Curtailing the Gap Between Civil Engineering Curriculum and Competencies Required in the Industry

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ABSTRACT

For civil engineers to have a successful career in the industry, they need to equip themselves with a wide array of technical and professional skills. A noteworthy gap exists between the skills students perceive important, and the skills industry deems important. Consequently, engineers are struggling for jobs and the industry is facing shortage of skilled engineers. Therefore, it is crucial to minimize these gaps to improve the industry outcomes. A mixed method (including quantitative and qualitative) approach was used in this study. Using content analysis of previous literatures, the skills were grouped together in broader categories on the basis of similarities. A preliminary survey was conducted to identify the necessary technical and professional skills from the industry. Factor analysis was employed on questionnaire surveys containing 16 technical, and 15 professional competencies from students and industry professionals. The results were sorted according to their relative importance index. Students rated project planning & scheduling and contract management & administration, whereas professionals ranked understanding construction & shop drawings and project planning & scheduling as the top two most important technical skills. According to student's decision making and critical thinking & problem solving, whereas according to industry professional's work ethics and continuous learning were top two professional skills. The results indicate that both groups of participants agree on the most important professional skills but disagree on the important technical skills. This gap can be reduced or alleviated by updating the curriculum to what industry needs. By incorporating the industry highlighted skills in the curriculum and helping students understand the level of importance of these skills growth of engineers in their profession, and industry as a whole can be improved. This study can serve as a first step to updating the undergraduate civil engineering curriculum to a more industry friendly version.

Keywords: Competencies, Civil Engineer, Students Perception, Skill Gap, Factor Analysis.

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CHAPTER 1: INTRODUCTION

1.1.Background:

The human endeavor involving imaginative design to depict the existing world while adhering to scientific principles, engineering models serve as functional abstractions to guide knowledge and inform the design of systems (Lopez-Cruz, 2022). Engineering is a people-serving profession and is associated very closely to the everyday lives of human (ASCE., 2019).

Engineering is a very dynamic and challenging field. An engineer needs to be equipped with a full arsenal of skills in order to tackle all the hurdles, cash every opportunity and dispose of any threats on a day-to-day basis (Russell, 2013). For a fresh engineering graduate entry into field is specifically hard. Engineering job market is growing dense. Educational institutes all around the world are producing more and more engineers every year. For an engineer to stand out during the recruitment process, they need to have a competitive edge over the other candidates. This can be achieved by having distinguishing attributes and a wide set of skills. The attributes that recruiters are looking for and an engineer should equip themselves with are soft skills like problem solving, communication, interpersonal skills etc (Remedios, 2012).

1.2.Civil Engineering and Industry 4.0:

The fashion in which civil engineering is practiced worldwide needs to be modified (ASCE., 2019). Civil engineering is an ever-changing field, with engineering professionals having to adjust to all the factors like socio-economical, environmental, and political (Russell, 2013). Each industrial revolution brings changes to the industry, labor, market, and education. Currently we are living in the fourth industrial revolution or the era of digitalization (Azmi et al., 2018). Like every other industrial revolution, industry 4.0 introduces a change in the skill set needed for an industry professional. The speed measure by which these changes are being brought cannot be overlooked (Xu et al., 2018). In this highly digitized environment, modern technological skills play a vital role in an employees' working. Knowledge is a primary requirement for an employer, but these soft skills or competencies help the job seeker to stand out and help employer transcend competition (Anastasiu et al., 2017).

Industry 4.0 demands a change in engineering curriculum, emphasizing on development of soft skills and effective communication between them and other stakeholders (Grebski & Grebski, 2018). Educational institutes are aware of technology changing the expectations of employers about the necessary competencies but change in curriculum is not always possible or easy to implement or is slower than desired (Jelonek et al., 2020). Universities need to focus on cognitive, socio-emotional, problem solving, and ICT skills along with the technical skills in educating students (Group, 2016).

This shift of focus towards the soft skills has prompted mixed response from the educational institutes (Yepes et al., 2012). Challenging the importance of professionally focused subjects some engineering programs have eliminated them from curriculum considering them unhelpful and focusing on technical knowledge, skills, and attributes (KSA's) (Ahn et al., 2012; Benhart & Shaurette, 2014; Hartmann et al., 2015). This causes a disparity between the industry needs and the curriculum, which can be challenging for graduates coming from such programs. The graduates from these programs might not be ready and fully equipped to work in a professional environment and may be dismissed and or their growth up the career chain may be slowed (Bhattacharjee et al., 2013).

1.3.Civil Engineering Curriculum:

The UG curriculum is the basic constituent in developing professional and skilled engineering workforce. Civil engineering curriculum has been traditionally noticed to focus on technical aspects of engineering (Rodriguez-Largacha et al., 2015). The method of teaching of civil engineering curriculum has been topic of many discussions (Ahmed et al., 2014; Simmons et al., 2021; Simmons et al., 2020). Educators are focused in higher education are focused on technical aspects of the curriculum or the content learning (Maghiar et al., 2015).

Number of students striving to gain higher education in Pakistan has increased (Higher Education Commision (HEC), 2021). With increasing number of university graduates a need to ensure quality candidates with necessary skills for the required job has arisen (Musekamp & Pearce, 2015). Globalization has impacted engineers to perform professionally in an increasingly complex system. Recently recruiters are giving more value to professional skills like leadership, communication, and teamwork to thin the competition and choose the best candidate for the job (LaFave et al., 2015).

The outcome of the higher education is the best candidate for a competitive job market (Eurobarometer, 2010), but previous research paints a different picture. The previous research depicts that there is a difference of perception between graduating students and employers about students' readiness for the field (Eurobarometer, 2010; Grebski & Grebski, 2018). A survey conducted by AACU (American association of colleges) in 2015 shows that students consistently rate themselves ready for the field after gaining formal education, but employers disagree (Trought, 2017).

Construction constitutes as one of the major sectors of the world's economy (Khattak & Mustafa, 2019). This demands the presence of skillful professionals to manage construction projects. For example, construction projects by their very nature are unique, complex, costly, have an impact on the human lives and the environment as well (Khattak & Mustafa, 2019). So, adapting to modern practices and acceptance of technology in the field of construction becomes very crucial. A traditional 4-year engineering program can install the necessary technical skills into the graduates but do these skills match the requirements of the industry? One of the missing elements in teaching the construction students is teaching them technical and management skills along with other areas of the job including legal, financial and computer skills (Vogel-Heuser & Hess, 2016).

Engineers in the initial stage of their career have less focus on acquiring professional skills (Bhattacharjee et al., 2013). Thus, engineers have more proficiency in technical skills than soft skills (Afroze et al., 2019). To ensure that engineers are well prepared to be a part of a professional workforce, industry and government agencies have urged engineering institutes to equip graduates with professional skills like leadership, teamwork, and interpersonal skills along with the technical knowledge (Bowman & Farr, 2000; DIRECTOR, 2004). Professional skills like leadership help move the field in a forward direction and improve the employability of engineers (Knight & Novoselich, 2017).

In the late 1980's competencies'-based education (CBE) was introduced into engineering curriculum. CBE is student centered and inspires the gain of useful skills needed to be successful in the industry (Burke, 1989). Competency was defined as something that a person can perform, and which meets or even exceeds his/her job requirements (Badger et al., 2008). The civil engineering curriculum needs to create a framework to link the development of competencies with the requirements of the job market.

1.4.Deficiencies of Civil Engineering Curriculum:

Engineering has always been challenged by threats and opportunity (ASCE., 2019). On a larger scale the profession is encompassed by challenges like worldwide competition, increasing population, reducing natural resources, climate changes etc (Tougwa, 2020). Engineers must be prepared to tackle these problems with a deeper and wider vision (Russell, 2013). Previous research supports that engineers themselves as well as the general public have an ill-informed perception of the engineering field. General public is not well informed about engineers and engineering. (Beagon et al., 2019). Engineers do not have an idea of their jobs and responsibilities in the field and hence lack the commitment to their profession. The impression of the perception involves an individuals' perception and personal experience. It is critical to change the people's perception about engineering and rebrand it.

Even though the set of necessary competencies for every industry has been changed but educational institutes are lacking the pace in admitting these changes into their curriculum. This introduces a gap between what is taught and what is required in the field. Accountancy court of Romania conducted a survey which discovered a surprising situation. It indicated that 55% of the graduating students think that skills necessary for their respective fields were acquired in the workplace and only 32% consider the educational institute as the primary source for the development of these competencies (Jaschik, 2015). Which further confirms the presence of a gap in industry and the classroom.

Royal academy of engineering in 2007 commissioned a report looking at engineering graduates. The report outlined a lack of competencies in the graduates which adversely effects the construction industry (Spinks et al., 2006). One of the problems highlighted in this report was the graduates' ability to relate with real life problems and hence lack of skill in solving those problems. The report urges educational institutes to include practical work and real-life examples in their curriculum to train their students to be ready for the field. Similarly, a report by Institutes of technology, Ireland soft skills like oral and written communication as well as other interpersonal skills be made part of earlier civil engineering curriculum (Shivnan et al., 2011).

Public sees the engineering as a too technical field. This paints engineers as nerds playing with their own tools. This image can make or break the perception of field and the success of professionals also depends on it (Ghaly, 2003). Civil engineering programs in the developed countries implemented changes to make the programs responsive to the societal needs. Some of these institutes brought upon these changes after receiving input from the industry practitioners. One of the problems in inducting these changes to the curriculum was highlighted by Weingradt. He suggests that most of the engineers enjoy doing just the engineering. They find it distracting to integrate the effect of their jobs on broader level (Mckendry et al., 2012).

