources, including symposiums, books, and online resources, suggesting a comprehensive approach to data collection. This distribution of sources enhances the diversity and depth of your study's dataset, potentially leading to well-rounded insights into competency-based education in engineering.

5.4 Findings and Results

Our research suggests that competency-based education is highly effective in engineering, emphasizing students' skills. In this approach, teachers' roles differ from traditional methods, mainly serving as guides and mentors. Additionally, our findings underscore the pivotal role of assessment in competency-based education. Moreover, competency-based education systems, as discussed [181], prioritize transparency by establishing explicit expectations for both teachers and students. This clarity includes what needs to be learned, the performance standards required for mastery, and the means of tracking progress during a course. Such transparency enhances student motivation and engagement. The subsequent sections of this study address the research questions outlined in Table 5.0, providing comprehensive responses to each inquiry.

5.4.1 Competency Model for Software Engineering

What do competency levels entail, and how do they influence a student who possesses limited skills?

The competency model for software engineering outlines the essential competencies necessary for software engineers engaged in the design and maintenance of software-intensive systems. This model categorizes competencies into skill areas, further detailing abilities within these areas, and associating job tasks with each skill. Figure 5.2 represents these activities on a five-tiered competency scale.

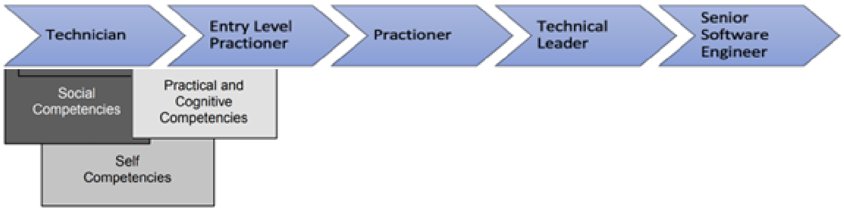

Figure 5.2: Competency levels

The competency model differentiates between various levels of expertise and responsibility within the software engineering field. A technician follows instructions, while an entry-level practitioner assists in tasks under supervision. A practitioner can perform tasks with minimal oversight, while a technical leader guides individuals and teams. An expert software engineer creates and modifies methods and tools. In some cases, companies may merge the technician and entry-level practitioner roles.

Moreover, a senior software engineer might serve as the ”lead engineer” within a software company and may be an industry authority shaping the software engineering profession. Table 5.2 provides an example of competency levels in requirements management, generally represented in five stages. It’s important to note that individuals with lower competency levels may excel in specific tasks but not necessarily in all of them. For instance, entry-level practitioners can carry out traceability analysis.

	Technician Activities	Entry Level Practitioner	Practitioner, Team Leader, Senior Software Engineer Activities
Skill Area	Software Requirements	Software Requirements	Software Requirements
Skill	Requirements Management	Requirements Management	Requirements Management
Competency Levels	Follows established procedures to assist with requirements management.	Utilizes relevant tools to assist with Management of requirements.	Requirements plans are put into effect. Ensures project requirements management plans. Modifies current instructions, models, methods, and approaches for standards management and develops new ones.

It's worth noting that certain situations, as exemplified by the practitioner level in Table 5.2, may demand individuals to be qualified to actively participate in or lead a specific job operation, like executing a management plan. The level of their involvement or leadership role can vary depending on factors such as the project's scale, scope, and complexity.

Furthermore, there is a widely accepted belief in education that success in both academic and vocational training necessitates the development of numerous qualities and characteristics [35]. Competencies are typically structured around three key dimensions: knowledge, skills, and dispositions. These dimensions work together to form a comprehensive understanding of competency. Figure 5.3 (sourced from the Council of Chief State School Officers, 2013) visually represents the interconnected nature of these competency elements.

In parallel, (ACM/IEEE, 2020) enhances the framework of expertise, ability, and disposition

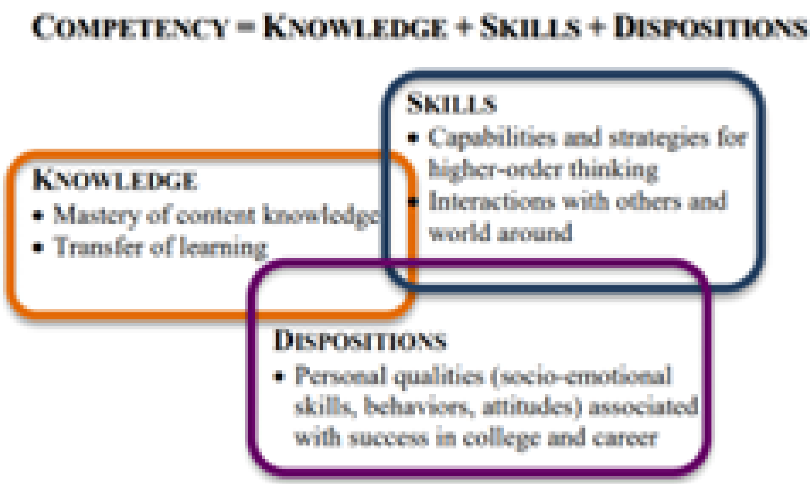

Figure 5.3: KSD framework

initially introduced in (ITC, 2017). While computing curricula have traditionally focused extensively on the knowledge dimension, the aspects of ability and disposition have received comparatively less attention. Building upon previous efforts, it is observed that competencies are founded on the K-S-D dimensions and incorporate tasks as a fundamental component, as illustrated in Figure 5.4 below:

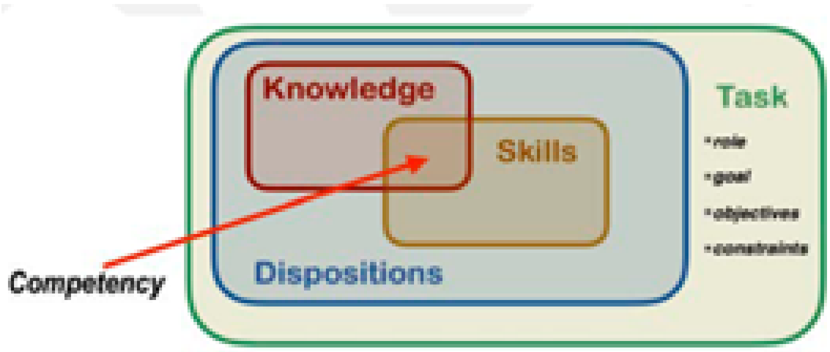

Figure 5.4: Conceptual Structure of the CC2020 Competency Model

The mentioned figure illustrate the four components of the competency model (knowledge, skills, dispositions, and task) with the following meanings.

5.5 Knowledge

This understanding is both conceptual and theoretical, representing a tangible attribute cultivated through effective competency-based education, with a weightage of 35 percent.

5.6 Skills

Skill is a quantifiable and observable expertise acquired through effective training and education [182]. Within the competency framework, the ”skills” component emphasizes the capability to proficiently execute various tasks. In essence, ”skills” represent the practical application of knowledge, and they are developed through continuous practice and experience over time. This amalgamation of ’know-what,’ ’know-how,’ and ’know-why’ collectively contributes to the ’know-what’ aspect of competency. To make any aspect of knowledge within a competency specification meaningful, it must be interpreted as a level of proficiency, accounting for 30 percent of the overall competency. This approach to the competency model aligns with a skill-based learning perspective, as outlined in ACM/IEEE (2020).

5.7 Dispositions

This component of competency focuses on the essential ”know-why” quality necessary for completing tasks effectively. It serves as an embodiment of the occupational value and contributes to the perception of dedicated proficiency in both ”know-what” and ”know-how.” Additionally, the dispositions component maintains and aligns knowledge and skill elements in accordance with the relationship between the indicator and the criterion [183]. Because dispositions are instrumental in guiding the ”better” or ”correct” application of knowledge and skill, they influence how these aspects are employed. In essence, dispositions play a moderating role in a professional’s proficiency when executing their responsibilities, as indicated by ACM/IEEE (2020), contributing 20 percent to the overall competency assessment.

5.8 Task

This component specifies the adept utilization of knowledge and how this proficiency is demonstrated through the disposition dimension. The task is presented as a conversational statement, providing a context to showcase disposition. Within this framework, the assignment incorporates a comprehensive theory of competency that encompasses all three competency dimensions (knowledge, skills, and disposition). As a result, task representations contribute to the development of an instructional approach that facilitates learners in achieving genuine proficiency in computing, accounting for 15 percent of the overall competency assessment.

5.8.1 Potential of Competency-Based Education

What are the pros and cons of applying competency-based education within the realm of software engineering? Research indicates that engineering students often possess strong academic qualifications but may lack certain essential skills and abilities necessary for both achieving high-quality success in their field and personal development [184]. Competency-Based Education (CBE) certainly has its strengths, but it also faces weaknesses and challenges. One of the concerns raised is whether CBE is effective in teaching students essential skills such as communication, prioritization, teamwork, and strong interpersonal skills. These soft skills are critical for success in various professions, including engineering, and their integration into a competency-based framework can be a challenge that needs careful consideration.[185][186][187]. The robust points of CBE are listed in table below.

Table 5.2: Table 5.2 Strengths of competency-based learning.

Authors	Robust points	Descriptions
[188][189][11]	Master prerequisite materials, Positive learning experience, lower dropout, and high attendance	CBE allows students to practice foundational material regardless of the present course continually. Success rises as students check prerequisites regularly, reducing dropout rates. Certain CBE programs aim to boost enrollment and prevent students from falling behind.
[190]	Facilitates student-centred and individualized learning paths	To meet the unique needs of atypical students, integrating diverse delivery methods like remote, electronic, and online learning is both possible and vital in CBE design.

Table 5.3: Table 5.3 Strengths of competency-based learning.

Authors	Robust points	Descriptions
[191]	The appropriate strategy for today's diverse student body	Working several jobs along with college is commonplace for young adults. Stopping students from falling behind and learning at their speed is suitable for them. CBE can educate non-traditional students in engineering programs. CBE is a practical approach in today's diverse student body
[192][193] [194] [195][196]	Positive student attitudes regarding the courses and curriculum, Better performance than the traditional approach, knowledge, and performance improvement.	Evidence suggests that CBE students outperform those in traditional courses with higher grades and success rates, along with improved general knowledge.

Despite its numerous advantages, competency-based education (CBE) also exhibits acknowledged weaknesses and uncertainties. While there is consensus that CBE has a positive impact on enhancing teamwork and leadership skills, there remains ongoing debate within the literature regarding its effectiveness in teaching students aspects like leadership, fostering constructive argumentation, and performing under pressure, as noted in previous studies [185][186][187]. Research findings indicate that engineering graduates often possess a well-rounded education but may lack the necessary professional skills required for high-quality job prospects [184]. Table 5.4 provides an illustration of the shortcomings of CBE in the context of engineering education.

Table 5.4: Table 5.4 Strengths of competency-based learning.

Authors	Strengths	Descriptions
[193]	Fulfil industrial expectations for more skilled professionals.	CBE could be the suitable approach to fulfil the industry's desires for better-qualified engineers. The competency and work market is getting more complex, and CBE systems will quickly adapt to meet those requirements.
[197][195][198][199][200][1	Improves knowledge-based and professional competencies.	Studying while working is exciting because it continuously pushes you to learn. CBE can enhance both technical skills and general knowledge.
[189][188]	Easy internship placement and employment	Studies have shown that those who have completed CBE courses can secure employment quickly.

Table 5.5: Strengths of competency-based learning.

Authors	Strengths	Descriptions
[171]	Fosters mutual comprehension between the educators and learners.	CBE promotes mutual understanding, with clear objectives and expectations for both teachers and students, reducing frustration and disappointment.
[201][195][202]	Enriches implementation of additional pedagogues in students such as project-based learning, problem-based learning, experiential learning, virtual reality, team-based learning, and scaffolding	CBE is designed to allow for other pedagogical practices, including project-based learning, enhanced learning outcomes, problem-based learning, scaffolding, team-based learning, and experiential learning.

Authors	Weakness	Descriptions
[203][11]	Lack of professional, contextual competence, and confidence.	Engineering students excel academically but struggle with success in the workforce, where creative and contextual skills are crucial. The integration of academic competencies into traditional education systems makes it challenging to deliver these skills effectively in a CBE format.

Authors	Weakness	Descriptions
[187]	Categorization	A key limitation of CBE is its segmentation of knowledge into discrete competencies. This restricts students' ability to connect ideas and implement them practically. In the 1970s, when CBE became more prevalent, it viewed capabilities as separate components, posing a significant challenge.

Authors	Weakness	Descriptions
[204]	Application/Implementation of CBE	Transitioning an engineering curriculum from traditional methods to competency-based models poses challenges, especially for educators and students used to conventional classrooms and courses.

Authors	Weakness	Descriptions
[205]	It fails to cater to the learning styles of the majority of students	Managers use competency-based approaches for re-skilling, but they may not enhance higher-order skills. Educators should support students who fall behind, and sticking to a timetable is essential.

Authors	Weakness	Descriptions
[206]	Increased chances of procrastination	Unmotivated students can struggle in competency-based instruction, which lacks set deadlines. Success depends on students' self-discipline and motivation, which varies among individuals.
[206]	It does not take social learning into account	Social learning, which involves observing and practicing, is valuable for students. However, competency-based learning often lacks these social learning opportunities.

5.8.2 Shifting to Competency-Based Instruction

What are the key differences between CBE and KBE, and what drives academia's shift towards competency-based learning?

Competence involves the acquisition of sufficient knowledge, effective communication skills, sound decision-making abilities, and the right attitudes to enable the proficient execution of activities and specific tasks up to a designated level of efficiency [207]. As a result, [208] this has been depicted as "the regular and thoughtful application of communication, knowledge, technical skills, critical thinking, emotions, core values, and self-reflection in everyday practice, aimed at benefiting both the individual and the community served." While in academic literature, "competence" and "competency" are often used interchangeably, "competency" typically denotes skill, while "competence" signifies the individual's capacity to effectively perform the required skill. The definition of "competence" draws from the individual's experience, aptitude, resilience, and judgment. It's crucial to keep in mind that this term can be easily mistaken for a similar concept: proficiency in one domain, such as law, does not equate to proficiency in another, such as medicine [209]. Within the framework of the European Qualifications Framework, competence is defined as encompassing responsibility and autonomy [210]. The figure depicted in Figure 5.6 asserts that within the KSD framework, a learner has the potential to acquire knowledge, skill, and disposition, but the acquisition of the task is not assured.

