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Solution proposals to Higher Software Engineering Education's Design-Reality Gaps in Rural India

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Declaration of Authorship

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I hereby declare that I have written this Diploma Thesis independently, that I have completely specified the utilized sources and resources and that I have definitely marked all parts of the work - including tables, maps and figures - which belong to other works or to the internet, literally or extracted, by referencing the source as borrowed.

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Abstract

A challenge of the Indian higher education system that exists for more than a decade is a mismatch between the skills of the engineering graduates and the needs of the industry, especially in the field of software engineering. The reasons and recommendations for this skill mismatch have been discussed in the past and explored in the literature. One of those reasons is the high privatization of higher engineering education in India. The majority of India's private higher education sector is composed of over 38.000 affiliated colleges that implement study programs based entirely on the curricula set by their affiliating universities. Furthermore, the majority of these affiliated colleges are located in rural India.

This thesis examined 1 of 80 affiliated colleges that are located in rural India and are implementing the same curriculum of an affiliating university. Through this examination that considered the reality of the students and teachers by conducting semi-structured interviews and observing both students and teachers, 5 gaps (incomplete student skills, unmet employability goal, inadequate teacher skills, improperly implemented teaching methods, missing curriculum evaluation) between a designed curriculum and its implementations were identified with the help of a Design-Reality Gap Analysis. Additionally, 3 further challenges (ever-changing course assignments, difficulties in self-learning, excessive student workload) were found that students and teachers face in their everyday life. For each of the identified gaps, solutions were proposed by the author of this thesis that aim to bridge the respective gap with regard to the identified challenges of students and teachers. Guidance notes were created that aim to enable curriculum designers and curriculum managers to apply the proposed solutions. In future work, the proposed solutions and guidance notes shall be evaluated to determine if they are suitable to reduce the identified gaps and challenges as well as if they can be applied at other colleges located in rural India.

Keywords: *Higher Education, Software Engineering Education, Computer Science Curriculum, Design-Reality Gap Analysis, Rural Education, ICT4D, India*

Kurzfassung

Eine Herausforderung, vor der das indischen Hochschulsystem seit mehr als einem Jahrzehnt steht, ist die Diskrepanz zwischen den tatsächlichen Fähigkeiten von Hochschulabsolvent:innen und jenen, die von der Industrie nachgefragt werden, insbesondere im Bereich der Softwareentwicklung. Die Gründe dafür und Empfehlungen zur Aufhebung dieser Diskrepanz wurden in der Vergangenheit bereits durch die Literatur diskutiert und erforscht. Einer dieser Gründe ist das hohe Ausmaß an Privatisierung der indischen Hochschulausbildung im Ingenieurbereich. Der größte Teil des privaten indischen Hochschulsektors besteht aus über 38.000 angegliederten Colleges (Engl. “affiliated colleges”), die Studienprogramme durchführen, welche vollständig auf den Curricula jener Universitäten basieren, an welche die Colleges angegliedert sind (Engl. “affiliating university”). Die Mehrheit dieser angegliederten Colleges befindet sich im ländlichen Indien.

Durch die Untersuchung eines von 80 angegliederten Colleges, welche das selbe Curriculum einer Universität umsetzen, wurden in dieser Arbeit mit Hilfe einer “Design-Reality Gap Analysis” fünf Lücken (Engl. “gaps”; unzureichende Fähigkeiten der Studierenden, unerfüllte Ziele in Bezug auf die Beschäftigungsfähigkeit, unzureichende Fähigkeiten der Lehrenden, unsachgemäß eingesetzte Lehrmethoden, fehlende Curriculum-Evaluierung) zwischen einem Curriculum und dessen Umsetzung identifiziert. Dabei wurde die Realität der Studierenden und Lehrenden durch semi-strukturierte Interviews und Beobachtungen von Studierenden und Lehrenden erhoben. Darüber hinaus wurden drei Herausforderungen ermittelt (sich ständig ändernde Kurszuteilungen, Schwierigkeiten beim selbstgesteuerten Lernen, übermäßige Arbeitsbelastung der Studierenden), mit denen Studierende und Lehrende in ihrem Alltag konfrontiert sind. Für jede der identifizierten Lücken wurden Lösungsvorschläge erarbeitet, welche darauf abzielen, die jeweilige Lücke zu schließen. Diese Lösungen basieren auf vorhandener Literatur und beziehen die Herausforderungen der Studierenden und Lehrenden mit ein. Mit Hilfe dieser Lösungsvorschläge wurden Leitfäden (Engl. “guidance notes”) erstellt, die es Curriculum-Designer:innen und Curriculum-Manager:innen ermöglichen sollen, diese Lösungsvorschläge anzuwenden. In zukünftigen Arbeiten soll festgestellt werden, ob die Lösungsvorschläge und Leitfäden dazu geeignet sind, die identifizierten Lücken und Herausforderungen zu reduzieren und auf andere Hochschulen im ländlichen Indien übertragen werden können.

Keywords: *Hochschulbildung, Software-Engineering-Ausbildung, Informatik Curriculum, Design-Reality Gap Analysis, Bildung in ländlichen Räumen, ICT4D, Indien*

Contents

CHAPTER 1

Introduction

1.1 Problem Statement

According to the United Nations (UN), more than 736 million people (10% of the world's population) were living below the international poverty line ($1.90 per day, [1]) in 2015. People living below the international poverty line are considered to live in extreme poverty, which means that they cannot fulfill their basic needs in certain areas of their life, such as health, education, water, and sanitation [2]. The percentage of the world's population living in extreme poverty dropped to 9.2% in 2017 and was expected to drop further to 7.5% in 2021. This estimation has been revised due to the global impact of COVID-19 [3]. Therefore, the extreme poverty rate is expected to rise again up to 9.4% by 2021, after a trend of decline since 1990 [4].

On September 25, 2015, the general assembly of the UN adopted the resolution "Transforming our world: the 2030 Agenda for Sustainable Development". This agenda consists of 17 different "Sustainable Development Goals (SDGs)", which are representing "a universal call to action to end poverty, protect the planet and improve the lives and prospects of everyone, everywhere" [5]. In order to measure the progress of achieving these goals, the UN is using the Multidimensional Poverty Index (MPI). The MPI complements the international poverty line in a way that it includes the deprivations people in extreme poverty are facing and therefore monitors poverty in different forms [6].

Cremin & Nakabugo describe that sustainable economic development needs social as well as human development. Furthermore, social and human development depends on "universal education with equitable access and assured quality" [7]. Education reduces poverty and its deprivations as well as the inequality between the rich and the poor [8, 9]. The SDGs are considering this concern by SDG 4: "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" [5]. The World Bank Group highlighted that people with a solid higher (post-secondary) education are required for a country's ability to innovate and to sustain a healthy growth over the long-term [10]. According to the Global MPI Report 2019, India reduced its poverty headcount ratio from 55.1% in 2005/2006 to 27.9% in 2015/2016 [11]. Even though "poverty reduction in rural areas outpaced that in urban areas", rural areas are poorer than urban areas [11]. Additionally, although poverty is decreasing in India, the inequality indicated by consumption, income, and wealth increases [12].

Due to the increasing demand for technically skilled workers as well as the growing employment opportunities in the IT sector in India since the 1980s, Higher Education Institutions (HEIs) in India responded by increasing the number of graduates in engineering disciplines. In order to cope with this growth while decreasing the investments from the government into the Higher Education (HE) sector, several state governments and the government of India urged the private sector to establish self-financed, engineering HEI [13, 14]. These institutions are meant to educate people to become engineers that meet the demands of the industry.

Although the number of engineering graduates exponentially grew from 1998 to 2008, the quality of education students received was insufficient, leading to a mismatch between the needs of the industry and the skills of the graduates [13, 14]. A survey of the World Bank confirmed this mismatch and pointed out that "64% of employers are only somewhat satisfied or worse with the quality of engineering graduates' skills" [15]. This skill mismatch is still observable. The National Employability Report by Aspiring Minds examined a sample of "more than 170,000 engineering students from more than 750 engineering colleges across multiple Indian states which graduated in 2018". According to this report, of the sample group, 52.5% are not able to write functionally correct code and 37.7% are not able to write compilable code. Additionally, they found out that candidates of colleges located in lower populated cities are overall less employable than the candidates from colleges of higher populated cities, regardless of the examined job role [16]. According to the definition of Indian urban and rural areas [17], the lowest-populated-cities bracket in the report of Aspiring Minds includes rural as well as urban areas with a population of up to 0.5 million people [16]. Students in rural areas are facing problems and limitations such as:

- limited access to education [18, 19]
- lower quality of education in general [19]
- insufficient infrastructure or overcrowded classes [20]

According to Aneja, most students in rural areas have a lack of relevant skills to take part in HE courses from the beginning, some students are forced by "the pressure of their parents" to gain HE admission [20]. Additionally, rural HEIs in poorer regions find it difficult to catch up with the adaptability of their developed counterparts, which are able to change their courses and syllabi according to the latest developments of their respective fields. As a result, rural students are falling behind students of HEIs, which are situated in urban India or other, more developed regions [20].

In 2019, more than 90% of the HEIs in India were private, so-called affiliated colleges, which implement curricula designed by nationally recognized state universities, also referred to as affiliating universities in this context [21, 22]. The affiliating universities define curricula, which are taught at affiliated colleges and conduct the examinations of the courses of the curricula. Although the affiliated colleges are eligible to offer additional courses, they are not allowed to adapt the given syllabi of the courses, the curricula or parts of the curricula [23]. The exact implementation of the curricula and the teaching methods used during the courses are decided by the affiliated colleges. The affiliating university assesses the actual implementation of the curricula it has designed on the basis of their standardized examinations at the end of each semester. According to the Annual Report 2018-2019 by the University Grant Commission (UGC), 40.489 such colleges exist in India and 60.53% of these colleges are located in rural areas [21]. According to Dubey et al. one of the reasons for previously mentioned skill mismatch is this huge privatization of the engineering education sector [14].

1.2 Motivation

The author of this thesis studies the Business Informatics master program at the TU Wien [24]. The curriculum of Business Informatics is based on the "Universtitätsgesetz 2002" (UG 2002) and according to §1 UG 2002, universities are "responsible for solving problems of humankind as well as contributing to the development of society and natural environment" [25]. Furthermore, the curriculum defines in its qualification profile of their students that the curriculum, among other things, is focusing on the analysis, design, implementation and evaluation of Information Systems and displays them as "socio-technical systems, which are including human and mechanical components" and that "modern Information Systems are playing a central role in nearly every economical, political and social interdependencies. They are a basic requirement for the developing digitalization of the economy and society" [26]. Sufficient Software Engineering (SE) skills are needed for the implementation of such Information Systems. Therefore, successfully teaching sufficient SE skills and competencies enables the development of the digitalization of the economy and society.

Furthermore, the author of this thesis has been involved in the ongoing development of the curricula of the Bachelor's degree program in Business Informatics and the Master's degree programs in Business Informatics and Data Science for several years as part of his voluntary activities within the Study Commission for Business Informatics. The author of this thesis was also a member of the Senate of the TU Wien, where he participated in the further development of curricula models ("Musterstudienpläne") and evaluated changes of various curricula of the TU Wien. Furthermore, the author acquired expertise in the field of quality assurance and quality enhancement in higher education by attending further training courses of the Agentur für Qualitätssicherung und Akkreditierung Austria (AQ Austria) on the accreditation and auditing of HEIs in Austria and by visiting the European Quality Assurance Forum [27, 28]. Additionally, the author of this thesis worked as a freelance expert for the AQ Austria in several program accreditations. The author participated in a total of 4 expert reviews of applications for the accreditation of study programs by private universities and universities of applied sciences [29, 30, 31, 32].

The author of this thesis and the thesis itself are part of the TU Wien, which is one of the Austrian universities with the responsibilities previously mentioned. Therefore, from the author's point of view, it is also up to the author and this thesis to fulfill these responsibilities. Additionally, the knowledge of the author about the development and the quality assurance as well as the quality enhancement of curricula gave the impulse to deal with the objectives of this thesis, which are described in the next section.

1.3 Objectives

The UN formulated specific targets for each SDG, such as target 4.4 of SDG 4: "By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship." As already mentioned in Section 1.1, the skills of engineering graduates do not match the needs of the industry in India. According to Dubey et al. this mismatch results from the "de-facto mass privatization of the engineering education", but the reasons why this "de-facto mass privatization" leads to the mismatch are not known [14]. As it also described in Section 1.1, a key characteristic of the private higher education sector is that it is mainly composed of affiliated colleges, which are responsible for implementing a curriculum that was designed by their affiliating university. However, the efficacy of the curriculum implemented by the affiliated college is evaluated only with the help of standardized tests, which in turn are based on the affiliating university's curriculum design.

This thesis aspires to contribute to target 4.4 of SDG 4 by providing insights into underlying problems of higher SE education in rural India. Therefore, the specific goal of this thesis is to examine the previously described key characteristic of the private higher education sector in the context of the private higher SE education sector in rural India. With the help of the resulting findings, solutions to problems of the private higher SE education sector shall be developed that help to increase the number of SE graduates with sufficient skills.

As it is explained in Section 2.1, the vast majority of study programs that also include the cultivation of SE skills are designated as Computer Science (CS) study programs. Therefore, in order to achieve the specific goal, this thesis takes a closer look at CS curricula that are implemented at Indian HEIs of the private higher education sector in order to determine whether and to what extent gaps exists between the implemented curricula and their intended design and how these gaps correspond to the skill mismatch found in the literature. In case such gaps exist, this thesis aims to propose solutions that can subsequently be applied by Indian HEIs in order to minimize these gaps.

Therefore, this thesis addresses the following research questions (RQ):

- **RQ1**: What gaps exist between a designed Computer Science (CS) curriculum and their implementations at Higher Education Institutions (HEIs) in rural India, exemplified by an affiliated college in rural Andra Pradesh, India?
- **RQ2**: What are appropriate solutions that help HEIs in rural India implementing CS curricula to reduce the identified gaps from **RQ1?**

Besides the list of identified gaps and solution proposals from the answers to **RQ1** and **RQ2**, the results of this thesis include a set of guidance notes that is meant to present the answers to **RQ1** and **RQ2** in a suitable, understandable manner for decision makers of the Indian higher education system. Two different guidance notes are developed, one for those who design a curriculum and another one for those who implement it. However, as this thesis only evaluates the implementation of curricula and not the design, the guidance notes for curriculum designers are intended to help them to design a curriculum in a way that reduces the identified gaps of the implementing HEI.

1.4 Methodology

During the first phase of this thesis, further information about SE with a focus on teaching SE as well as the Indian higher education system and the current status of the SE education in India are gathered via literature research.

The second phase of this thesis is an exploratory case study that examines the curriculum implementation of a partner institution, which is 1 of over 80 rural Indian HEIs that implement the same curriculum designed by a nationally accredited state university of Andra Pradesh. A single-case study based on the definition and characteristics of Yin is chosen as this thesis aims to take a deeper look into the realities of teachers and students in order to stand out from related work (see Section 2.3).

In the third phase of this thesis, the results of the first and second phases are used to propose solutions that aim to bridge the found gaps and therefore answer **RQ2**. The solutions are developed by the author of this thesis and are based on literature that examine problematic characteristics similar to those of the identified gaps. With the help of these solutions, guidance notes are created that aim to support the implementation of a curriculum as a curriculum manager or a curriculum designer.

1.4.1 Case Study Design

According to Yin, case studies such as the one in this thesis provide a profound insight into social phenomena from a holistic, real-world perspective. Furthermore, Yin states that the reason for a single-case study is to collect evidence about the circumstances of everyday situations, so that it can subsequently provide information about the social processes studied [33].

The case study of this thesis consists of semi-structured interviews, observations and a Design-Reality Gap Analysis (DRGA) in order to answer **RQ1** (see Sections 4.1 & 5.1). The semi-structured interviews and observations are thematically analyzed regarding the actual implementation of a CS curriculum at a partner institution as well as realities of students and teachers. Through the DRGA, differences between the design and actual implementation of the CS curriculum are then identified. Following Yin's characteristics of a case study, the DRGA triangulates its findings with the help of interviews, observations and information provided by institutions of the Indian higher education system [33]. The design of this thesis' case study is outlined in Figure 1.1.

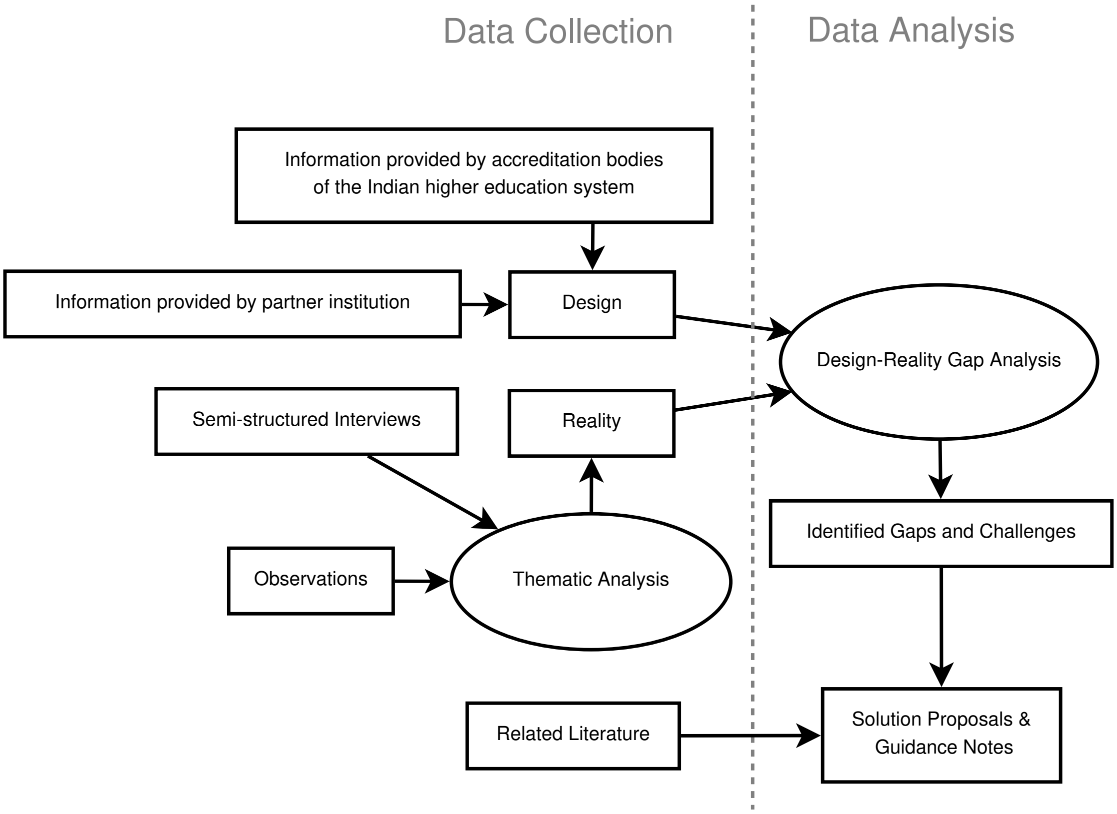

Figure 1.1: Design of this thesis' case study

1.4.2 Selecting the partner institution

As it is described in Section 2.3, this thesis aims to take a deeper look into the realities of teachers and students in order to stand out from related work. With the help of these realities, solutions should be proposed that are actually realizable for the people involved.

From the point of view of the author of this thesis, it is an advantage if the statements of teachers and students also correspond to the actual reality, which in turn requires an existing relationship of mutual trust.

For this reason, the author of this thesis collaborates with a college that has already worked with the TU Wien for several years through a variety of on-site and remote collaborations. Due to the already existing collaborations, it was possible to work with teachers and students of the partner institution in advance on another cooperative project, which was not part of this thesis. Thus, an initial relationship of trust could be established. Therefore, this college is chosen as a partner institution for this thesis.

The necessity for mutual trust was also confirmed for the author of this thesis during the interviews. For example, some students asked several times during the interviews if the recordings of the interviews might be seen by the faculty of the college, because they were afraid of negative consequences. After being assured by the author of this thesis that the recordings will not be shared with the faculty of the college, they began to open up and talk more about their problems and challenges. Additionally, those teachers with whom the author of this thesis had already worked in advance were, in the view of the author of this thesis, more open and much more willing to talk about existing shortcomings and problems.

1.5 Limitations

In order to distinguish this thesis from related work and to remain within the scope of a master's thesis, the following limitations are defined:

1. This thesis evaluates the implementations of a curriculum in relation to their underlying design. The design of the curriculum and whether it is suitable for increasing the number of CS graduates with sufficient skills is not examined by this thesis.
2. The results of this thesis are based on one implementation of one curriculum design. It is outside the scope of this thesis to examine whether a different implementation of the same curriculum would yield the same or similar results. Likewise, it is beyond the scope of this thesis to examine whether implementing a different but comparable curriculum design would yield the same or similar results.
3. When studying the implementation of the curriculum by examining the realities of students and teachers, social and cultural problems are not taken into account. Also, it is outside the scope of this thesis if labor policies such as employment protection, paid sick leave or unemployment benefits exist.
4. While this thesis identifies the gaps between the curriculum design and its implementations, it does not examine the root causes of the identified gaps and challenges.

5. The solutions developed for the identified gaps in this thesis are based on relevant literature and take the reality of the affected people into account. Nevertheless, it is beyond the scope of this work to evaluate for each solution whether it is actually suitable for closing the respective gap.

6. This thesis is developed from an external, European point of view. Furthermore, as the author of this thesis could not be on site due to a 2-year long international flight ban from March 2020 to March 2022, the collaboration took place exclusively remotely [34].

1.6 Organizational Issues

Due to the limited infrastructural possibilities in rural India, students and teachers often struggled with connection problems, which meant that meetings were often interrupted or cancelled. Difficulties also arose again and again in collaboration, for example, it often took several days for relevant information to reach the author of this thesis, or it was often only given on request. Likewise, it was rarely possible to get fixed plans for periods that lie more than 1-2 months in the future, which meant that it was usually only possible to work with provisional specifications. The partner institution also acted very dynamically in many aspects, so that sometimes exams suddenly took place over several weeks, and the students' time was then fully occupied.

The most serious organizational problem caused the failure of an experiment originally planned to find a suitable teaching method considering the local realities, using an existing mandatory course of the curriculum and change the teaching method in use. Therefore, this was removed from the methodology of this thesis.

CHAPTER 2

Related Work

This chapter outlines the current status of higher SE education in Indian. The problems and challenges of higher (software) engineering education as well as potential solutions to solve them are presented from the perspective of published literature.

As already described in detail in the problem statement of this thesis, India has been facing for decades the challenge that engineering graduates largely do not meet the needs of the industry (see Section 1.1). The National Employability Report by Aspiring Minds, which examined a sample of "more than 170,000 engineering students from more than 750 engineering colleges across multiple Indian states which graduated in 2018", on the one hand, gives a broad overview of the trend over the last years as well as the actual state of engineering student's employability and, on the other hand, analyzes current issues of the Indian HE system regarding SE education and formulates recommendations for the respective stakeholders [16].

Furthermore, there is evidence in the literature that India is not the only country to have this problem. One of Duell's recent works in this field gives a brief insight into the issues and challenges of the whole educational system itself, regarding the mismatch between the industry's needs and the skills as well as the employability of students, which are graduating from Indian, Indonesian and Thai universities [35]. Lee & Cheng published a field report about changing SE education in Taiwan, where they describe a very similar initial situation as it is written by the report of Aspiring Minds. They have successfully designed and implemented a module-oriented SE curriculum, which led to an increased number of offered courses as well as course participants [36].

2.1 Software Engineering Education in India

In India, the most popular engineering programs are Civil Engineering, Electrical Engineering, Mechanical Engineering as well as Computer Science & Engineering, which are mostly graduated with the academic degrees Bachelor of Technology (BTech) or Bachelor of Engineering (BE) [37]. Although the author of this thesis has not found official statistics from a national body or equivalent, there are websites of private providers, which list numerous study programs all over India. For example, at the time of the examination, "CollegeDekho" listed a total of 202314 courses at 20020 HEIs [38]. Limited to HEIs offering a BTech (filtering by BE was not possible) in CS, 2714 HEIs were listed, which in turn offer 3448 programs in this subject area [39]. In relation to that, filtering by SE, "CollegeDekho" listed only 14 HEIs that implement 16 corresponding programs [40]. In Software Development (SD), there were only 2 programs at 2 HEIs [41]. A similar situation was also found on a comparable website. The website "collegedunia" lists a total of 18317 HEIs [42] located in India. Filtering the list of HEIs by those that offer "BTech/BE" programs in CS, 3809 HEIs were listed [43]. For SE programs only 37 HEIs were listed and SD was not even available as a value for the respective filter [44]. Therefore, a CS and not a SE study program is examined in the context of this thesis.

Garg & Varma have published three different papers regarding SE Education at Indian universities in the last 12 years [45, 46, 47]. They are one of the few people, who have specifically done research regarding the topic of this thesis. They addressed India specific "people issues" (issues related to HE stakeholders such as teachers and students) in SE education and training as well as India specific issues and challenges in general for SE education, from the industry and the academic perspective [45, 46].

2.2 Higher Education Challenges of India

One of the main challenges of the higher education system in India is the number of graduates as well as the quality of education the graduates received [48]. The quantitative lack of engineering graduates led to a huge increase in the number of private engineering HEIs [14, 15]. Specifically in the Indian higher engineering education, the skills of graduates do not match the industry requirements, according to various studies over the last 15 years [14, 15, 49, 50, 51]. Industry requires graduates that do not need additional training [45, 50]

The following is a summarized overview of skills of (software) engineering graduates that are categorized in the literature as missing or insufficient in the context of the analysis of the skill mismatch:

- Communication skills (oral & written) [15, 46, 50, 52, 53]
- Ability to analyze and solve problems [15, 46, 50, 52]
- Collaboration, Teamwork and Social skills [15, 50, 52, 53]
- Creativity [15, 53]
- Reliability [15, 50]

- Self-motivated [15, 50]
- Willingness to learn, understand/take new directions [15, 46, 53]
- Technical skills [15, 53]
- Use of modern (software) tools [15, 52]
- Management skills [53]

The reasons for the skill mismatch are discussed in the literature and include:

1. Insufficient qualifications of the teaching faculty members [14, 49, 50]
2. Rigid curricula that cannot respond to changing needs of local industry [45, 50, 51]
3. Most of the teaching is focused on the theoretical aspects, which means that the practical applicability of what is learned is pushed into the background [45, 49, 51]
4. The extended usage of traditional methods such as memory based assessments instead of using project based assessments [45, 49, 50, 51]
5. Insufficient or non-existent quality assurance or quality management systems at the HEIs [49, 50]
6. Lack of sufficient infrastructure or research facilities [45, 49, 50]
7. Lack of cooperation and connections of the HEIs with the industry [49, 50, 51]

Dubey et al. attribute these reasons for the skill mismatch to the increasing privatization of the engineering education sector mentioned above [14].

2.2.1 Resolve the skill mismatch

Similar to the research regarding the challenges in India's higher engineering education, improvements to cope with described skill mismatch have been discussed at least over the last 15 years [15, 46, 49, 50, 51].

Mahanti et al. suggest teaching theories and models of the field with a connection to practices to strengthen students' understanding as well as to teach the applicability of theoretical knowledge. Additionally, when using project-based learning as part of a SE course, it should be ensured that practical projects do not only focus on on the Building part of the Software Development Life Cycle (SDLC) but also on the other parts such as Defining, Designing and Testing. Furthermore, group projects should be conducted in order to improve the teamwork skills of students. Additionally, they mention that the limited time a teacher can spend preparing their lessons leads teachers to reuse old materials and use traditional teaching methods. In order to overcome this problem, characteristics of a course such as the contents, the used teaching approaches and the provided study material should be evaluated periodically with the help and feedback of the students. The respective course should then be adapted with the help of the feedback and revised or new SE knowledge as well as requirements by the industry. One way of providing new SE knowledge or industry requirements would be courses taught by the industry. In addition to existing courses taught by faculty members, guest speakers from the industry should give lectures or seminars to students and faculty on technologies currently being used in the industry or other emerging trends in their respective fields [51].

Based on the findings of Mahanti et al., the work of Garg & Varma covers most of the above listed challenges of the Indian HE sector. Garg & Varma suggest that SE programs should consist of basic courses that have both basic SE knowledge and problem-solving skills related to the particular course as course objectives, which is similar to the structure of the knowledge areas discussed the guidelines for CS and SE curricula by Association for Computing Machinery (ACM) & Institute of Electrical and Electronic Engineers (IEEE) Society [54, 55]. However, Garg & Varma note that that these restructured programs would require different teaching approaches and assessment methods as currently used, so that the application of taught knowledge and skills is assessed. Regarding the cooperation between HEIs and industry, Garg & Varma suggest to cooperate via guest lectures and internships for teachers. Through these internships teachers would be able to teach SE knowledge more effectively with the help of their hands-on experiences from the industry [46].