1.5.Problem Statement:

A number of researches have been carried out to identify competencies that a civil engineering student should equip themselves with in order to adapt to the dynamic construction industry in every industrial revolution. But in order for these researches to be effective the point of view of both the students and the industry professionals needs to be monitored simultaneously. Developed countries are using these studies to update their curricula to keep up with the changing demands of the industry. But no such effort has been made by researchers in Pakistan. This research can be used to improve and update the curriculum according to the international standards.

1.6.Research Objectives:

- Identify the key skills required for a fresh graduate from the industry.
- Identify UG BECE students' and Industry Professional's perception about necessary skills for success in the field.
- Identify existence of any gap and provide suggestions for curriculum improvement.

1.7.Significance of this research:

A number of researches have been carried out in developed countries to identify the required competencies for Civil engineers (Jaschik, 2015; Polmear et al., 2020; Russell, 2013; Simmons et al., 2021). These studies point out that graduating civil engineers do not have the necessary skills that recruiters are looking for. As the key problems like environmental issue, natural resource depletion, waste management etc. grow, the role of civil engineers in advancing the society becomes more vital. Civil engineers should embrace the importance of professional skills as well as the necessity of acquisition of computer skills for the advancement of engineering profession (Ghaly, 2003). The rate of acceptance of these skills by the engineers is dependent on the liability they are willing to accept. High level of liabilities makes the engineers hesitant to take on new challenges and hence limits their growth.

The educators have a responsibility to produce not only technically sound engineers but the ones that have a complete skill set to operate in a global marketplace. This means to ensure that the graduates be well rounded and have exposures to all cultures and have practical knowledge as well as real world experience during the graduation program. Civil engineers themselves have a poor image of their own field. This projects a negative image on the public's vision of the field. This research also aims at suggesting measures to improve the field's perception in the eyes of the engineers and in turn the masses.

This research focusses on UG students' perception of the skills they need to be equipped with to be inducted into the field and then grow as a professional. We compare the students' perceived skills with the attributes that the recruiters find attractive in an engineering candidate. This will give us information into whether a gap exists in the field and the curriculum of civil engineering and then we can provide suggestive measures to educational institutes to mitigate this gap. The students will focus on the skills that they deem important for their success during their education.

CHAPTER 2: LITERATURE REVIEW

Construction industry has a significant impact on economy in most countries around the world. Especially for developing countries like Pakistan construction and development becomes a vital element of the economy. According to a report by Board of Investment Pakistan, construction contributes 2.53% of the total GDP of the country (Pakistan, 2020), which amounted to 992747 USD in the year 2021-2022, making construction the third highest GDP generating industry behind manufacturing industry in the industrial sector (Pakistan, 2022). Fitch solution estimates construction industry to grow to 2705.5 billion Pkr by 2028. This indicates the importance of construction and housing industry on overall economy of Pakistan.

2.1.Impact of Desirable Skills on an Engineer's Career:

The skills that a civil engineer brings to an organization decide the success of its projects and the firm's future in the long run. The universities education is simply not adequate for the graduating civil engineers to prepare them for their future roles (Back et al., 2012). This situation is not only problematic for the students but for the recruiters as well, as they are finding it hard to fill the open positions with competent candidates (Schäfer & Richards, 2007). Civil engineers have to sustain good working relationships with a diverse group of people, including their colleagues, firm owners, client, contractors and all other stakeholders of a project. With the evolution of project management, stakeholder management has emerged as a necessary skill for project management professionals (Saad et al., 2022).

Engineering candidates having the desirable skills that recruiters are looking for have higher chances of getting selected for a job and will grow into their leadership role. Manpower is the most important resource for an organization. Appropriately skilled human resources have a positive controlling effect on an organization's performance (Hitt et al., 2001). So, hiring competent engineers is significant to the firms (Newell, 2005). The employability and usefulness in an organization can be increased by developing curriculum towards providing students with industry related skills and by driving their perception towards the importance of these skills (Qenani et al., 2014).

(Ahmed et al., 2014) in their study conclude that rankings of skills or attributes in construction management are personal attributes, managerial skills, industry and business skills, professional attributes, legal and contractual skills, technical skills, and people skills. This research also ranks personal and professional skills ahead of technical skills and that is an area where civil engineering curriculum is lacking in most educational institutes. The importance of these skills is further confirmed as they overlap with studies performed earlier as well (Baharudin, 2006; Egbu, 1999; Young, 1989).

Engineers have lesser job opportunities as compared to business graduates (Jelonek et al., 2020). Employability of engineers is considerably low and there is room for improvement in their preparation for field (Ramadi et al., 2016). (Klebnikov, 2015) cites a Forbes article stating that fresh graduates are not completely ready to be employed in a professional workplace due to lack of knowledge in communication and critical thinking. This is a very basic indicator of a gap existing in education and practical.

2.2.Role of Educational Institutes:

The changings in engineering profession demand changes in the teaching methods for the future engineers. The National Academy for Engineering's report in 2004 discusses the need for focus on professional skills along with the technical KSA's in the engineer of 2020. But recent research still shows that engineers have a sound technical knowledge but are lacking in the professional skills that are necessary to move their careers ahead. The ability of any country to compete globally depends on a generation of engineers with industry appropriate competencies. It is the responsibility of construction engineering educational institutes to equip their students with the desirable skills for the field and to improve or update the curriculum to depict the future needs of the industry (Becker et al., 2011). But it is rather difficult for educators to teach these skills as well as for the students to learn them, because the quantification of these skills is difficult than the traditional technical skills (Shuman et al., 2005). Higher education institutes themselves are making efforts to develop the desired skills and the prominent international organizations are also playing their role in urging the institutes to update their curriculum to accommodate these skills (Agyemang & Fong, 2019).

There seems to be a consensus between researchers about the necessity of skills like problem solving, written and oral communication, presentation and leadership (Allen & Van der Velden, 2012). A review of the engineering curriculum points out the importance of acquisition of soft skills along with mathematics, physics and engineering sciences (Ramadi et al., 2016). The importance of the skills needs to be taught to the undergraduate students during their degree because the dependence of success in the field on these skills is increasing (Sharma & Sharma, 2010). (Ramadi et al., 2016) emphasized on the fact that the employment rate of engineering is considerably low and that there is room for improvement in their perception of what they need in the field.

Researchers previously have identified that there is a gap in the skills aspired in the UG civil engineering students during their bachelor's program and the skills regarded necessary by the engineering professionals (Ahn et al., 2012; Polmear et al., 2020). An engineer apart from having technical knowledge needs to have a broader skill set going beyond traditional skills (DIRECTOR, 2004; Simmons et al., 2021) in order to tackle all the environmental, socio-economical, and political factors associated with a project. Lack in soft skills reduces productivity of an engineer. (Clarke, 2016) considers skills like Leadership, problem solving, communication and teamwork more important than conventional academic results. The three pillars for a successful career of a civil engineer are knowledge, skills and attributes also known as KSA's (Simmons et al., 2020). The education focusses on technical KSA's, but the recruiters are asking for professional skills in a civil engineer along with sound technical knowledge (ABET, 2018; ASCE., 2019; Education), 2017).

(ABET, 2018) formalized the competencies an engineer from an accredited program should have. This criterion also included the soft skills that an engineer needs to attain to work in a globally competitive industry. Over the last few years, the focus on inclusion of these skills into engineering practice has been increasing. Project management body of knowledge defines 21 competencies as the key skills for a civil engineer to possess before entering the field. These are grouped into foundational, technical, engineering fundamental and professional categories. Recruiters everyday are focusing on problem solving, communication skills and leadership (Ahn et al., 2012) while the student's perception is that management is an essential skill for their success. (Bhattacharjee et al., 2013). The educational institutes teaching civil engineering as bachelor's program are focusing on technical KSA's, but the recruiter is hiring for a broader skill set and certain level of performance for job-specific skills.

2.3.Industry Needs:

In the current phase of industrial revolution i.e., Industry 4.0; soft skills have been highlighted more than the technical KSA's. The justification for that can be that every engineer gains certain technical knowledge for the job. So, for him to have a competitive edge over the rest of the candidates, he must be trained with professional skills as well. A study about skill development of industrial engineer (IE) in industry 4.0 rates critical thinking, collaborative and communication skills equally important as the technical knowledge. The study proposes a framework that does not only feature the necessity of hard skills but also the importance of soft and meta skills (Santiteerakul et al., 2019). Industry 4.0 has changed organizational processes, working, hiring techniques, skillset, and firm's hierarchy (Vogel-Heuser & Hess, 2016). But because educational institutes are lagging behind in updating curriculum and implementing the latest skills into the syllabus, these organizations are at a risk of having improperly skilled workforce (Macurová et al., 2017). Having a decreased demand for unskilled labor will be short term disadvantage against the long-term gains of updating the complete system (Weber, 2016). The major challenge is restructuring jobs and updating the curriculum at the same time (Kane et al., 2015).

A number of researches have been done surrounding the un readiness of construction engineering graduates for the field (Domal & Trevelyan, 2009; Trought, 2017; Zhao et al., 2015). Lack of proper education for project and construction management is contributing towards the decline of the industry. This has been linked to the rigidity of the curriculum, limited electives, lack of multi- disciplinary collaboration and a gap in the expectations of the industry and the perception of the students. (Naveed et al., 2017) concludes that a constant update of the curriculum is necessary in order to meet the ever-changing needs of this dynamic industry. The responsibility falls primarily on the government and the educators.