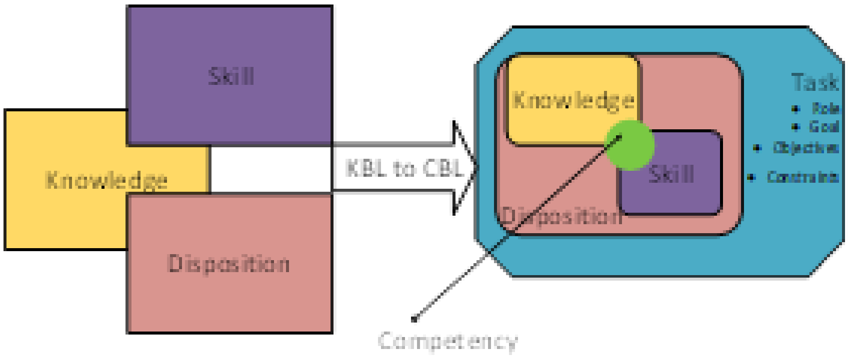

Figure 5.5: Integration of KSD & Competency framework

However, in the competency model, task descriptions provide a clear framework for the program to develop an educational approach that enables graduates to showcase their competency as proficient computing professionals. On a related note, [211][207] the essence of the distinctions between the two approaches, competency-based education and knowledge-based education, was outlined (Table 5.6).

Variables	**Knowledge-based Education**	**Competency-Based Education**
Curriculum guiding factor	Content: knowledge acquisition	Outcome: knowledge application
Process guiding factor	Instructor	Learner
Responsibility for content	Instructor	Instructor and learner
Analysing tool	Proxy, primarily subjective	Authentic: actual professional tasks
Assessment timing	Emphasis on summative	Emphasis on formative
Program fulfillment	Stable time	Variable duration to achieve competency.

Table 5.6: Table 5.6 CBE and KA-KU-LO differences

From another perspective, [207] [212] underscored distinctive characteristics of the competency-based education approach, such as:

(a) Competency typically revolves around achieving the desired outcome.

(b) Competency-Based Education (CBE) employs an assessment method based on individual capabilities, independent of the performance of others.

(c) CBE communicates product quality and pertinent outcomes to its competitors and other interested parties.

(d) CBE is self-governed and provides flexible learning opportunities tailored to various ages and learning styles.

Additionally, Figure 5.7 provides an overview of the elements of both Competency-Based Education and Knowledge-Based Education.

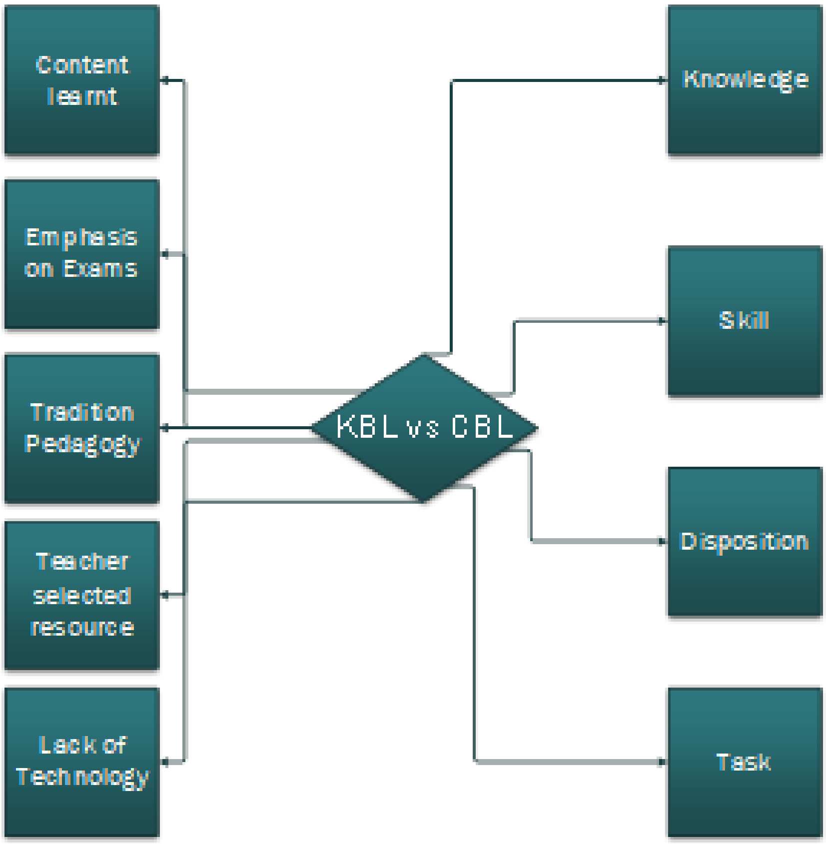

Figure 5.6: Knowledge-based learning vs competency-based learning

Knowledge-based learning is dependent on the subject being taught, prioritizing testing over competency. In KBL, the learning process primarily relies on instructor-led pedagogy, with the teacher taking the central role in delivering information to students. The instructor is responsible for selecting materials based on their preferences and availability. Integrating new technology into a knowledge-based learning environment poses notable challenges [213]. In contrast, competency-based education places a paramount emphasis on nurturing each student's capacity to perform tasks effectively. CBE fosters unique and adaptive learning experiences, instilling confidence in a candidate's capability to accomplish specific tasks. Unlike traditional methods that deliver pre-packaged content, CBE relies on an instructor's guidance, enabling trained individuals to learn more efficiently and effectively [214]. Table 5.7 provides a summary of the distinctions between traditional knowledge-based learning and the competency-based learning approach.

Table 5.7: The difference between the traditional and CBE approach

Distinguishing parameter	Traditional approach	Competency-based Education
Outcome	Understanding of academic content	Demonstration of learned knowledge and skill
Mindset	Fixed mindset	Growth mindset
Culture	Culture of compliance	Culture of empowerment
Support system	Need-based support to some students	Providing Customized instruction and support to all students
Pedagogy	One curriculum for all students	Tailored learning paths for every student
Assessment	One size fits all approach	Personalized learning approach
Proficiency standards	Different meanings for different people	Consistent meaning for everyone
Advancement	Time-based	Learning-based

Table 5.8: Comparison of Traditional approach and Competency-based Education

The conventional education system places its emphasis on memorization and comprehension of content, while CBE prioritizes the demonstration of acquired knowledge and skills. Traditional education adheres to a fixed mindset ideology, while CBE aligns with a growth mindset ideology. The conventional approach tends to promote a culture of compliance, whereas CBE encourages a culture of empowerment. In the traditional method, the support system is primarily tailored to the needs of a select few students, whereas in CBE, it offers differentiated instructional support to all students.

Regarding pedagogy, the traditional strategy relies on a uniform curriculum for all students, whereas CBE tailors an individual learning pathway for each student. The conventional educational system employs a one-size-fits-all assessment approach, while CBE utilizes a customized learning assessment method. In the traditional system, competence criteria may carry varying interpretations for different individuals, but in CBE, proficiency criteria serve a uniform purpose for all. Lastly, the traditional system's progress is determined by time-based milestones, whereas in CBE, it is driven by learning-based milestones.

5.8.3 Reasons Academia Shifting Toward Competency-Based Education

The conventional education system is not designed to effectively accomplish the objectives we have set or to provide the outcomes that our students, families, and nation require and deserve. The traditional system exhibits ten significant deficiencies that contribute to inequality and subpar achievement. Table 8 offers a comparison between the traditional and CBE approaches in terms of equity. These issues can be addressed through the redesign of a success-oriented curriculum that guarantees mastery for all students [9].

Table 5.9: Table 5.9 comparing traditional and CBE approaches with equity

	The Traditional System's Weakness	**Characteristics in Competency-Based Instruction**	**Hallmarks of High-Quality Competency-Based Education with Equity**
Mindset	The conventional system adheres to a rigid mindset: Students are ranked and categorized, leading to distinctions between winners and losers	English	French
Outcome	Focuses on a limited set of learning outcomes, prioritizing academic skills, rote memorization, and language comprehension. Fails to recognize that student success relies on a diverse range of foundational attributes, including social and emotional skills, and the application of these skills	English, French	Spanish
Support	Supports students with educational or psychological needs that slightly deviate from the standard, such as those in special education or those identified as gifted and talented	Mexican Peso	Spanish
Culture	Fosters a culture of conformity and structure within the educational environment. It depends on a centralized, hierarchical framework to uphold established roles, societal norms, and power dynamics	Brazilian Real	Portuguese

Table 5.10: Table 5.10 comparing traditional and CBE approaches with equity

	The Traditional System's Weakness	**Characteristics in Competency-Based Education**	**Hallmarks of High-Quality Competency-Based Education with Equity**
Pedagogy	Delivers a uniform curriculum to all students, irrespective of their age. Each year, the focus is on completing the curriculum.	Euro	French
Assessment	Assessment primarily serves a summative purpose to confirm what students have learned. Uniform tests are administered to all students concurrently and in the same format, assessing the same content at predetermined intervals or at the end of a unit.	Euro	German
Reliability	Offers significant flexibility in how educators, schools, and districts evaluate proficiency. Students are held to different standards across classes, schools, and communities.	Euro	Spanish
Learning infrastructure	Offers unclear learning objectives and achievement targets, providing little guidance on the duration of the learning process for students. Students receive grades without specific guidance on how to improve or revise their work.	Chinese Yuan	Chinese

Table 5.11: Table 5.11 comparing traditional and CBE approaches with equity

	The Traditional System's Weakness	**Characteristics in Competency-Based Education**	**Hallmarks of High-Quality Competency-Based Education with Equity**
Grading	Interpreting student assessments can be difficult, as they often provide mixed signals about students' knowledge and understanding.	Japanese Yen	Japanese

Ultimately, there exists a compelling incentive for transitioning towards competency-based education due to its focus on outcomes and efficiency. Figure 5.8 highlights five key strengths that underscore the necessity for competency-based education in the current educational landscape.

Figure 5.7: CBE strengths

Competency-based education (CBE) promotes lifelong learning [215] [216] by placing an emphasis on both academic knowledge and transferable skills. This approach ensures that students develop problem-solving abilities, become independent learners, and thrive in various new contexts. Moreover, CBE prioritizes student agency, enabling them to select their learning pace and function as independent, self-regulated learners. CBE also cultivates educational environments that prioritize growth, inclusivity, and empowerment for both students and educators. It seeks to instill a growth mindset in students, encouraging them to take ownership of their learning journey. Educators are likewise empowered and granted the flexibility to make decisions in the best interests of their students. Equity is a fundamental principle of competency education, ensuring that every student experiences growth and benefits, rather than just a select few. Competency-based education (CBE) employs a timely approach to instruction and support for students. In CBE, support isn't a reactive measure triggered by student failure; instead, it is provided proactively throughout the entire learning journey. The emphasis in CBE is placed more on the learning process than on the final outcome. It involves offering remedial learning opportunities, formative assessment, and consistent, constructive feedback to continually advance learning and skill development.

The pedagogical principles of CBE are structured to align with each student's unique learning needs and objectives. Educators don't approach and instruct students based solely on their age or grade level; instead, they start by assessing students where they are in terms of their academic foundations. This means that learning tasks are tailored to match the individual learning needs of students. The support systems provided to assist students in their learning and goal attainment are tailored based on students' social, emotional, and cognitive development. Furthermore, competency-based education (CBE) [181] systems prioritize transparency by establishing clear and unambiguous expectations for both teachers and students. Students are provided with precise information regarding what they are expected to learn, the level of performance required for mastery, and a clear understanding of their progress throughout a course. This clarity in learning objectives serves as a source of motivation and enthusiasm for students. Additionally, CBE empowers students by involving them in the learning process and allowing them to have a say in demonstrating their proficiency.

What sets CBE apart is its emphasis on what students have learned rather than the time spent in the classroom to cover a syllabus. In essence, Table 5.12 presents a list of competencies for software engineering courses, offering students the opportunity to acquire software engineering skills.

Table 5.12: Table 5.12 List of competencies for software engineering courses

Competency list in SE	Outcome
Computer programming and coding	Students showcase their proficiency in writing and executing various programs using the prescribed programming languages and implementing algorithms.
Software development	Students will assess user needs and subsequently design, test, and create software to fulfill those requirements. They will also have the ability to collaborate with natural systems.
Object-oriented design	Students will grasp the four essential elements of object-oriented programming, namely: a) Abstraction b) Encapsulation c) Inheritance d) Polymorphism
Software testing and debugging	Students will comprehend and develop various testing tools for software testing. They will also engage in analytical thinking regarding the composition of systems.
Problem-solving and logical thinking	Students will exhibit their capability to identify technical challenges and apply deductive reasoning to address problems, enhancing software for commercial applications.
Written and verbal communication	Students will demonstrate the most effective approaches for enhancing their verbal and written communication skills. They will be proficient in explaining technical or complex concepts to customers or stakeholders.

Table 5.13: Table 5.13 Competency list for software engineering courses

Competency list in SE	Outcome
Teamwork	Students may display their interpersonal attributes, including empathy, active listening, receptivity to feedback, and understanding.

5.8.4 Evaluation in Competency-Based Education

What is the Type of Assessment in Competency-Based Education?

In the past two decades, accreditation organizations and experts in education worldwide have emphasized the critical significance of incorporating trans disciplinary competencies into engineering education programs. This is aimed at better equipping learners for careers in the field of engineering [217]. Assessment plays a central and pivotal role in competency-based learning; it is the driving force behind the evaluation process [218]. A crucial step in ensuring that students effectively learn the course material is to design an adequate number of tasks that can accurately assess and determine their mastery. Competency-based education (CBE), being industry-driven, relies on assessments rooted in tangible outcomes and demonstrated proficiency. This approach ensures that assessment instruments are supported by concrete evidence. One effective tool for this purpose is the use of portfolios, which can efficiently gather, structure, and present this evidence [218]. In the context of competency-based education (CBE), assessment involves comparing a student's proficiency to predefined levels of success. CBE assessment encompasses both formative and summative approaches. Formative assessment is particularly valuable as it enhances the consistency of teaching and student learning throughout the learning process. On the other hand, summative assessment serves the purpose of measuring the attainment of specific outcomes or results [219]. As a result, assessment influences students' comprehension and retention of what they have learned. This shift from knowledge-based to competency-based learning signifies a comprehensive integration of information and attitude elements [162]. SThe main goal of competency-based education (CBE) assessment is to ensure that students are prepared and motivated to fulfill job requirements [220]. This is especially relevant for students in the initial phases of their education who are seeking guidance on which subjects to include in their study program [221]. It's essential to provide students with clear assessment requirements before they engage in learning activities, as this aids in their decision-making process [222]. In competency-based education, assessments are typically ongoing rather than being concluded with additional funding. According to this approach, these limitations appear to be addressed within colleges implementing competency-based learning. If a student does not succeed in an exam or a specific section of it, they require additional support. Competency-based education ensures that both students and teachers have a clear understanding of what needs to be learned. Students are empowered to make their own decisions and tackle challenges, even when the tasks are demanding. In competency-based education evaluation, the criterion is established based on the competencies that the learner is willing to demonstrate [223]. A concrete example is understanding how to communicate effectively and putting into practice wisdom, skills, and disposition.