The recommendations of Bloom et al. focus on the assessment methods and teaching approaches used at engineering HEIs. They suggest concentrating more on understanding the course objectives rather than memorizing them. This can be accomplished by using teaching approaches that encourage students to be active learners rather than just listening to lectures, taking notes, and then memorizing course content. These teaching approaches should enable the students to identify, analyze and solve a problem in their area of interest. As a further consequence, HEIs need to adopt assessment methods that are appropriate for assessing these “higher-ordering thinking skills” rather than the ability to memorize course content [15].

Mann et al. focus on the challenge regarding the lack of collaboration between HEIs and the industry. All but one of their recommendations propose structural industry participation in India’s HE sector or the HEIs themselves. These recommendations include to establish an Indian-wide committee with academic and industry experts in order to periodically update the curricula across India according to the industry requirements and the mandatory involvement of the industry in the governance of an HEI to ensure that its infrastructure meets the requirements by the industry. Furthermore, they suggest to hold additional training programs for students and faculty members in cooperation with the industry. At last, they recommend to increase the incentives for faculty members to improve their quality [50].

Similar to Mann et al. and Garg & Varma, Madheswari et al. state that traditional teaching practices are very teacher-centered and that these practices still in use should be replaced by teaching practices, which are focusing on the students in order to meet the current demands of the industry. They have created 4 recommendations on how to improve and make technical education more robust [49]:

1. "Enhance the teaching-learning process" by revising teaching practices in use, shifting to more student-centered practices and outcome based education.
2. "Up-skilling the faculty members" by training the respective members, offering certification courses, include the industry via specialization courses. Madheswari et al. state that training and skill development of the faculty members should be the "first priority to enhance the quality of engineering education".
3. "Enhancing students' attitude and participatin" by enhancing the already mentioned teaching-learning process (Recommendation 1), using more project-based learning, offering orientation program as well as specialization courses and create awareness of the job market situations.
4. "Upgrading the curriculum and facilities" by changing the scope of the curricula to introduce general skills development, to use research and project based learning, to foster innovation and creativity of the students as well as periodically revise and update syllabi and curricula to address changing needs.

2.3 Contributions of this thesis

Although there are various recommendations, the problem of (software) engineering graduates with insufficient skills still exists according to the already mentioned report by Aspiring Minds [16]. In this regard, no related work could be found that addresses the question of why the skill mismatch still exists, even though it has been studied for more than 10 years and recommendations for reducing the skill mismatch are available. From the author's point of view, there are several possible reasons for this, such as that the majority of the HE stakeholders are not aware of the recommendations, that the recommendations are known but are intentionally not taken into account or that the recommendations are not applicable.

Furthermore, no related work was found that evaluates curricula designs or implementations of Indian HEIs or suggest specific solutions to existing problems. It is this shortcoming that this thesis addresses: solutions are proposed that also take the actual realities of those impacted into account, in order to increase their applicability and realizability. In addition, these proposed solutions are summarized in short, concise guidance notes so that results of this thesis can also be easily redistributed and thus be accessible by stakeholders from many HEIs in rural India.

CHAPTER 3

Fundamentals

The fundamentals describe what is generally defined as SE knowledge and which skills are relevant at the level of a beginner in the field of SE. Furthermore, it explains how SE is primarily taught and what the characteristics of this teaching method are. It also introduces the Indian higher education system and explains its structure. In addition, the structures for quality assurance in the Indian higher education system and their quality criteria for HEIs are described.

3.1 Software Engineering Knowledge

The following section outlines a definition about which knowledge is contained in the domain of SE and how it can be divided into different knowledge areas. Furthermore, the individual knowledge areas as well as the respective basic skills are examined.

3.1.1 Knowledge areas

Bourque & Fairly list 15 knowledge areas in their latest Software Engineering Body of Knowledge (SWEBOK) guide. These areas cover different aspects of the SE domain which consider the SDLC such as requirements, design, testing, maintenance and further more. Every knowledge area is composed of "generally accepted knowledge" that every competent software engineer "should be equipped with this knowledge for potential application" [56].

As Sedelmaier & Landes mentioned, the SWEBOK guide defines its knowledge areas on a more abstract level of expertise, but doesn't list clear definitions of how to derive precise teaching goals or targets from the areas [57].

3.1.2 Sufficient skills

According to the Merriam-Webster dictionary, the noun "skill" is defined as "the ability to do something that comes from training, experience, or practice" [58]. The Cambridge Dictionary defines as "skill" as "an ability to do an activity or job well, especially because you have practised it" [59].

Sedelmaier & Landes criticize that there is no concrete definition of the correct way to derive learning objectives from the abstract knowledge areas on which both the SWEBOK guide and the ACM model curriculum are based on. As Sedelmaier & Landes work has been published in 2014, they refer to the second version of the SWEBOK guide by Bourque & Dupius [57]. In the opinion of the author of this thesis, this also applies to the third version of the SWEBOK guide.

Nevertheless, the IEEE society published the Software Engineering Competency Model (SWECOM), which is based on various resources of the IEEE Society such as the third version of the SWEBOK [56] and the standard curriculum of SE [55]. The SWECOM "describes competencies for software engineers who participate in developing and modifying software-intensive systems"[60, p. v] and is composed of five different elements: cognitive skills, behavioral attributes and skills, requisite knowledge, related disciplines and technical skills [60, p. 5]. The latter one of these elements is examined in the following section of this thesis.

Technical Skills according to SWECOM [60]

The technical skills are the main concern of the SWECOM and are categorized into two different skill areas: life cycle skill areas and crosscutting skill areas, whereby each skill area lists concrete skills and each of these concrete skills is broken-down into activities. Furthermore, each activity is specified for five different levels of competency: Technician, Entry level Practitioner, Practitioner, Technical Leader and Senior Software Engineer [60, pp. 8-12]. For example, the technician is able to "follow instructions" and the Entry level Practitioner is able to "assist in performance of an activity or performs an activity with supervision" [60, p. 12]. The technician level is equivalent to a two-year U.S. associate's degree, and the practitioner level is equivalent to an ABET-accredited SE degree program [60, pp. 12-14, 61]. Nevertheless, the SWECOM acknowledges that the skills it lists are not intended to be comprehensive, but rather to highlight the skills and activities they consider most important for a software engineer of the respective level working in this domain [60, p. 74].

Software Requirements Skills (life cycle skill area) This area covers activities that discover, analyse and manage the functional & non-functional attributes as well as the whole requirements engineering process of a software project [60, p. 25]. This area includes skill sets in requirements elicitation, analysis, specification, verification and management [60, pp. 27-30].

Software Design Skills (life cycle skill area) Within this area are activities that "develop and describe the software architecture of a system based on its software requirements" [60, p. 31] and includes skills in software (architectural) design strategies & methods as well as quality analysis & evaluation [60, pp. 32-39].

Software Construction Skills (life cycle skill area) The scope of this area includes activities that are used to transform the specified design into a concrete, functional software according to the requirements [60, p. 41]. Skill sets of this area are managing software construction, coding, debugging & testing as well as integrating & collaborating [60, pp. 44-48].

Software Testing Skills (life cycle skill area) This area covers activities that are used to assess the quality of a software product by analyzing the expected and actual behaviour of it [60, p. 49] and the skills which are required to do so are test planning, setting up test infrastructure, use test techniques and test measuring [60, pp. 51-56].

Software Sustainment Skills (life cycle skill area) According to SWECOM, this area includes, but is not limited to, activities related to maintenance, documentation, deployment, operation or retirement of software [60, p. 57]. They lists Software Transition, Support and Maintenance as the 3 skill sets of this area, which include entry-level activities such as assisting in the development of support material for operations, conducting retirement processes or identifying existing problems [60, pp. 59-65].

Software Process and Life Cycle Skills (crosscutting skill area) In this area, the SDLC is the focus, therefore this area includes, among others, those activities that deal with the definition, implementation, measurement or improvement of SDLC processes [60, p. 67]. Accordingly, activities such as the execution of defined SDLC processes, the interpretation of process responsibilities and the implementation of process improvements are listed by them [60, pp. 68-72].

Software Systems Engineering Skills (crosscutting skill area) This area deals with systems where software is one of many components but plays a critical role [60, p. 73]. Since this is where System Life Cycle processes and SDLC processes meet, this area primarily includes activities that address the integration of SE into Systems Engineering development models and enabling collaboration between SD and Systems Engineering teams along the System Life Cycle [62, 60, pp. 75-88].

Software Quality Skills (crosscutting skill area) This area includes both quality assurance and quality control of software [60, p. 89]. Their skills and activities developing "quality products" with the help of appropriate tools according to defined quality standards and models. Participation and collaboration in reviews and audits are also mentioned [60, pp. 92-100].

Software Security Skills (crosscutting skill area) The software security area covers the entire SDLC and includes activities such as developing software based on predefined recommendations and guidelines (similar to software quality skills) to avoid potential vulnerabilities or identifying potential risks through code reviews [60, pp. 101-106].

Software Safety Skills (crosscutting skill area) For safety-critical systems, i.e. those that can have a direct impact on "human life, health, integrity or the environment", the quality of the software is of crucial importance [60, p. 107]. Since this area also covers the entire SDLC, identifying potential risks and hazards and formulating safety requirements based on them are among the relevant skills and activities. The application of appropriate guidelines in the development and testing of such a system is also mentioned [60, pp. 109-114].

Software Configuration Management Skills (crosscutting skill area) SWECOM describes this according to its definitions in the IEEE Standard 828-2012 and the SWEBOK guide [63]. According to the latter, Software Configuration Management consists of the identification, control, status accounting and auditing of the software configuration as well as the release management and delivery of software [60, p. 115]. Therefore, skills in this area are, for example, the identification of software configuration items, the implementation of changes to the them or the building of software releases [60, pp. 117-122].

Software Measurement Skills (crosscutting skill area) Since quantifiable data obtained through measurement is used to evaluate processes, this area also affects all other areas of the SWECOM [60, p. 123]. Essentially, this area deals with the planning and execution of measurement processes. Thus, the collection of the corresponding data but also the identification of possible improvements of the measurement process in the skills and activities are mentioned. It is noticeable that independent activities in the area of planning are only carried out from the practitioner level onward [60, pp. 124-127].

Human-Computer Interaction Skills (crosscutting skill area) Due to the fact that the user interface often makes the difference between poorly usable or even unusable software and successful software, this area is mentioned separately despite its close similarity to other areas and affects the requirements elicitation, design and evaluation processes [60, p. 129]. Its skills and activities include, but are not limited to, identifying target users and their accessibility requirements, document use cases and interaction dialogues, analyzing a design according to an usability checklist as well as conducting usability tests [60, pp. 131-139].

3.2 Teaching Software Engineering

The following section discusses the requirements of learning environments for SE education and teaching approaches used in SE education, in particular project-based learning.

3.2.1 Learning Environments

Garg & Varma discuss the requirements of a learning environment for SE education as well as pointing out the challenges and limits of teachers and students in SE. According to them, learning objects, systemic- and climate requirements are the 3 types of requirements of a SE learning environment [47]. Learning objectives define the knowledge and skills which should be the outcome of a learning process. The CS Curriculum guideline defines different learning objects for each knowledge area. Systemic requirements are seen as facilitators of the "design, development, operationalization and usage of the learning environment in short and long term" and influence the teaching approaches in use [47]. Systemic requirements interact with or influence each other as well as learning objectives, for example: the ability to scale a learning environment with the number of student enrollments is influenced by the resource efficiency and vice versa. According to Garg & Varma, climatic requirements are reflected in the quality of teaching [47]. For example, the use of practical problems to achieve a learning objective is among these requirements.

Garg & Varma identified 10 systemic requirements. Of those 10 systemic requirements, 4 have been discussed in the context of an Indian SE education scenario:

Need for scalability As a result of the few number of institutes, the lack of experienced faculties and infrastructure, the classes tend to contain up to 200 students, which adds numerous challenges for teachers, for example a bigger administrative overhead or the impossibility of implementing more suitable teaching and learning practices such as active learning or personalized learning. As a result, the typical course is limited to theoretical aspects of SE, but they are neither discussed nor practiced.

Therefore, without any adaptions to handle this effect, a large class size reduces the effectiveness of the courses.

Motivation of students According to Garg & Varma the typical computer science students tend to favor direct programming without using SE processes such as testing or documenting in order to get quick results. Therefore, Indian students do not get motivated enough to learn or practice SE on their own or visiting respective course. As a consequence, teachers also prefer teaching a programming course instead of a SE course. Furthermore, through the need for the ability to work with higher levels of abstraction, especially undergraduates are more difficult to teach because of their lack of computing experience, the ability to deal with ambiguity and interpersonal skills. [64]

Need for for flexibility Because of the fast emergence of new concepts, paradigms and methods in SE, the respective curricula at Indian universities are evolving and therefore, courses and training in SE should be able to adapt to the evolving curricula.

Need for resource efficiency The Indian education system usually depends on limited infrastructure, where there only exist few resources for authentic projects or lab facilities. Furthermore, there is only limited availability of qualified and professionally experienced SE teachers and therefore, many teachers teach multiple subjects in 20+ hours per week, which require significant preparation time and, as a consequence, reduces the available time for unpopular subjects such as SE.

3.2.2 Teaching approaches

Teaching methods can be categorised as student-centred and teacher-centred [65, 66, 67]. Serin summarises teacher-centered approaches in his literature review as follows:

> *"In teacher-centered classrooms, the teacher is in charge of learning; therefore, he/she transmits knowledge to the students. As the teacher holds the ultimate authority, the students do not collaborate. The content is decided and the learning tasks are structured by the teacher. The instruction is delivered through lecturing and provision of feedback and correct answers are widely used. The teacher is the primary source of information and the textbook is the center of activities"* [65].

In contrast to this are student-centred approaches, where students have an active role and work cooperatively with other students to learn together [65]. A teaching method with these characteristics that is most commonly used in the field of SE is project-based learning [68].

Project-based learning

Various teaching approaches for SE or SD education are discussed in the literature [69, 70, 71, 72, 73, 74, 75]. According to Cico et al., who conducted a systematic mapping study of 126 papers regarding SE trends, 82.5% of the used teaching approaches in SE education are Project-based learning (PBL) approaches [68].

Wolpert defines the PBL approach as follows:

> *"PBL is the ongoing act of learning about different subjects simultaneously. This is achieved by guiding students to identify, through research, a real-world problem, local to global, developing its solution using evidence to support the claim, and offering the solution using a multimedia approach to presentation using skills based in a 21st-century set of tools. Kids show what they learn as they journey through the unit, interact with its lessons, collaborate with each*

> *other, and assess themselves and each other. They don't just take a test or produce a product at the end to show their learning"* [76].

A shorter definition is given by Valenzuela-Valdés & Fernández, who deal with PBL in the engineering field. They describe PBL as:

> *"A learner focused educational approach where the student extends previous knowledge to new problems through self-directed reflection, research and practice in solving a problem"* [77].

According to them, the PBL approach possesses 8 main characteristics [77]. These are as follows:

- Students are responsible for their own learning.
- Students routinely encounter the problem in their daily lives and can research it in more detail for free.
- Collaboration between students is a fundamental element.
- The self-directed learning of students is applicable to the problem.
- Lessons-learned and the concepts and principles used during the solving of the problem need to be analyzed afterwards.
- Conduct self and peer assessments after solving a problem and at the end of a course.
- The actions performed in PBL must correspond to those valued in the real world.

Project-based learning in SE education

There is already published work in the literature that investigate the application of the PBL method to SE courses [78, 79, 80, 81, 82, 83, 68].

In the experimental study of Souza et al., both the PBL approach and a teacher-centered learning approach were used and compared in introductory courses over the span of 2 years. They studied the students' perception of a practical project as a learning tool, but not which of the two approaches is more suitable as an educational method. According to their results, the group of students taught with the PBL approach positively perceived the elaboration of a project as a learning task. In addition, students of this group recognized the importance of engaging in practical applicability rather than being limited to only theory-based aspects. This was not the case for the group of students who were taught using the traditional teacher-centered learning approach. Students of this group expressed more negative aspects, both about a project as a learning task and about the processes used to document and develop the project [82].

Also applied to introductory courses, Thevathayan's work describes how the application of a PBL approach can address the different levels of prior knowledge of entry-level students, in order to provide a delight- and useful project experience for students with and without limited programming backgrounds. The approach was essentially to allow students to choose the projects so that those with more knowledge were given more complex tasks to achieve better grades. At the same time, it ensured that all students developed the core design skills. [83].

Peréz & Rubio studied small, heterogeneous teams of 9 students, who were in turn divided into 3 teams of equal size, always consisting of 3 roles: Team Leader, Editor, and Proofreader. In this way, the project was also divided into 3 sub-projects, each of which was then worked on by a team. Due to the regular rotation of roles, all students had different tasks to fulfill, which means that they were regularly faced with new challenges. They found, first, that academic performance of students improved and, second, that the students themselves valued their learning experience and the training [81].

Fioravanti et al. analyzed their application of a PBL approach in combination with project management in order to accomplish a more realistic representation of real world software projects. In their experiment, they investigated collaboration between graduate students, who acted as project managers, and a team of 8 to 10 undergraduate students, who acted as software developers. In their experience, the use of a PBL approach achieved positive results. For example, the majority of students found the approach used, the presence of leaders, and the use of real problems with real stakeholders to be positive [79].

Marques et al. examined the effect of "reflexive weekly monitoring" on initial SE project courses, which affected the students in a way that they recognized the importance of coordinated work early in the project and adjusted their behavior for their team's advantage. Furthermore, the students' "coordination, effectiveness, and sense of belonging to a team" improved [80].

A preliminary study by Günay et al. suggests that the PBL approach can increase the critical thinking and problem solving skills of senior-level undergraduate students [78].

3.3 India's Higher Education System at a glance

Universities for higher education already existed in ancient times in Nalanda, Taxila and Vakramsila. The present Indian higher education system emerged in 1823 and replaced the previous education system for the purpose of colonization: in the schools of the new system, "English and European sciences" were to be taught in order to "make the natives of the country thoroughly good English scholars" [84]. In 1948, one year after India became independent from the United Kingdom (UK) [85], the University Education Commission was set up "to report on Indian university education and suggest improvements and extensions". It recommended to form a commission similar to the University Grant Committee of the UK [86]. As a result, the nearly identically-named UGC has been formally established in 1956 by the Indian Government in order to coordinate, determine and maintain the standards of higher education in India [84]. Today, the Indian higher education system is still administered by the UGC, which is coordinating the educational standards of more than 40000 HEI [21, 22]. Besides the UGC another statutory (but not regulatory) body with similar responsibilities exists. The All India Council for Technical Education (AICTE) is responsible for the "coordinated development of a technical education system throughout the country, the promotion of qualitative improvements of such education in relation to planned quantitative growth, and regulation & proper maintenance of norms and standards in the technical education system and for the matters connected therewith" [87]. However, the Government of India is planning to merge both bodies into a Higher Education Commission of India [88].

3.3.1 Universities

According to the All India Survey on Higher Education (AISHE) Report 2018-2019, 993 universities existed in India in 2019 and 39.67% of the universities were located in rural areas. These universities have been categorized into 7 different types [22]. The following list outlines these different types and also provides the total number of universities of each type:

- Central university (46)
  These universities are established by a Central Act, which is an act by the Parliament of India [89, p. 4].
- State university (371)
  These universities are established by a Provincial/State Act, which is an act passed by legislature of a province/state [89, p. 7].
- Open university (16)
  These universities are specialized on distance education and therefore offer only distance degree programs.
- Private university (304)
  These universities are established by a Central/State Act with the help of a sponsor.
- Deemed university (124)
  These institutions are "high-performing" and therefore are declared as "Deemed to be" universities.
- Institute of National Importance (127)
  These institutions are established by "Act of Parliament" and are declared as such.
- Institute Under State Legislature Act (5)

3.3.2 Colleges

Indian Colleges are institutions “established or maintained by, or admitted to the privileges” of a university. In order to be allowed to provide and run degree programs, such colleges have to be attached to a university or university-level institution, because they are not allowed to award degrees on their own [22]. According to the Annual Report 2018-2019 by the UGC, which is based on data by the AISHE, 41935 such colleges have existed in 2019 in India and 60.53% of the affiliated and constituent collages are located in rural areas [21]. As already mentioned before, these colleges can be divided into 4 different types [21, 22]. The following list describes these different types and also provides the total number of colleges of each type:

- Affiliated colleges (38787) These institutions offer studies and the respective courses of their affiliating university and awarding the respective qualifications, in accordance with the rules and regulations of the affiliating university, i.e.: According to the UGC, state universities are allowed to affiliate colleges [90, 23]. The affiliating university defines the curricula, which are taught at the affiliated college, and conducts the examinations. Although these colleges are eligible to offer additional courses, they are not allowed adapt the given syllabi of the courses, the curricula or parts of the curricula [23].
- Constituent colleges (1702) In addition to the characteristics of affiliated colleges, constituent colleges are also maintained by a university.
- PG and Off Campus Centres (183) Share the same characteristics with constituent colleges, but in contrast are located outside the main campus of the maintaining university.
- Recognised Centres (1263) These centres are divided further into Study and Regional centres. Study centres are “established and maintained or recognized by the university for the purpose of advising, counseling or for rendering any other assistance required by the students” [22]. Regional centres are coordinating Study Centres in the context of regular/distance education.

Furthermore, 10725 “Stand Alone Institutions” exist, which are mostly located in rural areas (55.9%). These institutions are not affiliated by a university and therefore are not allowed to award university-level degrees. Instead, they run “Diploma level Programmes” [21].

3.3.3 Quality assurance in Higher Education

In India, there are several institutions that are working on quality assurance in higher education. In 1994, the UGC established the National Assessment and Accreditation Council (NAAC), which “conducts assessment and accreditation of HEIs such as colleges, universities or other recognised institutions” [91]. Besides the UGC and the NAAC, the

AICTE formed a similar board, the National Board of Accreditation (NBA), "in order to assess the qualitative competence of the programs offered by educational institution from diploma level to post-graduate level in engineering and technology, management, pharmacy, architecture and related disciplines, which are approved by AICTE" [92, p. 1]. In 2013, the NBA became administratively and financially independent from the founding AICTE and specifically evaluates technical HEIs [92, p. 1].

At its 532nd meeting, the UGC adopted the so-called "Quality Mandate", which sets new goals for improving the quality of the HE sector to be achieved by 2022. Among other things, students are to be equipped with essential professional and soft skills and each HEI must be accredited by the NAAC with a certain minimum accreditation score. Various initiatives are intended to help achieve these goals, such as the usage of Information and communications technology (ICT)-based learning tools, a mentoring program for non-accredited HEI, examination reforms and the regular revision of curricula [93].

National Assessment and Accreditation Council (NAAC)

The NAAC assesses and accredits HEIs and departments of HEIs [94]. Every university type, except open universities, as described in Section 3.3.1 and every type of college, except off campus centres, as described in Section 3.3.2 are able to apply for the accreditation & assessment process. In order to be eligible for this process, a HEI must exist for at least 6 years or has recorded two classes of graduates [95].

Furthermore, the NAAC recommends that every HEI should set up an Internal Quality Assurance Cell (IQAC) after its successful accreditation process, in order to improve and maintain efficiency of the HEI, structural conditions as well as equitable access to qualitative study and research programs. The IQAC should be composed of different stakeholders of the HEI such as teachers, management members, locals, students and professionals from the industry. Consequently, they have to dedicate themselves to the tasks of the IQAC [96]. The tasks of the IQAC include:

- Develop and apply benchmarks for the academic and administrative operations of the HEI
- Create and maintain a learner-centered environment that ensures the quality of education and promotes the improvement of faculty members to continuously acquire the knowledge and technology necessary for the participatory teaching and learning processes.
- Gather feedback from students, parents and others stakeholders of the HEI through an institutional, quality-related process.
- Organize workshops regarding quality related topics
- Coordinate quality-related activities and document measures that improved the quality

- Be the focal point at the HEI for quality-related best practices.
- Submit an annual quality assurance report to the NAAC

Accreditation criteria by the NAAC The set of accreditation criteria by the NAAC consists of 7 criteria and each criterion consists of several Key Indicators (KIs) which are weighted differently according to the type of the assessed HEI and the sum of weights of the KIs gives the weightage of the criterion. A complete overview of the criteria and the respective KIs is shown in Table 3.1. In contrast to the NBA, a more elaborate description of the criteria and the KIs by the NAAC has not been found by the author of this thesis.

National Board of Accreditation (NBA)

The major objects of the NBA include the assessment and accreditation of engineering education HEIs and programs as well as the continuous development of standards and parameters used during the respective assessment and accreditation processes [92, pp. 1-2]. The NBA categorizes the HEIs it is responsible for into to two different tiers. Although both tiers "are assessed with a similar set of criteria", the weighting of the criteria differs. Tier I institutions include the different types of universities listed in Section 3.3.1 and Tier II institutions include affiliated colleges as described in Section 3.3.2 [92, pp. 7-8]. Furthermore, only Tier I institutions that are accredited by the NBA are mutually recognized by the other 20 full members of the Washington Accord (WA) such as USA, UK, Japan and others [92, p. 4, 98]. Similar to the Bologna Process, the WA "is a self-governing, autonomous agreement between national organisations (signatories) that provide external accreditation to tertiary educational programs that qualify their graduates for entry into professional engineering practice" [99, 100]. The process of accreditation process used by the NBA is shown in Figure 3.1.