2.4.The Need for Curriculum Development:

The main points that define the civil engineering education include the present and future requirements of the recruiters, market competitiveness, technological development and criterion for accreditation set forth by civil engineering accreditation agencies. Research work done previously indicates that civil engineers must have interpersonal skills that were not highlighted in the past. In the past the major focus was on acquiring technical knowledge and skills. Most of educational institutes in the advanced parts of the world are accommodating these changes in their undergraduate programs in order to provide the industry with appropriately skilled engineers (Itani & Srour, 2016). But do so first you have to analyze the present gap between the preparation of students during their stay at the university and the requirements of the field (AlMunifi & Aleryani, 2019).

Research done at the very beginning of 21^{st} century and recent research paint a very similar picture of graduates un readiness due to disparity between education and industry needs. A shift towards demand of professional skills in the field in early 2000’s can be noted. (Winterbotham et al., 2002) research concludes that companies are rating personal characteristics and professional skills higher than technical capabilities. But the recent research even in advanced countries like America and Australia are still reporting the existence of this gap (Polmear et al., 2020). Which means that the alleviation of this gap by curriculum has either been very slow or non-existent.

A study performed in Middle East and African region showed significant gaps between mangers’ expectation and satisfaction with the graduates’ skills. The managers reflected that, graduates needed improvement in areas of communication, learning continuously, and time management (Ramadi et al., 2016). A Lebanese study discovered similar results as well. In this study the results revealed that engineering graduated lack proper communication skills, responsibility, and confidence (Baytiyeh & Naja, 2011). All these evidence points out to the need for improvements in the UG curriculum of Civil Engineering and development of an industry relevant curriculum.

The studies already performed describe that students feel that they received sufficient technical knowledge and expertise during their degree but were not exposed to practical scenarios that created a gap between their understanding of the field's requirements and their readiness to work under pressure in a professional environment.

2.5.Situation of Pakistan:

Construction industry is one of the biggest constituent of the economy of Pakistan (Pakistan, 2020). Due to a continuous growth of the construction industry, a need to train engineers to adapt to the latest construction and management practices in imminent (Naveed et al., 2017). Developing countries like Pakistan have the opportunity to utilize the untapped resources at their disposal effectively, transforming them into a valuable asset that can contribute to countries' success in a globally competitive market (Azhar et al., 2008).

Pakistan labor force survey 2020-21 suggests that unemployment rate in construction is the highest among the major industries. It stands at a whopping 25.4% (Statistics, 2021). This indicates that job market is growing dense which is also highlighted by the growth in the number of graduating engineers every year (Higher Education Commision (HEC), 2021). One of the key issues in the unemployment of graduate engineers according to (Sargent Jr, 2017) is a lack of required professional skills like communication, and critical thinking.

A review of published literature suggests a lack of studies evaluating the current undergraduate civil engineering curriculum imparting students with the necessary skills (Naveed et al., 2017). (Farooqui et al., 2008) emphasize the urgent necessity for Pakistan's construction Industry to adapt to the latest construction and management programs in order up to a standard that is globally acceptable, competent, and effective. A continuous revision is essential to make sure that this program align with international standards.

2.6.Expectancy Value Theory:

The most important step in preparing civil engineers is to understand what the employer is demanding and what students deem important. The success of an engineer, an organization and the industry depend on an individual having a broader skill set enabling him to adapt to the changing field practices and thrive. To better understand the hindrance in integration of professional skills in the highly technical curriculum of engineering many researches have been done. (Simmons et al., 2020) One of the barriers that the researchers came upon is that these competencies are not very well defined, which makes it harder to teach them and incorporate them into the curriculum.

The UG engineering students might have a well-defined but not essentially correct perception of the nature of the work to perform in their future career due to highly professional nature of engineering (Carbone et al., 2020). This perception of the possible future career dictates the students' purpose of life (McKnight & Kashdan, 2009). (Bates et al., 2019) work argues that professional purpose of UG students can be better instilled by connecting UG curriculum with work integrated learning activities like field trips and site visits. These techniques were found to be very effective for changing chemical and processing engineering students' perceptions of their future (Wolff et al., 2018).

Expectancy value theory states that students will learn and polish the skills that they perceive important. Students will be guided into making a choice after completion of their degrees according to their own knowledge, ability, and skills (Burke et al., 2005; Lizzio et al., 2002; Qenani et al., 2014). Students with high recognition of importance of soft skills like leadership are more likely to take part in activities that refine these skills and are contribute towards helping them grow more professionally (Smart et al., 2002).

CHAPTER 3: METHODOLOGY

The research utilized a mixed-method approach, combining qualitative (e.g., extensive review analysis) and quantitative (e.g., questionnaire survey) methods (Akotia et al., 2024). This sequential integration of methodologies is apt when a concept has not been hypothesized or when research questions are ambiguous within a particular context. The research framework is shown in Figure 1, with further elaboration on each part's details and the methods used to achieve its objectives provided below.

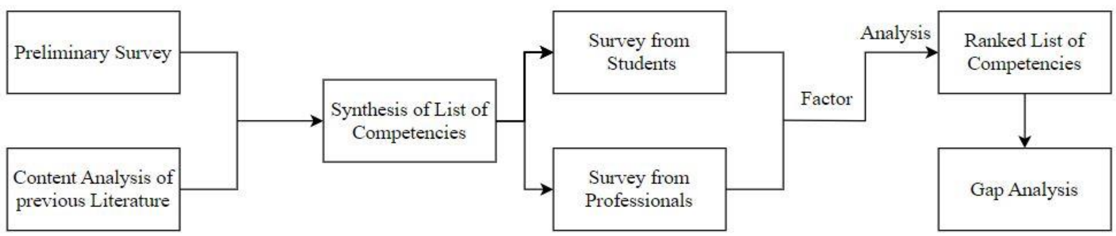

Figure 1: Flowchart for this study

3.1.Data Collection:

There has been a lot of debate over the data collection procedures, the criteria selection for the respondents, the acceptable number of responses, and the analysis techniques. When specialized studies require personalized data collection, questionnaire survey becomes the most appropriate technique (Naveed et al., 2017). Survey based data collection has been hailed as one of the most common techniques. It has been the leading data collection technique in social sciences but can be employed by almost any discipline. This technique sounds simple but it is not as easy as it looks (Story & Tait, 2019).

In order to gather data practically and efficiently from an adequate sample, this research employed the technique of questionnaire survey for data collection. This was a convenient method to enable respondents to submit their responses remotely. A great number of factors are needed to be considered while conducting a survey based research. Surveys should be carefully designed while keeping the target audience in mind. Some of the consideration while designing a survey questionnaire survey are:

- Having clear and unambiguous question,
- The BRUSO approach; brief, relevant, unambiguous, specific, objective, (Ozcan et al., 2023)
- Having at least one open ended questions e.g., additional comments/remarks,
- Use multitude of strategies to maximize the response rate, and
- Data testing and analysis technique based on the type of data collected.

3.1.1.Sample Size Selection:

Sample size selection is also a major step in a survey based study. Although the sample size depends upon the nature of respondents and technique employed to conduct the survey, a few standards have been quoted in the previous researches for the ease of researchers. (Demir, 2022) after combining the standards from previous literatures has created a range in which responses collected from less than 30 respondents are considered a small sample and responses from over 400 people is considered a large sample. Following this criteria 100-200 responses are an adequate sample for researchers.

3.2.Questionnaire Design

3.2.1.Likert Scale:

Usually survey based researches are conducted to gather responses from participants and get insights about un measureable constructs. This sort of data is diverse and ranges from behavioral observations to interviews with participants face to face. One most commonly used technique in the recent times for data collection of this type is a self-report Likert scale (Jebb et al., 2021). A Likert scale provides the respondents with a series of statements and a range of options like strongly disagree to strongly agree. This range can be divided into 3, 4, or 5-point floating scales depending on the type of data that needs to be collected. Using Likert's Scale researchers can quantify respondents' attitudes, perceptions, and behaviors.

3.2.2.Preliminary Survey:

The preliminary survey was conducted from engineers with at least 4 years of field experience. This was an open ended survey allowing respondents to enter the necessary skills manually. The results of preliminary survey were classified into broader categories to form a brief list of competencies using previous researches. The survey consisted of following four sections.

1) Demographics

2) Technical/ Hard Skills:

Q: Enumerate the technical skills that you would be looking for in a fresh (0-1 years) Civil engineering graduate seeking for a job. Rank the importance of the skills on a 5-point scale as well.

3) Professional/ Soft Skills:

Q: Enumerate the professional skills that you would be looking for in a fresh (0-1 years) Civil engineering graduate seeking for a job. Rank the importance of the skills on a 5-point scale as well.

4) Additional Comments:

This section was optional and was provided in order to get any additional information or remarks regarding the study or the survey itself.