The purpose and nature of assessment vary between different educational systems. Table 5.14 outlines the number of assessments in both methods, namely Competency-Based Education (CBE) and the traditional approach.

Table 5.14: Table 5.14 The evaluation in CBE and traditional approaches

Competency-Based Assessment	Traditional-based Assessment
Evaluation for learning and evaluation as learning	Assessment of learning
Formative, continuous, diagnostic	Summative in nature
Aligned with educational objectives	Assesses students' knowledge
Individual pathway	Uniform approach for all

In CBE, assessment is based on students' learning outcomes and is primarily formative in nature. In contrast, in knowledge-based learning, evaluation is predominantly summative as it focuses on students demonstrating their knowledge of the subject. In CBE, each student's success and the group's progress and proficiency in achieving learning outcomes are assessed. Assessment is integrated into every step of the learning process in CBE to offer students coaching and support in achieving competence [224]. This level of scrutiny aims to refine real-time expertise. Figure 5.9, extracted from the National Post secondary Education Cooperative's report "Defining and Assessing Learning," provides a simple yet powerful illustration of the competency-based model.

Figure 5.8: CBE strengths

As depicted in the figure, the initial stage encompasses attributes, characteristics, basic understandings, and acquired skills. The second row involves skills, talents, and knowledge acquired through learning. The third tier, competencies, focuses on understanding and capabilities. Competencies are ultimately demonstrated at the highest level. Assessment is crucial and continuous at all stages of this learning process. There are two primary methods for assessing learning in CBE.

a) Norm-referenced assessment.

b) Criterion-referenced assessment.

The term ”criterion-referenced assessment” was introduced in the field of education and educational psychology in 1962 to describe assessments that measure proficiency based on academic achievement. Criterion referencing places emphasis on higher-order cognitive skills, such as logical reasoning and the ability to write concisely and incisively [225]. Table 5.15 provides an overview of the differences and connections between criterion-referenced and norm-referenced assessments.

	Criterion-referenced assessment	Norm-referenced assessment
Purpose	Exemplify the developmental performance of the individual learners	Create a rating system for students about a group.
Design of assessment tasks	Consistent with the contents and anticipated results	Distinguishes between high and low achievers
Unit of score interpretation	Individual	Group
Score presentation	Grades assigned by criteria	Grades are derived from raw scores and typically follow a normal distribution. They are often categorized into broad intervals on the grading scale.

Table 5.15: Comparison of Criterion-referenced and Norm-referenced assessment

	Criterion-referenced assessment	Norm-referenced assessment
Score presentation	1. Able to accurately depict each student's actual progress and growth. 2. Enables the explicit incorporation of higher-order cognitive skills, ensuring that assessments accurately measure these abilities.	1. Able to make comparisons among individuals in a given population. 2. It can be scientifically adjusted to possess a specific width, known as the standard deviation. 3. Able to prevent the inflation of grades.
Disadvantages	1. Lack of regulation in grade allocation leads to grade inflation. 2. Less inclined to make comparisons with their peers.	1. Collaborative efforts can impact individual scores, potentially leading to unfair treatment of students within the group. 2. May underestimate the degree of factual differences among individual students.

In Competency-Based Education (CBE), numerous universities employ rubrics for student assessment, as highlighted in Learning (2010). Rubrics gauge how well data, documents, or artifacts reflect students' achievement of particular quality criteria or standards. Additionally, certain universities have developed their own standards-based report cards [226]. These report cards don't just list subject areas but also outline the specific expectations for each content area, going beyond traditional grading. They provide detailed information on the degree to which students meet these standards. Figure 5.10 illustrates the difference between traditional and Competency-Based Education (CBE) approaches using software engineering competency lists as assessment criteria. In CBE, students are expected not only to understand and explain concepts but also to design their own algorithms, showcasing their ability to create solutions, as emphasized by Goldman [227]. In Competency-Based Education (CBE), both formative and summative assessments are employed throughout the learning and teaching process. Students advance at their own pace, whether they have fully grasped the material or require extra time. Conversely, the traditional approach places importance on students being able to read, write, and explain algorithms for specific problems and possessing programming and coding skills. Summative assessment is the primary focus in this approach. In conventional education, students are expected to meet grade-level criteria for college and career readiness, often assessed through exams, tests, and quizzes to evaluate their understanding of course material. However, there is less emphasis on assessing what learners can achieve or how they can apply their knowledge to develop real-world systems [228].

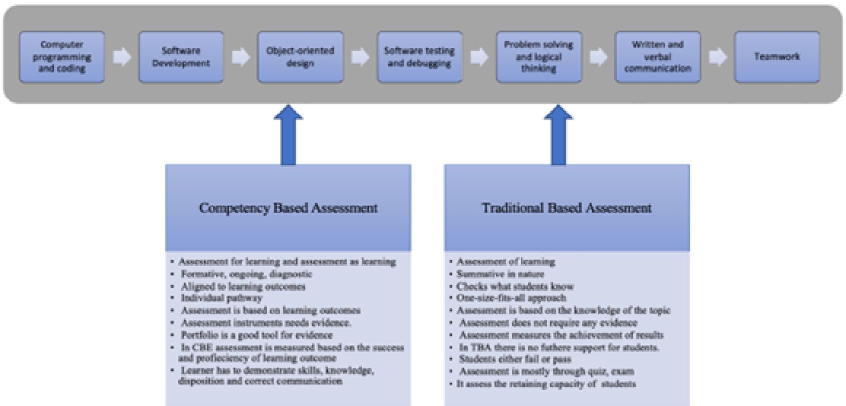

Figure 5.9: Contrast between conventional educational methods and CBE approaches using the software engineering competency list.

5.9 Discussion

The present finding focuses on exploring the strengths of CBE compared to knowledge-based learning, particularly in the context of software engineering education and training. CBE is highlighted as being industry-driven and equipping students to tackle real-world challenges while fostering a lifelong learning mindset. In today's interconnected world, where technology continuously advances and cultures blend, traditional educational institutions are no longer the sole sources of information. Students have easy access to information through the internet and modern technology, making it essential for educational systems to adapt and become more flexible and innovative. CBE's emphasis on measuring learning rather than time is seen as a crucial aspect of this flexibility. Furthermore, a competency-based curriculum has the potential to play a significant role in higher education by offering accessible opportunities that lead to demonstrated competence [224]. It can be deduced that competency-based education (CBE) is quickly gaining ground in engineering education, addressing diverse student needs, and meeting the demands of businesses and careers for well-prepared engineers [191]. Competency-based education (CBE) places a stronger emphasis on students' skills, abilities, and talents to perform tasks in a standardized manner. It specifically identifies a student's technical skills and behavioral competencies.

In CBE, teachers take on a different role compared to traditional approaches. They act as guides, mentors, and facilitators. Learning outcomes are clearly defined, rigorous, and shared among students. Evaluation in CBE is based on mastery rather than time or participation. Instructional methods and support in CBE are tailored to individual needs, relevant, diverse, and encourage student independence and responsibility. Additionally, the assessment process in CBE offers flexibility and allows students to choose how they demonstrate their knowledge and skills.

As a result, assessment plays a crucial role in CBE, driving the learning process and ensuring students attain competency. There are two main methods for assessing learning in CBE [225]: norm-referenced assessment and criterion-referenced assessment. Norm-referenced assessment seeks to determine what constitutes excellent, adequate, and poor performance among a group of learners, with the purpose of comparing learners within a cohort.

In contrast, criterion-referenced assessment categorizes students as either competent or not yet competent, without any middle ground. The goal is to measure learners against predefined standards.

The traditional education system has several shortcomings that lead to inequality and poor outcomes. It tends to label and rank students, resulting in winners and losers, without a focus on building students' capabilities and competencies. It often fails to recognize that student growth depends on social and emotional skills and their effective use. Therefore, support is typically provided to students with unique educational or psychological needs.

Traditional methods of assessment emphasize summative evaluation, where all students take the same test on the same subject either during or at the end of a semester [9]. Students enrolled in CBE courses that incorporate hands-on educational activities, such as laboratory work, are better prepared to undertake research projects and acquire advanced skills and knowledge required for employment or further education [229]. The number of studies on CBE in engineering education primarily focuses on non-content-based competencies that all students should acquire before graduation. There is a substantial body of literature that explores how to determine the professional or contextual competencies that engineering students should possess and how to improve students' achievement and assessment of these competencies. Regardless of the methodology used in engineering education, including CBE, the ultimate goal is to produce engineers who not only possess technical knowledge and skills but can also effectively collaborate with diverse groups of people in various contexts, allowing them to compete in the global market.

While the specific knowledge-based skills may vary by engineering specialty, there is a core set of professional competencies that all engineers should have upon completing their undergraduate degrees. These competencies include:

a) Leadership abilities b) Collaboration skills c) Effective communication skills d) Reflective behavior e) Multidisciplinary capabilities f) Considering a disciplinary perspective g) Understanding context h) Design skills

[191] In summary, CBE ensures that students are not only well-prepared academically but also equipped with the skills and competencies necessary for success in the engineering field. This approach prioritizes students' satisfaction and their ability to navigate their coursework effectively.

5.10 Conclusion

While competency-based education (CBE) requires a significant initial investment, it has the potential to transform instructors from enforcers into facilitators and promoters of education. However, the adoption of CBE in higher education is still in the process of shifting mindsets. This paper extensively examines the transition from traditional learning methods to CBE. Traditional education in this era is often seen as a waste of time and money for learners, as they invest time but receive less than they expect in return. Competency-based education aims to transmit knowledge and emphasizes the development of extensive skills that empower students to solve complex problems in various contexts. In our framework, competency comprises knowledge, skills, and task performance dimensions.

Furthermore, we have developed a model that integrates the KSD framework, allowing learners to acquire a competency framework that includes knowledge, skill, and disposition, with the task as an integral component. Unlike the KSD framework, the competency model provides a clear context for program development, enabling graduates to demonstrate their competence as computing professionals. We have highlighted the key differences between knowledge-based education and competency-based education, with a focus on the latter's emphasis on teaching software engineering courses.

In summary, competency-based education is recommended for its ability to accelerate students' acquisition of knowledge, skills, and value through continuous assessment. This shift redefines the roles of both instructors and learners in the education process.

Chapter 6

Coupling Project Based Learning and Gamification

6.1 Introduction

In the era of digital technology, education heavily depends on software, and game-based learning has become the dominant trend within the field of software engineering. Software has now become an essential component in our everyday lives and the global operations of businesses. As a result, the effectiveness of education is closely tied to the successful implementation of software projects and the development of personalized educational games. These custom-designed game resources are of paramount importance in addressing the increasing need for software engineers. They enable educators to deliver practical training through specialized teaching modules [230]. However, it is equally crucial to evaluate the proficiency of software developers educated through traditional teaching methods and juxtapose their skills with those trained using project-focused game-based learning. This comparative analysis is vital to ensure alignment with the expectations and needs of the software market. Furthermore, project-oriented learning in the context of software engineering education provides valuable insights into the effective development of essential software engineering skills. This paper aims to investigate how the adoption of project-based and game-based teaching approaches can improve the competence of software developers and engineers, equipping them to meet industry demands effectively [231].

6.2 Related Studies

[232] In an online course, an educational tool named Curatr, which incorporated gamification elements such as experience points, levels, and the option to select difficulty levels, was employed. The findings indicated a connection between the accumulation of skill points and task performance scores. Additionally, a relationship was observed between the level of engagement and the overall scores achieved. Interestingly, individuals who attained the highest overall scores did not necessarily possess the highest number of experience points, while those with the lowest scores had the fewest experience points. This suggests that experience points may not accurately reflect the quality or effectiveness of performance. Consequently, educators may consider implementing a minimum participation threshold as a factor when assessing effort, which could potentially impact final grades.

The idea of gamification, as showcased in ”Classroom Live” by [233], was implemented in a computer science course at the college level. The author took into account several aspects of game design, including structure, expertise, objectives, grades, and in-game rewards. As a result, students had a more enjoyable learning experience, and their engagement levels increased. Subsequently, [234] recommended the use of augmented reality and gamification methods in creating an augmented reality book for science education. By utilizing augmented reality, this book could offer 3D simulations of scientific experiments, thereby improving students' understanding of the concepts. Additionally, elements of game design such as onboarding, points, levels, tags, challenges, replayability, non-linear content, and customization were integrated to boost student motivation and active participation.

Likewise, as discussed by [235], badges, when coupled with points and leaderboards, can proficiently generate competition and symbolize the achievement of goals, success, and status. Moreover, badges have the potential to inspire students to enhance their performance by increasing their engagement, improving their skill acquisition, and devoting more time to learning. The overarching goal of gamification was to provide an alternative method to make the learning experience more captivating and gratifying.

On the contrary, [236] integrated two computer game mechanics, the leveling/experience points system and the achievement system, into an online educational platform known as Webwork. Upon analyzing the students' final levels and achievements, it was evident that those who excelled in their coursework also attained high scores in achievements. This implies that their high level of engagement can be attributed to the achievement system. Consequently, the results also indicate that the incorporation of the leveling/experience points system and the achievement system contributed to the students' success.

Furthermore, as demonstrated in our study [237], gamification can significantly enhance student engagement in the learning process. We investigated game design elements, including storytelling and feedback. Storytelling, involving the narrative aspect of the game, can effectively sustain students' interest and engagement. Therefore, the frequency, depth, and timeliness of feedback are also crucial for maintaining engagement throughout the learning journey. Kapp [237] also emphasized the importance of striking the right balance between learning and play as a critical factor for the success of a gamified educational approach.

Consequently, [238], we observed that students displayed limited enthusiasm for learning programming languages like C and C++ in the traditional classroom teaching method. This led to increased student interest in a gamified approach to learning these programming languages. In this gamification approach, a game-based strategy was proposed, incorporating elements such as levels, stages, points, and badges to motivate students. Additionally, students were assigned different skill levels, including Apprentice, Intermediate, Advanced, and Master, as they progressed through the gamified learning process.

Additionally, as shown by [238], it has been established that the objective of gamifying an educational environment or instructional approach is not achieved unless the aim of promoting "engaged, active learning" is seamlessly integrated into the game.

6.3 Motivation

Problem-based learning and gamification are cutting-edge methodologies that can offer a well-organized and all-encompassing approach to training. They are pivotal in assisting educators in delivering knowledge to software professionals. In the present age of digital learning, it becomes imperative to refine the problem-based learning system and integrate gamification to optimize its effectiveness, as emphasized in the work by [239].