Accreditation criteria by the NBA During the shown accreditation process the respective HEI or study program is assessed with the help of their set of accreditation criteria. The complete set of criteria as well as the weighting at the respective tier is listed in Table 3.3. This set consists of the following criteria, where the criteria no. 1 to 7 are used on the program-level and no. 8 to 10 on the institutional level:

Criterion 1 - Mission, Vision and Program Educational Objectives The first criterion is used to evaluate if the assessing study program has a vision, mission and program educational objectives. The vision and mission do not refer exclusively to the study program, but to the institution in which the study program is implemented. The specific goals of the study program are considered in the Program Educational Objectives (PEOs). The NBA defines visions as "futuristic statement that the institution would like to achieve over a long period of time" and the mission describes the path of development toward the vision. The PEOs of a study program "describe what the graduates are expected to perform and achieve during the first few years after graduation" [101, 102,

Criteria	Key Indicator	Weight			
		Univer-sities	Auton. Colleg.	Affil./Const. Colleg. UG	Affil./Const. Colleg. PG
Curricular Aspects	Curriculum Design and Development	50	50	NA	NA
	Curricular Planning and Implementation	NA	NA	20	20
	Academic Flexibility	50	40	30	30
	Curriculum Enrichment	30	40	30	30
	Feedback System	20	20	20	20
Teaching-Learning and Evaluation	Student Enrolment and Profile	10	20	40	40
	Catering to Student Diversity	20	30	50	50
	Teaching-Learning Process	20	50	50	50
	Teacher Profile and Quality	50	50	60	60
	Evaluation Process and Reforms	40	50	30	30
	Student Performance and Learning Outcomes	30	50	60	60
	Student satisfaction Survey	30	50	60	60
Research, Innovations and Extensions	Promotion of Research and Facilities	20	20	NA	NA
	Resource Mobilization for Research	20	10	15	15
	Innovation Ecosystem	30	10	NA	10
	Research Publications and Awards	100	30	15	25
	Consultancy	20	10	NA	NA
	Extension Activities	40	50	60	50
	Collaboration	20	20	20	20
Infrastructure and Learning Resources	Physical Facilities	30	30	30	30
	Library as a Learning Resource	20	20	20	20
	IT Infrastructure	30	30	30	30
	Maintenance of Campus Infrastructure	20	20	20	20
Student Support and Progression	Student Support	30	30	50	50
	Student Progression	40	30	30	25
	Student Participation and Activities	20	30	50	45
	Alumni Engagement	10	10	10	10
Governance, Leadership and Management	Institutional Vision and Leadership	10	10	10	10
	Strategy Development and Deployment	10	10	10	10
	Faculty Empowerment and Strategies	30	30	30	30
	Financial Management and Resource Mobilization	20	20	20	20
	Internal Quality Assurance System	30	30	30	30
Institutional Values and Best Practices	Institutional Values and Social Responsibilities	50	50	50	50
	Best Practices	30	30	30	30
	Institutional Distinctiveness	20	20	20	20
	Total	1000	1000	1000	1000

Table 3.1: Accreditation Criteria and Key Indicators (KIs) of the NAAC [97]

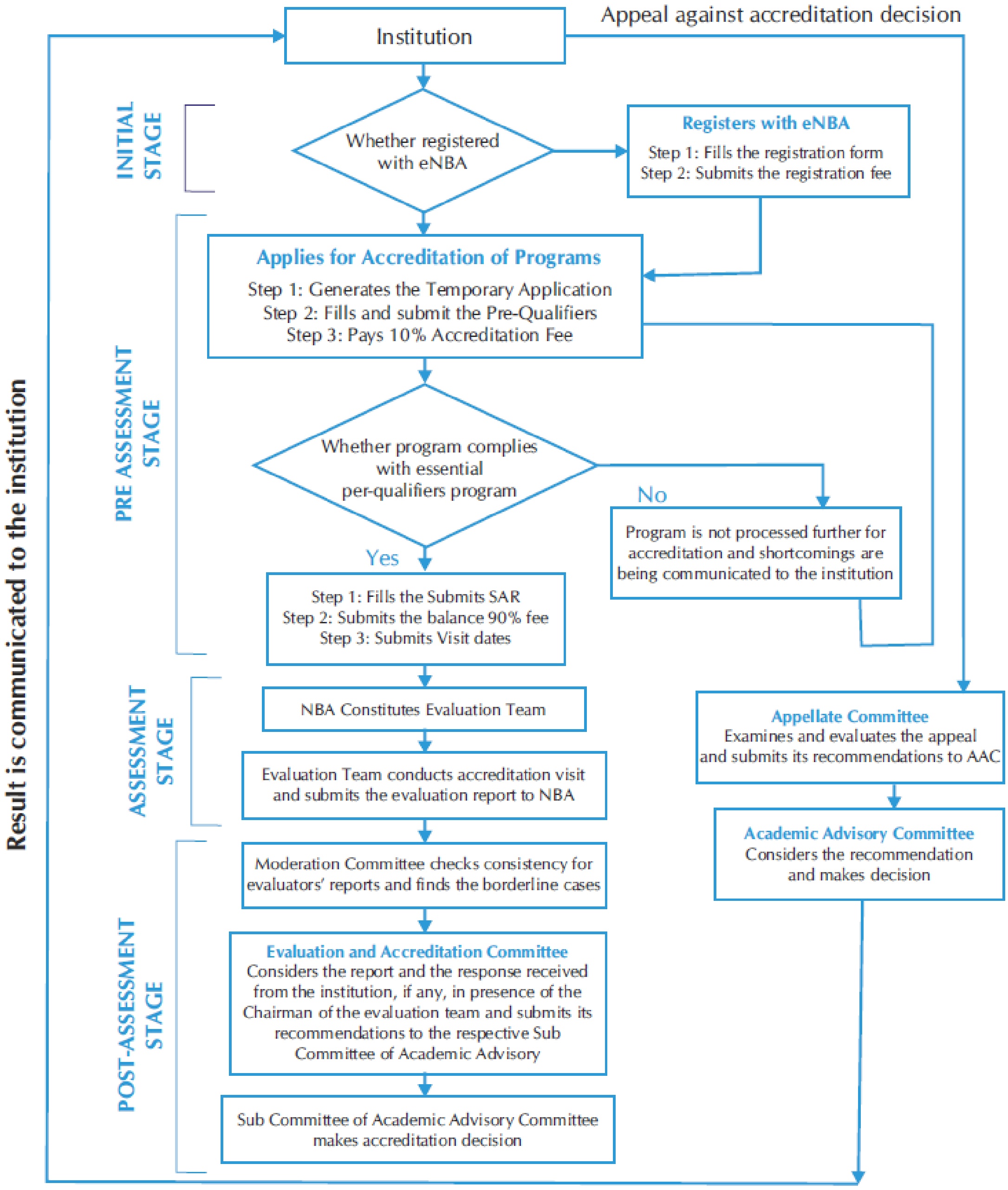

Figure 3.1: Accreditation process of the NBA [92, p. 13]

	PO 1	PO 2	...	PO 12	PSO 1	...	PSO 4
C101.1	1	3		2	-		-
C101.2	2	-		-	1		3
...							
C101.5	-	1		3	2		-
...							
C401.3	1	2		1	-		1

Table 3.2: Course articulation matrix according to an example by the NBA[102, p. 54][101, p. 53]

p. 10]. Furthermore, the NBA defines Program Outcomess (POs), which are necessary objectives for every engineering study program they assess as well as Program Specific Outcomess (PSOs) that are particularly defined for the study program. The POs are described as skills and attributes that a engineering student has to possess after graduation such as the ability to apply the learned mathematics, science and engineering knowledge or the ability to identify, analyse and solve complex problems. [101, 102, pp. 8-9]

Criterion 2 - Program Curriculum and Teaching-Learning Processes According to the second criterion, a study program should describe its structure (course titles, total number of contact hours, etc.), the alignment of the program curriculum along the POs and PSOs and initiatives about possible cooperation between the study program and the industry. Furthermore, the study program should include routines that are used to enhance the students' learning processes as well as the quality of teaching. More specifically, these routines can include ways to use pedagogical methods such as collaborative learning or using real world examples [101, 102, p. 11].

Criterion 3 - Course Outcomes and Program Outcomes For each of the curriculum's courses the study program should outline how the respective course objectives correlate with the POs and PSOs via a course articulation matrix. An example for a course articulation matrix is shown in Table 3.2, where C101.X represents a particular course objective. The number displays the strength of correlation in an interval of $[1, 3] \in \mathbb{N}$, where 1 marks a low, 3 a high correlation and "-" no correlation at all.

Criterion 4 - Students' Performance The HEI must ensure that the students' performance is monitored adequately.

Criterion 5 - Faculty Information and Contributions The HEI must ensure to provide a sufficient number of faculty members that teach the students of the study program adequately. Furthermore, the amount of teaching workload of the faculty members should allow them to also participate in activities besides teaching such as professional and curriculum development, mentoring students, training and interaction

No.	Criteria	Mark/Weightage	
	Program Level Criteria	Tier I	Tier II
1	Vision, Mission and Program Educational Objective	50	60
2	Program Curriculum and Teaching - Learning Process	100	120
3	Course Outcomes and Program Outcomes	175	120
4	Students' Performance	100	150
5	Faculty Information and Contributions	200	200
6	Facilities and Technical Support	80	80
7	Continuous Improvement	75	50
	Institution Level Criteria		
8	First Year Academics	50	50
9	Student Support Systems	50	50
10	Governance, Institutional Support and Financial Resources	120	120
	Total	1000	1000

Table 3.3: Set of accreditation criteria and Tier-weighting by the NBA [101, 102, p. 14]

with experts from the industry. Additionally, the study program enables faculty members to participate in Research & Development activities [101, 102, p. 12].

Criterion 6 - Facilities and Technical Support In order to enable the students to achieve the POs and PSOs of the study program, the HEI must provide and maintain sufficient infrastructure such as adequate laboratories, class rooms and meeting rooms [101, 102, p. 12].

Criterion 7 - Continuous Improvement The study program should be improved continuously by analyzing and evaluating the fulfillment of the POs and PSOs and using the resulting insights by revising courses, assessment methods and the curriculum itself. [101, 102, p. 13].

Criterion 8 - First Year Academics The HEI must provide a "first year of graduation study" that consists of courses in "science, mathematics, humanities and general engineering" [101, 102, p. 13].

Criterion 9 - Student Support Systems The HEI establishes systems that provide support for students such as mentoring programs, self-learning facilities, career preparation or offerings of co- or extra-curricular activities [101, 102, p. 13].

Criterion 10 - Governance, Institutional Support and Financial Resources The governance structure of a HEI that includes the distribution of authorities and responsibilities must be defined clearly. Furthermore, a HEI must ensure that the financial resources are sufficient to attain its Mission and PEOs [101, 102, p. 14].

CHAPTER 4

Data Collection & Thematic Analysis

The exploratory part of this thesis uses semi-structured interviews and observations to gather data about a CS curriculum's actual implementation in rural India. The interviews and observations were subsequently analyzed using the thematic analysis method by Braun & Clark [103]. The semi-structured interviews and observations as well as the thematic analysis are discussed in more detail in Section 4.1. The thematic analysis of the gathered data presented in this chapter is then further analyzed using the DRGA in order to answer the research questions of this thesis (see Chapter 5).

4.1 Methodology

In the following, the research methods used to collect the data, which were subsequently used to answer the research questions of this thesis, are described. This part of this thesis has been realized with a partner institution, which is an affiliated college of the Jawaharlal Nehru Technological University Anantapur (JNTUA) and is located in one of the states in the bottom 25 percentile of employability percentage of graduates [16]. Furthermore, the partner institution is 1 of over 80 affiliated colleges that implement the same curriculum designed by a nationally accredited state university. The students are examined by standardized tests developed by the affiliating university.

4.1.1 Semi-structured interviews

The semi-structured interviews were held with teachers working at the partner institution as well as CS students of the partner institution in order to to gather data about the actual implementation of the CS curriculum and the everyday life of teachers or students

Pseudonym	Role	Sex	Experience
Frankie	Teacher	Female	<1 year
Glenn	Teacher	Male	1-3 years
Jordan	Teacher	Female	1-3 years
Morgan	Teacher	Male	>3 years
Riley	Teacher	Male	>3 years
Nuru	Student	Female	4th Semester
Rory	Student	Female	4th Semester
Sam	Student	Male	4th Semester
Taylor	Student	Male	4th Semester

Table 4.1: Overview of the interviewed persons, their role and level of experience

at a HEI located in rural India in general. Therefore, the semi-structured interviews contribute to answering **RQ1** of this thesis.

Because of the significant importance of establishing a personal contact to subjects described by Saunders et al. as well as the exploratory character, the author of this thesis chose semi-structured interviews as an appropriate interview type for this part of the thesis [104, p. 324]. As it is outlined in Table 4.1, five teachers of the partner institution that hold one or more courses as part of the implemented CS curriculum were interviewed. Furthermore, four students of the fourth semester were interviewed to gather data about their everyday life and the challenges students can face in rural India. The interviews took place in a face-to-face setting and were conducted with the help of Zoom [105]. With the consent of the respective interview partner, the semi-structured interviews were recorded and documented through the transcription of the records afterwards. The author of this thesis chose a face-to-face format, since one can adapt the questions, clarifying doubts or make sure, that the questions have been understood correctly [106, p. 124].

Saunders et al. describe different aspects to consider when preparing a semi-structured interview [104, pp. 328-335]:

1. Level of knowledge
   "*You need to be knowledgeable about the research topic and organizational or situational context in which the interview is to take place*" [104, p. 328]. The interviews aim to gather data about the implementation of a prescribed curriculum from the points of view of teachers and students in emerging regions. In order to do so, the interviews have been held with students and teachers from a partner institution, which is located in rural India. Therefore, this thesis examines the partner institution's situational context and its organizational context described in Chapter 2.

2. Level of information supplied to the interviewee
   In case exploratory interviews are conducted, Saunders et al. describe that a list

of interview themes, which is given to a participants before their interview, may promote validity, reliability as well as the credibility by the participants. This would allow participants to prepare themselves for the interviews whereby they could come up with more detailed information or deliver material which helps at the exploratory study [104, pp. 328-329]. Therefore, the participants of the semi-structured interviews have been informed that the interview will cover questions about the CS curriculum in general, approaches and tools which are used when teaching classes as well as the everyday life of a CS student or a teacher at the partner institution.

3. Appropriateness of location
   According to Saunders et al. interviews should take place at a location in which the participant feels comfortable and is not disturbed easily [104, p. 329]. The partner institution provided a location which met the recommended requirements as best as the capabilities of the partner institution allowed it. Furthermore, it was ensured by the partner institution that the speed and reliability of the internet connection is a good as the region allows it. Despite this support from the partner institution, some interviews were conducted in the interviewee's home, as the partner institution had partially suspended operations due to measures taken against the Corona pandemic [3].

4. Nature of the opening comments to be made when the interview commences
   According to Saunders et al., "the first few minutes of conversation will have a significant impact on the outcome of the interview", especially if the interviewer and the participant haven't met each other before [104, p. 330]. During the opening of an interview, the interviewer should "demonstrate credibility and friendliness" in order to avoid that a participant will become bored or restive. Furthermore, Saunders et al. list recommendations which can be used at the opening of an interview [104, p. 331]. According to these recommendations, the following points have been conducted at the opening of each interview:

   - "The participant was thanked for considering the request for access and for agreeing to the meeting." [104, p. 332s, Box 10.9]
   - A brief introduction to engineering education in India and the existing problems according to the literature. Furthermore, the usage of the interview results as well as a general outline of the expected results of this thesis was presented to the participant.
   - It has been assured that the results of this interview are going to be anonymized so that nothing said by the participant can be related to them without their consent.
   - The participant got informed, that every question can be skipped and that the interview itself can be stopped at any time if the participants would like to do so.

- The participant is asked to give consent about the video- and audio-recording of the interview. If there was no consent, the respective interview has been noted and only handwritten notes were taken. Furthermore, it has been stated that every recording (if consent about recording has been given) is only accessible for the author as well as the co-supervisor and supervisor of this thesis.
- The participant got informed that the results of the whole study will be publicly available.
- At last, the participant was asked if there are questions about the interview procedure in general and has been informed how long the interview is about to take. Furthermore, it was asked again if the participant is still willing to do the interview and if the interviewer is allowed to record it.

5. Approach to questioning
Saunders et al. summarized many findings of the literature regarding the questions of an interview. According to their findings, questions need to be phrased as clearly as possible [104, p. 332]. Additionally, the question was repeated if the author of this thesis had the impression that the interviewee did not clearly understand the question or that the answer did not correspond to the question asked. Furthermore, all of the prepared questions are open questions in order to avoid bias [104, p. 332].

   Saunders et al. recommend that the questions are about real-life experiences instead of theoretical, abstract concepts. Therefore, the asked questions aim for the experiences of the participants in the respective topics. Specific questions about problems and challenges during the study program experienced by the participants are classified as sensitive questions by the author of this thesis. According to the recommendation of Healy & Rawlinson, sensitive questions are usually best to ask at the end of an interview, because that allows the participant to gain trust into the interviewer [107].

6. Scope to test understanding
In order to avoid "biased or incomplete interpretation" the interviewer should summarize the given answer of the participant and present the summary to the participant. This would allow the participant to correct falsely interpreted answers and add relevant further content [104, p. 334]. The author of this thesis paraphrased an answer during the interviews if the answer was either very long from the author's point of view or if the author did not understand the answer.

7. Approach to recording data
Conforming to Saunders et al., the interviews have been audio-recorded and notes had been taken by the interviewer. Additionally, for each interview its location, the date and time, if the participant is a teacher or a student as well as the immediate impression of the interview performance by interviewer was noted [104, p.334].

8. Cultural differences and biases
   Saunders et al. recognise that cultural differences may cause biases to influence the whole interview process and its results [104, p.335]. Therefore, the author of this thesis recognized the importance of the performance of the interviewer as well as the understanding of the questions by the participants, in order to avoid misinterpretations of questions and answers as well as biases due to cultural differences.

9. Performance of the interviewer
   According to Saunders et al. recommendation about the appropriateness of the researcher's appearance at the interview, the author of this thesis chose a similar style of clothing as the interview participants [104, p. 330]. Regarding the nature and impact of the interviewer's behaviour during the course of the interview, Saunders et al. describe the appropriate behaviour of an interviewer. The interviewer should maintain an open posture and enjoy or at least appear as someone who enjoys the interview, in order to encourage and appear open to the participant. Furthermore, the interviewer should avoid behaviour which could indicate a bias, for example: give a neutral, but not uninterested response to the answer of participants. For the purpose of behaving appropriately during the interviews, the author of this thesis conducted three test interviews with his co-supervisor and other colleagues. Furthermore, the interviews require to give participants enough time for answering so that they can formulate their response well. Furthermore, the interviewer must ensure, that his or her own views are not projected during the interview [104, p. 334].

Questions

The questions of the interviews are listed in Appendix A and were developed by the author of this thesis. They aim to collect qualitative data about the reality of the CS curriculum as perceived by teachers and students. Their focus is to gain insights about the current state of the implementation of the curriculum. Furthermore, the questions aim to collect experiences from the everyday life at the partner institution of students and teachers. The questions are categorized according to the OPTIMISM model of the DRGA, which is described in Section 5.1.1.

4.1.2 Observations

The observations were conducted in order to gain an insight into the actual implementation of a curriculum and to observe the everyday life of teachers and students from the view of an insider as well as to describe observable phenomena very detailed and to gain insights into unexpected aspects [106, p. 131, 108, p. 332]. Therefore, the observations contribute to answering **RQ1** of this thesis.

According to Sekaran & Bougie, observations include the "watching, recording, analysis and interpretation of behavior, actions or events" [106, p. 130]. The conducted observations are uncontrolled and participant. The uncontrolled setting is meant to ensure that teachers and students are behaving as naturally as possible and therefore, existing problems are not covered by different behavior of teachers and students. The author of this thesis is going to be an "observer as participant" by observing teachers conducting a course or project review sessions between teachers and students as well as working with groups of students on their final project while revealing the role of the author of this thesis as a researcher from his university [104, p. 294].

It is out of the financial and organizational scope of this thesis, to create a non-participant, controlled observation. Furthermore, the observation setting may enable one to learn and observe the existing problems of teachers from the view of an insider, which is seen as one of the main strengths of participant observation [106, p. 131]. Döring & Bortz, which describe this type of observation as qualitative, confirm, that the scope of this observation type are social interactions between the subjects and their environment. Furthermore, it enables one to describe phenomena very detailed and to gain insights into unexpected aspect, which corresponds to the asked research question [108, p. 332].

Döring & Bortz and Saunders et al. are providing guidelines for observations [108, 104]. Both guidelines were taken into account when planning and conducting the observations for this thesis. The observations took place in three different settings between March and June 2021:

1. Teachers were observed teaching a class. This was done by recording a video call in which the teacher was visible and audible in front of the whiteboard throughout the lesson. Both the teaching of a regular course and the teaching of a laboratory course were observed.

2. Two groups of 4 students each were observed working on their graduation project. The author of this thesis acted as an assistant teacher. He offered to help the group members when problems occurred in the project and to answer questions that arose during the implementation of the project. To this purpose, regular "office" hours were held and a Slack workspace was set up where the group members could ask questions at any time and also exchange information with each other [109].

3. Teachers and all final year students were observed in unregular project review sessions, in which the groups of students reported on the progress of their project and received feedback from the faculty on their progress.

An overview of the conducted observations is presented in Table 4.2. Both, the work with the groups and the project review sessions, were not recorded and the author of this thesis took notes during the observations. Therefore, the majority of these observations are secondary observations [104, p. 296].

Observations	Setting	Scope
A	As Observer	Curricular Course Sessions
B	As Observer	Project Review Sessions
C	As Participant	Assisting Final Project Group 1
D	As Participant	Assisting Final Project Group 2

Table 4.2: Overview of the conducted observations, their setting and scope

4.1.3 Thematic analysis

Although there is no common concrete definition of the term thematic analysis, it is widely used [103]. Braun & Clark characterize thematic analysis as a flexible and easy-to-learn method and is therefore suitable for researchers with no or few experiences in qualitative research. Furthermore, it is described as an advantageous method for research, where one is working participants as collaborators [103]. Since these advantages are consistent with the characteristics of this thesis and its author, the thematic analysis was used to analyze the semi-structured interviews and observations.

Braun & Clark outline a guide for conducting a thematic analysis, which has been taken into account when using the thematic analysis method for this thesis. According to them this method consists of 6 phases [103]:

1. Get to know the collected data
   Transcribe and read the data, write down initial ideas.

2. Generate initial codes
   Systematically create a coding of the interesting data features of the entire data set and collect the data relevant to each code.

3. "Searching for themes"
   Summarize codes on potential themes and create a collection of relevant data for each of them

4. "Reviewing themes"
   Review and refine the themes using the coded data extracts firstly and the entire data set secondly, generating a thematic map of the analysis.

5. "Defining and naming themes"
   Explain each theme in more detail, identify the essence of each theme and its contents and generate clear definitions and names for them.

6. Create conclusion
   Describe meaningful extracts from the themes and provide a concluding analysis of those extracts. Show how the analysis relates to the research questions.

The thematic analysis was carried out from two points of view. Thus, statements were analyzed in terms of how the real implementation of the CS curriculum actually takes place. The statements were also analyzed regarding respective problems and challenges a person or a group of persons expressed. The conclusions drawn from the thematic analysis regarding a student's or teacher's reality were then used to answer **RQ1** with the help of the DRGA (see Chapter 5).

4.1.4 Experiment

It is worth mentioning at this point that originally an experiment was planned in order to find a suitable teaching method that considers the local realities of students and teachers. At first, the course which was planned to take place from March to June. Due to the second Corona wave, which also occurred in the district of Anantapur, i.e. the district where the partner institution is located (51 active cases on 15.03.2021, 17.465 on 16.05.2021 and 1389 on 15.06. in the year of 2021), the partner institution was largely closed for students and lessons were held via distance learning [110]. The author of this thesis was also informed that the period in which the selected course was to take place would be extended. So the students would receive their topic already in March, but the results were expected to be presented in September 2021, whereas the students would have time to implement the project until the end of August 2021.

Both participant groups then elaborated the proposal of their project in mid-April 2021. The proposals consisted of a 1 to 2 page document that briefly summarised the basic topic of their work in an abstract and included a comparison between an existing system or problem and a system or solution they were proposing. After receiving the proposals, the author of this thesis set up a Slack workspace to facilitate remote collaboration between the author of this thesis and the groups, although it took 2 weeks for the groups to fully join [109].

At the beginning of May 2021, the partner institution was closed again due to the increasing number of active Corona cases, which meant that the groups could only work from home. The assigned teachers gave the groups the task of working out the architecture of their system, the basic structure and contents of the required modules and so on by the end of May.

During the review of the groups' elaborations at the end of May 2021, the author of this thesis was informed that the projects should be implemented by the end of June instead of August 2021. As a result, the originally planned, different teaching method could no longer be applied and thus caused the experiment to fail.

4.2 Thematic Analysis of Interviews and Observations

In the following section the conducted interviews and observations are thematically analyzed using the method of Braun & Clark, which is outlined in Section 4.1.3. In contrast to their method, the data were already assigned to the OPTIMISM dimensions in a first step and categorized accordingly. If a statement concerned several of these dimensions, it was assigned to both dimensions. After the generation of the codes, these were summarized to a corresponding theme. Subsequently, a thematic map was created for each dimension. With the help of the thematic maps the themes were refined again. Furthermore, the analyses are enriched with observations and statements made during the interviews.

4.2.1 Objectives and Values

The codes listed in Table 4.3 were generated during the thematic analysis of the interviews and observations with regard to the "Objectives and Values" dimension.

Nr.	Code	Interviews
1	want to become a Software Developer	Nuru, Rory, Sam, Taylor
2	interested into coding / programming languages	Nuru, Rory, Sam, Taylor
3	want more practical knowledge	Nuru, Rory
4	want to go to another country / away from home after graduation	Rory, Sam, Taylor
5	college provides additional courses for students and teachers	Morgan, Glenn, Jordan, Rory
6	additional courses are mandatory for students	Glenn, Nuru
7	additional courses teach software development and soft skills	Nuru, Rory, Glenn, Jordan, Morgan
8	(nearly) 100% of the students pass the exams	Morgan, Riley
9	curriculum updates merged courses that should be separated	Jordan, Morgan
10	merged courses combine conceptual content with emerging trends	Glenn, Jordan, Morgan
11	implementing colleges suggest curriculum update to university	Glenn, Jordan

Table 4.3: Extracted codes regarding the "Objectives and Values" dimension

The themes of this dimension have been elaborated using the codes listed in Table 4.3 and further data extracts from the interviews and observations. Additionally, Table 4.4 lists the Themes of this dimension and indicates the codes on which the respective theme is based. The Thematic Map of this dimension, shown in Figure 4.1, presents an overview of the results of the thematic analysis regarding this dimension.

Theme 1.1 (T1.1) - All of the interviewed students stated that they want to move to a major city or another country and work in the field of software development after graduating. This and the interest in programming or programming languages were the reasons for choosing the CS study program.

Theme 1.2 (T1.2) - Besides the study program itself, the participation and completion of extra-curricular courses of potential employers (internships) as well as the placement of students with a company at the end of the study program is seen as a crucial part of the study program.

Theme 1.3 (T1.3) - It is of great importance to teachers that all students of the partner institution graduate at the end of their studies. As a teacher, you feel proud when 100% of the students pass the exam at the end of the semester.

Theme 1.4 (T1.4) - The curriculum changes almost every two years. The reasons for this include feedback from the HEIs implementing the curriculum as well as emerging trends in CS.

Theme	Codes
T1.1	1, 2, 3, 4
T1.2	5, 6, 7
T1.3	8
T1.4	9, 10, 11

Table 4.4: Mapping of themes to codes regarding the "Objectives and Values" dimension

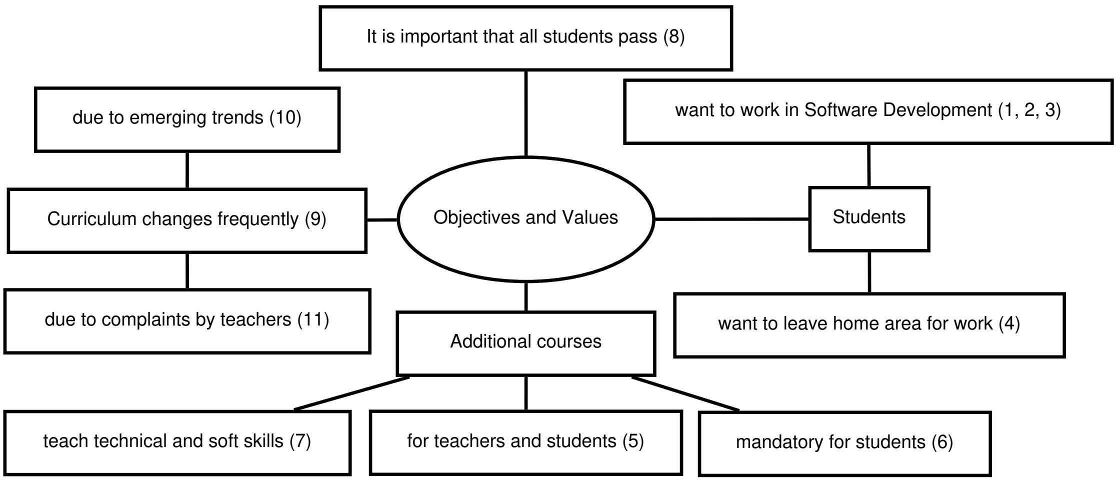

Figure 4.1: Thematic map of the "Objectives and Values" dimension

During the interviews, neither the goals nor the learning outcomes of the curriculum were mentioned in particular by teachers or students. However, it was stated that the curriculum is changed at intervals of a few, usually 2 years. According to Teachers Morgan, Jordan and Glenn, attempts are now often made to combine fundamentals with emerging trends within a course. The teachers have different opinions on this, with two of them describing this tendency as a weakness of the study program. Teacher Jordan states: *"They [affiliating university] have introduced C and Data Structures as one subject [...],* *which is like they have dumped everything to them [students]"*. Additionally, when asked about desired changes in the curriculum, Teacher Morgan answers: *"Now they [affiliating university] suddenly introduce Python with Data Science. Without knowing Python, how they [students] can understand Python with Data Science?"*. However, Teacher Glenn wishes for exactly that: *"[...] topics like Data Science, Data Architecture, Machine Learning, so these topics I'd like to suggest to add on for the courses [of the curriculum]"*.

Regarding the values associated with the implementation of the curriculum, it has been noted that some teachers seem to be very proud if 100% of the students pass the exams at the end of the semester. However, students have the feeling that they are mainly studying to pass the exams and not to really understand the acquired knowledge and to be able to apply it practically. For example, when asked what s_he would like to change about the topics of the courses, Student Nuru answered as follows: *"We [students] are learning [...] for the sake of exams only. Not learning the subject"*.

Students stated they are very focused on their own goal, which was to become a software developer or engineer, which is why all of the students interviewed started the CS study program. In this regard, both groups emphasised the importance of internships and placements and that the combination of them with the study program is essential. For example, Teacher Glenn described the strengths of the curriculum as follows: *"Here the main advantage for the students was we are providing the additional courses [extra-curricular courses held by companies]"*.