3.2.3.Primary Survey:

The results of preliminary survey were compiled to form a questionnaire for undergraduate civil engineering students and field professionals. The criteria for industry professionals following (Polmear et al., 2020) was set as having at least 10 years of experience in the construction industry and having held a management position. The respondents were asked to rank the competencies according to their level of importance on a 5-point Likert Scale (1 being the least important, and 5 being the most important). This survey presented the following questions:

1. Please provide a professional assessment by ranking the significance of the subsequent hard skills on a scale of 1 to 5 for a recent Civil Engineering graduate entering the Construction Industry. (Polmear et al., 2020)
2. Please provide a professional assessment by ranking the significance of the subsequent soft skills on a scale of 1 to 5 for a recent Civil Engineering graduate entering the Construction Industry. (Polmear et al., 2020)

3.3.Data Analysis

To answer the research question, data analysis was required (Ariono et al., 2022). However, due to complex and multidimensional nature of issues being investigated in the construction industry, a mixed-method offers an opportunity to address these issues extensively (Akotia et al., 2023). So, for qualitative analysis a more elaborate method needs to be used in the construction industry researches (Fellows & Liu, 2021).

3.3.1.Qualitative Analysis:

The qualitative analysis method uses interpretation of descriptive and contextual information as compared to quantitative analysis which uses data quantification approaches (Opdenakker, 2006). This is a deductive method which is more flexible than using mere quantitative approach (Umar, 2020). A content analysis of previous studies was utilized as a qualitative approach to analyze and classify the competencies identified from preliminary survey into broader categories.

3.3.2.Quantitative Analysis:

Figure 2. is the flowchart for the quantitative analysis in order to get a ranked list of competencies through factor analysis and relative importance index.

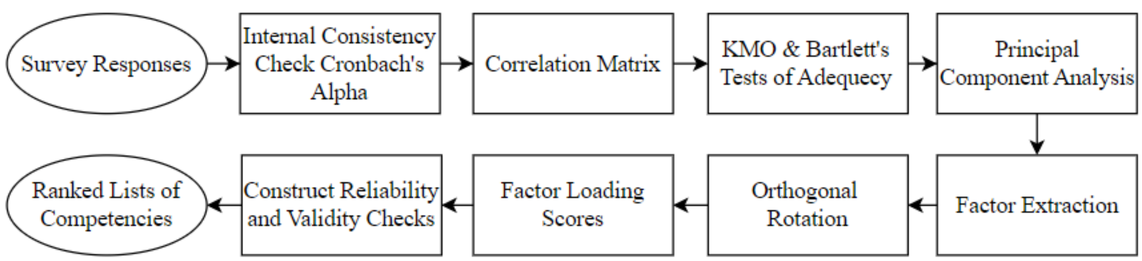

Figure 2: Flowchart for factor analysis of survey responses Cronbach's Alpha

3.3.2.1.Data Normality:

Most of the data analysis techniques assume the normal distribution of data, but it is not true for every case. The central limit theorem states that if the sample size for your data collection is sufficiently larger i.e. greater than 100 instances, then the mean of the sample will approximately be normally distributed. But if we want precise and accurate information we should still follow normal distribution trend (Altman & Bland, 1995;

Pallant, 2020). To check the normal distribution of data we first calculate mean of the sample. Then the significance of this mean value is checked using the significance level (P-value). The lower the P-value the higher is the statistical significance of the data set.

For any kind of statistical technique to be used we first need to understand what kind of distribution the data follows. Data normality refers to the fashion in which data is distributed in a data set. This checks whether the data has normal or Gaussian distribution. For a data to follow normal distribution trend, it needs to be symmetrical distributed around the mean. The majority of the data needs to be clustered around the mean with lesser data points going towards the tails.

Tests for Data Normality:

After the visual depiction of normality, statistical tests are applied to confirm whether the data is normally distributed or not. According to (Field, 2024) If the sample data is normally distributed the following should be true:

Table 1: Ranges of Standard Deviation According to the Percentage of Data

Percentage of Data	**Ranges of Standard Deviation**
68.2%	-1 to +1
95.4%	-2 to +2
99.7%	-3 to +3
0.3%	outside -3 to +3

There are various types of data normality tests including but not limited to: (Öztuna et al., 2006)

- Skewness
- Kurtosis
- Kolmogorov-Smirnov (K-S) Test,
- Shapiro-Wilk Test,

Skewness:

Skewness is the measure of normality of data. It is related to the mean, median, and mode of the sample. If the mean of the data is exactly in the middle, skewness will be zero. If the mean is to either side of the peak in a bell curve, the data is positively or negatively skewed according to the position of mean. If mean is to the left of center the data is negatively skewed and if the mean is to the right side of the center the data is positively skewed. Skewness indicates the symmetry or asymmetry of data (Tabachnick et al., 2013). Skewness is calculated using the following formula:

$$\mu'_{3} = \frac{\sum_{i}^{N}(X_{i}-X')}{(N-1)*\sigma^{3}} \tag{1}$$

Whereas

μ'_{3} = Skewness

N = Number of Variables in the Distribution

X_{i} = Random Variable

X' = Mean of the distribution

σ = Standard Deviation

According to (Gravetter et al., 2021; Hair Jnr et al., 2010) in order for the data to be normally distributed the skewness range should be within -2.58 to +2.58.

Kurtosis:

Kurtosis is the measure of how far is the data spread away from the mean value or how close is it to the mean. It is related to the standard deviation of the data. If the sample has small standard deviation the peak in the distribution chart will be pointy, whereas if the standard deviation of the sample is large the peak will be flattened (Field, 2024; Tabachnick et al., 2013). Kurtosis of a sample data is calculated using the following formula:

$$K = \sum_{i}^{N} \frac{(X_{i}-X')^{4}}{\sigma^{4}} \tag{2}$$

X_{i} = Random Variable

X' = Mean of the distribution

σ = Standard Deviation

According to (Gravetter et al., 2021; Hair Jnr et al., 2010) for the data to be normally distributed the kurtosis range of the data should be between -3 to +3.

Kolmogorov-Smirnov Test (K-S):

In this test we calculate the empirical cumulative distribution function (CDF) of the sample and compare it with the CDF of a normally distributed sample. The null hypothesis is that the sample data is normally distributed (Smirnov, 1948).

Shapiro-Wilk Test:

This test calculates a value based on the correlation between the sample data and expected normal values. The null hypothesis for this test is also that the sample data is normally distributed (Shapiro & Wilk, 1965). This test is more powerful in term of calculation the normality of data than the K-S test.

This research deals with perception of UG students about the necessary skills for their success. The insights provided by field professionals will also help guide the educational institutes to improve their curriculum so that the students graduating in the future can cope with the ever changing field of engineering. The research followed the following sequence: data collection through questionnaire surveys and then analysis of surveys.

3.4.Statistical Analysis:

Construction industry is one of the leading industries in the world. The data generated by this industry is massive in size accordingly. In the current era of technological advancement, the growth of data generation is exponential (You & Wu, 2019). The extraction of useful information from the huge data pool has become imminent for construction industry to grow. The correlations in data can provide us with pointers to improve certain aspects of the industry to help the consumers as well as the developers. This can help the stakeholders make proper decisions and help industry improve the performance of the construction projects.

There are a number of statistical analysis techniques that can be used to gather useful information from raw data. These techniques include but are not limited to:

- Descriptive Statistical Analysis,
- Inferential Statistical Analysis,
- Associational Statistical Analysis,
- Predictive Analysis,
- Prescriptive Analysis,
- Exploratory Data Analysis,
- Causal Analysis.

All the above mentioned techniques have their separate uses and advantages and can be used for a sample depending upon the type of desired outcome. For the purpose of this research I opted the exploratory data analysis from the above mentioned statistical analysis techniques.

3.5.Factor Analysis:

Factor analysis is a statistical analysis technique used to identify patterns and trend in a data set (Tabachnick et al., 2013). Using this technique, we can find relationships, validate assumptions, and test hypothesis between samples in a population (Tabachnick et al., 2013). It is a multivariate analysis technique most commonly used in IT, social sciences, education, and psychology (Taherdoost et al., 2022). The origin of factor analysis can be traced back to Pearson and Spearman in 1961 (Spearman, 1961). This indicates the rich lineage of this technique being used to gather useful information from a dataset. The main goal of factor analysis is to explain the relationships between a larger number of variables in a data set in terms of a smaller number of underlying factors or latent variables. It reduces a large number of variables into a few underlying factors and establishes dimensionality between these factors and latent constructs (Taherdoost et al., 2022).

There are two types of factor analysis techniques. One is Exploratory Factor Analysis, and the other is Confirmatory Factor Analysis. First one is used to extract underlying factors in a large data set when there is no preconceived hypothesis. If no hypothesis is made about the number of factors to be extracted or relationship between them, we use exploratory factor analysis. The factors are extracted using criteria such as Eigen values, scree plots, and or factor loadings. It is a more complex technique but can be applied to a small sample size. On the other hand, Confirmatory Factor Analysis is used to validate any sort of hypothesis about the underlying factors and their subsequent relationships made in the advance. In this technique we specify the factors in advance and only confirm the existence of any relationship between them (Williams et al., 2010). For the purpose of this research exploratory factor analysis technique was opted.

Although exploratory factor analysis is relatively complex but the process is linear and sequential. The main objectives of Factor Analysis according to (Thompson, 2004) are:

- Reduce the number of factors,
- Confirming the multi-collinearity between the factors that are supposed to be correlated,
- Confirming whether the underlying constructs are unidimensional in nature,
- Construct validity of data, and
- Inspection of factors and their relationships.

3.5.1.Data Adequacy Checks:

Before the extraction of any underlying factors or latent constructs certain tests are performed to confirm the adequacy of the collected data. These tests inform us whether the data is suitable for factor analysis or not. These checks provide the researchers with information about the grouping of items in survey data. Strength of correlation between items in a correlation matrix in Factor Analysis is a measure of data adequacy (Burton & Mazerolle, 2011). Kaiser-Meyer-Olkin (KMO) and Bartlett’s Test of Sphericity are some sample adequacy checks.