6.4 Overview of PBL and Gamification Approach

Project-based learning is an instructional approach that employs open-ended problems as a pedagogical tool, aiming to enhance student motivation and engagement. However, PBL faces challenges when it comes to seamless integration with traditional teaching methods. In contrast, contemporary product-based learning represents an evolution of the collaborative nature of project-based learning, with a focus on creating and developing a product that bridges the gap between educational requirements and industry demands. In this approach, the instructor plays a pivotal role within the project team, collaborating with students to bring the product's vision to life through the integration of project-based learning and gamification, as discussed in [240]. In this innovative teaching method, students take control of their knowledge and education as they collaborate within a team, collectively working towards achieving team success. This curriculum empowers students to become active learners rather than passive recipients of knowledge, aligning with their learning aspirations while also providing valuable experience in project management and teamwork.

Similarly, this approach centers around product-based learning by showcasing the process of designing and contributing to the development of software applications for both academic and industrial purposes. Furthermore, project-based learning cultivates positive attitudes, encourages social interaction, and nurtures an intentional learning mindset among students. It motivates them to pursue their learning goals with purpose and determination, as highlighted in [241].

Table 6.1: The list of game factors

No.	Game Factors	No.	Game Factors
1	Time limitations	12	Level
2	Team competitions and collaborative tasks	13	Leaderboards
3	Scoring mechanism	14	Feedback and continuous information
4	Rules	15	Unlocking content
5	Roles	16	Contest
6	Rewards	17	Communication with other players
7	Quiz	18	Challenges
8	Profiles	19	Badges
9	Points	20	Avatar
10	Notification	21	Alternative Activities
11	Location	22	Achievements

The table above presents details regarding various game elements that are taken into account by students. The primary advantages include the acquisition of points and badges, engaging in team competitions, tracking progress on leaderboards, and participating in challenges and competitive activities.

6.5 The Impact of Gamification and PBL on the Learning Process

In their research, Bartel and G. Hagel, as mentioned in [241], conducted an analysis of the use of gamification in the context of teaching design patterns in software engineering education. Their findings highlighted the significant role of factors such as self-perceived competency levels, leaderboards, and dynamic narrative elements in enhancing learning motivation. This approach involves the creation of a game and incorporates skill-based learning activities, along with a suggested process and standardized documentation plan.

Moreover, their research suggests that the integration of gamified design features into pattern learning has a substantial positive impact on motivation to learn. As discussed in [242], project-based learning in software engineering education provides a framework for effectively developing essential software engineering skills. Consequently, the structured incorporation of project-based learning, both within and beyond the classroom, is viewed as a viable solution to meet the contemporary demands in this field, as indicated in [243].

6.6 Creating a learning activity that combines PBL and Gamification

Problem-based learning is an educational approach that empowers students to nurture their problem-solving skills through practical experiences, facilitating the acquisition of new knowledge. This approach encompasses various developmental stages, including:

a) Clarification phase.

b) Designing and constructing the solution

The entire procedure summarizes the following, as depicted in the figure below [244].

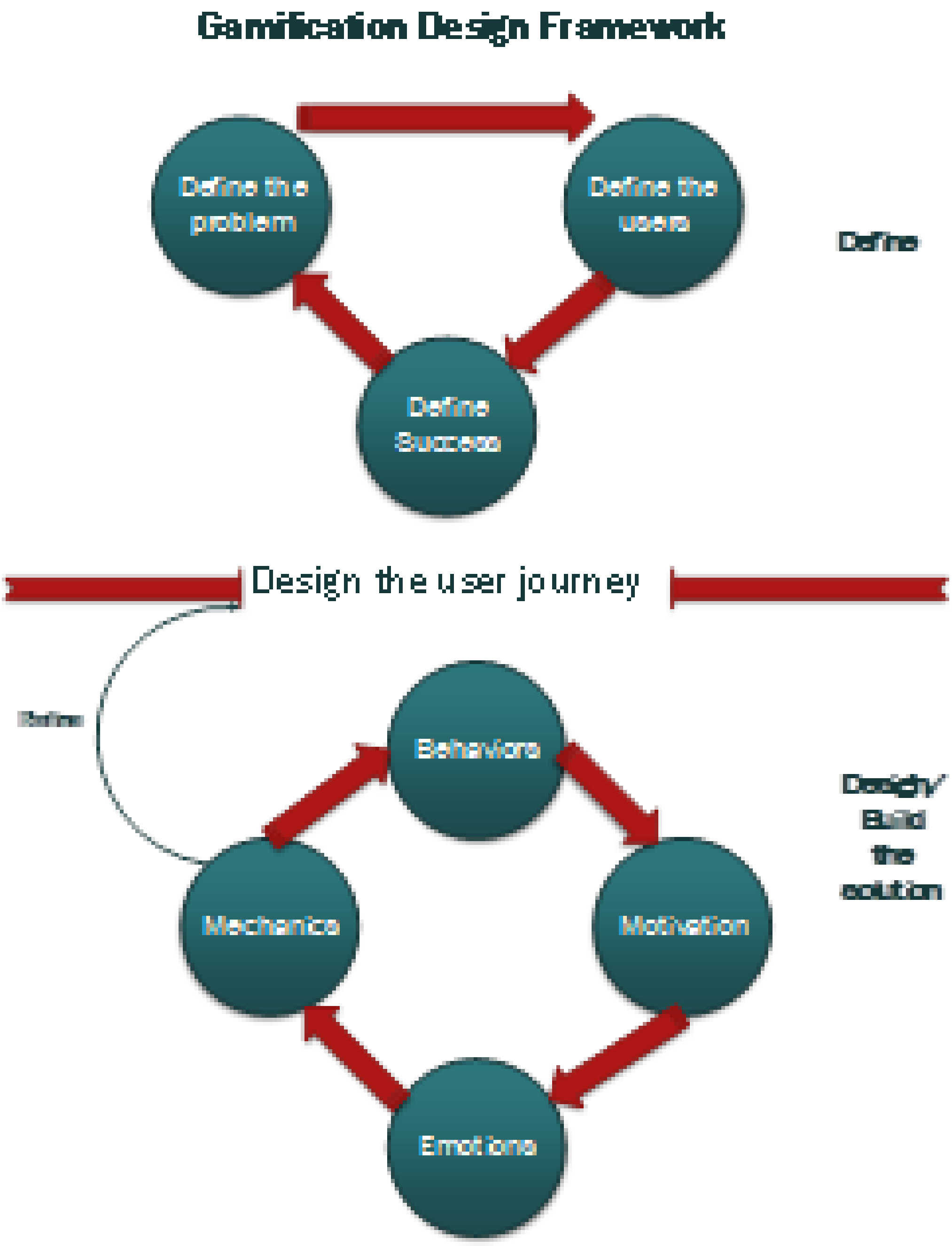

Figure 6.1: Gamification design framework

6.7 Coupling of Projects Based Learning–Gamifica-tion Learning

A study conducted by [231] involved the development and evaluation of a game-based learning system within a software engineering course. This system employs a role-playing strategy based on the digital game-based learning model, firmly grounded in educational theory. It seamlessly integrates academic, content, and technical knowledge. In contrast, Iron Range Engineering is an advanced undergraduate engineering program designed for accredited graduate students by ABET.

In the case of significant projects, this program prioritizes problem-centered education, fostering professional learning, collaboration, and industry involvement throughout the entire semester. Each team is provided with project space for working, collaborating, and conducting research alongside peers. This project-based approach not only offers valuable learning opportunities but also enables the practical application of engineering concepts. Furthermore, the figure below illustrates the quality of educational games.

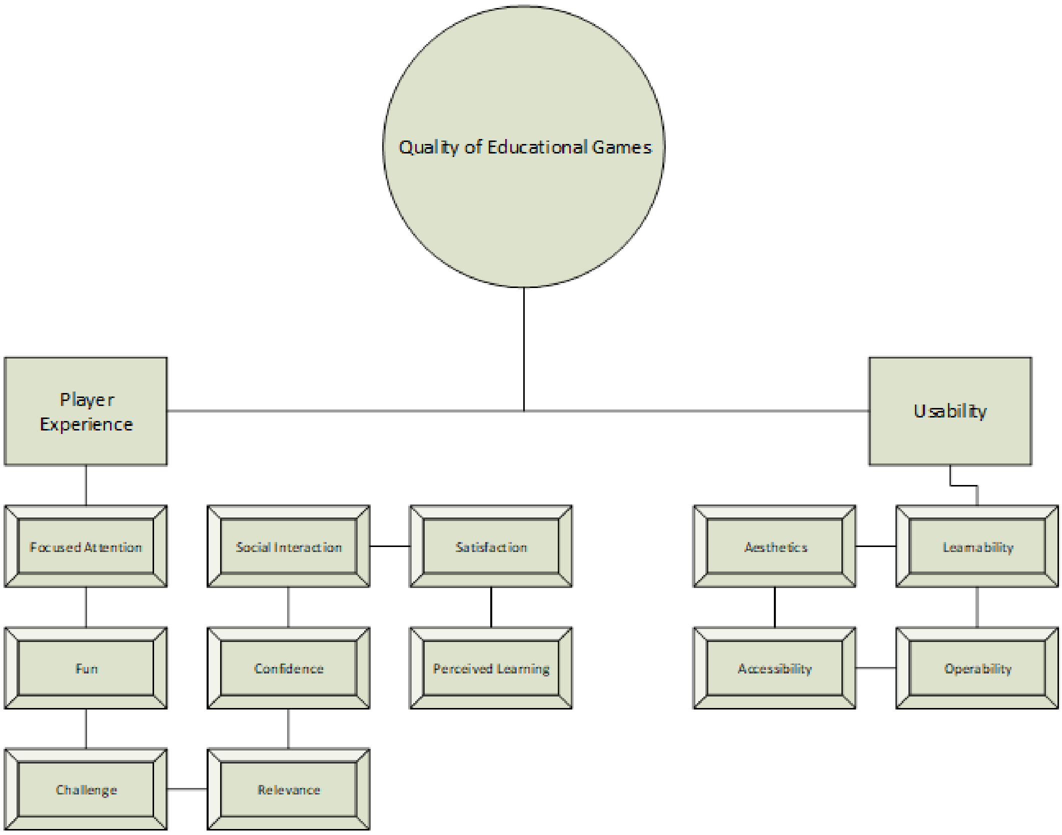

Figure 6.2: Educational games factors

6.8 Evaluation

Following their participation in PBL-gamification, students must undergo assessment, which comprises various components. Firstly, a substantial portion, ranging from 80% to 100%, is allocated to the completion of coursework projects. The remaining 20% of the evaluation is based on weekly assessments of individual lab work and in-class activities. Collaboratively prepared final reports contribute to 20% of the overall assessment. A functional prototype, subject to ongoing evaluation, carries a weight of 40%. Lastly, there is a mid-term test, accounting for 20% of the assessment, which is administered in a paper-based format.

The examination process follows a learning approach that combines research and the Problem-Based Learning (PBL) strategy. Its goal is to improve students' site programming skills for problem-solving purposes. This research initiative comprises four distinct phases, as detailed in the table below [245]

Table 6.2: Evaluation criteria and marks allocation

No.	Evaluation	Marks
1	Weekly appraisal and the assessment of individual student laboratory tasks.	20%
2	Mid-term examination	20%
3	Documentation of the final report	20%
4	Functioning prototype	40%
	Total Marks: 100%	

6.9 Proposed Work

Numerous project-based and game-based learning courses within the software engineering field exhibit areas that can be enhanced. There is substantial potential to broaden the adoption of the game-based approach among software companies and professionals. This expansion can be achieved through outreach platforms like LinkedIn, Facebook, and various open-source project tools. These platforms offer ample opportunities to share and advocate for innovative learning approaches in the software engineering domain, facilitating continuous improvement and skill development among professionals, as discussed in [246]. This initiative aims to bolster the sense of community among students, educators, and professional developers, creating an environment conducive to cross-learning.

Currently, many digital software process games are designed for solitary play, lacking the collaborative element. In single-player games, interaction and motivation among participants are limited. Furthermore, the existing architecture often does not facilitate educators in monitoring the performance of all enrolled players. Therefore, by fostering a more collaborative and community-oriented approach, the goal is to address these limitations and promote a more immersive and engaging learning experience, as suggested in [247].

6.10 Outcome of the Study

The study discussed the implementation of PBL-gamification for engineering students and emphasized the scientific and systematic evaluation of its impact. Effectiveness was assessed by measuring achievement in learning goals.

There's a prevailing perception that software engineering courses tend to be theoretical and may not be as captivating as fields like computer science, which encompass programming, algorithms, or data structures. PBL-gamification can change this perception by helping students recognize that a software engineering course goes beyond theory, making the curriculum more engaging.

Examples of gamification in this context include:

Graphic Designer Challenge: In this scenario, students are tasked with completing a magazine design within a specific time frame, simulating real-world design deadlines.

Millionaire Game: This game format involves students answering software engineering-related questions, earning virtual "money" for correct answers, adding an element of competition to the learning process.

Alphabet Brainstorming: This game encourages creativity and problem-solving as students brainstorm software engineering concepts or terms starting with each letter of the alphabet.

These examples illustrate how gamification can transform the learning experience, making software engineering courses not only informative but also engaging and interesting [248].

6.11 Conclusion

The practical software development courses and projects mentioned earlier serve as potent motivators for students, effectively bridging the gap between classroom learning and real-world work environments. This approach not only fosters competency development but also allows students to actively engage in projects or gamified activities.

Courses that seamlessly integrate a well-structured curriculum with project-based and gamified course materials have consistently demonstrated success, benefiting learners at both undergraduate and postgraduate levels. These strategies not only enhance students' interest and engagement but also provide dynamic learning opportunities through discussions and debates.

Moreover, the positive impact observed from implementing PBL and gamification in software engineering courses underscores the innovative nature of this pedagogical approach. As a result, there is potential for its broader adoption within engineering universities, promising an exciting avenue for future research in this field.

Chapter 7

Framework to Promote Collaboration Between Industry and Academia

7.1 Introduction

A university establishes both physical and virtual connections with students when they join as freshmen, and this engagement continues throughout their time on campus. The university maintains contact with students from enrollment until they successfully graduate.

After graduation and as students enter their careers, the university often relies on an alumni network as the primary means of staying connected with them. This alumni network serves as a vital communication channel, bridging the gap between the university and its graduates, enabling ongoing engagement and support for alumni as they progress in their professional lives [249]. Alumni typically encompass former students, faculty, and staff members of a university, college, or school. The term ”academia advancement” refers to the connections and collaborations between the educational institution and various community organizations, including alumni. These interactions and partnerships with alumni and other community entities play a crucial role in supporting and advancing the university's overarching vision and mission [250].

The collaborative partnership between industry and academia plays a pivotal role in fostering technological improvement, innovation, and cutting-edge research. It enables universities to remain highly relevant to the ever-evolving industry landscape. Additionally, alumni can serve as exceptional role models for current students, as they are often held in high regard.