4.2.2 Processes

The codes listed in Table 4.5 were generated during the thematic analysis of the interviews and observations with regard to the "Processes" dimension.

The themes of this dimension have been elaborated using the codes listed in Table 4.5 and further data extracts from the interviews and observations. Additionally, Table 4.6 lists the Themes of this dimension and indicates the codes on which the respective theme is based. The Thematic Map of this dimension, shown in Figure 4.2, presents an overview of the results of the thematic analysis regarding this dimension.

Theme 2.1 (T2.1) - Students are evaluated on the basis of questions defined by the affiliating university. In addition to the main exams by the affiliating university in the middle and at the end of the semester, teachers conduct smaller, additional assignments using the main exam questions on the most recently discussed topic on a weekly basis.

Theme 2.2 (T2.2) - Teachers present the course content and students listen or take notes. In addition, there is one project per semester and extra-curricular courses. Two of the interviewed teachers of curricular courses stated that they try to include real-world examples in order to make their topics more tangible. For example, one of the two teachers tested the Instagram registration page with her students using Selenium [111, 112].

Nr.	Code	Interviews / Observations
1	additional tests are conducted in curricular courses	Frankie, Glenn, Jordan, Morgan, Nuru, Riley
2	additional tests do not influence the grade	Glenn, Morgan
3	mandatory projects are conducted each semester	Glenn, Nuru, Rory, Sam
4	teachers mostly stand in front of class and present course contents	Nuru, Sam
5	teachers use blackboard/whiteboard for teaching	Glenn, Jordan, Morgan, Riley
6	teachers use PowerPoint slides for teaching	Glenn, Morgan, Riley
7	teachers use videos for teaching	Glenn, Jordan, Morgan, Riley
8	teachers use code assignments in practical courses	Sam, Taylor
9	teachers use real life examples in practical courses	Frankie, Jordan
10	students use ready-made solutions to solve assignments/project	A, B, C, D
11	teachers provide solutions to assignments	A, C
12	feedback of students is gathered every semester	Morgan, Rory
13	implementing colleges suggest curriculum update to university	Glenn, Jordan

Table 4.5: Extracted codes regarding the "Processes" dimension

Theme 2.3 (T2.3) - In both the practical courses and the mandatory projects, students are provided with solutions by their teachers, which students need to edit only slightly, if at all, in order to finish the respective assignment.

Theme 2.4 (T2.4) - A standard procedure for obtaining feedback from students about the teachers of the courses they visit exists. In this process, students rate the respective teacher on several aspects, for example, the "knowledge of the teacher on the subject" or the "Teacher's ability to organize lectures".

Theme 2.5 (T2.5) - Teachers can summarize their feedback into a collective complaint and forward it to the affiliating university, which can then be used by the committee responsible for the curriculum to change it.

The actual teaching methodology to be used for one or more courses is not specified in the curriculum; a distinction is only made between regular courses and laboratory courses. The actual teaching methods they use to teach the courses are left up to the teachers themselves. It was found that teachers mostly gave a lecture standing in front of the class to which students listened and asked questions when needed. For example, Teacher Glenn answered the questions about his_her teaching method as follows: *"Most of the time we'll [teachers] use blackboard, whiteboard with markers and sometimes we'll*

Theme	Codes
T2.1	1, 2
T2.2	3, 4, 5, 6, 7, 8, 9
T2.3	10, 11
T2.4	12
T2.5	13

Table 4.6: Mapping of themes to codes regarding the "Processes" dimension

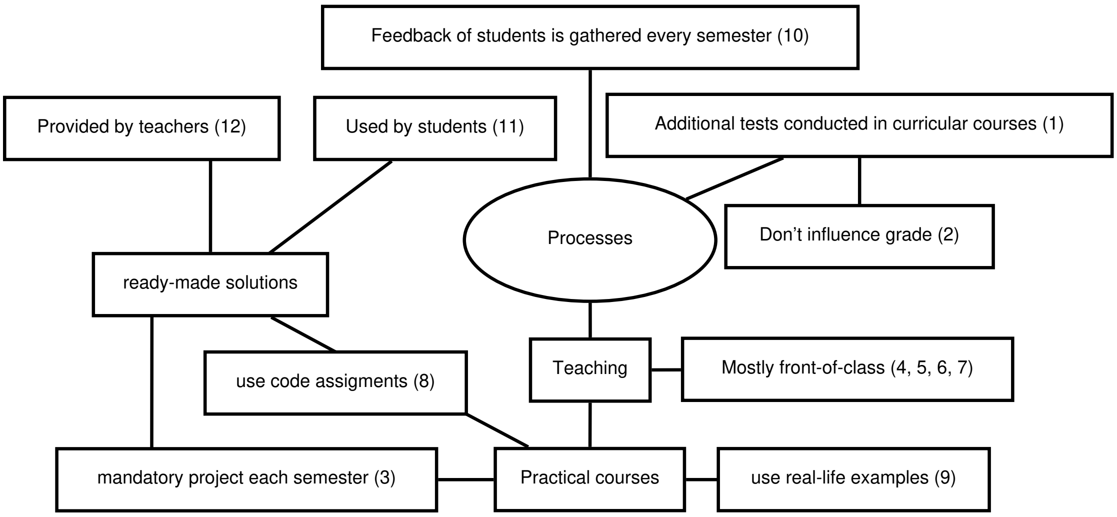

Figure 4.2: Thematic map of the "Processes" dimension

be switching back with ppts [PowerPoint presentations] also". Sometimes the teacher also involved students with follow-up questions. In Observation A, students wrote down the solutions to assignments of the curriculum presented by the teacher in advance and then entered them into the computer. In addition, students have to work on several projects regularly during their studies. Student Sam confirmed that they have to do a smaller project each semester: *"Yes, each semester we [students] have one project. Yearly, we have two minimum projects"*. In their last semester, students also have to do a graduation project. As described in Section 4.1.2, two groups of students were accompanied by the author of this thesis.

One group of students had to work out a "Hostel Management System" (Observation C), the other a "Payroll Management System" (Observation D). A Google search on 11 January 2022 for "hostel management system project" returned 20.3 million, for "payroll management system" 98.2 million results. These results included links to commercial and non-commercial websites that offer already completed projects in different programming languages and project reports matching the task description of the observed groups [113, 114, 115, 116, 117]. Additionally, on the web platform "scribd", a search on 11 January 2022 for the two project titles yielded around 61,000 documents for the hostel project and around 232,000 documents for the payroll project [118, 119]. Considering the first 50 results for each project, it is noted that they were very similar to the objectives of the project reports of the groups observed, both in terms of content and structure. Furthermore, almost all of the project reports from this set of results were written by students of Indian HEIs. In Observation D, the students confirmed that the teacher who officially supervises their project has provided them a link to a freely available project that they can take and work on to complete the assignment. As a result, this project has been copied almost completely by the group. They have only tried to create the impression that the project was developed by them specifically for the partner institution by, for example, replacing images on the project's websites.

Regarding the evaluation of students, it was found that students are evaluated solely on the basis of their scores on the mid and end exams. During a semester, two mid exams and one end exam are held. The mid exams account for 30%, the end exams account for 70% of the grade of the respective course. The questions of the end exam are prescribed by the affiliating university. The questions of the mid exams are prepared by the faculty themselves, but in reality they are mostly composed of questions from old end exams. In order to better track the learning progress, the faculty conducts smaller assignments on the individual course units at regular intervals. The questions asked in these assignments are also largely drawn from old end exams. If a student makes too many mistakes on theses assignments, Teacher Morgan stated that they offer remedial classes: *"So after class those who are weak students come to faculty and conduct remedial classes to improve the weak students like that"*.

Furthermore, Teacher Morgan confirms in the interview that they collect feedback about themselves from students of their courses throughout the partner institution: *"Every semester we [teachers] are conducting, we are taking feedback from the students on all faculty on all subjects."*. This procedure usually takes place before the exams at the end of a semester. A form is used on which questions are asked about the teacher of the respective course (see Appendix C). For example, the students should rate the "knowledge of the teacher on the subject", the "Clarity and understandability of Teacher's explanation" and the "Overall Teaching effectiveness of the teacher" either with "Excellent", "Good", "Fair" or "Poor". In total, the form consists of 13 different questions about the teacher: 4 questions based on the 4-point scale just mentioned, 6 questions based on different 3-point scales, 1 Yes/No question and 2 open questions.

Also, teachers collect their feedback on the curriculum and on individual courses. If problems are identified, they create a collective complaint, which is then sent to the affiliating university that is able to revise the curriculum. According to Teacher Jordan: *"We [teachers] can rise it as a collective complaint. Not from only [the partner institution itself], from the collective colleges we can rise this complaint after completion of the semester"*.

4.2.3 Technology

The codes listed in Table 4.7 were generated during the thematic analysis of the interviews and observations with regard to the "Technology" dimension.

Nr.	Code	Interviews / Observations
1	teachers use blackboard/whiteboard for teaching	Glenn, Jordan, Morgan, Riley
2	teachers use PowerPoint slides for teaching	Glenn, Morgan, Riley
3	teachers use videos for teaching	Glenn, Jordan, Morgan, Riley
4	practice-oriented courses are conducted in computer-labs	A
5	infrastructure is suitable for teaching	Glenn, Morgan, Riley
6	most students have a smartphone	Nuru, Rory, Sam, Taylor
7	most students do not have a laptop/PC	Nuru, Sam, Taylor
8	infrastructure is insufficient for self-learning	Rory, Taylor

Table 4.7: Extracted codes regarding the "Technology" dimension

The themes of this dimension have been elaborated using the codes listed in Table 4.7 and further data extracts from the interviews and observations. Additionally, Table 4.8 lists the Themes of this dimension and indicates the codes on which the respective theme is based. The Thematic Map of this dimension, shown in Figure 4.3, presents an overview of the results of the thematic analysis regarding this dimension

Theme 3.1 (T3.1) - Teachers describe the infrastructure and technologies provided as sufficient: the classrooms are equipped with blackboards or whiteboards and usually also projectors. The partner institution provides one laboratory per study program, which includes computer workstations.

Theme 3.2 (T3.2) - The majority of students do not own a laptop or computer, only a smartphone. Furthermore, students state that the infrastructure is insufficient for adequate self-learning.

Theme	Codes
T3.1	1, 2, 3, 4, 5
T3.2	6, 7, 8

Table 4.8: Mapping of themes to codes regarding the "Technology" dimension

For the teachers, it can be stated that in their opinion they have adequate infrastructure for teaching using their teaching methods. For example, Teacher Glenn acknowledged

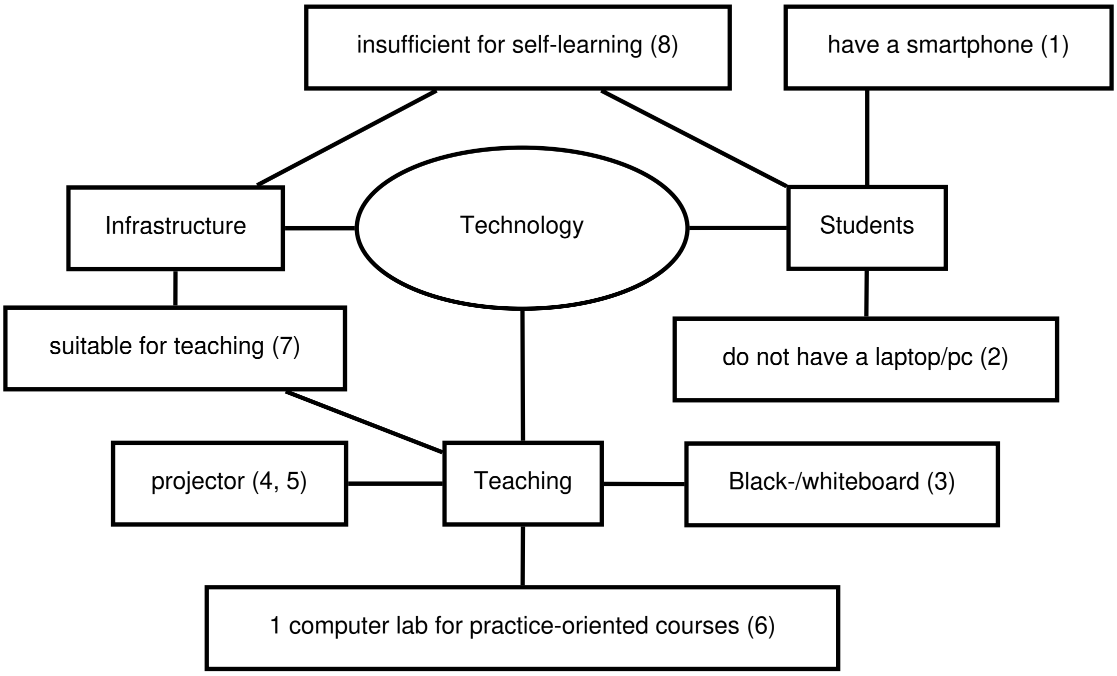

Figure 4.3: Thematic map of the "Technology" dimension

the suitability of the existing infrastructure for his_her class as follows: *"Yeah, we have good infrastructure at college which we can use for our courses"*.

Students agree that the infrastructure for teaching is sufficient, but they note that there is a big problem regarding the availability of adequate infrastructure for learning outside the classroom. While they have access to the rooms of the partner institution that are not in use and to the hostel, students in the hostel share a room with at least two, sometimes with eleven other students, which often makes concentrated studying impossible (see Section 4.2.6). Furthermore, Student Rory states that the computers available outside of class time are almost always already occupied by others and that only *"15% is having laptop and rest of them doesn't have a laptop"*. According to a survey conducted with students of an extra-curricular course, while 96% own a smartphone only 46% own a computer [120]. According to Student Rory, students without a laptop often ask students with such a device if they can borrow it for a PowerPoint presentation: *"when there is any seminar our friends will be asking"*.

4.2.4 Information

The codes listed in Table 4.9 were generated during the thematic analysis of the interviews and observations with regard to the "Information" dimension.

The themes of this dimension have been elaborated using the codes listed in Table 4.9 and further data extracts from the interviews and observations. Additionally, Table 4.10

Nr.	Code	Interviews / Observations
1	teachers use referenced books of curriculum to prepare course	Frankie, Glenn, Jordan, Riley
2	teachers use different internet platforms to prepare/conduct courses	Frankie, Glenn
3	students use YouTube for self-learning	Nuru, Sam
4	students use ready-made solutions from internet platforms for assignments	B, C, D

Table 4.9: Extracted codes regarding the "Information" dimension

lists the Themes of this dimension and indicates the codes on which the respective theme is based. The Thematic Map of this dimension, shown in Figure 4.4, presents an overview of the results of the thematic analysis regarding this dimension

Theme 4.1 (T4.1) - Teachers use referenced textbooks that are listed in the curriculum for each course. However, these are often limited or not available at all. Furthermore, they often use other resources than those listed in the curriculum to prepare or conduct their courses. YouTube, NPTEL and EduSkills were mentioned as examples [121, 122, 123].

Theme 4.2 (T4.2) - Students use platforms with freely available resources for self-learning or solving project assignments.

Theme	Codes
T4.1	1, 2
T4.2	3, 4

Table 4.10: Mapping of themes to codes regarding the "Information" dimension

In terms of information, it can be noted that in addition to the objectives and learning outcomes already mentioned above, the curriculum also contains a breakdown of the course content into individual topics, for which the curriculum also refers to specific books. Besides these referenced books, teachers also use other, free sources to prepare the lessons and for the lessons themselves like YouTube, NPTEL and EduSkills [121, 122, 123]. For example, Teacher Glenn answers the question about his method of preparing a course as follows: *"They [affiliating university] are giving some prescribed textbooks and reference books. Along with that we also go with the internet sources to get the present updated information about the content"*. However, according to Teacher Glenn, these books are usually hardly accessible, especially for students. Therefore, students almost exclusively use YouTube and the resources provided by teachers for learning and also to solve assignments.

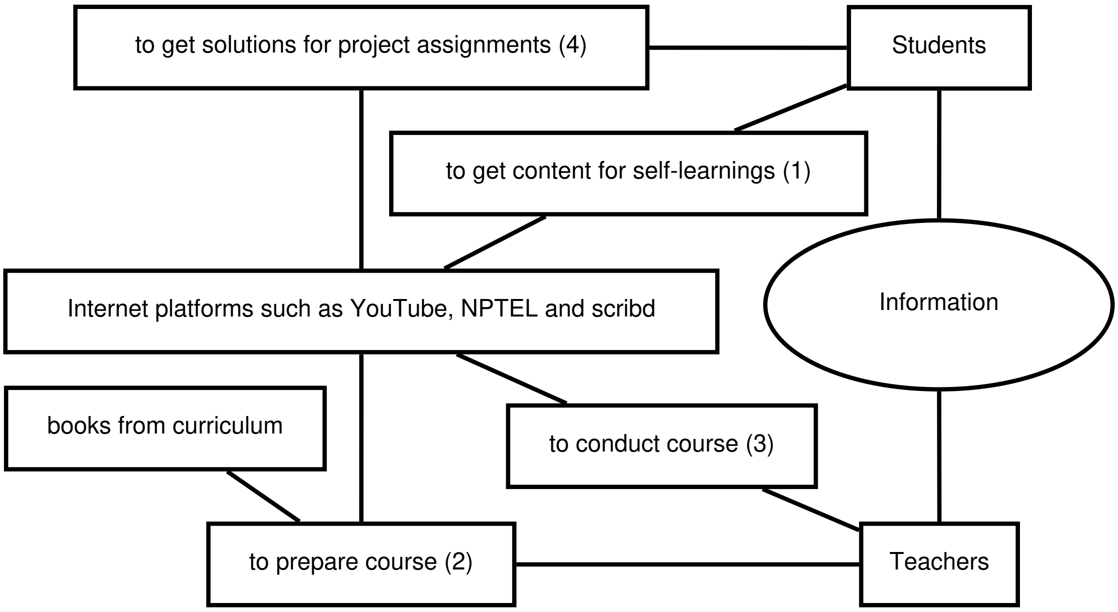

Figure 4.4: Thematic map of the “Information” dimension

4.2.5 Management Systems and Structures

The codes listed in Table 4.11 were generated during the thematic analysis of the interviews and observations with regard to the “Management Systems and Structures” dimension.

Nr.	Code	Interviews
1	no IQAC implemented at the college	Jordan, Morgan
2	assigned courses of teachers change frequently	Glenn, Morgan
3	taught different courses over the last semesters	Glenn, Morgan
4	teachers use different on- and offline structures for coordination	Frankie, Glenn

Table 4.11: Extracted codes regarding the “Management Systems and Structures” dimension

The themes of this dimension have been elaborated using the codes listed in Table 4.11 and further data extracts from the interviews and observations. Additionally, Table 4.12 lists the Themes of this dimension and indicates the codes on which the respective theme is based. The Thematic Map of this dimension, shown in Figure 4.5, presents an overview of the results of the thematic analysis regarding this dimension

Theme 5.1 (T5.1) - At the time of the interviews, there was no IQAC implemented at the partner institution.

Theme 5.2 (T5.2) - The courses are assigned to teachers by the management. Which teacher is responsible for which courses changes every few years, sometimes even annually or every semester.

Theme 5.3 (T5.3) - The teachers hold a weekly meeting in which, among other things, the organizational implementation, for example of laboratory units, is discussed and coordinated. In addition, the progress of students is also discussed.

Theme	Codes
T5.1	1
T5.2	2, 3
T5.3	4

Table 4.12: Mapping of themes to codes regarding the "Management Systems and Structures" dimension

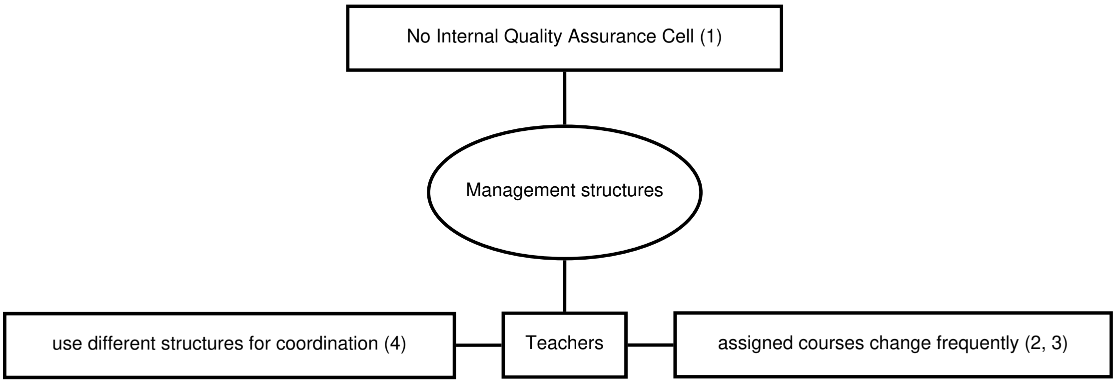

Figure 4.5: Thematic map of the "Management Systems and Structures" dimension

In order to implement the study program, the management assigns teachers the courses they have to offer according to the curriculum. When asked about the subjects taught by the respective teacher, most also gave a history of all the different subjects they had taught in previous semesters. Also, the explicit question of whether the courses were changed frequently was also answered affirmatively.

Furthermore, the teachers involved in the implemented CS curriculum hold regular meetings to make the best use of the limited laboratory capacity and to ensure that the courses are running smoothly, as well as to coordinate the scheduling of internships and placements. They also discuss the progress of individual classes at these meetings. An IQAC (see Section 3.3.3) or a structure with similar objectives did not exist at the time of the interviews.

4.2.6 Investment Resources

The codes listed in Table 4.13 were generated during the thematic analysis of the interviews and observations with regard to the "Investment Resources" dimension.

Nr.	Code	Interviews
1	teachers work 18 to 36 hours per week in teaching	Frankie, Glenn, Jordan, Riley
2	teachers work 36 to 48 hours per week in total for all responsibilities	Glenn, Riley
3	teachers need 2 to 3 hours to prepare a topic of a course	Frankie, Glenn, Jordan
4	teachers have additional responsibilities besides teaching	Frankie, Glenn, Jordan, Riley
5	college provides additional courses for students and teachers	Glenn, Jordan, Morgan
6	additional courses for students and teachers are for free	Jordan, Morgan
7	curricular courses are scheduled from 8:30am to 5pm, Monday to Saturday	Nuru, Rory, Sam, Taylor
8	extra-curricular courses are scheduled from 6pm to 7pm, Monday to Saturday	Rory, Sam, Taylor
9	occasionally special classes are scheduled for Sundays	Rory, Taylor
10	students have other college responsibilities in addition to their courses	Rory, Taylor
11	students do not have laptop due to lack of financial resources	Rory, Sam

Table 4.13: Extracted codes regarding the "Investment Resources" dimension

The themes of this dimension have been elaborated using the codes listed in Table 4.13 and further data extracts from the interviews and observations. Additionally, Table 4.14 lists the Themes of this dimension and indicates the codes on which the respective theme is based. The Thematic Map of this dimension, shown in Figure 4.6, presents an overview of the results of the thematic analysis regarding this dimension

Theme 6.1 (T6.1) - According to the interviews, teachers work up to 48 hours per week over 6 working days. Of these working hours, 18 to 36 hours are spent on teaching responsibilities.

Theme 6.2 (T6.2) - Teachers also have other responsibilities than teaching such as the organization and supervision of additional courses and examinations, conducting charity projects for the local community or administrating the IT infrastructure of the partner institution. Additionally, teachers also attend additional courses provided by the management.

Theme 6.3 (T6.3) -During the semester students have classes from 8:30 a.m. to 5:00 p.m., including breaks. After an hour break, extra-curricular courses are usually taken from 6:00 to 7:00 p.m., after which there should be an additional 3 hours of study once or twice a week. This is all from Monday to Saturday, Sundays are usually free, although it sometimes happens that a course is held on Sunday as well or that students need this day to prepare for an exam.

Theme 6.4 (T6.4) -Students are assigned by faculty to help with various events, not always taking into account their curricular and other extra-curricular responsibilities.

Theme 6.5 (T6.5) -According to one of the interviewed students, most of the students in general do not have enough financial resources to buy a laptop.

Theme	Codes
T6.1	1, 2, 3
T6.2	4, 5, 6
T6.3	6, 7, 8
T6.4	10
T6.5	11

Table 4.14: Mapping of themes to codes regarding the “Investment Resources” dimension

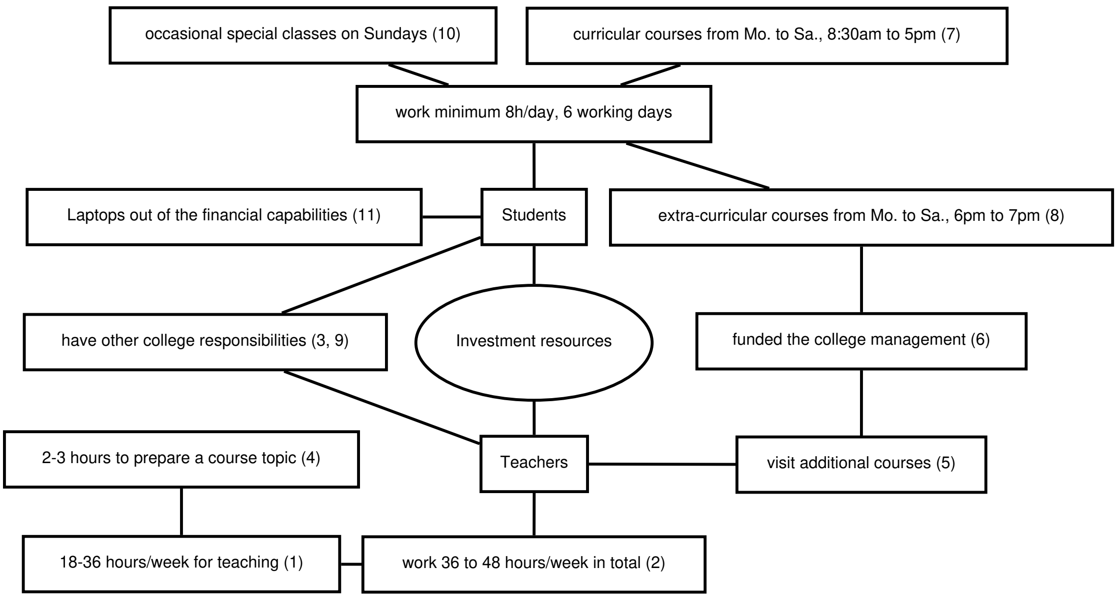

Figure 4.6: Thematic map of the “Investment Resources” dimension

In terms of the time investments of both groups, it was found that both students and teachers have a work week that consists of 6 days. Teachers say they work up to 48 hours per week, with 18 to 36 hours spent on teaching, depending on their assigned courses. Other responsibilities, such as IT administration, supervising exams, or charity work for the local community as part of their work for the partner institution, then take up the rest of their time. Research activities were not mentioned by teachers during the interviews.

Students have very intense days from Monday to Saturday, from 8:30 a.m. to 7:00 p.m. (including breaks) and sometimes even on Sunday mornings. In addition, there are other tasks assigned to them by teachers or the management, which they cannot refuse. These sometimes lead to a missed course session, which is not taken into account subsequently. According to some students, the psychological pressure on students is very hard and the workload often seems unmanageable. For example, Student Rory stated: *"I think here students' life is very tough situation. That means [...] students are not only permitted to only study. They'll be having many other works"*. All but one of the students interviewed confirmed that they have other responsibilities at the partner institution besides studying.

Regarding financial resources, for some students financial constraints make it very difficult to buy a laptop, especially due to the COVID-19 pandemic [3]. Student Sam stated: *"[...] we [students] cannot ask the parents I want to buy laptop because Corona times there is no work"*. Furthermore, the space available for students to study or work at the hostel also depends on a student's financial resources. According to one student, some students share a room with one or two fellow students, while others share a room with up to 11 fellow students, depending on the amount of rent they can pay.

4.2.7 Staffing and Skills

The codes listed in Table 4.15 were generated during the thematic analysis of the interviews and observations with regard to the "Staffing and Skills" dimension.

The themes of this dimension have been elaborated using the codes listed in Table 4.15 and further data extracts from the interviews and observations. Additionally, Table 4.16 lists the Themes of this dimension and indicates the codes on which the respective theme is based. The Thematic Map of this dimension, shown in Figure 4.7, presents an overview of the results of the thematic analysis regarding this dimension

Theme 7.1 (T7.1) - Most teachers did not gain professional experience before entering the higher education sector as a teacher. Typically, teachers came to the partner institution directly after finishing their postgraduate studies.