Kaiser-Meyer-Olkin (KMO):

This test is suggested when the cases to variable ratio is less than 1:5 but it is not limited just to that. There are various schools of thoughts for acceptable KMO value for factor analysis. According to (Tabachnick et al., 2013) a KMO value of 0.50 or higher is adequate for factor analysis. Whereas (Netemeyer et al., 2003) quotes a KMO correlation value from 0.60-0.70 as suitable. As a rule of thumb a KMO value of less than 0.50 suggests that data is inadequate for factor analysis.

Bartlett's Test of Sphericity:

This test gives a Chi-square value which should be significant ($p<0.05$). This test indicates that the correlation matrix is not an identity matrix. The converse suggests that there is no correlation between the variables in the data (Tabachnick et al., 2013).

So, if KMO correlation value is higher than 0.5 and Bartlett's test indicate that correlation matrix is not identity matrix, data is suitable for factor analysis.

3.5.2.Factor Extraction:

Factor extraction is the main step in factor analysis. This process identifies the underlying factors and latent constructs from a larger number of variables in a dataset. It transforms a large number of variable into smaller number of constructs using their factor loading values. There are various methods for factor extraction but the two very common techniques are Principal Component Analysis and Common Factor Analysis.

3.5.2.1.Principal Component Analysis (PCA):

PCA reduces the number of variable into components. These components are linear combinations of the original variables. The principal components extracted account for the maximum variance in the data. PCA when used in its entirety is a little bit different than factor analysis, but they are often used together because their output looks similar. Some of the major differences between PCA and factor analysis are that factor analysis is a linear combination of factors whereas PCA as mentioned earlier is a linear combination of components or constructs. Moreover, error in factor analysis is separated which in principal component analysis isn't (Schreiber, 2021).

PCA most of the time is not used in its entirety. Researchers normally use a shortened version of PCA where a smaller number of variables are retained. This result is similar to that of factor analysis because the remaining factors do not account for all the variance of the variables (Gorsuch, 1990). PCA is the most common technique for factor analysis as it is a default for many statistical analysis tools.

3.5.2.2.Construct Validity:

(Hair Jnr et al., 2010) says that the measured latent constructs should be represented by the set of variables. This confirmation is known as construct validity. Construct validity can be proven by the following checks:

Convergent Validity:

This refers to the degree to which similar latent constructs are measured with different variables. It means that the extent to which factors that are being loaded to a certain component are supposed to be loaded together. For this factors with good factor loadings (>=0.50) are used. (Hair Jnr et al., 2010) refers to average variance extracted (AVE) as an apt measure for convergent validity as it explains the extent of shared item variance between the constructs. An AVE value >0.50 is acceptable for convergent validity (Fornell & Larcker, 1981). But according to Fornell-Larcker an AVE value of less than 0.50 is acceptable if composite reliability of the constructs is greater than 0.60. Formula for calculation of AVE is:

$$AVE = \sum \lambda^2/N \tag{3}$$

Whereas

λ = Factor loading of variables on a construct

Discriminant Validity:

If a tool development involves latent variables discriminant validity is used. Also named divergent validity is to confirm that two or more constructs have significant differences between them. It confirms that a certain latent construct has distinguishable differences with another construct (Hair Jnr et al., 2010). Which means that the variables that are not supposed to be correlated are actually not correlated and are loaded onto a different construct. According to Fornell-Larcker criteria the square root of average variance extracted of a construct should be greater than the correlation between the constructs proving that every latent construct s unique (Fornell & Larcker, 1981).

$$\sqrt{AVE} > Correlation\ Between\ the\ Constructs \quad (4)$$

3.5.2.3.Construct Reliability:

After the construct validity the reliability of the measured construct is also determined. A reliable construct will maintain its consistency within a certain range if measured repeatedly (Sujati & Gunarhadi, 2020). Construct reliability is measured according to the following technique:

Composite Reliability (CR):

It is also known as internal consistency and can be measured using either alpha or omega. If the output model of constructs proves uni-dimensionality and factors are not cross loaded the researcher might use alpha otherwise they should use omega (Sujati & Gunarhadi, 2020). If composite reliability value is greater than 0.60 the construct is reliable (Ringle et al., 2020). The formula for calculation of composite reliability is:

$$CR = (\sum\lambda)^2 / ((\sum\lambda)^2 + \sum (1 - \lambda^2)) \quad (5)$$

Whereas

λ = Factor loading of variables on a construct

Cronbach's Alpha:

Alpha checks whether the measured constructs are reliable and internally consistent or not (Shrestha, 2021). An alpha value of greater than 0.80 is acceptable for composite reliability to be proven (Ringle et al., 2020).

Relatively Importance Index (RII):

Relatively importance index describes the significance of particular causes and their effects by taking into consideration their likelihood of occurrence (Aibinu & Jagboro, 2002). The higher the value of RII, the higher is the impact of a particular factor (Kassem et al., 2020). RII can be calculated using the following formula:

$$RII = \sum \frac{W}{(A*N)} \quad (4)$$

Whereas

RII = Relatively Importance Index

W = Weightage given to each factor by the respondents

A = Highest weight (i.e., 5 in this case)

N = Total number of respondents

2.6. Flowcharts

Figure 3 represents the activities that have been performed in the research so far in their respective order.

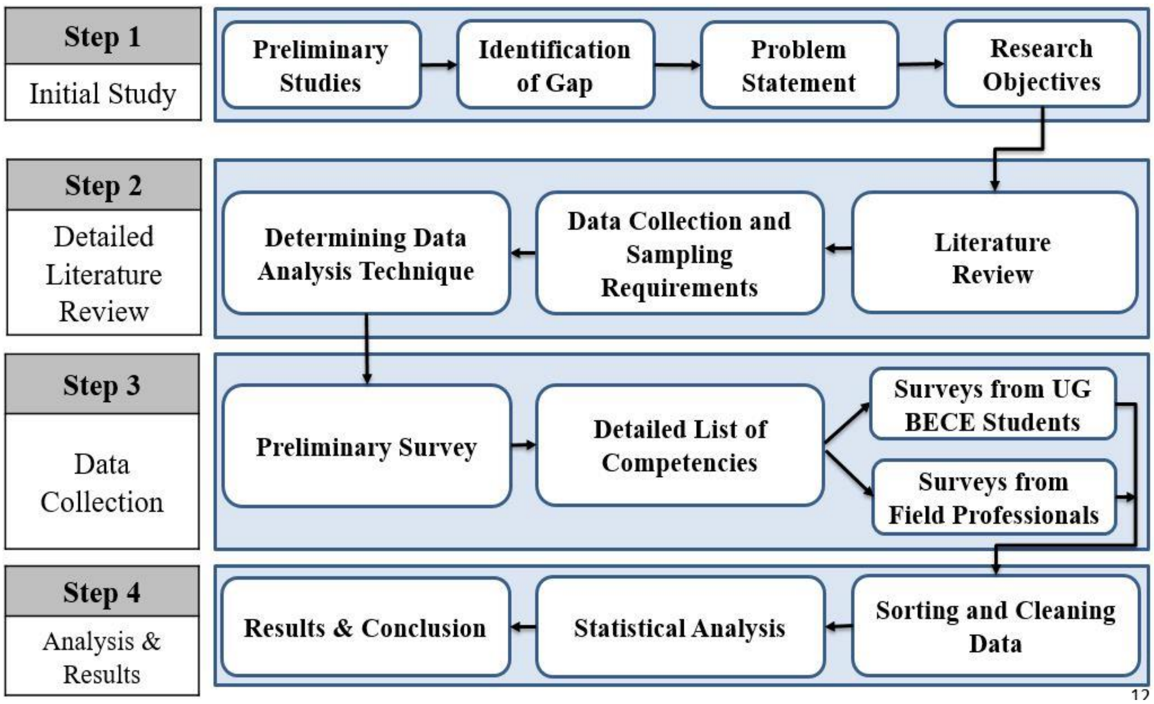

Figure 3: Flowchart of the Research Process

CHAPTER 4: RESULTS & ANALYSIS

4.1.Survey Analysis:

4.1.1.Preliminary Survey Results

105 responses were collected as a result of preliminary survey (n =105), identifying a total of 74 competencies; 44 Technical & 30 Professional Skills. The list of these skills identified by the respondents is provided below:

Table 2: Competencies Identified by 2019 Graduates

Sr. No	Technical/ Hard Competencies	Professional/ Soft Competencies
1	Scheduling	Communication Skills
2	Project management/ administration	Leadership
3	Cost accounting	Teamwork
4	Structural Analysis	Decision Making
5	Knowledge of design	Critical Thinking
6	AutoCAD	Adaptability
7	Contract administration skills	Problem Solving
8	Health and Safety Management	Conflict Resolution
9	Concrete Mix Design	Presentation Skills
10	Understanding of Construction Materials	Ethics
11	Primavera	Attention to Detail
12	Understanding construction & shop drawings	Collaboration
13	Surveying	Interpersonal Skills