When alumni return to the university to offer their assistance, it not only adds credibility to the institution but also gives students a compelling reason to take pride in being part of a successful educational establishment. Alumni, who have gone through the same academic journey and faced similar challenges, can provide invaluable insights and guidance to current students. Their experiences in time management, financial planning, self-discipline, character development, and leadership are often regarded as valuable advice and a source of inspiration for today's students.

Alumni involvement can contribute to building students' confidence, enhancing motivation, and instilling a culture that aligns with the university's intended message. In this way, alumni play a crucial role in shaping the educational experience and future success of the university's students [251].

Collaboration is becoming increasingly essential for effectively addressing industrial challenges [252]. In recent years, universities and industries have recognized the significant benefits of aligning academic affairs, student affairs, and alumni services around common goals. Student affairs professionals and alumni affairs counterparts can collaborate effectively, as both strive to enhance the institution's reputation and the experiences of those connected to it. They work with the same community but at different stages of their relationship with the university. When this collaborative approach is established and maintained, it brings significant advantages to both student and alumni affairs [253].

University education represents the highest level of academic instruction, providing students with a wealth of knowledge, research capabilities, and the opportunity to build valuable connections with peers, professors, and other scholarly figures. These relationships are of paramount importance for graduates, as they can spark new ideas and collaborations beyond their degrees. Consequently, both industries and academia actively encourage and endorse the cultivation of these relationships [254][255]. Indeed, both academia and industry have recognized the importance and advantages of forming partnerships. However, many industries still face challenges in effectively fostering and maintaining these collaborations [256][257]. It is crucial to address questions such as:

How does the university's interaction with its alumni align with the institution's needs? In what ways does alumni engagement with the university satisfy their own requirements? Neglecting to address these questions could lead to ineffective and resource-intensive efforts. While there is a growing emphasis on promoting collaboration, ongoing research has identified diverse forms of cooperation. Yet, industries continue to grapple with identifying the most efficient approaches for initiating and sustaining partnerships. These challenges emphasize the significance of establishing well-defined guidelines and principles that govern the initiation, execution, and success of such partnerships [257].

Collaboration between the academic and industrial sectors is increasingly recognized as a means to enhance innovation through the exchange of information. This concept is supported by a growing body of research that approaches the topic from various angles. However, this research is often fragmented and lacks a comprehensive overview.

Moreover, a notable gap between industry and academia arises from the mismatch between educational systems and industry requirements. Educational institutions remain a fundamental pillar of all societal endeavors and cannot be overlooked [258]. There exists a substantial disparity between the curriculum taught to students and the expectations of the industry within the current education system. This disconnect is contributing to a decrease in productivity.

One pressing challenge faced by the industry is the widening gap between their needs and what educational institutions are providing, which grows with each passing day [259]. Alumni input should be a primary resource for identifying current industry needs. Alumni play a crucial role in the institution's advancement after completing their degrees. They can effectively bridge the divide between academia and industry by organizing events such as conferences, expert talks, inviting guest faculty, and facilitating student workshops focused on cutting-edge research [260]. The enthusiasm and commitment of alumni can be immensely valuable for activities like fundraising, engagement, marketing, and product promotion. To harness these benefits, educational institutions must maintain continuous communication with their graduates even after they have finished their studies. This article underscores the significant role of alumni in fostering collaboration between industry and academia. It's important to note that the term ”alumni” can encompass not only former students but also instructors and other individuals associated with a school or program. Alumni associations are organized and official networks comprising individuals who share a common programmatic or educational connection [261].

Alumni affairs departments at most colleges and universities employ various strategies to engage alumni as valuable partners, aligning their efforts with other campus groups and industries to collectively enhance and enrich the college experience. Consequently, we propose a collaborative model that leverages alumni interactions to strengthen industry-academia collaboration. This model includes various programs that effectively bridge academia and industry through alumni involvement, benefiting both parties.

To delve deeper into this concept, the paper is organized as follows: - Section II discusses the partnership between academia and industry. - Section III examines the functions and duties of alumni in fostering collaboration between industry and academia. - Section IV presents the suggested collaborative model. - Section V delves into the validation of the research. - Sections VI and VII offer an extensive discussion and summary of the research's discoveries.

7.2 Collaboration between the Academic and Industrial Sectors

"Academia" is a comprehensive term encompassing the entire community involved in higher education and research, including students, educators, and researchers. Its origins lie in Greek, signifying a vast realm of knowledge creation, advancement, and transmission across generations. Universities, as integral parts of academia, undoubtedly possess the research capabilities, drive, and expertise needed to disseminate essential education to diverse segments of society through training and various educational programs [262]. In contrast, the term "industry" encompasses all economic activities related to the production of goods or services. It represents a link in a broader chain, starting with the extraction of raw materials, progressing through the manufacturing of finished products, extending into the service sector, and ultimately culminating in research and innovation. Industries, the nations in which they operate, and their economies are intricately interconnected within a complex web.

At the same time, academic institutions are under significant pressure, driven by rising expectations from stakeholders and learners [263]. Effective collaboration between industry and academia is essential to enhance their ongoing efforts through mutual support. A recent paper, [264], highlighted the significance of increased cooperation among three crucial groups: academics responsible for developing educational technologies, educators and students who utilize these technologies, and academics with expertise in researching their effectiveness. The paper also outlines five levels of collaboration between academia and industry, as illustrated in Figure 7.1 (source: [265]).

Undoubtedly, commerce stands as one of the most innovative forms of collaboration in human history, where one party purchases a service or product from another. A notable advantage of such partnerships lies in the transparency regarding the contributions and benefits of each partner. Collaborations between industry and academia that involve commercial transactions, with the research party acting as a conventional customer, can be advantageous in specific situations for driving productive research projects. The clarity concerning the commitments and exchanges between both parties is a significant advantage compared to many other forms of cooperation.

However, every partnership between industry and research introduces ethical challenges, particularly when the industry partner is unaware of the primary research objectives. The central concern often revolves around evaluating the potential harm to participants, including the loss of time and resources [266]. Collaboration between industry and academia serves various purposes. Industries gain advantages from a pool of highly skilled human resources, including researchers and students. They also benefit from access to advanced technology and information, along with the opportunity to utilize sophisticated research infrastructure [258]. According to certain studies, university research can contribute to as much as 10 percent of digital products or technologies [267]. Academics increasingly seek collaboration with industry for several reasons, including securing additional funding, gaining access to industry-specific technologies, and generating revenue through patenting. In fact, partnering with industry has become a fundamental component of funding for academia, supporting research and development initiatives within the higher education sector. These collaborations often involve contributions from international organizations and technology firms, serving as a substantial source of support in many countries [268]. Furthermore, collaborations with other sectors provide the opportunity to address complex challenges in academia, encompassing resource availability, knowledge exchange, and skill development for individuals. Given the profound impact and economic significance of these outcomes, it is imperative to effectively manage collaborations between industry and academia to optimize the advantages for both parties [269]. Around two decades ago, design-related fields played a pivotal role in the emergence and growth of the user experience (UX) field. This evolution is clearly visible in both academic and industrial contexts, with a growing number of UX journals, conferences, and a flourishing job market.

However, in the realm of formal education programs in user experience, academia has not made the same strides as it has in conceptualizing and researching the field of user experience [270]. Additionally, the model presented in this study holds significant promise for amplifying this collaboration. The success of such collaboration hinges on the extent to which academia and industry recognize the value of partnering to enhance educational and industrial services for the betterment of society. Realizing this objective is attainable when both institutions leverage alumni as a means of connection and cultivate strong relationships with their alumni networks.

This engagement presents numerous opportunities for professional and personal development for both academia and industry.

Figure 7.1: Five levels of IA closeness

At the ”no-contact” level of closeness, academia and industry function separately, dealing with their distinct challenges. During this phase, academia primarily concentrates on conducting research and publishing to progress academic knowledge and scholarship.

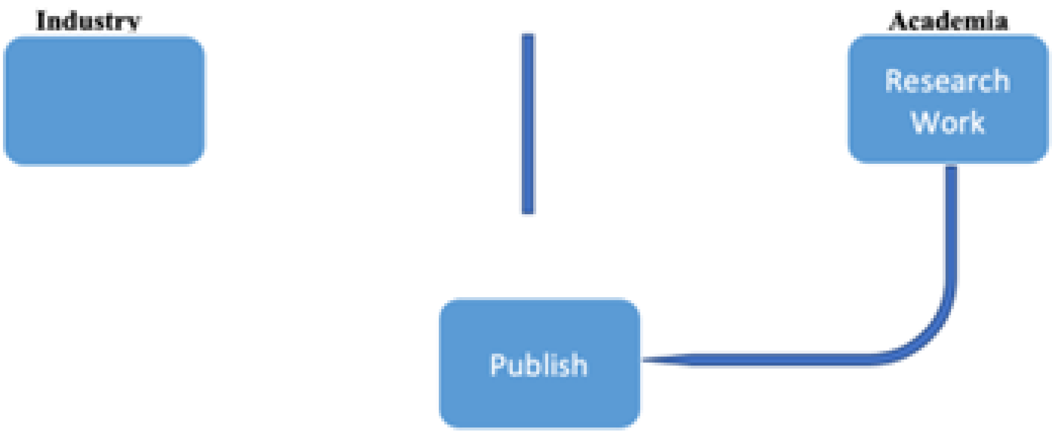

Figure 7.2: Industry and academia with no contact

As a result, when there is no interaction between industry and academia, the following activities do not experience enhancement, and the gap between the two widens [266].

1. Lack of incentives.
2. Absence of a foundation for a center of excellence and significance.
3. Lack of knowledge diffusion through peer-to-peer interaction.
4. Alumni not participating as mentors to students.
5. Failure to recruit top-tier faculty.
6. Absence of structures for effective interface.
7. Underutilization of academia-industry research and development labs.
8. Lack of a dedicated cell for entrepreneurship development and technology incubation.
9. Inability to facilitate technology transfer from the laboratory to market access.
10. Limited opportunities for technology transfer toward commercialization.
11. Absence of a research park to foster enterprise growth.
12. No establishment of venture capital funds to support innovative entrepreneurship.

The "rumor" or hearsay level represents the second stage of proximity between industry and academia. During this phase, academia becomes aware of challenges prevalent in the industry. They hear about issues and shortcomings in industrial systems. Academia actively engages in developing novel methods and approaches to address these existing problems in industrial systems. In response to industry concerns, as depicted in Figure 7.2, academia devises solutions and publishes the findings in academic journals and conferences. However, at this stage, academia does not share these solutions with the industry. Consequently, for academia to share these solutions with the industry, there is a cost involved, as these solutions have been developed and researched by their own scholars. To address this, the third level of closeness becomes relevant.

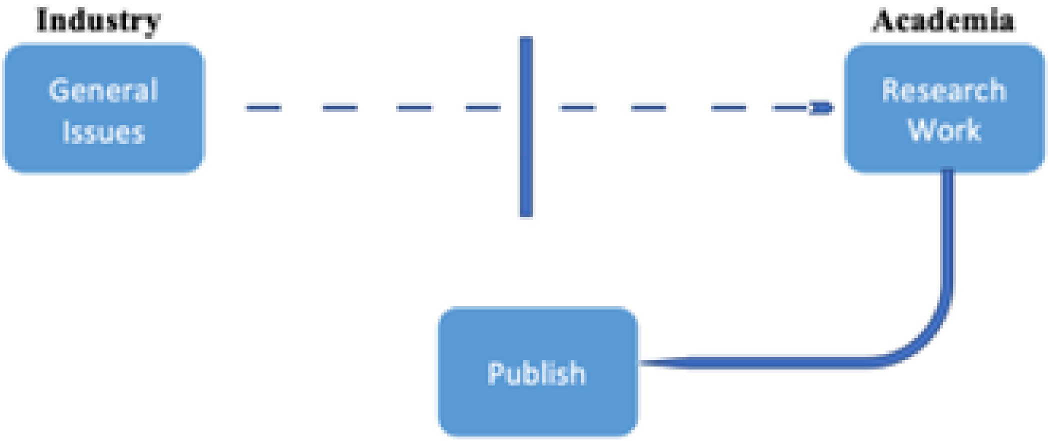

Figure 7.3: Hearsay between the industry and academia

As indicated by [265], the ”commercial pitch” represents the third stage of closeness between academia and industry. In this phase, academia actively initiates contact with the industry to discuss the challenges that the industry is encountering. Academia proactively seeks opportunities by approaching industry partners and making proposals to offer their solutions and methodologies. Since academia does not offer these solutions to the industry for free, their intention is to sell their approaches.

This level of proximity aims to bridge academia and industry by recognizing industrial challenges and devising solutions for them. However, it involves a trade-off between cost and quality. The more an industry is willing to invest, the higher the quality of solutions it can expect to receive. According to Figure 7.4, academia works on developing solutions to address industry-wide issues and monetizes its research findings in this context.

The fourth level of proximity is known as the ”offline stage.” During this stage, there is direct communication between industry and academia, as illustrated in Figure 7.3. Industry

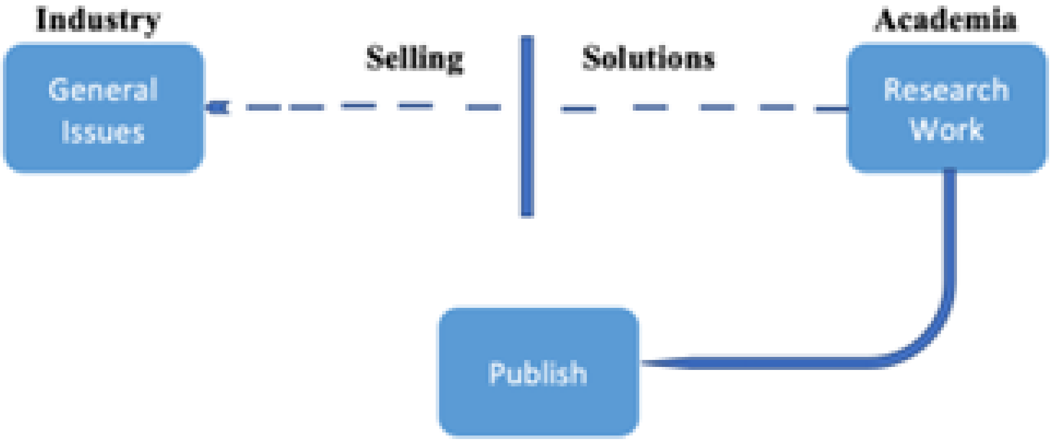

Figure 7.4: Sales pitch between industry and academia

presents its specific challenges to academia, and academia participates in offline collaboration with the industry. This collaboration entails conducting research on the presented challenge and developing a set of ready-made solutions, which are subsequently provided to the industry.