Theme 7.2 (T7.2) - According to teachers, the frequent change of assigned courses often leads to the situation that teachers have to teach subjects in which they have little or no previous experience or knowledge. As result, teachers were not able to evaluate students' projects properly.

Nr.	Code	Interviews
1	teachers usually do not have professional experience in the subjects they teach	Frankie, Glenn, Riley
2	teachers came directly from college into HE sector	Frankie, Glenn, Riley
3	teachers often do not have teaching experience before joining the college	Frankie, Jordan
4	assigned courses of teachers change frequently	Glenn, Morgan
5	taught different courses over the last semesters	Glenn, Morgan
6	teachers are not able to evaluate projects of students correctly	B
7	occasionally teachers seem to teach subjects without deeper knowledge	Nuru, Rory
8	teachers are good in general	Rory, Sam, Taylor
9	students are not able to work independently on their final project	B, C, D
10	students use ready-made solutions from internet platforms for assignments	B, C, D
11	teachers provide solutions to assignments	A, C

Table 4.15: Extracted codes regarding the "Staffing and Skills" dimension

Theme 7.3 (T7.3) - Students also state that it happens that teachers teach a course without having deeper knowledge in the respective subject. Nevertheless, the majority of the interviewed students think that their teachers are good in general.

Theme 7.4 (T7.4) - Students of the final semester were not able to elaborate a small software project on their own, but instead relied on ready-made solutions, which they slightly modified.

Theme	Codes
T7.1	1, 2, 3
T7.2	4, 5, 6
T7.3	7, 8
T7.4	9, 10, 11

Table 4.16: Mapping of themes to codes regarding the "Staffing and Skills" dimension

Regarding the skills of teachers, it was found that most teachers interviewed did not have any practical experience in the industry. Those who decide to pursue a teaching career usually come to a HEI directly after completing a post-graduate degree program and take over teaching certain courses there as needed, regardless of how experienced they are in the respective subject areas, which affects the quality of teaching according to some of the students. For example, Student Nuru confirmed that teachers often give the

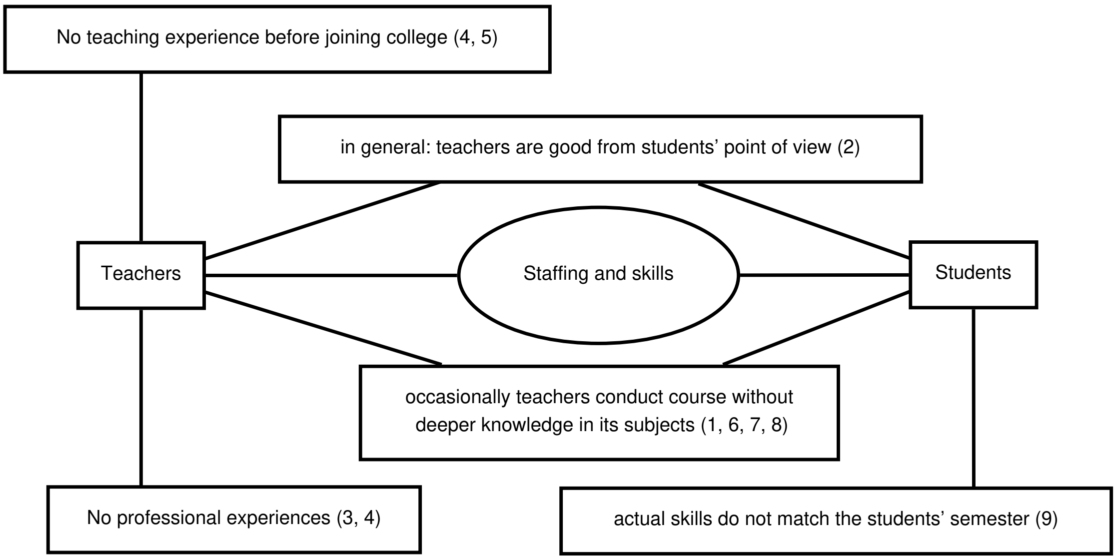

Figure 4.7: Thematic map of the "Staffing and Skills" dimension

impression that they do not know the subject they are teaching. Therefore, especially experienced teachers who have been able to teach their subjects for a long time are more popular among students, although young teachers also stand out positively, especially when they work with practical examples that tie in with the reality of students as it is mentioned in Section 4.2.2.

During Observation B it was noted that teachers were not able to evaluate graduation projects sufficiently. For example, one group presented the configuration file of a development environment for several minutes as source code of the website they have developed for their project. Since the configuration file was written in XML, it was structured similarly to the source code of a website. However, from the point of view of the author of this thesis, an experienced person from the field of CS would have noticed very quickly that the tags used in HTML were not present and that it could therefore not be a website. Furthermore, during the presentation it was recognizable which file was displayed, including its path. Therefore, from the point of view of the author of this thesis, it was easily recognizable for an experienced person from the SE field that a configuration file of the development environment was shown. However, this was not noticed by any of the teachers.

Regarding the skills of students, as described in Section 4.2.2, it was noted through Observations C & D that students in the eighth and final semester were not able to independently analyse problems that arose in the context of their graduation project and work out possible solutions on their own. Instead, students limited themselves to the procedure of trying to modify already existing projects that were found on the internet or brought in by colleagues, as if they had been developed by themselves. However, it was still claimed that it was entirely their own work and not a plagiarised one. For example, one of the supervised groups only admitted that it was a copy after asking several times and being confronted with the source. It turned out that in the beginning they have received the link to the project from their supervising teacher.

4.2.8 Milieu

The codes listed in Table 4.17 were generated during the thematic analysis of the interviews and observations with regard to the "Milieu" dimension.

Nr.	Code	Interviews
1	college provides additional courses for students and teachers	Glenn, Jordan, Morgan
2	students move to major cities for jobs after graduation	Glenn, Jordan
3	no local industry for CS graduates in the area of the college exists	Glenn, Jordan
4	teachers have additional responsibilities besides teaching	Frankie, Glenn, Jordan, Riley
5	students have other responsibilities to the college in addition to their courses	Rory, Taylor

Table 4.17: Extracted codes regarding the "Milieu" dimension

The themes of this dimension have been elaborated using the codes listed in Table 4.17 and further data extracts from the interviews and observations. Additionally, Table 4.18 lists the Themes of this dimension and indicates the codes on which the respective theme is based. The Thematic Map of this dimension, shown in Figure 4.8, presents an overview of the results of the thematic analysis regarding this dimension

Theme 8.1 (T8.1) - Additional courses are provided for both teachers and students. Company-related courses offered on the EduSkills platform, for example on AWS and Cisco, are attended by both students and teachers [124, 125]. Individual companies hold extra-curricular courses for students on certain topics, such as programming with Python or Java, so-called internships. Those students who do well in their course from the company's point of view then have the chance of getting a job after their graduation.

Theme 8.2 (T8.2) - Both students and teachers state that the local industry near the partner institution has no need for graduates of the CS curriculum. In this respect, Bangalore and Hyderabad are mentioned as the cities where students are most likely to live and work after completing their studies.

Theme 8.3 (T8.3) - The partner institution interacts with the local community through charity work on the one hand and events open to everyone in the area on the other.

The charity work focuses on the support of villages or slums by students and teachers in various activities. The events are organised on various occasions, such as International Women's Day or Independence Day [126].

Theme	Codes
T8.1	1
T8.2	2, 3
T8.3	4, 5

Table 4.18: Mapping of themes to codes regarding the "Milieu" dimension

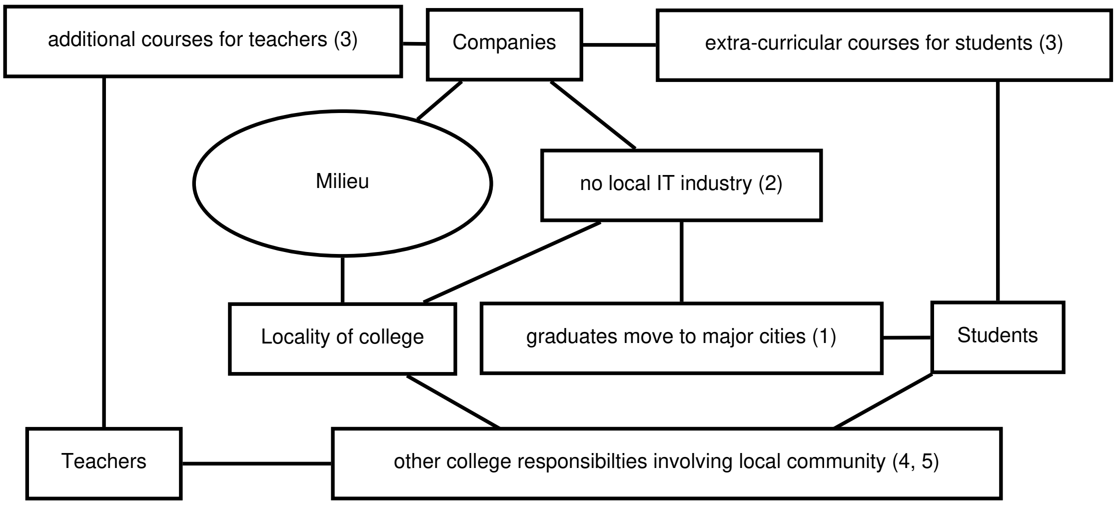

Figure 4.8: Thematic map of the "Milieu" dimension

Concerning the milieu of the curriculum's implementation, it was found that the external stakeholders consist of the JNTUA as the affiliating university, the companies that are interested in graduates of the study program and the local community in or near the area of the partner institution.

Several companies cooperate with the partner institution and offer additional courses in Java or Python programming, for example, as internships that take place independently from the curriculum. Furthermore, students of the last semester have the chance to get a job at a company by passing additional exams, which are called placements. Teachers and students have confirmed that taking part in internships and placements is mandatory. For example, when asked whether students work near the partner institution or move away after graduation, Teacher Glenn explained: *"After they [students] graduated we'll [teachers] bring the companies for the recruitment to the college itself and whatever the placement examinations are, we'll be organizing that they take an exam in college and wherever they get selected they'll moving to those remote locations"*. When asked where they would like to work in the future, all the students answered that they would like to live and work somewhere other than their home town, for example in Bangalore or Hyderabad, but also outside India.

Additionally, the partner institution offers company-related courses from the EduSkills platform. Teachers Glenn and Morgan stated that both, students and teachers, attend courses on this platform, for example on AWS or Cisco [124, 125] services. Furthermore, Teacher Jordan confirmed that in addition to their teaching responsibilities, s_he and the partner institution also support children and their parents who live in small, "backward" villages.

According to a report by the management of the partner institution, the faculty carries out a social responsibility projects with students between the end of the fourth semester and the beginning of the fifth semester. Students develop projects on topics such as "Applications for drones in agriculture", "Applications of solar technologies for rural purpose" or "Smart irrigation for saving water". The social responsibility project became known to the author of this thesis only after the completion of data collection through observations and interviews, as it was introduced within a curriculum revision that has been developed in parallel with this work. As a result, it was not possible to collect more detailed data on it.

CHAPTER 5

Design-Reality Gap Analysis

This chapter presents the analysis of the thematically analyzed gathered data presented in Chapter 4 with the help of the DRGA, which is is described in Section 5.1.1. Then, solutions for bridging the identified design-reality gaps are proposed. As it is previously described in Section 4.1, this thesis has been realized with a partner institution, which is 1 of over 80 affiliated colleges that implement the same curriculum designed by a nationally accredited state university.

5.1 Methodology

The thematic analysis of the gathered data is further analyzed using the DRGA. The DRGA, which is explained in more detail in Section 5.1.1, was used in order to determine the differences between the design and the actual implementation of the CS curriculum and thus to be able to answer **RQ1**. As in the Chapter 3, the DRGA also analyzes the thematically analyzed data along the OPTIMISM dimension that are based on the DRGA by Bass & Heeks [127].

While conducting the DRGA, the author of this thesis noticed that there is thematically analyzed data which, strictly speaking, would not be taken into account by the DRGA, since no opposing design part existed to certain realities. These data, which therefore do not represent gaps between design and reality in the strict sense, are summarized in Section 5.3.2 in further detail after the DRGA.

The identified gaps and challenges were each summarized in a separate list for the purpose of an overview, followed by more detailed description of each gap/challenge and the findings from the DRGA they are based on. If findings of two or more different dimensions were related, they were combined into one gap, such as G1.

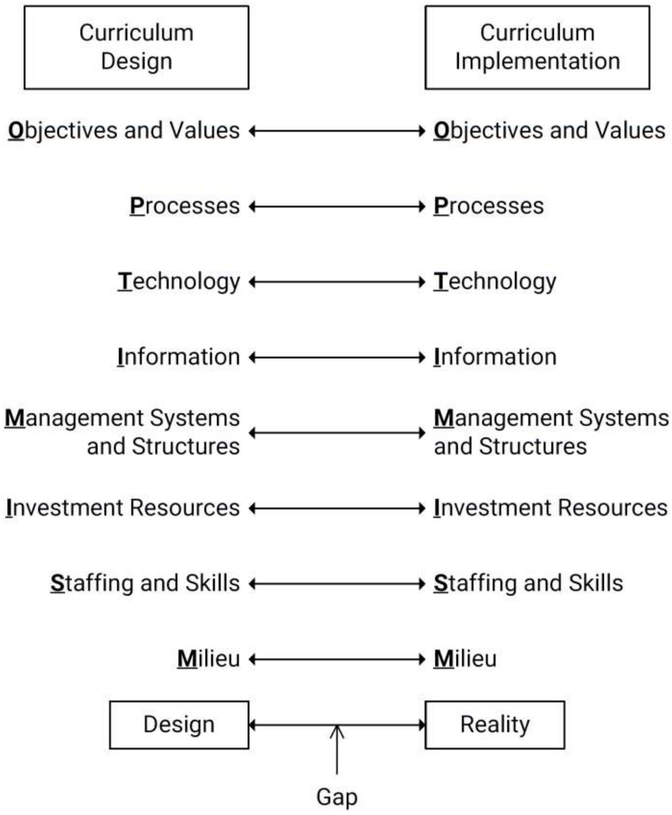

Figure 5.1: Adapted OPTIMISM model of Bass & Heeks [127, p. 6]

5.1.1 Design-Reality Gap Analysis

The DRGA framework was originally designed by Heeks and is used as a tool to analyze the deviation as well as the extent of deviation of the resulting reality from its planned design, especially for Information and Communications Technology for Development (ICT4D) projects [128]. This can be applied to the evaluation of an implemented IT/IS system, for example, to e-government projects, but also to a curriculum or its modified version [127, 129, 130, 131]. Bass & Heeks adapted the DRGA and used the OPTIMISM model, which is shown in Figure 5.1, to consider the dimensions of a curriculum or the modification of it. Along these dimensions, the gap between the design of the curriculum and the realized implementation of it were examined.

With the help of the DRGA, it was examined whether and to what extent the design of a CS curriculum deviates from the implementation in reality. The existing curriculum as well as publicly available information about the curriculum and its environment are used to conclude the design part of the DRGA analysis. The reality part of the DRGA is based on the perceptions and experiences of teachers and students of the partner institution, which were gathered by semi-structured interviews and observations.

5.2 Design-Reality Gap Analysis of the Curriculum and its Implementation

In the following section, the differences between the curriculum developed by the affiliating university and its implementation at the partner institution, among others, are outlined using the DRGA. The following DRGA is structured according to the OPTIMISM dimensions by Bass & Heeks, which are examined in Section 5.1.1. As it is described in Section 5.1.1, for each of these dimensions, the Design part is based on the CS curriculum itself and information that the affiliating university communicates through its websites. As the affiliating university of the partner institution is accredited, the Design part is complemented with the NBA and NAAC guidelines and criteria discussed in Section 3.3.3 The Reality part consists of the thematically analyzed interviews and observations of teachers and students, which are described in Section 4.2, as well as information that the partner institution communicates through its website.

5.2.1 Curriculum

The curriculum consists of several documents, each of them containing the regulations for up to two academic years [132, 133, 134]. Each academic year consists of 2 semesters. At beginning of the document the courses that are held in the respective semester are listed for each semester (see Table 5.1). Each course is categorized, for example, into Basic Science (BS), Engineering Science (ES) or Professional Core (PC). Furthermore, for each course it is defined how many hours per week the course is taught in the respective semester and by which method. Thus, a distinction is made between Lecture (L), Tutorial (T), and Practical (P) hours. The amount of hours then determines the credits, which are used as a unit for the course workload.

No.	Course Code	Course Name	Category	Hours/Week			Credits
				L	T	P	
1.	20A54304	Discrete Mathematics & Graph Theory	BS	3			3
2.	20A05301T	Advanced Data Structures & Algorithms	PC	3			3
3.	20A05301P	Advanced Data Structures & Algorithms Lab	PC			3	1.5
...	...	...	...	...	...	...	...

Table 5.1: Example of course overview in the curriculum [133, p. 3]

The majority of the curriculum consists of the course descriptions. The course description includes the “Course Objectives”, “Course Outcomes”, and the contents of each course unit. In addition, text books, reference books and online learning resources are listed (see Appendix B).

5.2.2 Objectives and values

This dimension considers the objectives of the curriculum and the values it wants to transport through its implementation.

Design

The objectives and values of a curriculum are considered by both bodies, the NBA and the NAAC. As described more specifically in Section 3.3.3, the NBA recognises this dimension with their first criteria, which describes that an institution must have a vision and a mission and a curriculum possesses multiple POs and PSOs. The NAAC lists "Institutional Vision and Leadership" and "Institutional Values and Social Responsibilites" in its set of KIs (see Table 3.1).

The affiliating university and the partner institution are both communicating their individual vision and mission as well as the curriculum's POs and PSOs with the help of their websites. The vision and mission of the affiliating university are both listed on their website's frontpage [135]. Regarding the POs and PSOs, all of the curricula offered on the affiliating university website do not contain general or specific objectives, but they do explain within their Methodology page which teaching methods they use to achieve certain objectives. Theses POs include initiating leadership in their students and prepare them "to meet project requirements of the industry" [136].

The curriculum includes a wide variety of CS courses, such as "Object Oriented Programming", "Software Engineering", "Web and Internet Technologies" or "Operating Systems" [132, p. 3, 133, p. 3, 134, p. 1-3]. As it is described in Section 5.2.1, the CS curriculum defines objectives and learning outcomes for each course of the curriculum. In addition, each course is divided into individual units whose learning outcomes are also listed. In the laboratory courses, there is usually only one unit, which also has objectives and outcomes [132, p. 47]. Furthermore, it was noted that the course articulation matrix recommended by the NBA to outline the relationship between POs/PSOs and courses is not indicated in the latest version of the curriculum reviewed [132, 133].

Reality

The vision and mission of the partner institution are outlined at their website [137]. Furthermore, they also published a vision statement for their curriculum implementation (*"Excellence in creating globally competent professionals and leaders in the field of computer science & engineering"*) and mission statements for their curriculum implementation such as *"Developing Communication Skill, Teamwork and Leadership Qualities for Continuing Education Among the Students, Through Project-Based and Team-Based Learning"* or *"Empowering Students for Employability, Aspiring Higher Studies and to become an entrepreneur"* [138].

Additionally, they list PSOs for their curriculum implementation such as *"The ability to understand, analyze and develop computer programs in the areas related to system* *software, multimedia, web design, big data analytics, and networking for efficient design of computer-based systems of varying complexity"* or *"The ability to apply standard practices and strategies in software project development using open-ended programming environments to deliver a quality product for business success"* [138].

Since the mission statements of the curriculum implementation and the PSOs were published after the interviews, students and teachers could not be interviewed about them explicitly. Regarding the courses and their objectives, it was found that they change almost every two years due to a revision by the JNTUA (see T1.4). According to teachers, there is a tendency for courses that combine the basics with new topics to replace the existing courses.

Teachers seemed to be very concerned that as many students as possible pass the final exams (see T1.3). It can be stated that it is particularly important for teachers that 100% of the students pass the exams at the end of the semester, regardless of the skills that students actually possess afterwards. From the point of view of the author of this thesis, teachers fully trust the end exams by the affiliating university to be able to check the actual learning success and those students who have passed all the exams are then also expected to achieve the goals and learning outcomes of the curriculum and therefore have mastered the skills listed in the curriculum.

However, some students feel that in this curriculum implementation they mainly study for the exams, but not to acquire the knowledge that a software developer should have from their point of view. Students are very focused on their own goal, which is to become software developers or engineers (see T1.1).

Regarding the role of extra-curricular courses, it is noted that both students and teachers confirmed that the curriculum implementation only seems to be useful through the combination of the curriculum and internships. Furthermore, teachers and students have confirmed that the placements at the end of their studies, whose role was described in more detail in Section 4.2.8, are seen as a crucial part of the curriculum implementation as they help students to enter the respective labour market in the first place (see T1.2).

Gap Analysis

As required by both accreditation organisations, the affiliating university formulates objectives and learning outcomes for the individual courses in its curriculum that the partner institution implements. The POs and PSOs are not listed in the curriculum, but the program-specific visions, missions and objectives are described analogously on the websites of the partner institution. The students' goal to become a software engineer aligns with the program-specific vision statement of the partner institution in terms of becoming a "competent professional". The frequent changes to the curriculum and its courses are in line with the recommendations of the accreditation bodies regarding the continuous improvement of a curriculum. However, it was outside the scope of this thesis to determine whether the curriculum actually improves as a result of the constant changes.

Dimension Finding 1 (DF1): One of the two findings of this gap concerns the objectives of the curriculum and whether students actually achieve these objectives by completing the implemented curriculum in the end: The subject areas listed in the PSOs, in which students are supposed to be proficient at the end of their studies, correspond to the contents and objectives of the courses in the curriculum. However, through the observations of the author of this thesis regarding the teachers' confidence in the JNTUA examinations and the students' statements about their studies, it is found that it is never examined whether the objectives of the courses are actually achieved and whether students have actually acquired the respective skills at the end of their studies.

Dimension Finding 2 (DF2): The other finding in this dimension concerns the employability of students after graduation. Although this topic is not explicitly considered in the curriculum and is therefore not a part of the curriculum in the proper sense, it is mentioned in the teaching methodology of the affiliating university. According to their methodology, they designed the curricula that will equip the students with employability [136]. Additionally, the partner institution's program-specific missions include to make students employable [138]. The partner institution pursues this mission exclusively with courses that are not part of the curriculum but are offered by companies. According to students and teachers, this combination of curricular and extra-curricular courses is what makes it possible for students to enter the job market later on. Furthermore, from the point of view of the author of this thesis, the existing combination of the implemented curriculum with internships and placements only determines whether the skills and knowledge that students have acquired through their studies fit into the respective companies involved, but not whether the objectives of the curriculum have actually been achieved. Therefore, it is determined whether the respective students are employable at a corresponding small subset of companies, but not their employability in a broader sense. Therefore, it is noted that students do not achieve the goal of general employability through the implemented curriculum alone. However, it was out of the scope of this thesis to determine whether the curriculum itself already enables general employability.

5.2.3 Processes

The "Processes" dimension includes teaching approaches, assessment methods and evaluation processes that are used for conducting and revising a curriculum.

Design

Both the NBA and the NAAC take this dimension into account, each with its own criterion. In addition to the Teaching-Learning process, the NAAC criterion also covers the evaluation and revision of the processes themselves and includes student satisfaction. As described in Section 3.3.3, the NBA recommends that teaching approaches and assessment methods in use are described in the curriculum. Nevertheless, no teaching methods are listed in the curriculum examined, but the courses are divided into theory courses and practice-oriented laboratory courses. Furthermore, no assessment methods or evaluation processes in use are described in the curriculum.

The affiliating university states its teaching methodology on the institutional level on its website. According to this methodology, they take advantage of student-centered teaching approaches, using interactive teaching-learning methods such as group discussions, seminars and project-based learning, which are also to included in the assessment alongside the examinations at the end of the semester [136]. The curriculum lists objectives and learning outcomes for each course, but teaching methods are neither prescribed nor described in it.

Reality

The partner institution specifies through one of their program-specific mission statements that they use project-based and team-based learning for the implementation of the curriculum [138]. According to teachers and students, the teaching methods used depend on the respective teacher, but are overall highly teacher-centred since teachers mainly present the contents of a course and students participate by listening, taking notes or asking questions (see T2.2). Although the laboratory classes aim to be practice-oriented, in some laboratories the actual teaching method is nevertheless teacher-centered, as students type the previously presented solution for an assignment into the computer, which means that students do not work out the solutions to the laboratory assignments themselves (see T2.3). Therefore it can be noted that the partner institution uses teacher-centered teaching approaches almost exclusively. However, the partner institution conducts project-based learning with projects that students have to work on each semester in small groups of 3 to 4 students.

Furthermore, during their last semester, students are supposed to work on a concrete project and write a report about it. However, the author of this thesis observed that both students and teachers tend to use ready-made solutions instead of trying to develop their own solution (see T2.3). Under the corresponding project titles, tens of thousands of these reports and ready-made solutions for these projects, which show great similarities to each other, can be found on various commercial and non-commercial web platforms. From the point of view of the author of this thesis, this indicates that copying instead of actually creating a solution to a certain task seems to be a widespread phenomenon, at least in the context of the Indian higher education system.

Students are evaluated solely on the basis of their scores on the examinations in the middle and at the end of the semester and are prescribed and designed by the affiliating university of the partner institution. Apart from these examinations, teachers also use smaller tests, which do not seem to be relevant for the evaluation of students, in order to regularly check their learning progress. These tests are largely based on written tests whose questions are given by the affiliating university or have already been given in the past for the same tests (see T2.1.

Regarding feedback processes, students and teachers confirmed that student feedback is gathered at least once per semester (see T2.4). Students rate their teachers on different criteria on a 3 or 4 point scale (see Appendix C). These criteria include the teacher's knowledge of the course content, the ability to organize the course, or the teacher's effectiveness in teaching the course. There is also a feedback process between the partner institution and the affiliating university through which teachers can share their feedback about the curriculum and its courses with the affiliating university in order to initiate changes to the curriculum (see T2.5).

Gap Analysis

In contrast to the recommendations of the accreditation bodies, the curriculum does not contain specifications on the teaching approaches or assessment methods to be used, nor do internal guidelines of the partner institution or anything similar exist. Similarly, there are no routines to improve both the teaching and learning process. Furthermore, it is noted that the curriculum includes the observed graduation project, but not the smaller ones in the previous semesters mentioned by students during the interviews [134, p. 3]. However, the graduation project is only listed in the course overview of the last semester, but unlike the other courses, it is not explained and described in more detail in the curriculum.

Dimension Finding 3 (DF3): A gap between PBL in theory and its actual implementation at the partner institution was found, for example in the observed graduation project course. This course used both project-based and team-based learning, as outlined in one of the program-specific mission statements mentioned above. One difference in this regard is that the implementation of PBL at the partner institution has a different understanding of this teaching methodology: It has been observed that both students and teachers tend to copy a ready-made solution from somewhere else instead of developing their own solution to a problem. A similar approach was also observed in the laboratory courses where the teacher provided a solution instead of letting students work out the solution to an assignment by themselves.

Dimension Finding 4 (DF4): Even though the teachers themselves regularly communicate with each other and with their supervisors in weekly meetings, no quality assurance or enhancement processes have been found that evaluate and revise courses in a regular and institutional way. However, feedback is solicited from students in which they evaluate their teachers and their abilities at the end of each semester. Nevertheless, contrary to the NAAC criteria, student satisfaction is not sought in an institutional manner.

5.2.4 Technology

The technology dimension sums up the infrastructure that is needed to implement a curriculum.

Design

This dimension is also represented by a separate criterion by both the NAAC and the NBA. According to both bodies, a HEI must ensure that access to adequate infrastructure is provided so that students can complete the curriculum and the faculty can teach it. The NBA adds that a HEI has to offer self-learning facilities. The curriculum itself does not contain any specifications as to which infrastructure and technologies are to be used in order to be able to implement the curriculum.

The affiliating university specifies the infrastructural requirements in the affiliation regulations. In the case of a permanent affiliation, for example, the computer-student-ratio, the available internet bandwidth and the electricity and water supply are considered. In addition, it is also checked whether adequate equipment is available for each curriculum implemented at the college, whereby the adequacy is oriented towards AICTE standards [139, pp. 7-11].

Reality

The partner institution has a comprehensive description of various physical facilities that are located on their respective campuses [140]. According to the thematic analysis of this dimension, the facilities are overall adequate for conducting the respective curriculum when it comes to its individual courses (see T3.1). However, the available facilities for self-learning are very limited, especially in terms of existing computers available. Furthermore, the computers available outside of class time are almost always already occupied by others, and since most students only have a smartphone and not a laptop, they cannot, for example, continue working on projects or deepen practical knowledge (see T3.2).