14	Understanding of Plan Reading	Writing Skills
15	Site planning and management	Continuous Learning
16	MS Office	Networking
17	Knowledge of construction equipment	Passion for Work
18	Risk planning, assessment and control	Assertiveness
19	Personnel/ Resource management	Cultural Competence
20	Change Order Management	Self-Awareness
21	Understanding of Engineering Structures	Persistence
22	Knowledge of building codes and regulations	Humility
23	Scope review	Result Oriented
24	Understanding of Labor Productivity	Experience
25	Economic and financial analysis	Flexibility
26	Interpreting contract documents	Multi-Tasking
27	Revit	Confidence
28	Knowledge of bidding procedures	Integrity
29	Claims preparation	Organizational Structure
30	Logistics Planning	English Speaking
31	Environment Impact Assessment	
32	Project Delivery Methods	
33	Time Management	
34	Computer Proficiency	

35	construction industry supply chain	
36	MS Project	
37	Quality Assurance & Control	
38	Entrepreneurship	
39	Knowledge of project closeout and handover procedures	
40	Material Testing	
41	Building Information Modelling	
42	Bar Bending Schedule	
43	Knowledge of the permitting process	
44	Stakeholder Management	

4.2.Qualitative Analysis

To streamline the list of identified skills, previous research findings were utilized to categorize and consolidate similar skills into groups. This classification was done on the basis of Engineering fields e.g.; the scheduling competencies were grouped together under Project Planning & Scheduling. This class included Primavera P6, MS Project, and Time Management. Similarly, Knowledge of design, Understanding of engineering structures, Bar bending schedule, Knowledge of building codes and regulations, and Concrete mix design were grouped together under Structural Analysis & Design. The tables with the main competency group and underlying competencies were compiled and provided below:

Table 3: Categorized List of Technical Competencies

Technical/ Hard Competencies			
Sr. No	**Main Category**	**Sub Category**	**References**
		Primavera	

1	Project Planning & Scheduling	MS Project	(Wali & Othman, 2019)
		Time Management	(Larco et al., 2018)
2	Manage Cost Accounting	Economic & Financial Analysis	(Ahmed et al., 2014)
3	Perform Structural Analysis & Design	Understanding of Engineering Structures	(Roësset Jose & Yao James, 2002)
		Knowledge of design	
		Knowledge of building codes and regulations	
		Bar Bending Schedule	(Andersen et al., 2007)
		Concrete Mix Design	
4	Understand Construction & Shop Drawings	AutoCAD	(AutoCAD & Step-by-Step)
		Understanding of Plan Reading	
5	Evaluate Construction Materials & Testing		
6	Conduct Building Stakeout & Survey		
7	Coordinate Site Planning & Management		
8	Knowledge of Construction Machinery & Equipment		

9	Plan, Assess & Control Risk		
10	Oversee Personnel/ Resource management	Labor Productivity, Stakeholder Management	(Sang, 2015)
11	Utilize Contract Management & Administration Skills	Change Order Management	(Syal & Bora, 2016)
		Claims preparation	
		Interpreting contract documents	(Ahmed et al., 2014)
		Knowledge of the permitting process	
		Project Delivery Methods	
		Knowledge of project closeout and handover procedures	
		Implement Knowledge of Bidding Procedures	
		Conduct Scope Review	(Koc & Gurgun, 2022)
12	Apply Building Information Modelling	Revit	(López et al., 2018)
13	Implement Computer & IT Skills	MS Office	(Gann & Senker, 1998)
14	Ensure Quality Assurance & Control		

15	Conduct Environment Impact Assessment		
16	Ensure Health & Safety Management		

Table 4: Categorized List of Professional Competencies

Professional/ Soft Skills			
Sr. No	**Main Category**	**Sub Category**	**References**
1	Communication Skills	English Speaking	(Riemer, 2007)
		Writing Skills	
		Presentation Skills	
		Interpersonal	
2	Leadership	Assertiveness	(Simmons et al., 2021)
3	Teamwork	Collaboration	(Chiocchio et al., 2011)
4	Work Ethics	Flexibility	
		Humility	(Smith & Kouchaki, 2018)
		Integrity	
		Passion for Work	
5	Continuous Learning		
6	Critical Thinking & Problem Solving		

7	Detail Oriented	Attention to Detail	
		Result Oriented	
8	Conflict Resolution		
9	Networking		
10	Persistence		
11	Self-Aware		
12	Cultural Competence		
13	Multi-Tasking		
14	Decision Making		
15	Adaptability		

By grouping the competencies together, I shortlisted the number of competencies to 31; 16 Technical & 15 Professional Skills.

4.3.Quantitative Analysis

Survey 2 Analysis

The respondents were divided into following two subgroups:

1- Industry Professionals (n = 101)

2- Undergraduate Students (n = 205)

The male to female ratio for industry professionals were 24.25:1 and for undergraduate students were 19.5:1.

4.3.1.Data Normality Test:

In order to perform any further statistical analysis on the data it had to be checked whether the data was normally distributed or not. For this purpose, the mean ranking value for each of the competencies' in both subgroups were calculated. Then the following techniques were employed to check the distribution of data:

Firstly, using Microsoft Excel was used to plot the graphs for each of the competencies with ranking values on X-axis and the response frequency on Y-axis. The response frequency was the number of times a certain competency was given a certain rating; e.g., Project Planning & Scheduling was given a rating of 5 on 58 instances in the undergraduate student's surveys. The curve for each of competency was plotted. The visual representation of the graph suggested the normal distribution of data as almost all the curves were essentially bell curves.

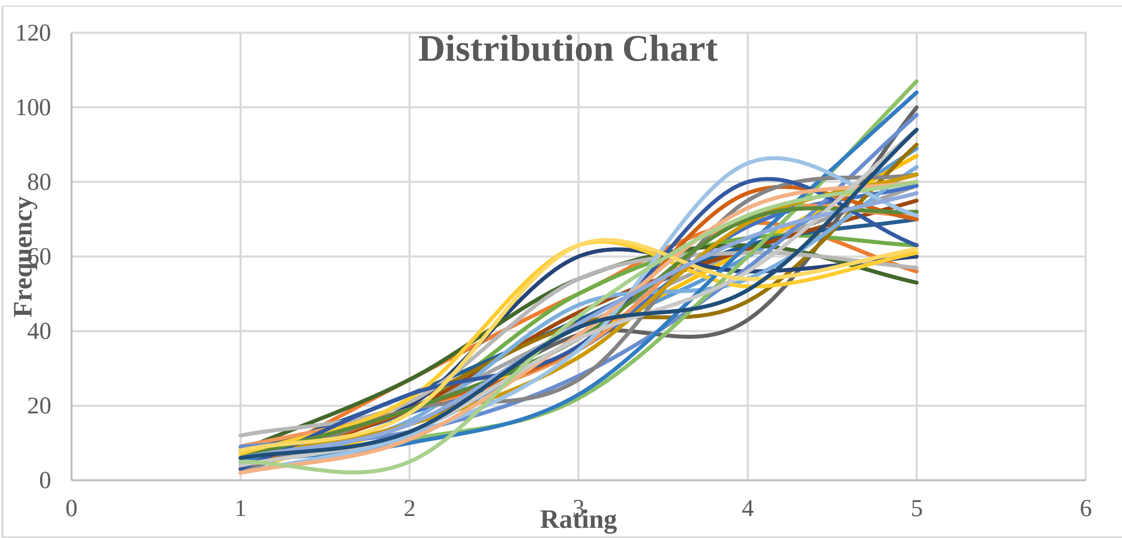

Figure 4: Standard Normal Distribution Chart for UG Students Data

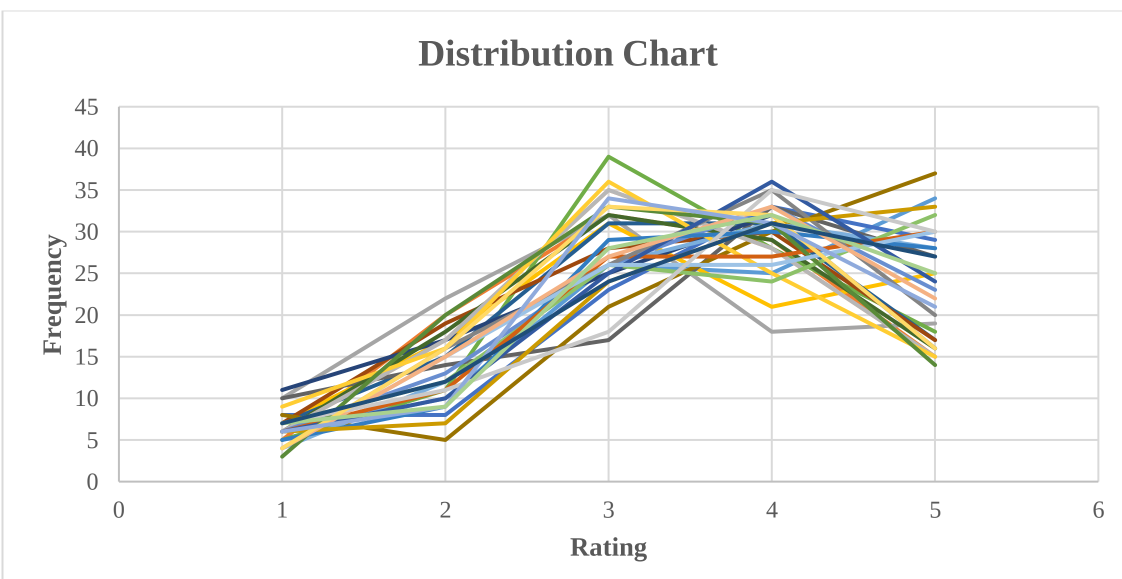

Figure 5: Standard Normal Distribution Chart for Professionals Data

A graph with normalized values of frequency was also plotted. This suggested that data was normally distributed. The formula used to calculate the normalized values was as below:

Normalized Response Frequency = Response Frequency / The Respective Rating

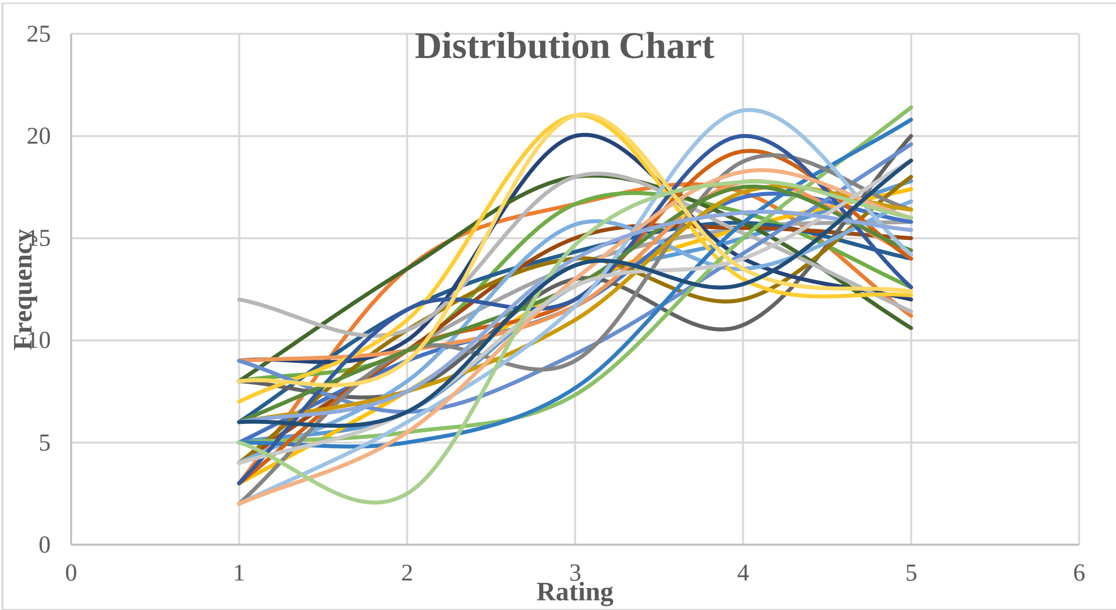

Figure 6: Standard Normal Distribution Chart for Normalized UG Students Data

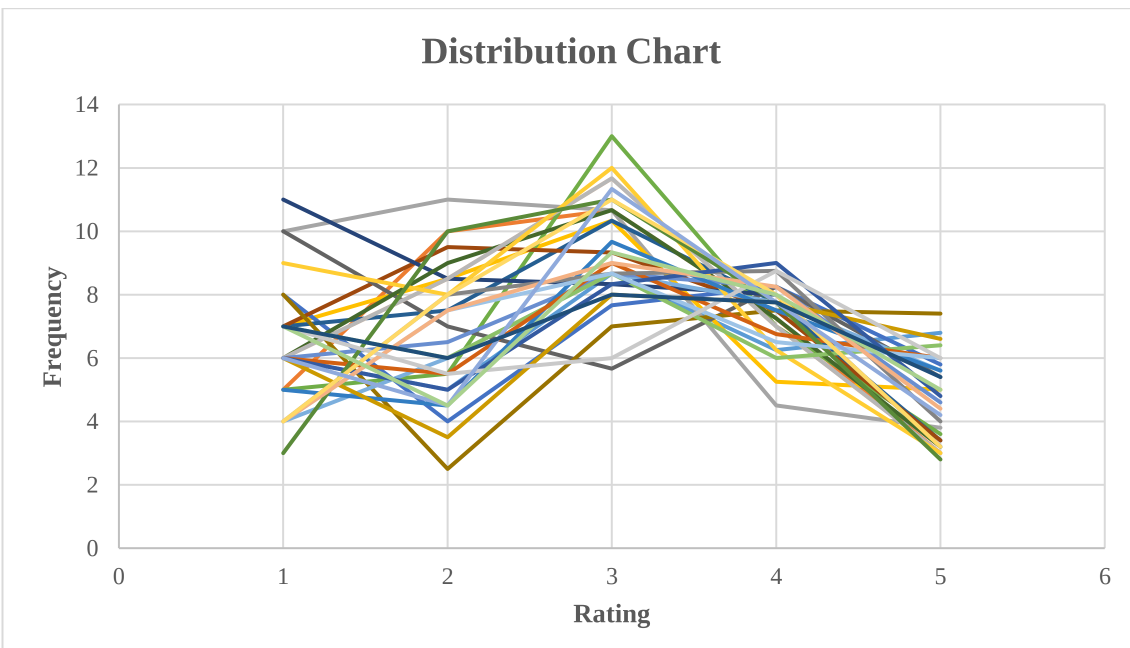

Figure 7: Standard Normal Distribution Chart for Normalized Professionals' Data

Skewness Check:

After the graphical representation the skewness value was calculated for each of the competencies for both subgroups. In order to check whether the data was normally distributed or not the skewness ranges for both subgroups' data were calculated. Both sets of data proved to be normally distributed according to the skewness check.

Table 5: Skewness Ranges

Data Type	Sample Skewness Range	Acceptable Skewness Range
Field Professionals' Data	-0.923 to +0.020	-2.58 to +2.58
Undergraduate Students' Data	-1.387 to -0.400	

Kurtosis Check:

After skewness the Kurtosis value for each competency for both subgroups was calculated. Ranges for subgroups were within the acceptable kurtosis range mentioned below. So, the data once again was proved to be normally distributed while using kurtosis as a metric.

Table 6: Kurtosis Ranges

Data Type	Sample Kurtosis Range	Acceptable Kurtosis Range
Field Professionals' Data	-0.926 to +0.077	-3 to +3
Undergraduate Students' Data	-0.701 to +1.474	

4.3.2.Factor Analysis:

Statistical Package for Social Sciences (SPSS): IBM SPSS is a tool used for statistical analysis of data. Although the name suggests its use is social sciences but it can be used for data analysis in any field. This is the most commonly used tool in this regard. This tool takes robust amount of data and after applying the statistical analysis of your choosing generates the results. In my case I used SPSS for principal component analysis. For this purpose, firstly the data was imported in the form of an excel file (.csv) to the SPSS using simply the import tab. After importing, SPSS classified the data into rows and columns. The columns in SPSS are referred to as variables, whereas the rows are referred to as cases. If the user's input data consists the titles of each column SPSS will use them otherwise it will assign software generated titles of the columns.

After preprocessing, collection type was needed to be assigned from scale, ordinal, and string. I chose the scale data type depending on my input. Then factor reduction technique was applied from the analyze tab in order to perform the principal component analysis. This further asked about the metrics that was needed as an output. The following were selected:

- Correlation Matrix,
- KMO and Bartlett's test of Sphericity,
- Scree Plots,
- Component Matrix, and
- Rotated component Matrix according to Varimax rotation.

The Scree plot is a graph between the component number and its respective Eigen Values. The underlying constructs in the component matrix are created by SPSS by retaining the components in the Scree plot with Eigen value greater than 1. Then applying Varimax rotation, a rotated component matrix is generated. This matrix contains the factor loading values of each original variable on the newly measured constructs. The software was also instructed SPSS disregard factor loading values below 0.50 as these values are small and do not explain the maximum variance between the variable and the component. The output of this rotated component matrix was used for further analysis.

Table 7 is the output of the rotated component matrix for technical competencies for both subgroups i.e., students' data and professionals' data. The table shows the values for factor loadings. The technical competencies were loaded on one latent construct. This means that all the technical competencies are dependent on a single underlying component. Λ in the following table denotes the values for factor loading of variables on the construct.

Table 7: Factor Loading for Technical Competencies

Technical Competencies	**Factor Loadings (λ)**	
	Students Data	**Professionals Data**
Project Planning & Scheduling	0.587884	0.79469
Procurement Management	0.648595	0.770636
Cost Accounting	0.558739	0.805993
Contract Management & Administration Skills	0.533193	0.80753
Site Planning & Management	0.555837	0.774206
Resource Management	0.527915	0.761438
Health & Safety Management	0.617695	0.593003
Plan, Assess & Control Risk	0.61602	0.746302
Structural Analysis & Design	0.723257	0.759098
Understand Construction & Shop Drawings	0.700536	0.563882
Building Stakeout & Survey	0.692696	0.667691

Construction Machinery & Equipment	0.703833	0.73454
Quality Assurance & Control	0.719462	0.646289
Construction Materials & Testing	0.728201	0.669615
Information Technology (IT) Competencies	0.660725	0.524555
Building Information Modelling	0.636585	0.675854

Table 8 is for the factor loadings values of professional competencies for both data sets; students, and professionals. All the variables are loaded onto a single latent construct, proving that these variables are grouped together under one variable. All the smaller coefficients below 0.5 were ignored because they are not loaded significantly on a construct.