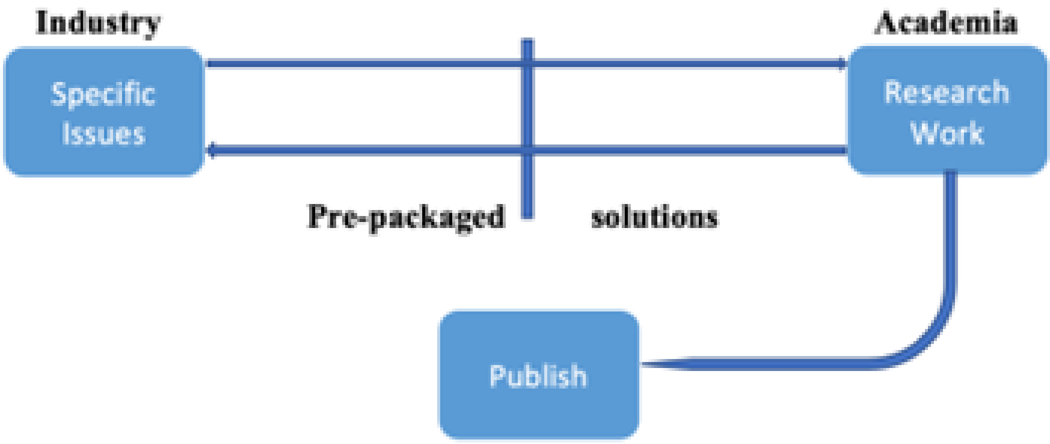

Figure 7.5: Sales pitch between industry and academia

The highest level of proximity is often described as the ”united team” or ”one team,” as depicted in Figure 7.4. During this stage, industry and academia establish a close and collaborative partnership. Together, they identify various industry-specific challenges. Initially, they customize solutions, improve and validate them through shared efforts, and subsequently publish the results. Ultimately, they function as a unified team, leveraging their strong ideas and collective potential to work towards common goals.

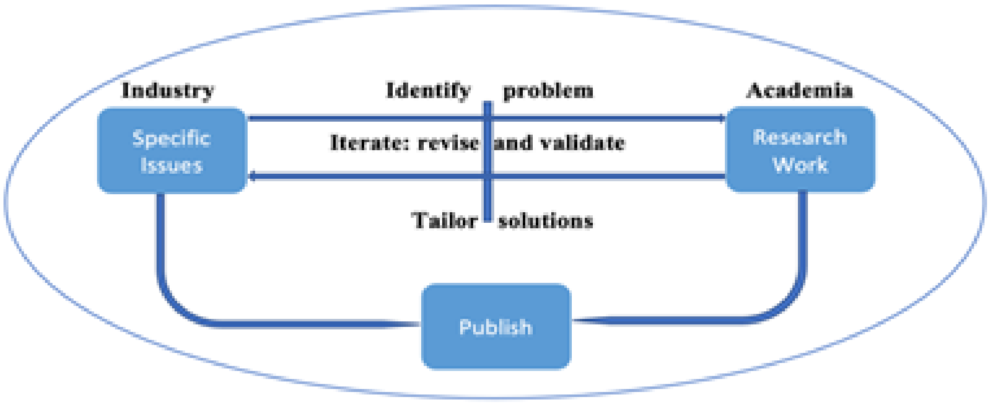

Figure 7.6: Sales pitch between industry and academia

7.2.1 Current Industry Challenges

In the last ten years, researchers and professionals have conducted numerous studies that emphasize the significant benefits of collaboration between industry and academia. This type of partnership is widely acknowledged for its advantages, particularly for technology companies. Additionally, many engineering students and educators profit from these collaborations by exchanging information and gaining practical experience. Figure 7.7 illustrates the potential benefits for students arising from the collaboration between academia and industry [52]. However, interaction and cooperation between academia and alumni are relatively rare for several reasons:

a) Alumni often feel that universities haven't provided them with valuable information or incentives.

b) Efforts to engage alumni are often centered around obtaining financial contributions for universities.

c) Academic institutions often prioritize and favor more productive and experienced alumni members over current, less productive alumni representatives.

d) The relationship between academia and alumni can sometimes be strained.

Furthermore, there are several barriers that hinder academia's involvement with their alumni [259].

Figure 7.7: Potential students' advantages

Certainly, the educational and industrial systems are the fundamental pillars of the technological world. Within the realm of education, numerous frameworks and philosophies have been introduced and put into practice [271]. However, the gap between industry expectations and institutional outcomes continues to widen with each passing day. It's imperative that alumni input takes a central role in understanding the current needs of the industry, as their contributions continue to benefit the institution even after they graduate. To bridge the divide between industry and academia, alumni can be instrumental in hosting conferences, delivering expert talks, and organizing student workshops focused on the latest developments. Engaging alumni can prove to be a potent tool in this effort [260]. Garousi [272] conducted a comprehensive analysis of industry-academia collaboration and identified several existing challenges and best practices. Table 7.1 provides a concise summary of various challenges faced by industries, along with corresponding recommended best practices.

Table 7.1: Industries challenges.

References	Challenges
[273][272]	**Inadequate research relevance** 1. The research outcomes have no practical relevance. 2. Researchers lack a comprehensive understanding of industry-relevant issues.
[274]	**Inadequate training, expertise, and competencies** 1. Insufficient education in software engineering. 2. Limited understanding of the researcher's business context and the practical technologies employed.
[275]	**Lack of enthusiasm or dedication** 1. Failure to fulfill commitments regarding access and time.
[276][277]	**Incompatibility of industry and academia** 1. Differences in terminology and communication methods. 2. Varied communication modes and information flow orientations.

Table 7.2: Industries challenges.

References	Challenges
[4][274][272]	**Factors relating to people and organizations** 1. Rigidity and reluctance to adapt to change. 2. Instability and discontinuity within the organization. 3. Collaboration within a team. 4. Challenges of both technical and organizational nature.
[274][265][239]	**Concerns about management** 1. Challenges in defining clear and achievable project objectives. 2. The need for a substantial time and effort commitment.

Table 7.3: Industries practices.

References	Best practices
[278] [4][239] [272]	1. Depend on long-term planning. 2. Facilitate researchers with frequent and prompt access (making solutions practical and attainable). 3. Conduct workshops and seminars (offering insights into industry-related issues).
[239][279] [280]	1. Industry becomes more open to engagement in education. 2. Changes occur in the content of academic courses. 3. Implement the case study method (case studies are valuable tools for sharing knowledge and expertise). 4. The researcher and the industry site should be located in close proximity to each other.
[281][273]	1. Top teams and their mindsets are required. 2. Maintain regular contact through meetings (enables internet connectivity). 3. Interaction with experienced practitioners is essential. 4. Collect data by directly engaging with practitioners.

Table 7.4: Industries practices.

References	Best practices
[282][273] [280][269]	1. Employ the case study method (for experimental purposes only). 2. Ensure management involvement on the industry side (to minimize the organization's influence). 3. Foster awareness and communication.
[277][283]	1. Researchers should possess appropriate presentation and communication skills during early sessions. 2. Demonstrate the benefits of the research solution to the industrial partner (highlight the value of time-saving solutions).

7.2.2 Strengths of the Current Industry

The industry is actively engaged in comprehensive development efforts. They often seek immediate collaboration with academia, prioritizing investments that yield measurable outcomes. Figure 7.8 outlines five potential strengths of the industry in the context of engineering education, which can also be considered advantages for academia [284].

Figure 7.8: Five Key Industry Strengths Beneficial to Academics

To begin, having industry experts instruct courses provides software engineering professors with a deeper understanding of industry priorities and how to incorporate them into college lectures. The way instructors interact with industry professionals attending classes differs from their interactions with university students. Industry experts often have very specific and precise requirements, whereas university students typically have broader objectives.

Furthermore, alumni, especially those pursuing careers in teaching, act as a valuable bridge between educators and the industry. Many software professionals have completed significant industrial projects while working on their dissertations, which may have contributed to their careers in the industry. After graduation, both alumni and instructors' perspectives naturally evolve. Alumni may realize that an instructor's role extends beyond the dissertation topic or the undergraduate courses taught by the instructor. These roles allow for more extensive and adaptable communication as technology and industrial demands change over time.

On the other hand, instructors' research and teaching activities are less constrained in terms of scope and time compared to practitioners' industry responsibilities. Therefore, alumni may turn to their advisors and instructors for longer-term insights and alternatives to their current practices. From the instructor's standpoint, maintaining close contact with alumni can facilitate communication and provide a valuable channel to the software industry. This connection enables instructors and researchers to identify emerging topics and trends that can be integrated into their academic and professional programs [285] [284].

Another essential aspect to consider is the potential for industrial experts to bring their knowledge and real-world experience into regular college classes. Experienced software engineers often offer a different perspective on real-world challenges compared to what is typically covered in academic settings. Professionals bring a unique viewpoint that allows students to grasp the significance of themes that may have been overlooked previously.

For instance, many software engineering students tend to emphasize the coding phase as the most critical step in software development. This phase involves creating the final product and is often the focus of early software classes. Educators may find it challenging to convey the broader aspects of software development, such as the importance of early stages or administrative and organizational concepts. Students might be more engaged with professionals who can provide insights from their real-world experience. Professionals can justify decisions made for non-technical reasons, making the learning experience more engaging for students. Learners are often highly receptive and eager to learn from real-world examples.

Software professionals can contribute to education in various ways, from giving brief presentations to teaching entire courses. To maximize this collaboration, software professionals should understand how their expertise aligns with other disciplines in the curriculum. It's evident that software developers should work closely with instructors to determine which topics can be effectively taught, to what extent, and what outcomes can be expected. Additionally, software professionals can leverage their expertise to develop and teach courses within their own organizations [284].

As a result, software engineering often takes a more theoretical approach compared to many other engineering fields. It's clear that industrial companies could greatly benefit from access to innovative ideas and approaches emerging from academic theoretical research. They can also benefit from data on the effectiveness and appropriate application of these ideas. In return, the software industry can provide valuable insights into methods and techniques that may be applicable in academic research.

Furthermore, the results of laboratory experiments can serve as a pilot study for further investigations within industrial organizations. Moreover, the distinction between students and software professionals is increasingly becoming blurred in many instances. Students often work as consultants or hold part-time or full-time positions in the industry. Conversely, professionals sometimes return to college to further enhance their knowledge and skills [286]. In conclusion, the literature on software engineering education contains numerous articles addressing team project courses and the essential skills needed for effective collaboration in software teams. We firmly believe that it is highly beneficial for students to learn software engineering concepts and methods through a combination of traditional lectures, academic exercises, and hands-on experiences that closely mirror real-world industrial practices. Therefore, incorporating industry relevance into software engineering projects is crucial, even if presenting a complete industrial project to students can be challenging.

On the other hand, industrial firms can contribute substantial portions of practical application requirements that can be integrated into college sessions, including homework assignments, class projects, and demonstrations. An example of this kind of industrial engagement is discussed by Jaccheri in [287]. Another illustration can be found at the Norwegian University of Science and Technology, where a company acts as a client with varying levels of involvement depending on the specific scenario and project requirements.

7.3 Roles of Alumni in Collaborations between Industry and Academia

The term ”alumni” is broad and can encompass students, instructors, and individuals associated with a school or program. However, it’s important to note that alumni associations are formal and structured networks comprising individuals who share a common educational or programmatic connection. These associations serve as official organizations that facilitate ongoing engagement and collaboration among alumni [261]. An active and supportive alumni network is of paramount importance for the success of an institution. When a graduate leaves a university, their perception of the institution tends to remain static. However, it’s crucial to keep alumni informed about the university’s ongoing developments and progress. Maintaining strong alumni connections benefits both the university and its graduates. In this context, professionals in higher education alumni relations emphasize the importance of an engaged alumni network and how the landscape is evolving. To navigate this changing landscape successfully, it’s essential for researchers and practitioners to collaborate closely throughout the partnership process [265].

Bachelor’s degree programs typically require three to four years of study to complete. However, it’s crucial for students to also establish industry contacts during their academic journey. Without these connections, the credibility of their qualifications can be questioned. Unfortunately, only a small percentage of college students manage to gain work experience while pursuing their degrees. Consequently, many graduates seek new career opportunities upon completing their studies. For those without industry contacts, finding employment can be a challenging endeavor [288].

Many alumni associations establish partnerships with university career services to facilitate the exchange of information regarding job placement opportunities for incoming students and alumni. Some universities also provide their alumni and students with access to online job recruitment and search tools, such as MonsterTRAK.com. These platforms empower job seekers to explore a database of job openings, both nationally and internationally, enhancing their prospects for finding suitable employment opportunities [253].

One key factor often associated with career success is the ability to find a mentor who can assist students in transitioning from college to the workplace. Alumni are particularly well-suited for this role, drawing upon their experiences to help students navigate the world of employment, work effectively, and secure job opportunities. There are numerous benefits to alumni engaging directly with students, especially as they make their initial career decisions. Alumni can offer practical guidance and support to students pursuing degrees in fields related to their own careers. In addition to the personal satisfaction that comes from contributing to another person's growth, participating alumni have the opportunity to witness students who may one day become candidates for positions within their own organizations.

Furthermore, many alumni associations offer programs such as job shadowing and mentoring, summer job placements, and internships for current students. These programs help connect alumni employers with potential employees and provide valuable opportunities for students to gain real-world experience and guidance as they prepare for their careers [284].

As a result, alumni tend to be among the university's most passionate supporters. Molly Southwood, the University of Bath's Head of Alumni Relations, emphasizes the importance of an engaged alumni network, stating that it allows the university to harness the strengths and knowledge of its graduates for the benefit of current students, the institution itself, and fellow alumni. Alumni can become some of our most dedicated members and strongest advocates, but this can only happen if we maintain a connection with them and keep them engaged.

The role of the alumni network is summarized in Figure 7.9. Alumni who possess exceptional talents and expertise can share their knowledge with current students through speeches, newsletters, and even social media. In some cases, alumni may even play a role in helping students secure job opportunities and start their careers.

Alumni can play a crucial role as international ambassadors for the college in various contexts. For instance, at the City University of London, where "more than 45% of City's students are international," according to Celia Enyioko-Hanniford, the director of the alumni communications

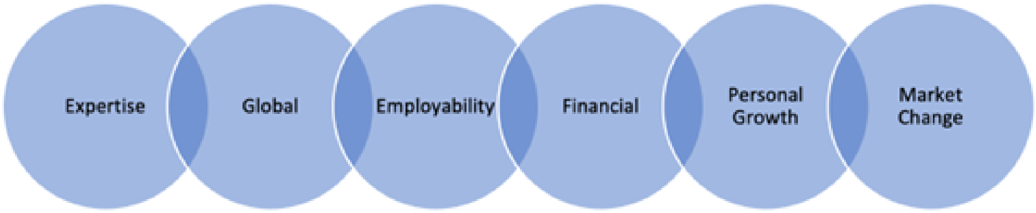

Figure 7.9: Role of alumni network in IAC

office, they help showcase what life is like in London to prospective students, encouraging them to choose the university for their studies. In today's highly competitive job market, such endorsements provide students with a valuable advantage.