Gap Analysis

Overall, the partner institution provides an adequate infrastructure for the delivery of curricular and extra-curricular courses with no differences between the design and reality.

Dimension Finding 5 (DF5): In terms of the infrastructural needs of students, it is noted that there are very few learning spaces available for all students at the partner institution and the availability of computer workstations outside of courses is very low, which in turn would be of great importance for CS students to work independently on software development skills, for example.

5.2.5 Information

This dimension considers the contents of the curriculum that are necessary when implementing it.

Design

The NAAC addresses this dimension using the “Curricular aspect” criterion. As it is shown in the Table 3.1, depending on the type of HEI, the NAAC assesses either the design and development or the planning and implementation of the curriculum. Furthermore, as described above in Section 3.3.3, according to the NBA, each curriculum should both reflect its structure and show which courses contribute to which goals and to what extent. In addition, the NBA specifies more concrete contents of a curriculum through a criterion specifically described for this purpose.

In addition to the objectives and outcomes, the curriculum describes the contents of each course, divided into topics and refers to those books on which the contents are based. Furthermore, it lists online learning resources for further studying and specific assignments for laboratory courses. In some of the courses, the assignments are also divided into weeks, so that it is indicated in which week of the semester which assignments of a course are to be discussed.

Reality

The referenced books for each course in the curriculum are often used by teachers to prepare their courses. Furthermore, teachers use resources from other platforms such as YouTube or NPTEL to prepare and conduct their courses (see T4.1). Similar to the teachers, students use such platforms for self-learning. However, students also tend to use ready-made solutions from different internet platforms to solve assignments (see T4.2).

Gap Analysis

Apart from the limited availability of the books listed in the curriculum, the thematic analysis of the gathered data do not reveal any major gap between design and reality. A deviation of the contents listed in the curriculum from those actually taught in the corresponding course could not be found. The existing online learning resources were added in the latest version of the curriculum and therefore were unknown by the interview partners [141, 133].

5.2.6 Management Systems and Structures

This dimension describes management systems and structures that are used for the implementation, conduction, evaluation and revision of a curriculum. The curriculum itself does not describe the structures and systems needed to implement it. However, as it is described in Section 3.3.3, the “Quality mandate” of the UGC aims to have all HEI accredited to NAAC standards by 2022. Furthermore, the NAAC recommends alike systems and structures at HEI after they have been accredited. Therefore, for this dimension, the Design part is composed by the concepts of the NBA and NAAC regarding this dimension.

Design

The NAAC and the NBA use criteria to verify that systems and clearly defined structures are in place to govern an HEI, enabling the implementation and conduction of a curriculum in the first place (see Section 3.3.3), but they take different approaches regarding the systems and structures for evaluating and revising a curriculum. As described in Section 3.3.3, the NBA in its seventh criterion, requires that a curriculum needs to be regularly analyzed, evaluated, and revised, but does not specify a concrete system for doing so. Similarly, the NBA states in its fourth criterion that the HEI must ensure that it can adequately monitor the students' performance. The NAAC, in turn, calls for the establishment of a dedicated committee at each institution for the purpose of quality assurance, the already mentioned IQAC. As it is shown in Table 3.1, the NAAC uses several key indicators, such as "Evaluation Process and Reforms", "Student Performance and Learning Outcomes", or "Student satisfaction survey", to verify the existence of management systems for quality assurance. Both the NAAC and the NBA take into account the support of students through their own systems. According to the NBA, the respective institution must set up a system that supports students on the one hand and offers various programs and activities on the other. In addition, the NAAC also takes into account the commitment of alumni with the help of its own indicator. The curriculum itself does not list any systems or structures necessary for its implementation, conduction, evaluation or revision.

Reality

The examined partner institution has a separate management position for each department, which in turn is headed by a director and a chairperson. It was found that the faculty members have informal systems, such as a weekly meeting of all teachers that are involved in the implementation of the curriculum (see T5.2). They use these for content-related but also organizational coordination in order to be able to implement the respective program. However, no IQAC or comparable organizational structure was found to exist (see T5.1).

According to the interviews and the perceptions of the author of this thesis, the partner institution has a functioning management structure. However, during the interviews, teachers and students confirmed that the allocation of teachers to courses changes quite frequently due to managerial decisions (see T5.3). As a result, teachers sometimes have little or no previous experience in the courses they are assigned to teach and therefore often have to familiarise themselves with the subject matter first.

Gap Analysis

In comparing the reality and design according to concepts of the NBA and NAAC, a gap was identified in the systems for evaluating or revising the curriculum.

Dimension Finding 6 (DF6): Although an affiliated college cannot revise the curricula it implements, there should still be a structure for evaluating them. Moreover, the partner institution conducts not only courses of the curriculum, but also extra-curricular courses that are offered by companies and other stakeholders. Since these are outside the direct control of the affiliating university, they can be directly controlled and revised by the management of the partner institution.

5.2.7 Investment Resources

The "Investment Resources" dimension displays the resource needs of a curriculum in terms of financial resources of the HEI and time resources of the respective faculty members. However, it was outside the scope of this thesis if labor policies such as employment protection, paid sick leave or unemployment benefits exist.

Design

As explained above in Section 3.3.3, according to the NBA, teachers' time resources must be sufficient to actually implement the curriculum. Furthermore, the NBA emphasizes that there must be time resources for other activities in addition to teaching responsibilities of the faculty members. The NAAC, on the other hand, does not have a criterion nor a key indicator that considers faculty resources. In contrast, both bodies consider financial resources. The NAAC lists "Financial management and resource mobilization" as a key indicator (see Table 3.1) and the NBA, through its tenth criterion, requires that an institution's financial resources must be sufficient for implementing the curriculum in order to meet its objectives and those of the HEI. As it is described in Section 5.2.1, the curriculum specifies the weekly hours for each course and divides them into hours for lectures, tutoring and practicals. On average, the latest version of the curriculum specifies 28 hours per semester [132, p. 3, 133, p. 3].

Reality

When collecting the data, financial resources of the partner institution were not considered, as the focus was on the everyday life of teachers and students and their resources. It was found that students with fewer financial resources have a hostel room with more people per square meter, which means that there is less potential learning space available for those students. Additionally, the lack of a computer due to their financial constraints makes it difficult for most students to independently learn or deepen their knowledge outside of courses (see T6.5).

Regarding the time resources, it was found that teachers work approximately 48 hours on 6 days per week, whereby 18 to 36 hours are necessary for their teaching responsibilities (see T6.1). Additionally, teachers have other responsibilities such as administrating the IT infrastructure or conducting charity projects and events for the local community (see T6.2).

Students also work for 9.5 hours per day, including breaks, for 6 days per week minimum. Their responsibilities include curricular and extra-curricular courses as well as helping to conduct events of the college (see T6.3 and T6.4). From the point of view of the author of this thesis, the students' intense schedule barely leaves them time to deal with subjects more intensively or even to recover completely. Students expressed the existence of very high pressure and a partial overtaxing of their time resources even without a corresponding question from the interviewer.

Teachers did not make any statements of their own accord that indicated that they felt overburdened with their workload or that their time resources may be insufficient for conducting their courses.

Gap Analysis

Based on teachers' statements, it is determined that their time resources are sufficient to implement the curriculum in reality, so no difference between design and reality in this dimension could be determined with regard to the teachers.

Dimension Finding 7 (DF7): Regarding the students, it was found that their situation causes some of them considerable stress and is very burdensome for some of them, although strictly speaking no difference can be found between design and reality. Therefore, from the point of view of the author of this thesis, it is important to note that the time resources of students are not taken into account by the accreditation authorities, the university or the partner institution. Although the curriculum specifies the number of hours students spend in lectures or laboratories, it does not take into account the time resources required to learn the material. In addition, the extra-curricular activities, including additional courses offered by companies, are also not taken into account.

5.2.8 Staffing and Skills

This dimension describes the skills that students learn during their studies according to the curriculum as well as the skills that faculty members should possess to teach parts of the curriculum.

Design

The skills of faculty members are taken into account by the NAAC in the accreditation process with the help of the key indicator "teacher profile and quality" (see Table 3.1). The NBA devotes a separate criterion to this dimension, which requires the respective institution to ensure that a sufficiently large number of faculty members are available in order to be able to adequately implement the curriculum. The NBA also considers the workload of faculty members and their ability to work besides of their teaching duties such as their own development or mentoring students (see Section 3.3.3). The curriculum describes for each course and partly also for each unit of a course the skills that a student should have after completing the unit or the course. The curriculum does not contain any information about the skills teachers need to conduct their courses.

Reality

According to the interviewed teachers, they usually have no practical experience at the beginning of their careers; many started their teaching career at the partner institution itself and therefore also had no teaching experience at first (see T7.1). They acquire the skills and knowledge required for the individual courses on their own. Furthermore, due to the above-mentioned demand-oriented assignment of courses to teachers and the resulting frequent changes in these assignments, teachers sometimes have very different skill levels in the courses they are supposed to conduct, whereby it often happens that teachers have to teach a course in which they have no previous experience or skills (see T7.2 and T7.3).

When working with students on their graduation project, it has been observed by the author of this thesis that students were not able analyse or solve even small problems by themselves at the end of their studies (see T7.4). In the case observed, students copied a ready-made solution for their project assignment provided by their supervising teacher and tried to modify it. Although they had a ready-made solution, they were not able to change the source code of it in such a way that a different image was displayed than that of the copied solution.

With regard to the teachers, observations of the regular review sessions of this course, as it has been described in Section 4.2.7, have shown that they are mostly not capable of carrying out an actual evaluation of a software project (see T7.1). Regarding the concrete observed situation, from the point of view of the author of this thesis, an experienced person from the field of CS or SE would have noticed very quickly that shown source code is very different to a common website and that a configuration file of the development environment was shown so it could therefore not be the website created by the respective group members. Additionally, as already stated in Section 5.2.3, some teachers tended to use ready-made solutions instead of helping students to develop their own solution to their project assignment (see T2.3).

Gap Analysis

Empirically evaluating whether the skills of the teachers are sufficient for the actual implementation of the curriculum or whether students actually acquire the skills specified in the curriculum was outside the scope of this thesis. Also, it was not empirically examined whether both students and teachers have the technical skills according to SWECOM that have been described in the Fundamentals of this thesis (see Section 3.1.2) [60].

Dimension Finding 8 (DF8): However, from the point of view of the author of this thesis, there are indications that there is a big gap between the skills that students should have by design at the end of their studies and those that they actually have in reality. One of these indications was found through the interaction of the author of this thesis with student groups in the context of their graduation project. In this specific case, it was found that students did not possess certain skills that they would have acquired through several courses of the curriculum. According to the course descriptions in the curriculum, at least one course, Web and Internet Technologies, should have enabled them to solve at least small problems in the observed context, especially since they are students in their final semester in a 4-year CS degree program [134, pp. 44-45].

Dimension Finding 9 (DF9): Most teachers have no professional experience before they start teaching, and some of them have no teaching experience either. In addition, teachers are not informed by the curriculum or the partner institution about potential teaching methods and the teaching methods applied. Therefore, it is not assured that teachers are able to implement PBL in such a way that it can help students to actually achieve the learning objectives. Furthermore, when observing teachers in a situation where they were reviewing students' projects, it was found that they were not able to detect errors and inconsistencies in the presented projects. However, from the point of view of the author of this thesis, obvious errors or inconsistencies of the type observed must be noticed by a person who teaches in this subject area and is supposed to supervise such projects. As described in the Design-part of this dimension, while both accreditation bodies, NBA and NAAC, address teachers and their quality, the curriculum itself and the affiliating university as well as the partner institution do not seem to have sufficient quality requirements for teachers. However, the observed skills of teachers indicate to the author of this thesis that teachers do not have the skills required by the accreditation bodies' design for the adequate implementation of the entire curriculum in reality.

Dimension Finding 10 (DF10): The curriculum design does not specify the skills and experiences that a teacher must have to be able to teach a certain course. Thus, no gap between design and reality in the strict sense can be determined. However, it is noted that the implementation of the curriculum requires constant reassignment of courses based solely on demand and not on the existing skills and experiences of the respective teachers. Teachers report that it is always very challenging when they have to teach subjects in which they have no previous experiences or skills. Students confirm that it often happens that teachers give the impression that their skills and experiences in the respective topics of the course are not sufficient to be able to conduct the course adequately.

5.2.9 Milieu

The Milieu dimension includes the key factors of the institution's environment and the way the environment and the institution mutually influence each other.

Design

Both, the NAAC and NBA consider this dimension in considering the collaborations between faculty members of the HEI and the industry. The NAAC also takes the social responsibilities of a HEI into account.

The curriculum considers this dimension through a mandatory 'Community Service Internship/Project' for 6 weeks during the students' summer vacation after the fourth semester [133, pp. 50-56]. Like the other courses in the curriculum, the description for it contains a detailed plan for its implementation and the objectives of the project.

Reality

The companies are not directly involved in the implementation of the curriculum itself and no direct or indirect influence of the companies on the implementation of the curriculum itself could be determined. Nevertheless, companies from the cities of Hyderabad and Bangalore, which are interested in graduates of the partner institution, are cooperating with the partner institution via additional courses and job offerings for graduating students (see T8.1 and T8.2).

From the point of view of the author of this thesis, the fact that the additional courses besides the curricular courses as well as the placements at the end of the last semester are mandatory for students means that the combination of the implemented curriculum with extracurricular courses offered by companies from the partner institution's environment is understood as a coherent "study program" by both students and teachers.

The local environment of the institution is taken into account on the one hand through various events such as the Independence Day and on the other hand through social responsibility projects, through which the students deal with topics that affect the local environment (see T8.3).

Gap Analysis

The examined institution integrates its environment through curricular and extra-curricular activities of students and teachers. Likewise, through collaborations with different companies, the partner institution provides extra-curricular courses that the students would have to attend to. Due to the numerous found links between the institution and its environment, no gap between the design and the reality is found in this dimension. However, the very high importance of these collaborations between companies and the partner institution should be noted, as this contributes significantly to the success and also, according to students, to the enrolments for the curriculum implementation.

5.3 Identified Gaps and Challenges

This section provides an overview of the identified gaps and challenges, followed by a more detailed description of each gap/challenge and which findings of the DRGA they are based on. Figure 5.2 presents an overview of the findings of each dimension and on which of these findings the identified gaps and challenges are based on.

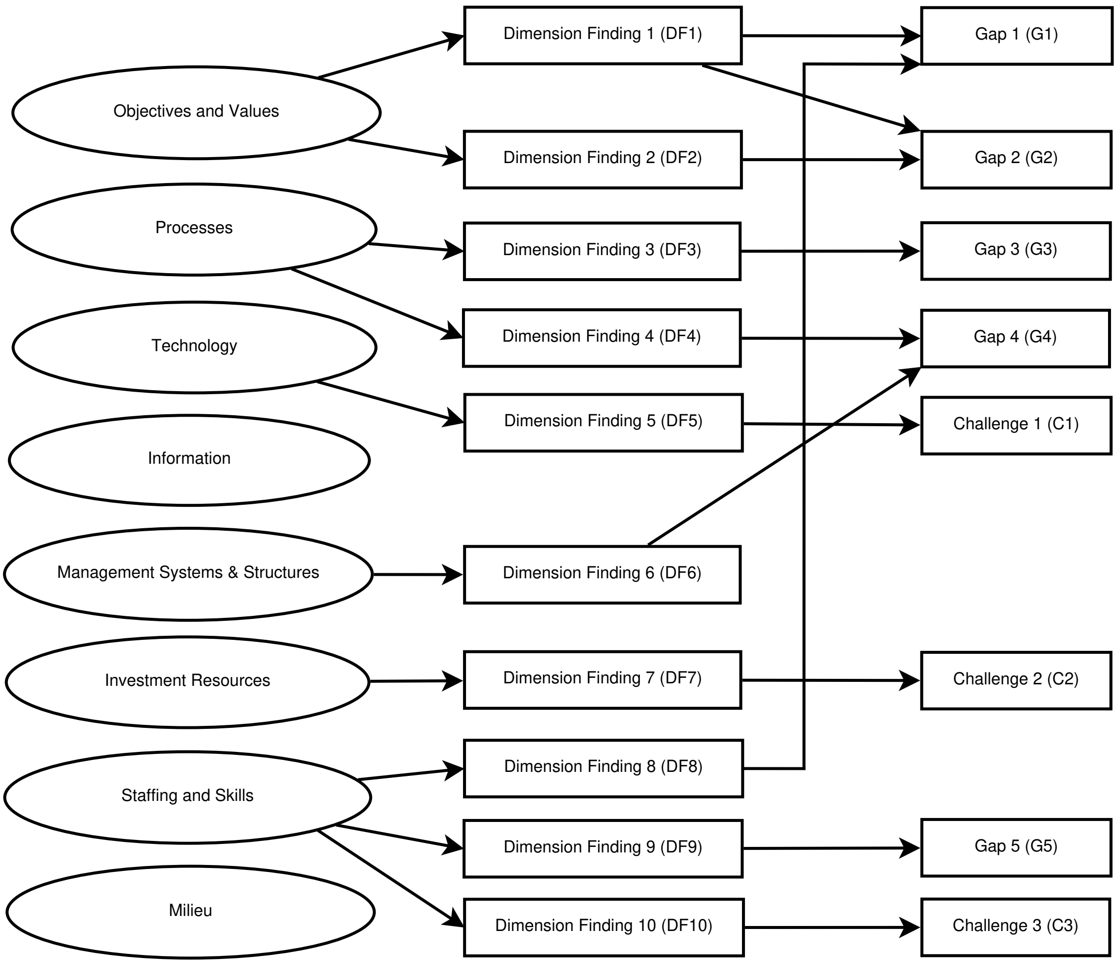

Figure 5.2: Mapping of dimension findings to gaps and challenges

As it is already mentioned in Section 5.1, the author of this thesis noticed that the DRGA would ignore challenges and problems mentioned by students and teachers unless they are taken into account by the design of the curriculum. However, from the point of view of the author of this thesis, these challenges and problems should also be taken into account in order to find realizable solutions for the gaps. Therefore, they are explained in Section 5.3.2. Similar to the identified gaps of Section 5.3.1, an overview of the identified challenges is provided, followed by a more detailed description of each challenge and the findings of the DRGA the respective challenge is based on. Again, as already mentioned in Section 5.1, if two or more findings from different dimensions were related to each other, they were combined into one gap, such as **G1**.

5.3.1 Identified Gaps

The gaps that were identified with the help of the DRGA are summarized as follows:

Gap 1 (G1) - Incomplete Student Skills - Students do not have the skills they should have according to the curriculum at the end of their studies.
Based on **DF1** & **DF8**

Gap 2 (G2) - Unmet Employability Goal - Students do not achieve the goal of the designed curriculum that students are equipped with general employability through the implemented curriculum.
Based on **DF1** & **DF2**

Gap 3 (G3) - Improperly Implemented Teaching Methods - The teaching methods broadly formulated by the affiliating university and the affiliated college are not properly implemented.
Based on **DF3**

Gap 4 (G4) - Missing Curriculum Evaluation - There is no management structure dedicated solely to the evaluation of the curriculum and to quality assurance as well as quality enhancement of the curriculum implementation. Furthermore, there are no institutional processes in place for quality assurance and quality enhancement.
Based on **DF4** & **DF6**

Gap 5 (G5) - Inadequate Teacher Skills - Teachers do not have the relevant skills and professional experience to implement the curriculum adequately.
Based on **DF9**

Gap 1 - Incomplete Student Skills

This gap results from the analysis of the differences between design and reality in the dimensions "Objectives and Values" and "Staffing and Skills" (see Sections 5.2.2 & 5.2.8).

In the "Objectives and Values" dimension, it was found that it is of foremost importance to teachers that as many students as possible pass the standardized final examinations and not whether the students actually achieve the course objectives and acquire the respective skills, which was also confirmed by students (see DF1). Additionally, the circumstance that according to teachers (nearly) 100% of the students pass the examinations is contrary to the findings of the "Staffing and Skills" dimension, namely that students do not have the skills that they should have at the end of their studies according to the curriculum (see DF8).

Therefore, based on the findings of the "Objectives and Values" (DF1) as well as the "Staffing and Skills" (DF8) dimensions, students do not have the skills they should have according to the curriculum at the end of their studies.

Gap 2 - Unmet Employability Goal

This gap results from the analysis of the differences between design and reality in the "Objectives and Values" dimension.

Although in the "Objectives and Values" dimension it was found that the PSOs are aligned with the objectives of the individual courses, according to the findings in the "Staffing and Skills" dimension, these course objectives are not being met (see DF8). Consequently, the PSOs of the curriculum are not met either (see DF1).

Furthermore, it was also found that the partner institution attempts to achieve the employability goal of the curriculum specifically through extra curricular courses (see DF2. Therefore, the employability goal is not achieved through the curriculum. As described in DF2, it is also noted that the resulting employability of the students is, in the view of the author of this thesis, limited to those companies that carry out the corresponding extra curricular course.

Gap 3 - Improperly Implemented Teaching Methods

This gap is based on findings of the "Processes" dimension 5.2.3. From the point of view of the author of this thesis, the lack of experience of teachers described in Gap 5 (see Section 5.3.1) is one reason for this gap.

Although both the curriculum design and its implementation consider teaching methods such as PBL, they are not properly implemented. As described in the fundamentals in Section 3.2.2, the PBL methodology is particularly committed to analysing and solving a problem independently to a large extent, either alone or in a group. However, it was found that, the implemented interpretation of this teaching method at the partner institution is contrary to the PBL methodology, as students do not work out solutions to the assignment independently and both teachers and students tend to use ready-made solutions (see DF3). In the view of the author of this thesis, this implemented interpretation of PBL is not sufficient for students to actually achieve the intended learning objectives and acquire the respective skills that they should have according to the curriculum. Therefore, the actual implementation of the teaching methodologies constitutes a large gap between design and reality.

Gap 4 - Missing Curriculum Evaluation

The "Processes" as well as the "Management Systems and Structures" dimensions of the curriculum were examined with regard to the evaluation of the curriculum (see Sections 5.2.3 & 5.2.6). It was found that no processes exist to evaluate or revise the implementation of the curriculum (see DF4). Furthermore, no management systems or structures were found that deal specifically with quality assurance and thus the evaluation and revision of curricula (see DF6).

Gap 5 - Inadequate Teacher Skills

In the "Staffing and Skills" dimension it was found that teachers lack both teaching knowledge and professional experience (see Section 5.2.8).

Regarding professional experience, it was found that most of the teachers did not have any experience in a professional setting before becoming a teacher at the partner institution. This lack of professional experience was particularly evident in those situations where the teachers had to review students' projects. It was found that none of the teachers were able to recognize even minor errors or inconsistencies in presumably elaborated small software applications (see DF9).

Furthermore, teachers were not able to properly implement other teaching methods that were not teacher-centered. For example, it was found that teachers in different courses provide students with solutions in advance instead of letting students work out the solutions themselves (see Section 5.3.1.

5.3.2 Identified Challenges of Teachers and Students

The challenges that were identified during the DRGA, which do not fit into a corresponding gap due to a missing design part, but should nevertheless be considered from the author's point of view, are summarized as follows:

Challenge 1 (C1) - Difficulties in Self-Learning - The self-learning spaces and computer workstations available are not adequate to allow the majority of students sufficient self-study opportunities outside of course rooms.
Based on **DF5**

Challenge 2 (C2) - Excessive Student Workload - Students feel overburdened by their perceived workload. Additionally, their time resources and their satisfaction are not sufficiently taken into account.
Based on **DF7**

Challenge 3 (C3) - Ever-changing Course Assignments - Teachers face the challenge of teaching courses about subject areas that are often new to them due to the frequent changes in their teaching assignments.
Based on **DF10**

Challenge 1 - Difficulties in Self-Learning

This challenge results from DF5 found in the "Technology" dimension (see Section 5.2.4): Students find it very difficult to work independently on curriculum-related topics, to study for them or to educate themselves. One reason for this is that only very few students have their own computer or laptop available. Another reason is the lack of space available for students. In addition, students are only allowed to stay outside the campus until a certain time in the evening, which means that potential places outside the campus are also only available to a limited extent.

Challenge 2 - Excessive Student Workload

According the findings of the “Investment Resources” dimension described in Section 5.2.7, another very significant challenge is the workload that students have (see DF7). Due to the combination of curricular and extra-curricular courses, students are usually busy from early in the morning until 7:00 in the evening, with the exception of some smaller breaks and a longer lunch break, continuously for 6 days per week. This also leaves students relatively little time for self-study of content, even if a computer and a suitable study space were available to them.

Challenge 3 - Ever-changing Course Assignments

This challenge concerns the constant reassignment of teachers to courses that was found in the “Staffing and Skills” dimension (see Section 5.2.8). It was found, that teachers are get courses assigned according to the staffing needs of the faculty. However, it frequently happens that teachers with no previous experience in the respective subject areas of a course have to teach this course by themselves. From the point of view of both the teachers and the students, this situation constitutes a new challenge every semester (see DF10).

CHAPTER 6

Closing Gaps & Overcoming Challenges

In this chapter, solutions to reduce or bridge the gaps and challenges that have been identified in Sections 5.3.1 and 5.3.2. Finally, to provide an overview, all the solutions found are listed in Table 6.1, including the gaps and challenges the respective solution is intended to solve and the literature the corresponding solution proposed by the author of this thesis is based on.

6.1 Methodology

For each gap identified in Section 5.3.1, solutions for bridging the design-reality gaps from the author's point of view are developed and categorized into smaller, short-term and easier to implement solutions as well as sustainable, long-term solutions. These solutions are based on literature that deal with the problematic characteristics of the corresponding gap and how to address them. When selecting the literature that the solutions are based on, the author of this thesis aimed for work that has studied the respective problems as closely as possible to the context of this thesis. Since the evaluation of each of these solutions is beyond the scope of this thesis, the solutions are to be considered as solutions proposed by the author of this thesis based on literature and his impressions and experiences, which the author of this thesis gained in the course of the examination of the partner institution. As described in Section 8.1, the proposed solutions shall be evaluated in future work.

6.2 Bridging Gap 1: Incomplete Student Skills

One of the gaps found concerns the difference between the skills that students should have at the end of their studies according to the curriculum and those that they actually have (see **G1**). The skills that students are supposed to learn in the curriculum are assessed at the partner institution almost exclusively with the help of predefined written tests. In their systematic literature review, Sokhanavar et al. found that authentic assessment helps to improve the students' satisfaction and performance and thus to really achieve the teaching goals. It also improves students' reflectiveness and self-awareness as well as soft skills such as critical-thinking and problem-solving skills. In authentic assessment, students engage in several tasks designed to connect their understanding of the knowledge they have learned to real-life situations. Authentic assessment uses tools such as presentations, projects, exhibitions, portfolios, case studies or reflection journals [142].

6.2.1 Equip Students with Hands-On Experience (S1.1, short-term)

As a first step, teachers of laboratory courses are advised to stop presenting the solutions of the practical assignments in advance, so that students can also gain hands-on experiences. Furthermore, in order to help the students to actually achieve the educational goals of the curriculum, the currently periodic assignments should also consider the previously mentioned authentic assessment tools instead of using only tests composed of questions taken directly from the curriculum or previous mid and end exams.

6.2.2 Utilize Authentic Assessment (S1.2, long-term)

The guidelines that are described in Section 6.4 should also include information on methods and tools that enable the authentic assessment just described. This would enable teachers who have no experience in this method to introduce it in their courses. Furthermore, teachers need to be supported in its implementation by the partner institution.

6.3 Bridging Gap 2: Unmet Employability Goal

Among the gaps found, one describes the shortcomings in achieving the general employability goal of the designed curriculum (see **G2**). With the help of extra-curricular courses, the affiliated college tries to provide students with employability. However, this has the consequence that these are not necessarily in line with the curriculum and the students' workload is increased.

Borah et al. confirm that the form of industry collaboration implemented at the partner institution, which they call course-based collaboration, is widely used in India. Another possibility they mentioned is a project-based collaboration, in which students work out a real-world ICT project as a group of 3 to 4 students either within a semester or an academic year [143]. Projects of this kind are conducted by students at the partner institution, but without industry collaboration. In addition, Borah et al. describe factors that can hinder collaboration, such as the rigidity of a curriculum, although they do not take into account the students' time available in addition to their studies [143].