In terms of program outcomes, the university has maintained its reputation as one of the top institutions in the UK for graduate employability and starting salaries. Alumni often show their generosity through fundraising efforts, driven by their loyalty and gratitude toward the university. These financial contributions enable the university to offer life-changing scholarships and financial assistance to deserving students who might otherwise face challenges in continuing their education. Additionally, alumni support helps the university provide modern teaching and research facilities.

While an engaged alumni network undoubtedly benefits the university, it also holds advantages for the alumni themselves. As Kenneth Okoroafor (BSc Economics and Accountancy 2005) shared in an interview for the annual alumni magazine, being part of this network has been personally fulfilling. He mentioned, "I've learned a lot about myself and my career. As graduates evolve and new alumni emerge, the job market naturally changes. What worked in the past may no longer be effective for a new generation of graduates. This implies that approaches may need to be revised and adapted." [289]. Alumni Affairs plays an active role in several university initiatives that benefit both students and the institution. These collaborative programs encompass efforts to enhance the overall quality of student life, initiatives aimed at orienting and welcoming new students to campus, and activities designed to attract and retain students [253]. Numerous academic institutions have implemented initiatives in partnership with their admissions departments that actively engage alumni in the recruitment of prospective students. Research by Hanson has identified several factors that accurately predict which alumni are most likely to advocate for their alma mater. These factors include the institution's reputation, the alumni's sense of social identification with the school, the number of years since their graduation, and their respect for alumni leaders. Many schools and universities have robust recruitment strategies that involve institutional rituals and traditions, and these efforts are often supported and promoted by parents, faculty, and alumni. The key to a successful alumni recruitment program is identifying elements that foster a strong connection to the institution, its current students, and its alumni network [290].

7.4 Proposed Model

The proposed framework is designed as a collaborative approach that leverages the influence of alumni to strengthen the partnership between the industry and academia. The term 'alumni engagement' encompasses a broad range of activities, as referenced in studies by Di et al. (2014), Farr (2018), and Snijders (2019). Fostering interaction is a global priority, particularly for the educational systems of developed nations, as highlighted by Coates (2010). Many universities and alumni organizations frequently organize various events to engage their alumni. However, after an initial successful engagement activity, its appeal tends to wane, and participation levels decline over time. There's often a lack of clarity for alumni groups and universities on how these events fit into a broader engagement framework and how to generate diverse ideas to cater to alumni needs. Unfortunately, many universities underestimate the importance of alumni engagement, resulting in limited allocation of time and resources to this crucial endeavor. This lack of enthusiasm within academia underscores the need for a structured alumni engagement model, as discussed by Parthasarathy (2018). We have developed an innovative engagement model, as depicted in Figure 7.10, to strengthen collaboration between the industry and academia. This model defines the roles and responsibilities of alumni in relation to both sectors. According to our model, alumni can contribute significantly to academia and industry in various capacities, including as mentors, advocates, researchers, supporters, ambassadors, educators, internship providers, and as a valuable workforce.

The main objective of this model is to enhance and nurture the connections between academia and the industry by promoting active engagement with alumni. Alumni, who are former students of academia, represent both the present and future workforce of industries. When academia and industries maintain positive connections with alumni and create opportunities for them to mentor and offer internships to current and prospective students, it establishes a productive avenue for interaction.

Moreover, the model underscores the significance of a reciprocal relationship between the

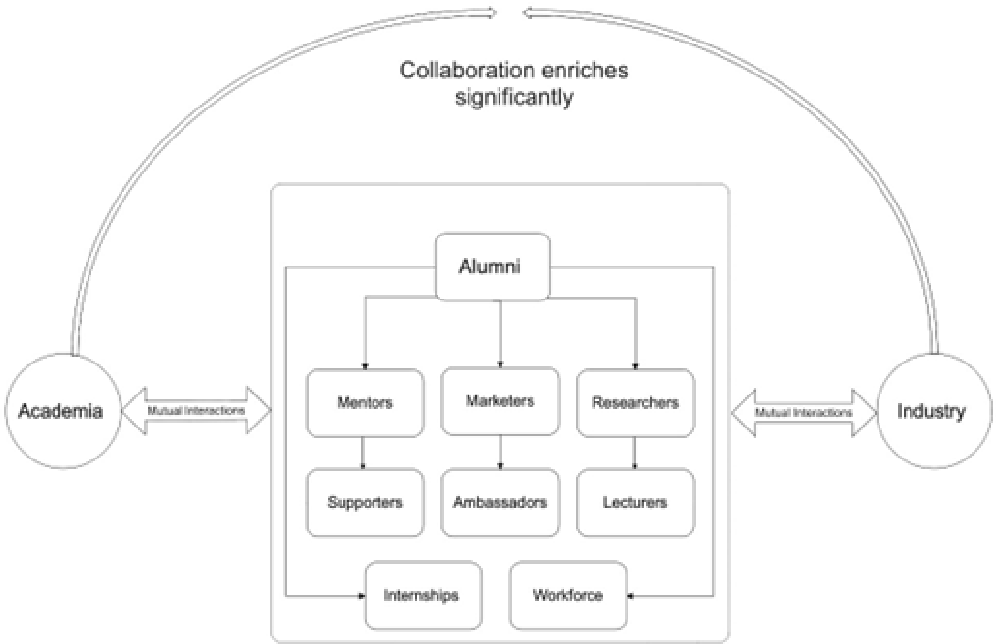

Figure 7.10: A model for enhancing industry-academia collaboration through alumni engagement

industry, academia, and alumni. Strong engagement with academia encourages alumni to become more supportive of their educational institutions. The various roles that alumni can assume, as illustrated in Figure 10, are elaborated as follows:

a) **Alumni as mentors:** Research on mentoring undergraduate university students has predominantly focused on instructor-to-student mentoring [291, 292]. However, there has been limited exploration of alternative forms of mentorship involving university students, such as interactions with alumni mentors, creating a gap in knowledge on this subject. In [293], qualitative research was conducted to gain deeper insights into the expectations and experiences of undergraduate students who were mentored by alumni through a mentorship program facilitated by the university's career center.

   The study's findings revealed that many participants sought guidance from their alumni mentors regarding both their academic pursuits and job-related aspirations. Interactions between university students and their alumni mentors occasionally included university-specific information that the students found valuable. According to the interviewees, these interactions with alumni mentors were highly beneficial as they provided insights into both industry and educational aspects. Students reported experiencing increased confidence, greater career clarity, and reduced stress in their current situations, all attributed to their enhanced understanding of potential future career opportunities resulting from their mentoring interactions with alumni.

Various factors drove students to seek mentorship from alumni. Some were exploring different majors and wanted insights into potential career paths, while others had specific career goals and sought guidance in those areas. For instance, a student interested in software engineering actively sought a mentor with expertise in that field.

b) **Alumni as marketers:** Academic institutions heavily rely on their alumni associations for ongoing support and should, therefore, nurture, retain, and develop strong alumni partnerships, as discussed in [294]. This collaboration is typically facilitated through the alumni association, which not only acts as a marketing tool but also serves as a representative for the university and its alumni. Some colleges, as highlighted in [295], utilize their alumni organizations as a marketing tool to foster positive relationships with their alumni.

The foundation of a successful relationship lies in recognition and mutual respect. When both parties acknowledge and value each other's roles and contributions, a sense of belonging is established. In this context, academic institutions seek to leverage the support of their current students, alumni, and the wider community for various initiatives. The alumni network proves to be an effective tool for promoting, organizing, and managing specific projects. Universities continuously seek contributions from their alumni, necessitating an approach where the university treats its alumni as valued clients, understanding that the better they serve their alumni, the higher the quality of their service.

Universities often employ mass marketing strategies, incurring significant costs to maintain or expand their market presence [139]. Marketing budgets continue to grow, with institutions investing heavily in an integrated marketing mix targeting potential students. However, there is a growing realization of the potential benefits of applying relationship management principles to graduate marketing. As highlighted by Shaik and McAlexander [294] [139], alumni play a dual role as both a marketing instrument and spokesperson for the university, influencing the perception of the university among the public and prospective students. Alumni engagement can encompass various activities, from participating in alumni events and purchasing university-branded products to assisting with enrollment decisions and contributing to the university's financial resources.

c) **Alumni as researchers** The strength of the connections between alumni and their alma mater has been recognized as a significant factor influencing alumni engagement. A lasting and meaningful relationship motivates alumni to contribute more actively and positively to their alma mater, as discussed in [296]. This support from alumni can take various forms, including generous financial contributions, providing oral recommendations to others to engage with their alma mater, participating in advisory boards, and offering managerial support, as explored in [297] [298].

In the context of collaborative research, the question arises: Does the quality of alumni relationships have an impact on faculty behavior? This question is addressed in [107], where the collaborative tendencies of alumni faculty members are compared to those of non-alumni faculty members. The study provides insights into whether alumni connections influence faculty engagement in collaborative research.

Furthermore, alumni can be a valuable resource for academia when conducting applied research, as highlighted in [299]. Their practical experience and industry knowledge can contribute significantly to the success of applied research initiatives within academic institutions.

d) **Alumni as supporters:** Alumni are often regarded as some of academia's most dedicated supporters. An active and engaged alumni network provides educational institutions with the opportunity to leverage the knowledge and capabilities of their alumni for the benefit of current students, the institution itself, and the broader community. A strong alumni network can bring substantial advantages to academia, as alumni can contribute in various ways, both financially and through non-monetary support. This makes alumni a valuable and influential group, as discussed in [300].

Student engagement, in particular, revolves around the sense of attachment that learners feel toward their academic institution. This attachment is demonstrated through their attitudes and behavioral traits, as mentioned in [301]. It is founded on two key factors: attitudes and behaviors, as highlighted in [302]. Attitudes regarding alumni attachment encompass a desire to offer financial support, a wish to stay connected with the academic institution, an interest in receiving updates about the institution, and a commitment to participating in the alumni organization, as noted in [300]. On the other hand, behavioral alumni attachment is frequently expressed through financial contributions, which play a vital role in supporting academia's growth, programs, facilities, and scholarship opportunities.

Therefore, universities and colleges often seek to raise funds from their alumni.

Alumni can serve as valuable supporters of academia in numerous ways, including mentoring, sponsoring, providing internships for students, hosting events, organizing conferences, and collaborating with students on research endeavors within the academic setting. Their involvement and support contribute significantly to the overall success and development of educational institutions.

e) **Alumni as ambassadors** Universities that attract a substantial number of international students undoubtedly cultivate a larger pool of global ambassadors. Both domestic and international graduates assume the role of ambassadors for their educational institution and, to some extent, for the country where they pursued their studies. During their time abroad, they acquire knowledge, curricula, systems, and policies, and upon returning to their home countries, they may implement these experiences and strategies, as highlighted in [303].

Lomer's research findings also suggest that international students are often eager to engage in the culture and politics of the host country and undergo professional training. They aim to actively participate in academic and local communities, gaining an understanding of ”British values” and acquiring knowledge about life in the United Kingdom. It is expected that they have a positive experience, form enduring relationships with faculty and fellow students, and develop a sense of political empathy for the UK's interests. After completing their studies, these students are anticipated to return to their home countries, where they can exert influence, especially as they advance in their careers. Maintaining contact with the United Kingdom and their host institution is considered essential. These expectations are propagated through policies, alumni networks, and organizational channels.

f) **Alumni as lecturers:** Many universities actively involve their alumni in educational activities by inviting them to lecture, participate in panel discussions, and share their real-world experiences as guest faculty members. These initiatives have a dual benefit, serving both students and alumni, as emphasized in [253].

For students, it's crucial to gain insights into various careers and the professional world while still in academia. Understanding the skills necessary for success in the job market is essential for directing their studies effectively. Allowing students to interact with alumni who work in their field of study can be a powerful motivator for them to remain engaged in their academic pursuits and make informed career decisions, as highlighted in [304].

In the field of engineering and beyond, there's a growing recognition of the importance of integrating ”real-world” experiences into the classroom. Many educators advocate for strategies that facilitate student interactions with alumni and other industry professionals, including mentorship programs. Utilizing alumni as guest faculty members is a valuable approach for academia to tap into their industry-based experiences and provide software engineering students with insights from the field.

g) **Alumni as internship providers:** Alumni hold a special place in academia as the most loyal and enduring members of their alma mater. When they transition into the industry, they become valuable connectors between academia and the professional world. Their direct access to recruiting and internship opportunities within their industry is a significant asset. Moreover, a positive relationship between the institution and its alumni opens up more internship possibilities for current students, thanks to the support of alumni who work in relevant companies.

One key to achieving success in one's career is finding a mentor who can assist individuals in navigating the transition from academia to the workplace. Alumni are uniquely positioned to serve as mentors. They can leverage their expertise to help current college students explore the job market, build professional networks, and secure employment opportunities, among other valuable guidance they can provide.

h) Alumni offer several advantages when working directly with students, especially as students make their initial career choices. Alumni are in a unique position to provide practical education and support to students pursuing degrees in fields related to their own careers. This engagement not only provides personal satisfaction from contributing to another person's development but also allows alumni to witness students who may eventually become candidates for positions within their institutions. Many alumni organizations support initiatives like job shadowing, mentoring programs, summer job placements, and internships for newly enrolled students. They also facilitate connections between alumni employers and potential job seekers, creating valuable opportunities for both students and alumni.

i) **Alumni as workforce:** The alumni aspect encapsulates many of the key attributes that alumni exhibit when fulfilling their roles as promoters, guides, educators, representatives, and advocates for their alma mater and the industry. Beyond the challenges linked to demographics, the mindset of the modern workforce has a substantial impact on organizations and their ability to remain effective. Alumni represent the exclusive labor pool accessible to both academia and industry, serving as the driving force behind the growing collaboration between these two sectors. In the realm of academia, alumni, acting as a workforce, can make substantial contributions to the advancement of education on both local and global scales by aiding students in acquiring the essential knowledge required to meet industry demands, engaging in practical research, and actively participating in industry-sponsored events.

As a result, the previous model is comprehensive and actively applied to assess the educational and professional needs of alumni. It is crucial for both industry and academia to recognize alumni's requirements, roles, and the opportunities they present for strengthening the collaboration between these two sectors. What do alumni consider essential, and how can their contributions further enrich this partnership? Additionally, it is of utmost importance to solidify the connection with alumni, ensuring that their ongoing engagement with academia remains robust and consistent.