However, an excessive workload can lead to students studying only superficially or even dropping out of their studies. They may also lose their self-confidence or suffer from anxiety and depression [144]. A distinction can be made between objective and perceived workload. It is important to mention that a reduction of the objective workload does not necessarily lead to a reduction of the perceived workload, but too much perceived workload that causes too much stress has a negative impact on students' academic performance [145, 146]. For example, project-based learning can lead to more hours being spent objectively, but students do not perceive this as an increased workload due to the additional motivation provided by this teaching approach [147].

6.3.1 Involve Reviewers with Professional Experience (S2.1, short-term)

A first, realistically implementable possibility within the existing structures would be that external partners from companies participate in the project review sessions of the ongoing annual and graduation projects described in Section 4.2.2. In this way, they could evaluate the projects together with teachers and provide feedback that also includes a professional point of view. From the point of view of the author of this thesis, this could compensate the lack of professional experience of teachers and thus lead to students receiving a more realistic feedback.

6.3.2 Establish Experts with Professional Experiences as Teachers (S2.2, long-term)

Another and, from the author's point of view, more sustainable possibility would be to combine both forms of collaboration and the mandatory semester projects. As it also described by Borah et al., instead of offering courses, companies could offer real-world projects and work them out with student groups [143]. In a short introductory phase, teachers from the college could teach the theoretical fundamentals, which, however, would also have to be applied by the projects of the external partners. Subsequently, experts from the industry would supervise students in the development of their project. In this way, the theory remains with the college itself and the practical content is taught by external partners. This ensures, on the one hand, that the projects remain within the scope of the curriculum, and, on the other hand, that the projects are supervised by persons who also have professional experience in the relevant subject area of the project. This would free up teaching capacities, but also reduce the overall workload of students, as the extra-curricular courses would no longer be required and the existing annual projects could be used to make students a little more industry-ready, which in turn is in the interest of the companies. Borah et al. also describe additional possibilities for designing a course based on collaboration between companies and an HEI [143, pp. 8-9]

The possibility of combining curricular and extra-curricular courses and the subsequent elimination of the extra-curricular courses currently taking place, would thus already reduce the objective workload of students and teachers. If the goals of the students are taken into account, the possibility of working with a company as part of the already mandatory project would also increase the motivation of the students, which as a consequence would also reduce the perceived workload by students of the partner institution and therefore also tackle the challenge regarding the students' workload (see **C2**).

6.4 Bridging Gap 3: Improperly Implemented Teaching Methods

One of the gaps found is that teaching methods are not implemented as specified by the curriculum and the college (see **G3**). Teachers sometimes come to the partner institution without any prior pedagogical knowledge and teach courses in which they have little or no prior knowledge of the subject areas. However, those who teach certain subjects should already have expert knowledge in the subjects they teach and also have knowledge about pedagogy in general [148]. Teachers should know about the principles of learning and understand how their teaching can help students learn in the best possible way. In particular, teachers should know how students learn and process information in their own individual way. Knowledge of teaching techniques in turn helps to teach students more effectively [149]. Furthermore, assessment methods are important for the learning process to be shaped, as they strongly influence it [150].

6.4.1 Equip Teachers with Pedagogical Basics (S3.1, short-term)

In order to promote the proper usage of adequate teaching and assessment methods and thus swiftly narrow this gap, new teachers would need to be taught the necessary basics of teaching and learning as well as the assessment of the knowledge imparted. Therefore, the college should support teachers by offering pedagogical (online) courses similar to the EduSkills courses mentioned in Section 4.2.4 and encourage as well as providing the time for teachers to continue their education not only in technical subjects.

6.4.2 Develop Teaching Guidelines (S3.2, long-term)

In order to provide teachers with the necessary teaching fundamentals in a manageable, scalable manner, it would be necessary, in the view of the author of this thesis, to create guidelines for teaching at the partner institution. These guidelines should explain the above topics briefly and in a way that is understandable for new teachers and include examples of possible teaching approaches and assessment methods. Nevertheless, this should not replace the above-mentioned courses, because even in the long term, teachers' pedagogical knowledge should be continuously enhanced. This would enable teachers to broaden and deepen their knowledge of teaching, learning and assessment methods. In this way, teachers would be able to continuously improve their teaching guidelines based on the latest academic insights in pedagogy.

Furthermore, the implementation of the curriculum should consider whether and how certain courses can be taught using other teaching methods to further reduce the perceived workload of students and therefore, the respective challenge **C2**. However, the change of teaching method must be accompanied and monitored to prevent students from being overloaded by the change [144]. Additionally, as students are evaluated solely on examinations prescribed and designed by the affiliating university, the change of teaching method should not worsen the student's grades.

6.4.3 Establish a Buddy System for Teachers (S3.3, long-term)

The college should implement a "buddy system" whereby experienced teachers from the college accompany new teachers at the beginning of their employment at the college [151]. In this way, especially teachers who are still at the beginning of their teaching career could be equipped relatively quickly with the necessary basics of teaching and the corresponding teaching methods. According to Eisner, who studied a similar system but in a business school of a public college in New Jersey, both the new and the experienced teachers benefit from such a system [152]. The work of Ghani et al, which was conducted with secondary education science teachers in Malaysia, advises the implementation of accompanied training when establishing such a system to ensure that teachers implement it correctly [153].

6.5 Bridging Gap 4: Missing Curriculum Evaluation

Another of the gaps found describes the lack of structures or systems in place for quality assurance and quality enhancement of the curriculum (see **G4**). It has been found that no appropriate structures at the partner institution are implemented to evaluate curricular and extra-curricular courses as well as teachers. One approach to narrowing the gap would be to establish the aforementioned IQAC. According to Sawant, a highly autonomous IQAC would result in quality standards being met in teaching, learning and evaluation of a curriculum [154]. In particular, students should be involved in the implementation and ongoing development of the curriculum, as their feedback is one of the most effective tools for quality improvement in higher education [155].

Furthermore, the satisfaction of students depends strongly on the places where they can study. Providing a quiet environment where they can work alone or in groups is crucial to increasing student satisfaction [156]. Both Dhaqane & Afrah as well as Mansoor & Ali, who surveyed students from universities in Sri Lanka and Somalia, found a strong positive correlation between student satisfaction and performance [157, 158]. Therefore, it would be essential for the partner institution to provide learning spaces that students are satisfied with in order to bridge this gap and also improve the students' academic performance. However, from the point of view of the author of this thesis, it is important to consider that students need to have the time resources in order to make use of these learning spaces.

6.5.1 Enhance Existing Evaluation Processes (S4.1, short-term)

As a first step, the management should document the current evaluation processes and ensure that they continue to be carried out. Furthermore, the existing feedback forms for students should be extended so that they also take into account the students' satisfaction and perceived stress and workload. This allows the management to take this parameters into account when planning and implementing the curriculum, both in the short and long term. For example, to discover and consequently solve existing problems in courses or to optimize the course of the corresponding semester in the following academic year. In this way, the challenge of the excessive workload of students (see **C2**) can also be taken into consideration during the implementation of the curriculum, in order to avoid the consequences of an excessive workload that have previously been described in Section 5.3.2.

Additionally, anonymous feedback should also be gathered from teachers in order to consider their resources and needs. For example, they could be asked whether they can manage the time available to them, whether they need further education, or what the college can do to improve the teachers' situation.

6.5.2 Establish Quality Assurance & Enhancement (S4.2, long-term)

In the long term, an IQAC or a similar structure with the same responsibilities should be established that specifically takes care of the topics of quality assurance and quality improvement. On the one hand, this structure can take over the collection of the feedback from students and teachers mentioned above, and on the other hand, it can evaluate the feedback, summarize the findings and formulate concrete, realizable improvements for the management. Additionally, to learn more about a curriculum being implemented at the college, the college should meet regularly with other colleges that are implementing the same curriculum. In this way, the implementing colleges could exchange ideas and experiences about the implementation of the curriculum or compare the results of different measures in order to learn from each other.

In order to also tackle the infrastructural challenge of sparsely available self-learning spaces (see **C1**), the IQAC should monitor which rooms are unused at which times. This makes it possible, when creating the schedule for the actual implementation of a semester, to plan the courses in such a way that individual rooms can be declared entirely as learning spaces for students. Therefore, by utilizing unused rooms, the supply of learning spaces could be increased by at the latest the next time a semester is planned, without having to make infrastructural changes or build new rooms. In the longer term, there should be spaces that are explicitly declared as learning spaces and are also designed accordingly, in order to sustainably increase the students' satisfaction and thus the students' academic performance. Therefore, these spaces should address the different needs of students, for example individual, small booths to enable quiet learning or larger rooms with sufficient capacity and equipment to enable work in groups.

6.6 Bridging Gap 5: Inadequate Teacher Skills

The last of the gaps found describes the teachers' lack of skills that they would actually need in order to be able to teach the curriculum adequately (see **G5**). Chaubey et al. have studied critical factors for good teaching in engineering education in India. According to them, a good teacher must have, among other things, pedagogical skills suitable for teaching the subjects they are supposed to teach. They must also have a basic, in-depth understanding of the subject matter in those very subjects [159]. However, the current practice at the college, where teachers regularly have to teach courses for which they do not have the appropriate pedagogical skills and for which the existing subject knowledge is insufficient, is diametrically opposed to the findings of Chaubey et al.

6.6.1 Maintain Teacher-Course-Assignments (S5.1, short-term)

Keeping the assignment of teachers to courses longer and also to the subject areas of their courses, both teachers and students would experience a higher continuity. Thus, the challenge of frequent changes of courses, which was expressed by both teachers and students, would at least be reduced (see **C3**). This would also give teachers the chance to build and deepen their knowledge in the subject areas of their courses. Reassignment should then only happen if the particular teacher leaves the college or their wishes change and a reassignment would be possible.

6.6.2 Consider Needs and Interest of Teachers (S5.2, long-term)

New teachers should be recruited considering both their subject areas and interests as well as the courses to be implemented at the college, in order to increase the chance that teachers are willing to teach their assigned courses longer. In addition, the colleges' management must also continuously address the needs of teachers for this purpose. Thus, by addressing teachers' interests, the challenge of frequent changes of their assigned courses would likewise be positively impacted (see **C3**). Rao's work on the needs of teachers working in a college in Andra Pradesh should be considered for this purpose, as the college studied in this thesis is located in the same state and thus examines the interests of teachers in a very similar context [160].

6.6.3 Establish a Handover Protocol (S5.3, long-term)

If frequent changes of assigned courses continue to be necessary, one possibility would be to create a general handover protocol applicable to every course in the curriculum. This could include, for example, possible procedures on how teachers can support their potential successors in taking over the respective course. Additionally, a part of this protocol could be basic material of a course from the curriculum that the affiliating university provides, for example ready-made PowerPoint slides for the course units. This would avoid that every new and possibly inexperienced teacher first has to collect the literature available for him_her in order to be able to prepare his_her courses accordingly. This in turn could, from the point of view of the author of this thesis, not only help to close the gap between the required and actual knowledge of the teachers, but also at least reduce the challenge of frequent changes of assigned courses, if this challenge remains (see **C3**).

Solution	Description	Time Horizon	Gap	Challenge	Based On
S1.1	Equip Students with Hands-On Experience	Short-term	G1		[142]
S1.2	Utilize Authentic Assessment	Long-term	G1		[142]
S2.1	Involve Reviewers with Professional Experience	Short-term	G2		[143]
S2.2	Establish Experts with Professional Experiences as Teachers	Long-term	G2	C2	[143]
S3.1	Equip Teachers with Pedagogical Basics	Short-term	G3		[148, 149, 150]
S3.2	Develop Teaching Guidelines	Long-term	G3	C2	[148, 149, 150]
S3.3	Establish a Buddy System for Teachers	Long-term	G3		[152, 153]
S4.1	Enhance Existing Evaluation Processes	Short-term	G4		[155]
S4.2	Establish Quality Assurance & Enhancement	Long-term	G4	C1	[154]
S5.1	Maintain Teacher-Course-Assignments	Short-term	G5	C3	[159]
S5.2	Consider Needs and Interest of Teachers	Long-term	G5	C3	[159, 160]
S5.3	Establish a Handover Protocol	Long-term	G5	C3	[159]

Table 6.1: List of proposed solutions including the gaps and challenges the respective solution is intended to solve and the literature it is based on

6.7 Guidance Notes

In this section, guidance notes are presented that have been developed based on identified gaps and the proposed solutions described the previous Sections 5.3.1 and 6. The guidance notes are modelled on those published by EdTech Hub in collaboration with the UNESCO Chair in ICT4D, which aim to provide targeted advice to decision-makers on their most important specific issues [161]. The guidance notes consist of a short contextual description and then contain highly adaptable recommendations that can be used as goals for decision-makers, combined with examples of how these have already been achieved elsewhere and further readings [162].

The guidance notes are provided for both, curriculum designers and curriculum managers. Each of those contain a description of its target audience that are based on the identified gaps and challenges of **RQ1**, the guidance that is based on the proposed solutions of **RQ2** as well as further readings to enable the target audience to familiarize themselves even more closely with the solutions. As the guidance notes are intended to be presented as independent documents, they are also included as appendices to this thesis (see Appendix D).

As it is described in Section 1.4, the evaluation of the guidance notes' efficacy was outside the scope of this thesis and therefore must be examined by future work (see Section 8.1).

6.7.1 Target Audience

These guidance notes are aimed at HEIs in rural India that are implementing a CS curriculum. However, to indicate possible applicability to other implementing HEIs in a similar context or with similar characteristics, the target audience is defined on the basis of broadly formulated problem statements. If one or more of these problem statements apply to an implementing HEI, it is within the target audience of these guidance notes. The following problem statements were formulated by the author of this thesis and are based on the gaps identified in the course of this thesis (see Section 5.3.1):

- "Students do not meet the goals of the curriculum at the end of their studies", based on **G1**.
- "The implementing institution attempts to ensure student employability exclusively through extra-curricular courses", based on **G2**.
- "The intended teaching methods and assessment approaches are not executed sufficiently", based on **G3**.
- "The implementing institution has no dedicated structures to evaluate or improve their implementation of the curriculum", based on **G4**.
- "(Potential) Teachers do not have relevant professional experiences or pedagogical skills to implement courses of the curriculum adequately", based on **G5**.

For curriculum managers, it is described that the respective guidance note is intended for them if their own HEI faces one or more of these problems. For curriculum designers, the guidance note is intended for them if one or more HEIs implementing their CS curricula face one or more of these problems.

6.7.2 Guidance for Curriculum Designers

The guidance note for curriculum designers is intended to help them design the curriculum in a way that enables implementing institutions, despite their challenges, to provide a high-quality study program in which students achieve the goals of the curriculum. In this context, curriculum designers are persons who are responsible for creating or revising a CS curriculum. For example, they define the objectives of a curriculum, the contents of the individual courses, the learning outcomes or the skills that students should have at the end of their studies of the respective curriculum. In the context of the partner institution, these would be the persons at the affiliating university who specify the curriculum taught at the partner institution.

The following guidance is based on the proposed solutions described in Section 6:

1. "The designing HEIs should include information about suitable teaching approaches for the courses of the curriculum. Particularly for laboratory courses, the curriculum should include instructions on teaching them: First present the task, then let the students work it out by themselves and answer further questions, if any, and only afterwards present the respective solution", based on **S1.1**

2. "The designing HEIs should determine topics for the final project work in a way that the respective topics are not too ambitious, but feasible for the students and assessable for the teachers of the implementing institutions", based on **S1.1**

3. "The designing HEIs should include authentic assessment methods and tools for the examinations they prescribe to affiliated HEIs and the end of each semester", based on **S1.2**.

4. "The designing HEIs should offer courses for (new) teachers of the partner institutions to equip them with basic pedagogical knowledge. Subsequently, teaching guidelines with pedagogical fundamentals as well as teaching and assessment approaches that are suitable for the courses of the curriculum should be developed and provided to the partner institutions", based on **S3.1** and **S3.2**

5. "The designing HEIs should supply curriculum managers with information about possible quality assurance and quality enhancement measurements. Among other things, suitable methods for evaluating the implemented curriculum should be provided on the basis of concrete instructions, for example, ways of evaluating the workload of students and teachers and the possibilities of using these results afterwards", based on **S4.2**.

6. "The designing HEIs should provide its implementing institutions with a platform to help them exchange ideas, learn from each other and share Good Practices in a similar context", based on **S4.2**.

7. “The designing HEIs should provide a handover protocol for teachers taking on one or more courses in the curriculum, along with the curriculum. In this regard, basic materials tailored to teachers should be provided for each course”, based on **S5.3**.

6.7.3 Guidance for Curriculum Managers

The guidance note for curriculum managers is intended to enable the his_her implementing HEI, despite its challenges, to provide a qualitative study program in which students achieve the goals of the curriculum. In this context, curriculum managers are people who are responsible for implementing a CS curriculum at a HEI. This includes providing the necessary infrastructure, employing and managing teaching staff or ensuring and improving the quality of courses within the scope of their possibilities. In the context of the partner institution, the person ultimately responsible for this would be its director, who can delegate the responsibilities.

1. “The implementing HEIs should provide guidelines for teaching that contain basic information about how students learn and possible ways of teaching them. Particularly for laboratory courses, the curriculum management should instruct teachers to first present the task, then let the students work it out by themselves and answer further questions, if any, and only afterwards present the respective solution”, based on **S1.1**

2. “The implementing HEIs should develop guidelines for the assessment of students beyond the mandatory mid-term and final examinations, including information on authentic assessment and the tools and methods appropriate for it, but also taking into account the workload perceived by students”, based on **S1.2**

3. “The implementing HEIs should try to collaborate with industry experts within the curricular courses. The industry experts should bring practical experience to the study program, for example by supervising project reviews or working with teachers in the development and supervision of project work”, based on **S2.1** and **S2.2**

4. “The implementing HEIs have to equip new teachers with pedagogical basics and provider guidelines for suitable teaching approaches and assessment methods. This could be achieved by offering courses for (new) teachers of the respective institution to equip them with with the contents just mentioned. Additionally, teaching guidelines with pedagogical fundamentals as well as teaching and assessment approaches that are suitable for the courses of the curriculum should be developed”, based on **S3.1** and **S3.2**

5. A “buddy system” for teachers should be established so that newly hired teachers who have little or no teaching experience are mentored by experienced teachers. Through this system, new teachers are supposed to be integrated into the HEI

from the very beginning and learn from experiences already acquired by their more senior colleagues", based on **S3.3**

6. "The implementing HEIs should establish a internal structure or body that regularly evaluates the curriculum and reports possible improvements to the curriculum management based on the evaluation results. This evaluation should at least consider feedback on the study program by both students and teachers. Additionally, the perceived and objective workload as well as the satisfaction of students and teachers should be monitored and taken into account", based on **S4.1** and **S4.2**

7. "The implementing HEIs should avoid changing teachers' assigned courses frequently. This will allow them to become more proficient in the subject area of their courses and deepen their respective knowledge in it. Thus, both students and teachers could benefit from the higher continuity", based on **S5.1**

8. "The implementing HEIs have to ensure that the teachers' interests and needs are addressed in order to prevent the necessity of reassigning courses due to a frequent loss of teachers. Nevertheless, the implementing HEIs should provide a handover protocol to assist newly assigned teachers in taking over a course in a way that minimizes knowledge loss through the handover process", based on **S5.2** and **S5.3**

CHAPTER 7

Discussion of Results

In this chapter, the results of this thesis from Chapter 5 are compared with the objectives of this thesis from Section 1.3. Furthermore, they are compared with the findings of related work described in Chapter 2.

As mentioned in Section 1.3, this thesis aims to provide insights that help to increase the number of SE graduates with sufficient skills. As it is outlined in Chapter 2, the reasons for the insufficient skills of (software) engineering graduates have been studied repeatedly in recent years through similar work. Likewise, numerous suggestions exist in the literature on how to overcome this problem. However, as it is described in Section 1.1, the problem still exists. The reasons why the problem still exists, although it has been known for at least 10 years, are unclear.

Dubey et al. attribute the reasons for the mismatch between the skills of engineering graduates and the needs of the industry to the high privatization of the higher engineering education sector [14]. As described in Section 3.3, the private sector of the higher education system in India largely consists of affiliated colleges, which in turn implement the curriculum of a state university at their own. Furthermore, the related work in the literature examining the existing skill mismatch among engineering graduates did not examine the design of the existing curricula or address the question of whether and to what extent students' actual skills differ from those they should have according to the curriculum.

Therefore, this thesis examines the implementations of a given curriculum using the implementation of 1 of 80 affiliated colleges located in rural India that are implementing the same curriculum. This thesis determines whether and which differences exist between the design of the prescribed curriculum and its actual implementation through answering **RQ1**. Furthermore, solutions to overcome these differences are proposed in the course of this thesis by answering **RQ2** (see Section 1.3). Based on the answers to **RQ1** and **RQ2**, guidance notes (see Appendix D) were developed that summarize the differences and the proposed solutions for decision makers of the context that was examined by this thesis. However, as described in Section 6.7.1, broadly formulated problem statements were used in describing the target audience for the guidance notes. This attempts to generalize the proposed solutions in order to make them applicable in other contexts, for example, outside of rural India or other curricula.

As already mentioned in the Limitations, neither social nor cultural problems were taken into account in this thesis. Likewise, potential labor policies were not examined (see Section 1.5). From the point of view of the author of this thesis, these factors might have a direct or indirect influence on the implementation of the curriculum. Therefore a root cause analysis of the identified gaps and challenges is noted as possible future work in Section 8.1.

Furthermore, this thesis was developed from an external, European point of view (see Section 1.5). The influence of the local, Indian view is reflected by the answers, which were given in the course of the interviews, whereby these were also analyzed thematically by the author of this thesis. Therefore, this thesis provides a starting point for future work, which shall be carried out in cooperation with local researches on site (see Section 8.1).

From the point of view of the author of this thesis, it is important to note for the evaluation of the proposed solutions that the solutions were not proposed together with stakeholders of the partner institution (see Section 1.5). Therefore, from the point of view of an insider, these are all proposals coming entirely from external sources. In order to include the local perspective in the solutions, one way to evaluate the solutions proposed in this work together with local people would be to use the so-called PDIAtoolkit [163]. This toolkit was developed at the Center for International Development at the Harvard University and is used to analyze problems and develop solutions for them in an iterative process. In future work, the gaps identified in this thesis can be used as the already previously mentioned starting point in a way, that the gaps are the problems to analyze. Through the toolkit, the gaps' root causes shall be analyzed and solutions shall be designed together with local people, which in turn can be compared to the proposed solutions of this thesis.

7.1 Comparing the Identified Gaps & Challenges

The identified gaps listed in Section 5.3.1 between the fixed curriculum and its implementation at a HEI answer **RQ1**. Concurrently, existing challenges of students and teachers were identified that are relevant for solving the underlying problems from the point of view of the author of this thesis, although they are not gaps in the actual sense (see Section 5.3.2). By comparing the identified gaps and challenges found in this thesis with the reasons given in the related work for the skill mismatch in higher engineering education (see Section 2.2), it is found that the reasons largely correspond to findings of this thesis. Table 7.1 provides an overview of the identified gaps and challenges that correspond those aforementioned reasons.

Reason for skill mismatch	Related Work	Gap / Challenge
The almost exclusive use of teacher-centered teaching methods and the lack of teaching on practical applicability	[45, 49, 51, 50]	G3
Insufficient structures for quality assurance and quality improvement	[49, 50]	G4
Insufficient qualification of the teachers, both from a technical and pedagogical perspective	[14, 49, 50]	G5
The partial lack of sufficient infrastructure	[45, 49, 50]	C1

Table 7.1: Related work that correspond to identified gaps / challenges

As mentioned previously, it was beyond the scope of this thesis to evaluate whether the design of the curriculum is capable of equipping students with sufficient SE skills (see Section 1.5). However, as noted in Section 5.2.2, the designed curriculum specifies both theoretical and practical courses on, for example, object-oriented programming or SE. Nonetheless, the objectives of these courses are not met in the implementation of the curriculum (see **G1**). Furthermore, it was found that the affiliating university aims to make the students employable through their curriculum design. As it is also mentioned in Section 1.5, it is not within the scope of this thesis to determine whether the design of the curriculum is sufficient to make students employable. However, it was found that only the extra-curricular courses offered by the partner institution in collaboration with companies make students employable, at least for the companies involved (see **G2**).

7.2 Comparing the Proposed Solutions

The fact that the skill mismatch still exists in spite of the recommendations known from the related work described in Section 2.2.1 can have many reasons from the point of view of the author of this thesis, such as that these recommendations are not known, they are intentionally not taken into account or they are not applicable. The actual reason for this was not found in related work, but to address at least the last of these potential reasons, it was determined for the purpose of this thesis that solutions for solving this problem should be as specific as possible. This, and the involvement of those people who either have to implement these solutions or are directly affected by them, are intended to ensure that the solutions are actually applicable. Therefore, the problems and challenges of the students and teachers that implements a CS curriculum and to whom, consequently, the solutions are directed, were gathered when answering **RQ1**.

The solutions elaborated in Chapter 6 answer **RQ2** and are addressed to those who are responsible for the creation and revision of a curriculum as well as to those who have to implement the curriculum. This includes both the teachers and the management that is responsible for the teachers and ultimately the implementation of the curriculum. From the point of view of the author of this thesis, the recommendations of the related work are rather abstract and do not seem to take local realities into account. For this reason, more concrete and realizable solutions were proposed within this thesis, which shall be evaluated by future work (see Section 8.1). Table 7.2 provides an overview of the proposed solutions that correspond to recommendations that have already been proposed in related literature.

Recommendations for skill mismatch	Related Work	Proposed Solution
Shift to student-centered teaching approaches and teach applicability of theoretical knowledge	[15, 46, 49, 51]	S1.1
Use methods to also assess skills and not only memorized knowledge	[15, 46, 49]	S1.2
Include industry experts with the help of (extra-)curricular courses	[46, 49, 50]	S2.1, S2.2
Additional training for teachers	[46, 49, 50]	S3.1
Periodically evaluate the curriculum and its courses	[49, 51]	S4.1, S4.2
Consider incentives for teachers	[50]	S5.2

Table 7.2: Related work that correspond to proposed solutions

In the related work, the continuing education of teachers only addresses professional experiences in their respective fields, but not pedagogical knowledge nor experiences. Likewise, the related work recommends to improve the teaching-learning process by other teaching methods and other examination methods, whereby the focus should be on student-centered approaches. However, they do not mention any concrete examples except for PBL.

Other recommendations of related work were already implemented at the partner institution. As described ins Section 2, Mann et al. recommend additional training for students and teachers. This additional training is realized through extra-curricular courses at the examined partner institution, but according to the students, the mandatory nature of these courses leads to an excessive perceived workload (see **C2**)

CHAPTER 8

Conclusion and Future Work

One of the major challenges of the Indian higher education system, which is also observed in other countries of the global south, was explained in more detail in the problem statement of this thesis: For years, the skills of the students at the end of their studies do not match the needs of the industry. As it is described in the context of this thesis, the skills in question, as well as reasons and recommendations for this skill mismatch, have been discussed in the past and explained in the literature. One of the reasons for this skill mismatch is the high degree of privatization in the higher education system in India.

In the fundamentals of this thesis, it was described that there are over 38,000 private colleges in India that offer study programs based entirely on the curricula set by their affiliating universities. The colleges themselves are not allowed to make any changes to those curricula and their students are evaluated solely on the basis of standardized tests by that same university. Based on this, this thesis investigated through a Design-Reality Gap Analysis (DRGA) if and which differences exist between a curriculum designed by an affiliating university and its implementations at affiliated colleges.This was done by examining 1 of 80 affiliated colleges implementing the same curriculum of an affiliating university.

The examination of the affiliated college involved the gathering of data about the reality of the students and teachers. Thus, semi-structured interviews were conducted with students and teachers, through which data was collected about their everyday life such as personal objectives, teaching from the points of view of students and teachers or the time resources they need to invest. Additionally, data was collected by observing both students and teachers. For example, teachers were observed during their teaching responsibilities and students were observed during the elaboration of assignments within one of their curricular courses. Afterwards, the gathered data was thematically analyzed along the OPTIMISM dimension used in the DRGA. The results of this thematic analysis then served as the reality part of the DRGA.

In addition to the curriculum itself, the design part of the DRGA included information such as the vision and goals of the affiliating university, in order to provide a more complete picture of the curriculum and specifically its goals.

The design was compared with reality for each OPTIMISM dimension of the curriculum and the findings of the gap analysis of each dimension were described. The identified gaps were elaborated based on the dimension findings in the results of this thesis and answer **RQ1** of this thesis. The summarized gaps are as follows:

1. Incomplete Student Skills **(G1)**
2. Unmet Employability Goal **(G2)**
3. Improperly Implemented Teaching Methods **(G3)**
4. Missing Curriculum Evaluation **(G4)**
5. Inadequate Teacher Skills **(G5)**

This thesis aspires to reduce the mismatch between the skills of the graduates and the needs of the industry. For this purpose, solutions for the affiliating universities (curriculum designers) on the one hand and solutions for the affiliated colleges (curriculum managers) on the other hand were developed in order to bridge the identified gaps.

While conducting the DRGA, the author of this thesis found that students and teachers face challenges when implementing the curriculum that, strictly speaking, are not to be considered as identified gaps, because the curriculum does not contain design counterparts for those expressed realities. Nevertheless, from the point of view of the author of this thesis, these should be also taken into account in the development of possible solutions, in order to be able to develop solutions that can actually be realized by the responsible persons. The identified challenges are elaborated in the results of this thesis and are summarized as follows:

1. Difficulties in Self-Learning **(C1)**
2. Excessive Student Workload **(C2)**
3. Ever-changing Course Assignments **(C3)**

For each identified gap, solutions were developed by the author of this thesis using existing literature. The proposed solutions are elaborated in the results of this thesis and answer **RQ2** of this thesis. The proposed solutions are summarized as follows:

1. Equip Students with Hands-On Experience **(S1.1)**
2. Utilize Authentic Assessment **(S1.2)**

3. Involve Reviewers with Professional Experience **(S2.1)**
4. Establish Experts with Professional Experiences as Teachers **(S2.2)**
5. Equip Teachers with Pedagogical Basics **(S3.1)**
6. Develop Teaching Guidelines **(S3.2)**
7. Establish a Buddy System for Teachers **(S3.3)**
8. Enhance Existing Evaluation Processes **(S4.1)**
9. Establish Quality Assurance & Enhancement **(S4.2)**
10. Maintain Teacher-Course-Assignments **(S5.1)**
11. Consider Needs and Interests of Teachers **(S5.2)**
12. Establish a Handover Protocol **(S5.3)**

Guidance notes for curriculum designers and curriculum managers were then created on the basis of these proposed solutions. In addition to the details of the proposed solutions, these also contain a description of the target audience for which the solutions are intended, as well as further readings to enable the target audience to familiarize themselves even more closely with the respective topic. The guidance note for the curriculum designers aim to support them in designing a CS curriculum in a way that they support the adequate implementation of the CS curriculum at, for example, affiliated colleges. The guidance note for curriculum managers contains solutions that can be implemented by affiliated colleges. Thus, affiliated colleges do not have to wait for suggestions of improvement by the affiliating university, but they can use the proposed solutions to implement improvements within the scope of their possibilities and responsibilities.

The proposed solutions and the guidance notes were developed by the author of this thesis, but were not evaluated subsequently, because evaluating each of the proposed solutions would have exceeded the scope of this thesis. However, as mentioned previously, literature was used in the development of the proposed solutions that included recommendations for the problematic characteristics of the respective gap for which the proposed solution is intended to be applied. In order to determine whether the proposed solutions are actually suitable for this purpose, future work shall therefore evaluate these proposed solutions.

8.1 Future Work

This section explains what opportunities arise from the results this thesis and what steps can be taken next to move closer to the larger goal behind this thesis: increasing the number of CS graduates with sufficient skills.

8.1.1 Design of the curriculum

This thesis examines the gaps between the implementation of a curriculum and its design. So, in order to contribute to the reduction of the skill mismatch , this thesis assumes that the curriculum is suitable to teach engineering graduates skills that fulfill the needs of the industry in India, since the curriculum examined was designed by a nationally accredited state university. However, from the point of view of the author of this thesis, the curriculum itself should be evaluated in further work to determine whether the structure and content are fundamentally suitable for equipping students with sufficient skills at the end of their studies. The ACM & IEEE guidelines for CS curricula shall be used in the evaluation of the curriculum's design and the skills to be acquired through the curriculum can be compared, for example, with the SWEBOK skills [54, 56]. In this way, the curriculum would be studied in relation to international concepts.

Furthermore, design changes shall be studied in future work. For example, students could be taught self-learning skills at the beginning of their studies, so that they can use online resources to improve their software development skills outside of curricular and extra-curricular courses. Additionally, it shall be examined how an increase in the share of practical laboratory courses affects the students' skills, given that the gap of insufficiently implemented teaching methods has been bridged.

8.1.2 Analyze root-causes of the design-reality gaps

Through the DRGA, gaps between the design and implementations of a curriculum were identified, but also problems and challenges of the students and teachers were found. However, it was beyond the scope of this work to also investigate the actual causes of the particular gaps or challenges. For example, it is not known whether the teaching methods are used incorrectly due to insufficient knowledge or against better knowledge.Therefore, future work shall investigate on the basis of which problems the respective design-reality gap occurs. Additionally, it shall be examined whether and how underlying problems influence each other in order to be able to counter them more effectively.

8.1.3 Evaluate the proposed solutions

The proposed solutions for overcoming gaps between the real implementations of a curriculum and its design are based on literature, but they were nevertheless developed by the author of this thesis.Each of the proposed solutions shall be examined in future work to evaluate whether the respective solution is actually suitable to close its design-reality gap. From the point of view of the author of this thesis, the proposed solutions shall be evaluated at the partner institution of this thesis or at 1 of the other 79 HEIs that are implementing the same CS curriculum.

Create and evaluate teaching guidelines

From the point of view of the author of this thesis, the "Teaching guidelines" mentioned in **S3.2** should be formulated in cooperation with one or more HEIs that are situated in a similar context. These "Teaching Guidelines" may already take into account the challenges of teachers identified in order to make them as applicable as possible for the teachers. Likewise, when developing these teaching guidelines, it should be taken into account that they are intended to help equipping teachers with more basic pedagogical knowledge and to make them familiar with the advantages of student-centered approaches in a way that they actually use them in suitable situations.

Establish a Buddy System for Teachers

One solution proposed in this thesis is the establishment of a buddy system to assist in the onboarding of new teachers, so that they learn sufficient teaching skills as quickly as possible. This proposal is based on two works, each of which investigates a buddy system for teachers, but in different contexts. Therefore a buddy system shall be developed and evaluated at HEIs in rural India.

8.1.4 Generalizability of the identified Design-Reality Gaps

The design-reality gaps were identified by examining the curriculum implementation at 1 of more than 80 HEIs. It is therefore yet to be evaluated whether the same or similar design-reality gaps also occur in the more than 79 other HEIs that implement the same curriculum design. Further work shall therefore examine whether similar gaps are identified in other implementations of the same curriculum. In addition, further work shall examine whether the identified design-reality gaps also occur in implementations of other CS curriculum designs.

8.1.5 Root-causes and impact of computer science brain drain

Both teachers and students confirmed during the interviews that all students strive to move to a major city after graduation, for example, to work as software developers. From the point of view of the author of this thesis, it shall be investigated what the causes and effects of the constant move of computer science graduates from rural India to its major cities are.

8.1.6 Impact of changes in student workload and their necessary time investments

The excessive stress experienced by students and the amount of time resources students devote to curricular and extra-curricular activities is one of the identified challenges. Although this is not part of the DRGA in the strict sense, the author of this thesis considers this challenge as necessary to take a closer look on. Therefore, future work shall examine the effects of reducing the necessary time resources at a HEI that is embedded in the same or a similar context and whose students require a similarly high time investment. From the author's point of view, both the objective and the perceived workload should be evaluated. Likewise, it shall be examined how alterations of the workload affect the same students.

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Acronyms

ACM Association for Computing Machinery. 12, 16, 100

AICTE All India Council for Technical Education. 23, 25, 67

AISHE All India Survey on Higher Education. 23, 24

AQ Austria Agentur für Qualitätssicherung und Akkreditierung Austria. 4

BE Bachelor of Engineering. 10

BTech Bachelor of Technology. 10

CS Computer Science. 4–7, 10, 12, 19, 31–33, 35, 38, 40, 41, 49, 54, 55, 59–62, 67, 72, 73, 89–91, 95, 99, 100

DRGA Design-Reality Gap Analysis. 6, 31, 35, 38, 59–61, 74–76, 78, 97, 98, 100, 101

HE Higher Education. 2, 9, 10, 12, 13, 25, 53

HEI Higher Education Institution. 2–5, 10–13, 15, 23–26, 29, 30, 32, 40, 44, 53, 67–70, 74, 83, 89–92, 94, 100, 101

ICT Information and communications technology. 25, 82

ICT4D Information and Communications Technology for Development. 60, 88

IEEE Institute of Electrical and Electronic Engineers. 12, 100

IQAC Internal Quality Assurance Cell. 25, 48, 49, 69, 85, 86

JNTUA Jawaharlal Nehru Technological University Anantapur. 31, 56, 63, 64

KI Key Indicator. 26, 27, 62, 104

MPI Multidimensional Poverty Index. 1, 2

NAAC National Assessment and Accreditation Council. 24–27, 61, 62, 64, 66–71, 73, 74, 104

NBA National Board of Accreditation. 25, 26, 29, 30, 61, 62, 64, 67–71, 73, 74, 104

PBL Project-based learning. 20–22, 66, 73, 77, 96

PEO Program Educational Objective. 26, 30

PO Program Outcomes. 29, 30, 62, 63

PSO Program Specific Outcomes. 29, 30, 62–64, 77

SD Software Development. 10, 17, 20, 125, 126

SDG Sustainable Development Goal. 1, 4

SDLC Software Development Life Cycle. 11, 15, 17, 18

SE Software Engineering. 3–5, 9–12, 15–17, 19–22, 54, 72, 93, 95, 125, 126

SWEBOK Software Engineering Body of Knowledge. 15, 16

SWECOM Software Engineering Competency Model. 16

UGC University Grant Commission. 3, 22–25, 68

UN United Nations. 1, 4

WA Washington Accord. 26

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APPENDIX A

Questions of the semi-structured interview

A.1 Teachers

Objectives and values

- From your point of view, what are the strengths of the CSE study program?
- From your point of view, what are the weaknesses of the CSE study program?
- Do your students learn sufficient skills for future work environment?
- Would you like to share anything else?
- Would you like to ask me anything?

Processes

- How do you design your courses?
- How do you prepare for your courses?
- How do you teach your students? (Which teaching approaches do you use?)
- How do you evaluate/assess your students?
- Are there other assessment methods apart from the JNTUA tests?
- How do you assure the quality of your course?
- How do you evaluate your course?
- Do you gather feedback of your students about the course? If yes, how?

Technology

- Which infrastructure can you use for your courses?
- Which infrastructure can you use to prepare your courses?
- From your point view, is the infrastructure suitable for the CSE study program?

Information

- How do you select the study material you use for your classes?
- How do teachers exchange information with each other?

Management systems and structures

- Are you allowed to make changes on the curriculum? If you would be allowed to change the curriculum (for your course), what would you change?
- What are the further education/training opportunities for teachers of your institute?
- (How do you further educate or train yourself?)

Investment resources

- How much time do you have to prepare your classes?
- How much time to you spend in a class room?
- What are you working on besides your teaching responsibilities?

Staffing and skills

- Which subjects do you teach?
- Which experiences do you have regarding the subjects you teach?
- Which teaching approaches do you know about?

Milieu

- How does the local industry influence your courses?

A.2 Students

- In which semester and year are you?

Objectives and values

- What do you like about your study program?
- What do you not like about your study program?
- Would you like to share anything else?
- Would you like to ask me anything?
- What role does creativity play for you in your studies?
- What are your plans after graduation?

Processes

- How do you participate during SD/SE courses?
- How do your teachers teach their SD/SE courses?
- How have you been evaluated in your visited SD/SE courses?
- How can you give feedback about your visited SD/SE courses?

Technology

- Which technologies (e.g. computers, phones, etc.) are you using for your SD/SE courses?
- Which technologies in use do you own?

Information

- How do you get to know about offerings of co- or extra-curricular activities of the college?

Management systems and structures

- How can you participate in the development of the CSE study program?
- How can you participate in the development of the taught courses?
- If you are allowed to change the study program, what would you change?
- If you are allowed to change the way your teacher works with you, what would you change?
- If you are allowed to change the curriculum (for your courses), what would you change?

Investment resources

- What year and semester are you currently in?
- How many hours do you visit lectures per week?
- How many hours do you study per week?

Staffing and skills

- How do you apply learned (theoretical) knowledge of the SD/SE courses you have visited?
- What did you learn in your visited placement trainings?

Milieu

- What do you know about the job market in which you would participate after you graduate?

APPENDIX B

Course Description of "Advanced Data Structures and Algorithms"

<table>
<tr><td>Course Code</td><td colspan="2" rowspan="2">Advanced Data Structures & Algorithms</td><td>L</td><td>T</td><td>P</td><td>C</td><td></td></tr>
<tr><td>20A05301T</td><td>3</td><td>0</td><td>0</td><td>3</td><td></td></tr>
<tr><td>Pre-requisite</td><td>Data Structures</td><td>Semester</td><td colspan="5">III</td></tr>
<tr><td colspan="8"></td></tr>
<tr><td colspan="8">Course Objectives</td></tr>
<tr><td colspan="8">• Learn asymptotic notations, and analyze the performance of different algorithms.
• Understand and implement various data structures.
• …</td></tr>
<tr><td colspan="8">Course Outcomes</td></tr>
<tr><td colspan="8">After completion of the course, students will be able to
• Analyze the complexity of algorithms and apply asymptotic notations.
• Apply non-linear data structures and their operations.
• …</td></tr>
<tr><td>Unit-I</td><td colspan="5">Introduction to Algorithms</td><td colspan="2">9 hrs</td></tr>
<tr><td colspan="8">Introduction to Algorithms:
Algorithms, Pseudocode for expressing algorithms, Performance Analysis-Space complexity, Time complexity, Asymptotic</td></tr>
<tr><td>Unit-II</td><td colspan="5">Trees Part-I</td><td colspan="2">8 hrs</td></tr>
<tr><td colspan="8">…</td></tr>
<tr><td colspan="8">Textbooks</td></tr>
<tr><td colspan="8">1. Data Structures and algorithms: Concepts, Techniques and Applications, G A V Pai.
2. Fundamentals of Computer Algorithms, Ellis Horowitz, Sartaj Sahni and Rajasekharam, Galgotia publications Pvt. Ltd.</td></tr>
<tr><td colspan="8">Reference Books</td></tr>
<tr><td colspan="8">1. Classic Data Structures by D. Samanta, 2005, PHI
2. Design and Analysis of Computer Algorithms by Aho, Hopcraft, Ullman 1998, PEA.
3. Introduction to the Design and Analysis of Algorithms by Goodman, Hedetniemi, TMG.</td></tr>
<tr><td colspan="8">Online Learning Resources</td></tr>
<tr><td colspan="8">https://www.tutorialspoint.com/advanced_data_structures/index.asp
http://peterindia.net/Algorithms.html</td></tr>
</table>

APPENDIX C

Feedback Form

Name of Teacher				
Department				
Subject and Subject Code				
Year				
Knowledge of teacher on the subject	Excellent	Good	Fair	Poor
Clarity and understandability of teacher's explanation	Excellent	Good	Fair	Poor
Teacher's willingness to help	Excellent	Good	Fair	Poor
Approximate percentage of classes not engaged by teacher in the subject	<10%	10% to 25%	>25%	
Whether the teacher dictates note only without explanation	No		Yes	
Teacher's ability to organize lectures	Excellent	Satisfactory	Inadequate	
Speed of presentation	Just Right	Too Fast	Too Slow	
Does the teacher encourage questioning	Yes	Sometimes	No	
Behaviour of teacher	Pleasant	Indifferent	Unpleasant	
Sincerity of teacher	Sincere	Not Sincere	Unable to judge	
Overall teaching effectiveness of the teacher	Excellent	Good	Fair	Poor
Indicate briefly strengths and weakness of teacher				
Any other relevant information (Mannerism, peculiarities etc. of teacher)				

APPENDIX D

Guidance Notes

INSO - Industrial Software
Institute of Information Systems Engineering | Faculty of Informatics | TU Wien

Guidance Note for Curriculum Designers in rural India

Computer Science and Engineering (CSE) Curriculum

Developed by: **Lukas Bürstmayr, Paul Spiesberger, Raoul Vallon & Thomas Grechenig**

August 16, 2022

1 Context

A challenge of the Indian higher education system that exists for more than a decade is a mismatch between the skills of the engineering graduates and the needs of the industry, especially in the field software engineering. The reasons and recommendations for this skill mismatch have been discussed in the past and explained in the literature and include the high privatization of higher engineering education. The majority of the private higher education sector is composed of over 38.000 affiliated colleges that implement study programs based entirely on the curricula set by their affiliating universities. The majority of these affiliated colleges are located in rural India. The authors of this Guidance Note examined 1 of 80 affiliated colleges in rural India implementing the same CSE curriculum of an affiliating university [1].

Based on the findings of this study, solutions were proposed by the authors that aim to bridge the respective gap, using existing literature and keeping challenges of students and teachers in mind. Based on these proposed solutions this Guidance Note was created that aims to enable curriculum designers to apply some of these proposed solutions.

Caveat: Solutions to problems differ and heavily depend on the context of each Higher Education Institution (HEI). The here stated solutions can only be seen as proposals and require constant local evaluation.

1.1 CSE Curriculum Designers

CSE Curriculum designers are persons who are responsible for creating or revising a Computational Science and Engineering (CSE) curriculum. For example, they define the objectives of a curriculum, the contents of the individual courses, the learning outcomes or the skills that students should have at the end of their studies of the respective curriculum.

1.2 Target Audience

The following guidance was developed for CSE curricula in rural India and is intended to help in the creation or revision of a CSE curriculum. However, if the implementing partner institution faces one or more of these challenge, then the following guidance can be applied there as well:

- Students do not meet the goals of the curriculum at the end of their studies.
- The implementing institution attempts to ensure student employability exclusively through extra-curricular courses.
- Students feel overburdened by the amount of perceived workload.
- (Potential) Teachers do not have relevant professional experiences or pedagogical skills to implement courses of the curriculum adequately.
- The intended teaching methods and assessment approaches are not executed sufficiently
- The implementing institution has no dedicated structures to evaluate or improve their implementation of the curriculum.

2 Guidance

The following guidance for curriculum designers is intended to help them design the curriculum in a way that enables implementing institutions, despite their challenges, to provide a high-quality study program in which students achieve the goals of the curriculum.

1. The designing HEIs should include information about suitable teaching approaches for the courses of the curriculum.

   Example: Particularly for laboratory courses, the curriculum should include instructions on teaching them: First present the task, then let the students work it out by themselves and answer further questions, if any, and only afterwards present the respective solution.

2. The designing HEIs should determine topics for the final project work in a way that the respective topics are not too ambitious, but feasible for the students and assessable for the teachers of the implementing institutions.

   Example: A small application for a specific task the students are familiar with instead of building a comprehensive software system.

3. The designing HEIs should include authentic assessment methods and tools for the examinations they prescribe to affiliated HEIs and the end of each semester.

   Examples for authentic assessment tools: Presentations, projects, exhibitions, portfolios, case studies or reflection journals.

4. The designing HEIs should provide a handover protocol for teachers taking on one or more courses in the curriculum, along with the curriculum. In this regard, basic materials tailored to teachers should be provided for each course.

   Example: Whenever a teacher's course assignment changes, the predeceasing teacher should make the used material available to his or her successor.

5. The designing HEIs should offer courses for (new) teachers of the partner institutions to equip them with basic pedagogical knowledge. Subsequently, teaching guidelines with pedagogical fundamentals as well as teaching and assessment approaches that are suitable for the courses of the curriculum should be developed and provided to the partner institutions.

   Example: A course that teaches teachers how to use portfolios and reflection journals in their courses.

6. The designing HEIs should supply curriculum managers with information about possible quality assurance and quality enhancement measurements. Among other things, suitable methods for evaluating the implemented curriculum should be provided on the basis of concrete instructions

   Example: Provide implementing institutions concrete ways of evaluating the workload of students and teachers as well as the possibilities of using these results afterwards.

7. The designing HEIs should provide its implementing institutions with a platform to help them exchange ideas, learn from each other and share Good Practices in a similar context.

   Example: Establish an annual forum where the implementing institutions meet and report on their learnings of the previous academic year(s).

2.1 Further Readings

In order to follow the guidance, a few examples are listed below:

1. The study this Guidance Note is based on [1].
2. Comprehensive guide for teaching Computer Science [2].
3. Attributes of good teaching in higher engineering education in the context of India [3].
4. Authentic assessment of students' learnings [4].
5. Assessing course experiences, teaching quality and student engagement [5].
6. Suggestions and their costs when designing learning spaces [6].
7. Quality of higher engineering education from the students' perspective in India [7].
8. Students' perceptions about learning places [8].

References

[1] Lukas Bürstmayr. "Solution proposals to Higher Software Engineering Education's Design-Reality Gaps in Rural India". Diploma Thesis. TU Wien, 2022.

[2] Orit Hazzan, Noa Ragonis, and Tami Lapidot. *Guide to Teaching Computer Science. An Activity-Based Approach*. 3rd ed. Springer, Cham, 2020. ISBN: 978-3-030-39359-5. DOI: 10.1007/978-3-030-39360-1.

[3] Aabha Chaubey, Bani Bhattacharya, and Shyamal Kumar Das Mandal. "Attributes of good teaching in engineering education in Indian subcontinent". In: *Sādhanā* 43.11 (2018), p. 188. ISSN: 0973-7677. DOI: 10.1007/s12046-018-0946-3.

[4] Zahra Sokhanvar, Keyvan Salehi, and Fatemeh Sokhanvar. "Advantages of authentic assessment for improving the learning experience and employability skills of higher education students: A systematic literature review". In: *Studies in Educational Evaluation* 70 (2021), p. 101030. ISSN: 0191-491X. DOI: 10.1016/j.stueduc.2021.101030.

[5] Hamish Coates. "6 - Tools for effective student feedback". In: *Student Feedback*. Ed. by Chenicheri Sid Nair and Patricie Mertova. Chandos Learning and Teaching Series. Chandos Publishing, 2011, pp. 101–118. ISBN: 978-1-84334-573-2. DOI: 10.1016/B978-1-84334-573-2.50006-9.

[6] Deborah Lynn Christoffersen et al. "Considerations for creating library learning spaces within a hierarchy of learning space attributes". In: *The Journal of Academic Librarianship* 47.6 (2021), p. 102458. ISSN: 0099-1333. DOI: 10.1016/j.acalib.2021.102458.

[7] Pradeep Kumar Choudhury. "Student assessment of quality of engineering education in India: evidence from a field survey". In: *Quality Assurance in Education* 27.1 (Jan. 2019), pp. 103–126. ISSN: 0968-4883. DOI: 10.1108/QAE-02-2015-0004.

[8] Ronald Beckers, Theo van der Voordt, and Geert Dewulf. "Learning space preferences of higher education students". In: *Building and Environment* 104 (2016), pp. 243–252. ISSN: 0360-1323. DOI: 10.1016/j.buildenv.2016.05.013.

INSO - Industrial Software
Institute of Information Systems Engineering | Faculty of Informatics | TU Wien

Guidance Note for Curriculum Managers in rural India

Computer Science and Engineering (CSE) Curriculum

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August 16, 2022

1 Context

A challenge of the Indian higher education system that exists for more than a decade is a mismatch between the skills of the engineering graduates and the needs of the industry, especially in the field software engineering. The reasons and recommendations for this skill mismatch have been discussed in the past and explained in the literature and include the high privatization of higher engineering education. The majority of the private higher education sector is composed of over 38.000 affiliated colleges that implement study programs based entirely on the curricula set by their affiliating universities. The majority of these affiliated colleges are located in rural India. The authors of this Guidance Note examined 1 of 80 affiliated colleges in rural India implementing the same CSE curriculum of an affiliating university [1].

Based on the findings of this study, solutions were proposed by the authors that aim to bridge the respective gap, using existing literature and keeping challenges of students and teachers in mind. Based on these proposed solutions this Guidance Note was created that aims to enable curriculum managers to apply some of these proposed solutions.

Caveat: Solutions to problems differ and heavily depend on the context of each Higher Education Institution (HEI). The here stated solutions can only be seen as proposals and require constant local evaluation.

1.1 CSE Curriculum Managers

CSE Curriculum managers are people who are responsible for implementing a Computational Science and Engineering (CSE) curriculum at a HEI. This includes providing the necessary infrastructure, employing and managing teaching staff or ensuring and improving the quality of courses within the scope of their possibilities.

1.2 Target Audience

The following guidance was developed for CSE curricula in rural India and aims to help HEIs that implement a CSE curriculum. However, if the implementing institution faces one or more of these challenge, then the following guidance can be applied there as well:

- Students do not meet the goals of the curriculum at the end of their studies.
- The implementing institution attempts to ensure student employability exclusively through extra-curricular courses.
- Students feel overburdened by the amount of perceived workload.
- (Potential) Teachers do not have relevant professional experiences or pedagogical skills to implement courses of the curriculum adequately.
- The intended teaching methods and assessment approaches are not executed sufficiently
- The implementing institution has no dedicated structures to evaluate or improve their implementation of the curriculum.

2 Guidance

The following guidance is intended to enable the implementing institutions, despite their challenges, to provide a quality program of study in which students achieve the goals of the curriculum.

1. The implementing HEIs should provide guidelines for teaching that contain basic information about how students learn and possible ways of teaching them.

   Example: Particularly for laboratory courses, the curriculum management should instruct teachers to first present the task, then let the students work it out by themselves and answer further questions, if any, and only afterwards present the respective solution.

2. The implementing HEIs should develop guidelines for the assessment of students beyond the mandatory mid-term and final examinations, including information on authentic assessment and the tools and methods appropriate for it, but also taking into account the workload perceived by students.

   Examples for authentic assessment tools: Presentations, projects, exhibitions, portfolios, case studies or reflection journals.

3. The implementing HEIs should try to collaborate with industry experts within the curricular courses. The industry experts should bring practical experience to the study program.

   Example: Industry experts shall supervise project reviews or work with teachers in the development and supervision of project work.

4. The implementing HEIs should avoid changing teachers' course assignments frequently. This will allow them to become more proficient in the subject area of their courses and deepen their respective knowledge in it. Thus, both students and teachers could benefit from the higher continuity.

   Example: Increase teacher retention by taking their needs into account.

5. The implementing HEIs have to ensure that the teachers' interests and needs are addressed in order to prevent the necessity of reassigning courses due to a frequent loss of teachers. Nevertheless, the implementing HEIs should provide a handover protocol to assist newly assigned teachers in taking over a course in a way that minimizes knowledge loss through the handover process.

   Example: Whenever a teacher's course assignment changes, the predeceasing teacher should make the used material available to his or her successor.

6. The implementing HEIs have to equip new teachers with pedagogical basics and provider guidelines for suitable teaching approaches and assessment methods. This could be achieved by offering courses for (new) teachers of the respective institution to equip them with with the contents just mentioned. Additionally, teaching guidelines with pedagogical fundamentals as well as teaching and assessment approaches that are suitable for the courses of the curriculum should be developed.

   Example: A course that teaches teachers how to use portfolios and reflection journals in their courses.

7. A "buddy system" for teachers should be established so that newly hired teachers who have little or no teaching experience are mentored by experienced teachers. Through this

system, new teachers are supposed to be integrated into the HEI from the very beginning and learn from experiences already acquired by their more senior colleagues.

Example: New teachers will be accompanied by a senior teacher in preparing or delivering course units during the first weeks.

8. The implementing HEIs should establish a internal structure or body that regularly evaluates the curriculum and reports possible improvements to the curriculum management based on the evaluation results.

   Example: Assign a person to focus exclusively on the evaluation of study programs and the use of these evaluation results. This evaluation should at least consider feedback on the study program by both students and teachers. Additionally, the perceived and objective workload as well as the satisfaction of students and teachers should be monitored and taken into account.

2.1 Further Readings

1. The study this Guidance Note is based on [1].
2. Comprehensive guide for teaching Computer Science [2].
3. Students' perceptions about learning places [3].
4. Forms of collaboration between the industry and HEIs [4].
5. Attributes of good teaching in higher engineering education in the context of India [5].
6. Quality of higher engineering education from the students' perspective in India [6].
7. Suggestions and their costs when designing learning spaces [7].
8. Assessing course experiences, teaching quality and student engagement [8].
9. Handbook for relatively inexperienced teachers [9].
10. Retention of teachers in India [10].
11. Authentic assessment of students' learnings [11].

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[3] Ronald Beckers, Theo van der Voordt, and Geert Dewulf. "Learning space preferences of higher education students". In: *Building and Environment* 104 (2016), pp. 243–252. ISSN: 0360-1323. DOI: 10.1016/j.buildenv.2016.05.013.

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