7.5 Study Validation

Indeed, effective communication plays a pivotal role in any collaborative endeavor. Software and service industries, in their quest to remain competitive, consistently seek to improve their software engineering capabilities. This involves accessing individuals with the right expertise and expanding the company's existing knowledge base. On the other hand, academia endeavors to fulfill both aspects of competence by educating software developers who are ready for industry employment and conducting scientific research that advances industry knowledge and improves industrial processes [280]. Alumni are some of academia's most dedicated and long-lasting members, often feeling a deep connection to their alma mater. Their role becomes particularly significant when they work in the industry, as they have direct access to job and internship opportunities within their respective fields. Furthermore, when a university maintains strong ties with its alumni, it opens up additional internship prospects for current students through the assistance of alumni who are employed at various organizations. A key factor associated with success in one's career is the presence of a mentor who can help students transition from academia to the professional world. Alumni are uniquely qualified for this role, drawing upon their experiences to assist students in navigating the job market, building professional networks, and securing employment, among other valuable insights [253]. Many educational institutions fail to recognize the significance of alumni engagement, resulting in a lack of investment in this area. Unfortunately, academia often shows little interest in this vital endeavor. Having a model for alumni engagement could help us comprehend the various elements that contribute to this connection and enhance the effectiveness and precision of alumni engagement efforts [305]. Following that, we introduced a novel collaborative approach centered on alumni influence, aimed at enhancing industry-academia collaboration in the field of engineering. What sets this model apart is its ability to harness the potential of alumni within both industry and academia to bolster partnerships and deliver a wide range of services to academia. These services encompass technical research support for students, guest lectures by industry professionals, the sharing of practical industry knowledge, the facilitation of student internships within academia, the organization of workshops focusing on research and innovation, and numerous other academic opportunities.

7.6 Discussion

We have developed an innovative model that places alumni at the core to enhance industry-academia collaboration. This model is crucial for bridging the gap between academia and alumni, as well as for strengthening academia's ties with industry. Alumni with exceptional skills and experience can share their knowledge and expertise with current students through various means such as speeches, newsletters, and even social media. In some cases, alumni can even assist students in finding jobs and kickstarting their careers.

Figure 10 in the model illustrates the most common roles and responsibilities of alumni, which can contribute to enhancing the connection between industry and academia, provided that alumni maintain a strong affiliation with academia during and after their academic journey. Alumni play a vital role in sustaining and strengthening the collaboration between industry and academia, ensuring its longevity.

An engaged and supportive alumni network is crucial for the success of any academic institution. After graduating, a former student's perception of the university can become static. However, it is essential to keep them regularly informed about the university's progress. Alumni connections benefit both the university and the alumni themselves. In this context, experts in alumni relations within higher education emphasize the importance of an engaged alumni network and how it adapts to changes in the market [265]. While some academic institutions may overlook the potential of their alumni, others actively engage them by inviting them to participate as guest faculty members, join panel discussions, and share their experiences with current students. These initiatives are highly beneficial to both students and alumni, as they provide valuable educational opportunities and help reconnect alumni with their alma mater [253]. The innovative model, which centers around alumni participation in both industry and academia, serves as a valuable tool for all academic institutions to establish strong ties with their alumni and enhance their collaboration with the industry. This approach ensures that students graduate with the relevant industry experience.

In the context of industry-academia collaboration, fostering close relationships is crucial to enrich ongoing activities through mutual support. Wohlin, in a study from 2013, introduced a five-tiered system of proximity between industry and academia, emphasizing the importance of frequent interaction between the two. The more these organizations engage with each other, the more effective their collaboration becomes. When industry and academia work together as a cohesive team, they can achieve more productive outcomes, particularly in developing solutions for industry-specific challenges, which academia is well-equipped to address.

Furthermore, Wohlin highlighted that a strong industry-academia relationship often involves academia presenting solutions and approaches to industry challenges and requesting compensation in return for their problem-solving services related to specific industrial issues. Both industry and academia face their own unique challenges and concerns in this collaboration. As per the source, [259] the present challenge faced by the industry is the ongoing expansion of the disparity between what the industry anticipates and what educational institutions deliver. To effectively identify the present industry needs, it is suggested that alumni input should take precedence as the main information source. These alumni, having gained practical experience subsequent to their graduation, play a role in advancing the institution.

The rift between industry expectations and academic outcomes can be bridged by harnessing the influence of alumni to organize events such as conferences, expert lectures, and student workshops that focus on the latest advancements and innovations in the field [260]. To overcome current industry difficulties, several best practices are presented to the current industry challenges [272] for overcoming current industry difficulties. Firstly, there is a need to set long-term goals and provide researchers with timely and regular access to develop pragmatic and feasible solutions to the industry's challenges. exposes researchers seminars provides researchers with exposure to industry issues and challenges. Maintaining regular communication through meetings is another crucial practice. In summary, researchers need to possess effective presentation and communication skills, as well as the ability to showcase the advantages of their research solutions to industrial partners. Academic engagement serves as a vital avenue for transferring academic knowledge into the industrial sector, with many companies valuing it more than the mere licensing of university patents [306]. Figure 8 outlines the five key strengths of the industry that are advantageous to academia. Firstly, the industry functions as a learner by sending software experts to academia to teach courses, helping students better understand industry priorities. Furthermore, the industry serves as a bridge between educators and the business world, with alumni playing a pivotal role. From an educator's standpoint, maintaining a close connection with alumni can facilitate communication, providing a unique avenue for educators and researchers to gain insights into trending topics and patterns in the software industry for integration into their academic and professional programs [284]. In conclusion, the innovative model centered on alumni influence relies on a robust and engaged alumni network for the success of both academic institutions and industries. This network of alumni can leverage their expertise to help students navigate the world of work, secure employment, and gain insights into their chosen careers. Moreover, alumni who engage directly with students have a distinct advantage, especially as students embark on their initial career journeys. Alumni are uniquely positioned to provide guidance and mentorship to students pursuing degrees in fields related to their own career experiences. Several studies [307] have discussed the relationship between industry and academia using various best practices and theoretical models. However, neither study has proposed a model based on alumni influence to strengthen industry-academia collaboration. Our study introduces a novel model that relies on the influence of alumni to enhance the connections between industry and academia. This approach aims to reinforce and establish these connections by actively involving alumni in both academia and industry. When both academia and industry maintain strong ties with their alumni and actively engage them in academic activities such as mentoring and offering internships to current and future students, it fosters a positive and beneficial channel of communication. Furthermore, this approach promotes mutual interactions between industry, academia, and their alumni, where alumni who maintain close relationships with their alma maters are more inclined to support and contribute to these institutions.

7.7 Conclusion

In conclusion, it's crucial to emphasize the mutual benefits of a partnership between industry and academia, as both entities require a high level of commitment and collaboration. Their relationship can be likened to that of earth and water; they cannot function independently. However, in many cases, there exists a significant gap in collaboration between industry and academia. What academia teaches often does not align with industry requirements, and academia may not produce what the industry needs. This disconnect highlights the need for a bridge to facilitate effective interaction and collaboration between these two organizations.

The five levels of closeness discussed in section two serve as valuable factors that bridge the gap between industry and academia, allowing them to enrich their ties and work together as a cohesive team. The findings from our model demonstrate that when alumni actively participate in various activities, such as conducting workshops, delivering lectures to students, mentoring student research projects, and offering internship opportunities, it strengthens the partnership between industry and academia. The connection between academia and alumni encourages alumni to be more supportive of their academic institutions. However, academic engagement and collaboration with alumni remain relatively uncommon for various reasons, including the following:

*) alumni believe universities have failed to provide them with valuable information and incentives,

*) alumni are tracked solely to obtain funding contributions to universities,

*) Academic institutions generally treat productive and experienced alumni members better than current and much less productive alumni delegates, and the relationship between academia and alumni continues to be strained.

*) Additionally, we summarized some of the best practices available in industry and academics for overcoming existing barriers in Table 1.

The collaborative model introduced in this study represents a significant enhancement of the current state of industry-academia collaboration, leveraging the influence of alumni. Alumni play a pivotal role in promoting collaboration by actively participating in academic activities, including guest faculty roles, student mentoring, seminar delivery, applied research, marketing, and various forms of support for academia. The core of this model revolves around fostering mutual interaction between industry and academia, facilitated through strong alumni connections. This interaction offers numerous opportunities for professional and interpersonal growth for both sectors.

When academia prioritizes and actively encourages the engagement of alumni with current students, it enhances its reputation as a high-quality educational institution. In summary, a supportive and engaged alumni network is a critical factor in the success of both industry and academia. Future research endeavors could expand on this concept by conducting comprehensive surveys across various organizations and academic institutions, yielding impactful insights, and further strengthening the relationship between industry and academia.

Chapter 8

Conclusion

8.1 Summary of the Work

In conclusion, this thesis has explored the teaching and learning of software testing courses in an educational environment and addressed several key aspects related to curriculum design, instructional methods, and the impact of external factors such as the COVID-19 pandemic. The research delved into the necessary expertise, skills, and abilities required for software testing courses at both undergraduate and postgraduate levels, highlighting the importance of hands-on learning opportunities and practical experience to bridge the gap between academic education and industry needs.

The systematic literature review conducted in this study shed light on the inadequacies in teaching software testing skills, despite established curricula by leading academics and experts. It emphasized the need for refining and enhancing testing activities to increase student engagement and better prepare them for industry roles. This critical analysis of the existing literature contributed valuable insights to the field of software testing education.

The thesis also examined the software engineering curriculum and course offerings at Delhi Technological University, comparing it to the SE curriculum guidelines of ACM/IEEE. The strengths and weaknesses of the current curriculum were identified, and recommendations were made to address the shortcomings. Furthermore, the study touched upon the state of engineering education in India, providing a comprehensive view of the challenges and opportunities in the country's academic landscape.

The impact of the COVID-19 pandemic on education was also a focal point of this research.

The investigation covered various aspects, such as students' psychological and mental health, technological advancements, digital learning satisfaction, changes in the educational system, and the transition to online learning. Despite the negative consequences of the pandemic, it also accelerated technical advancements and experimentation with new modes of education worldwide.

Competency-based education emerged as a crucial theme in this thesis, offering a promising approach to transform traditional learning modes and empower students with valuable skills and knowledge. The model for integrating the Knowledge-Skill-Disposition (KSD) framework and the competency-based learning approach showcased the efficacy of competency-driven assessment methods in software engineering courses. This competency-based approach was deemed more suitable and recommended for teaching software engineering, providing a clear pathway for students to demonstrate their proficiency in the field.

The incorporation of practical software development courses and gamification strategies exhibited positive effects on student interest, engagement, and learning outcomes. These innovative instructional methods were found to be particularly effective for both undergraduate and postgraduate students. The potential for further research and implementation on a larger scale in engineering universities was highlighted, indicating a promising future for the enhancement of software engineering education.

The collaborative model proposed in this study emphasized the importance of industry-academia collaboration, with alumni playing a central role in fostering strong ties between the two sectors. The active participation of alumni in academic activities, such as guest faculty teaching and mentoring, presented numerous opportunities for professional and personal growth. This alumni-driven approach has the potential to significantly enrich the current status of industry-academia collaboration and improve the overall educational experience for students.

In conclusion, this PhD thesis contributes valuable insights and recommendations to the field of software engineering education and training. It addresses the gaps in teaching software testing skills, advocates for competency-based learning approaches, explores innovative instructional methods, and emphasizes the significance of industry-academia collaboration through engaged alumni networks. The findings and recommendations presented in this research can serve as a foundation for future studies and further advancements in software engineering education, ultimately enhancing the preparedness of graduates for the dynamic demands of the industry.

8.2 Application of the Work

The study we conducted has significant implications for software engineering education and training:

- The proposed model assists in bridging the gap between theoretical knowledge and practical application by enhancing the partnership between industry and academia.
- The proposed model emphasises modern instructional techniques such as competency-based education, project-based learning, and gamification, which have been shown to increase student engagement and retention of knowledge.
- The proposed model's ultimate goal is to better prepare students for the workforce, so that they are able to implement their skills in real-world industry settings upon graduation.
- Assist educators and academicians on enhancing their teaching skills and methods, including developing a clear syllabus, incorporating active learning strategies, promoting independent thinking, and providing timely feedback.
- Assist the instructors in enhancing their course content by offering guidance on curriculum design, incorporation of relevant and updated materials, and ensuring alignment with course objectives and learning outcomes.
- It helps to improve the content of a curriculum by introducing relevant and up-to-date materials, designing engaging and effective learning activities, and ensuring alignment with the course objectives and learning outcomes.
- Create an enjoyable and valuable learning experience by utilizing engaging teaching methods, promoting active participation, and providing opportunities for practical application and critical thinking.

8.3 Future Work

Future efforts to enhance instructional abilities and methodologies, enhance course content, and make the learning process enjoyable and beneficial could include the following:

1. Conducting studies regarding the most up-to-date pedagogical methods and incorporating them into educational methods.
2. Developing and implementing innovative methods of instruction that are tailored to the diverse requirements and learning styles of individuals.
3. Collaboration with professionals in the industry to ensure course content is current and pertinent to the needs of the industry.
4. Internships, initiatives, and case studies provide students with practical application and experiential learning opportunities.
5. Utilizing technology and digital tools to enhance the experience of learning, such as online lecture platforms, discussion forums, and virtual simulations.
6. Facilitate group work, team initiatives, and peer review to promote peer-to-peer learning and collaboration.
7. Incorporating diverse viewpoints and fostering inclusiveness by incorporating multicultural and social justice issues into the curriculum.
8. Designing assessments that measure students' mastery of course material and their ability to apply it in real-world situations.
9. Engaging in ongoing professional development to remain abreast of emerging trends and best teaching practises.
10. To continuously enhance teaching practises and course content, feedback from students and colleagues is sought.
11. Implementing gamification and project-based learning to make the learning process more interactive, enjoyable, and engaging for students, while also fostering their creativity, problem-solving, and collaboration.

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Supervisor’s Biography

Prof. Ruchika Malhotra

Head
Department of Software Engineering
Delhi Technological University
Email: ruchikamalhotra@dtu.ac.in

Educational Qualifications:
Postdoc (Indiana University-Purdue University Indianapolis, USA), Ph.D (Computer Applications)

Prof. Rajni Jindal

Department of Computer Science & Engineering
Delhi Technological University
Email: rajnijindal@dtu.ac.in

Educational Qualifications:
MCA,ME,Ph.D

Author’s Biography

Massoud Massoudi

Research Scholar
Department of Software Engineering
Delhi Technological University
Assistant Professor
Parwan University, Afghanistan
Email: massoud.massoudi@hotmail.com

Educational Qualifications:
M.Tech (CSE), B.Tech (CS)