Table 8: Factor Loading for Professional Competencies

Professional Competencies	**Factor Loadings (λ)**	
	Students Data	**Professionals Data**
Leadership	0.628208	0.688068
Decision Making	0.641471	0.607651
Critical Thinking & Problem Solving	0.667327	0.62991
Written & Oral Communication Skills	0.664272	0.717499
Conflict Resolution	0.640991	0.595267

Work Ethics	0.698199	0.871094
Detail Oriented	0.669347	0.793615
Networking	0.639883	0.582518
Team Player	0.713294	0.874694
Adaptable	0.764104	0.848943
Continuous Learning	0.665478	0.815222
Cultural Competence	0.673497	0.783602
Self-Awareness	0.681729	0.819166
Persistence	0.760898	0.79289
Multi-Tasking	0.747817	0.544865

KMO measure of sample adequacy was provided by SPSS after the data reduction step. These values for both sets of surveys should individually be greater than 0.5. The check was passed for both students' and professionals' datasets. The values are provided in table 9.

Then using Microsoft Excel, the average variance extracted values were calculated to satisfy the construct validity criterion.

Then I used Microsoft Excel to calculate the construct reliability i.e., composite reliability.

Then I used IBM SPSS once again to calculate the Cronbach's alpha using the scale function.

Construct Reliability:

After getting the factor loading values they were checked for construct reliability and construct validity. Construct reliability is checked using two metrics; composite reliability and Cronbach's Alpha.

Composite reliability for both latent constructs for both sets of surveys was calculated using equation (5). The values for composite reliability and the criteria for passing the check are mentioned in table 9.

Cronbach's Alpha for the underlying variables for both datasets was calculated using IBM SPSS. The scale function was used for the technical competencies first and then the professional competencies later. The values and criteria for passing the Cronbach's Alpha test are provided in table 9.

Construct Validity:

Two metrics for evaluating construct validity were employed. These were convergent validity and discriminant or divergent validity.

Convergent validity was calculated using equation 3. This value should be greater than 0.5 but the values for datasets were found to be lesser than the criteria. But even if these values are lesser than 0.5 but the composite reliability is greater than 0.60, the data set is found to have convergent validity. The convergent validity is also known as average variance extracted.

Discriminant validity was calculated using the Heterotrait-monotrait ratios. This validity is confirmed by checking that the square root of average variance extracted of a construct should be greater than the heterotrait correlations between constructs. This check was passed as well. The correlation matrices are attached as appendices A1-A6. The value and criteria for discriminant validity are mentioned in table 9.

Table 9: Data Adequacy, Reliability, Validity Values

Metrics	**Criteria**	**Students Data**		**Professionals Data**	
		Technical	**Professional**	**Technical**	**Professional**
Composite Reliability	> 0.6	0.917224	0.92966	0.941639	0.946452

Average Variance Extracted (AVE)	> 0.5	0.411888	0.469373	0.505782	0.546505
√AVE	> 0.46	0.641785	0.685108	0.711183	0.739259
Cronbach's Alpha	> 0.7	0.941	0.946	0.955	0.961
KMO Measure of Sampling Adequacy	> 0.5	0.95		0.785	

The heterotrait-monotrait (HTMT) correlations were calculated using the correlation matrix for both datasets achieved from IBM SPSS. The monotrait correlation are correlations between the variables of one construct. The heterotrait correlations are correlations between the variables of two different constructs of a single dataset. These were calculated by taking average of the values of correlation matrix under their respective category. The HTMT ratios should be less than 0.90. As shown in table 10 our data passed this check as well.

Table 10: HTMT Ratio Calculations

HTMT Ratio Calculations		
	Students Data	**Professionals Data**
Monotrait Correlations		

TC	0.499985339	0.520203422
PC	0.544241665	0.623557804
Heterotrait Correlations		
TC-PC	0.436738125	0.478938955
HTMT Ratio		
TC-PC	0.837233461	0.840921004

4.3.3.Relatively Importance Index (RII)

The relatively importance index of all the competencies were calculated using the following formula:

$$RII = \sum \frac{W}{(A*N)} \quad (6)$$

Whereas

RII = Relatively Importance Index

W = Weightage given to each factor by the respondents

A = Highest weight (i.e., 5 in this case)

N = Total number of respondents

The competencies from students' data are listed in the table 11 sorted according to largest to smallest RII score:

Table 11: Sorted Competencies According to RII from Students Data

Students Data			
Technical Skills	**RII Score**	**Professional Skills**	**RII Score**
Project Planning & Scheduling	0.809756098	Decision Making	0.846829268

Contract Management & Administration Skills	0.809756098	Critical Thinking & Problem Solving	0.844878049
Structural Analysis & Design	0.806829268	Continuous Learning	0.817560976
Understand Construction & Shop Drawings	0.794146341	Leadership	0.816585366
Site Planning & Management	0.793170732	Adaptable	0.812682927
Quality Assurance & Control	0.793170732	Conflict Resolution	0.810731707
Cost Accounting	0.788292683	Persistence	0.810731707
Plan, Assess & Control Risk	0.780487805	Multi-Tasking	0.808780488
Construction Materials & Testing	0.771707317	Team Player	0.805853659
Health & Safety Management	0.763902439	Work Ethics	0.80097561
Resource Management	0.752195122	Written & Oral Communication Skills	0.787317073
Procurement Management	0.744390244	Self-Awareness	0.787317073
Building Stakeout & Survey	0.734634146	Networking	0.778536585
Building Information Modelling	0.734634146	Detail Oriented	0.772682927

Information Technology (IT) Competencies	0.726829268	Cultural Competence	0.740487805
Construction Machinery & Equipment	0.722926829		

Figure 8 is a graph with relatively importance indices on x-axis and their corresponding competencies along the y-axis for students' data.

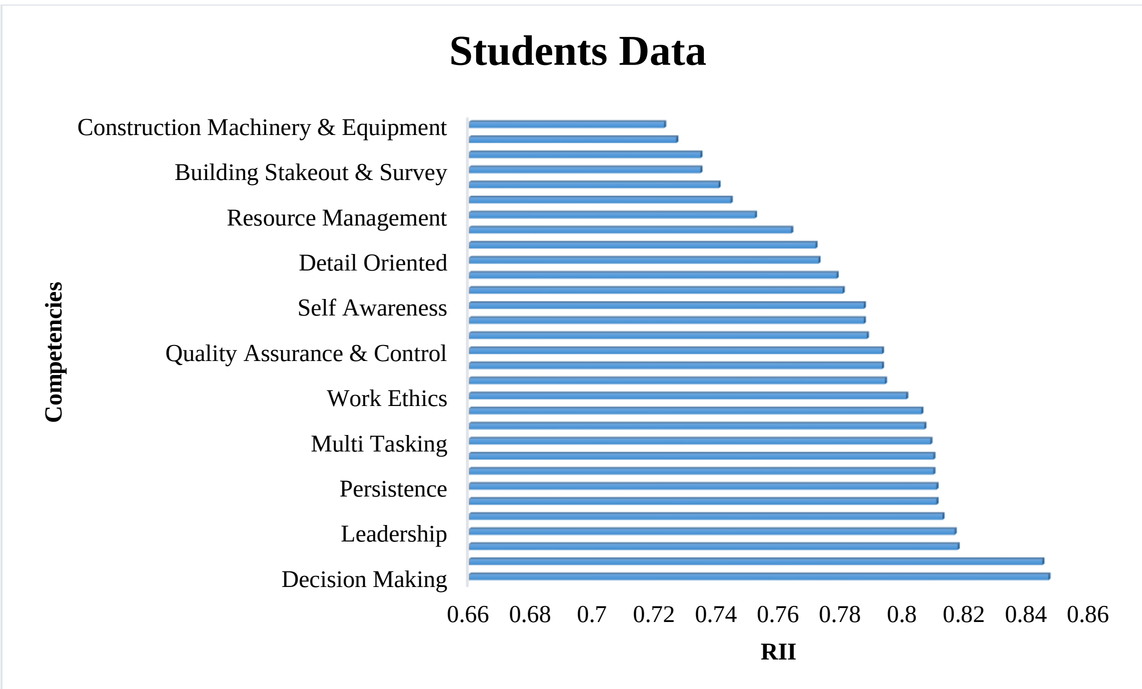

Figure 8: Relatively Importance Index Chart for Students' Data

The competencies from professionals' data are listed in the table 12 sorted according to largest to smallest RII score:

Table 12: Sorted Competencies According to RII from Professionals Data

Professionals Data			
Technical Skills	**RII Score**	**Professional Skills**	**RII Score**

Understand Construction & Shop Drawings	0.764356436	Work Ethics	0.754455446
Project Planning & Scheduling	0.740594059	Continuous Learning	0.738613861
Site Planning & Management	0.732673267	Critical Thinking & Problem Solving	0.732673267
Quality Assurance & Control	0.732673267	Written & Oral Communication Skills	0.726732673
Construction Materials & Testing	0.712871287	Team Player	0.724752475
Structural Analysis & Design	0.704950495	Decision Making	0.722772277
Resource Management	0.685148515	Detail Oriented	0.722772277
Contract Management & Administration Skills	0.679207921	Persistence	0.716831683
Health & Safety Management	0.671287129	Multi-Tasking	0.716831683
Plan, Assess & Control Risk	0.661386139	Leadership	0.706930693
Construction Machinery & Equipment	0.661386139	Adaptable	0.706930693
Procurement Management	0.657425743	Self-Awareness	0.702970297
Information Technology (IT) Competencies	0.657425743	Conflict Resolution	0.700990099

Building Stakeout & Survey	0.64950495	Cultural Competence	0.679207921
Building Information Modelling	0.641584158	Networking	0.665346535
Cost Accounting	0.627722772		

Data in table 12 is presented in the graph below. The graph contains RII values on x-axis and the competencies list on the y-axis.

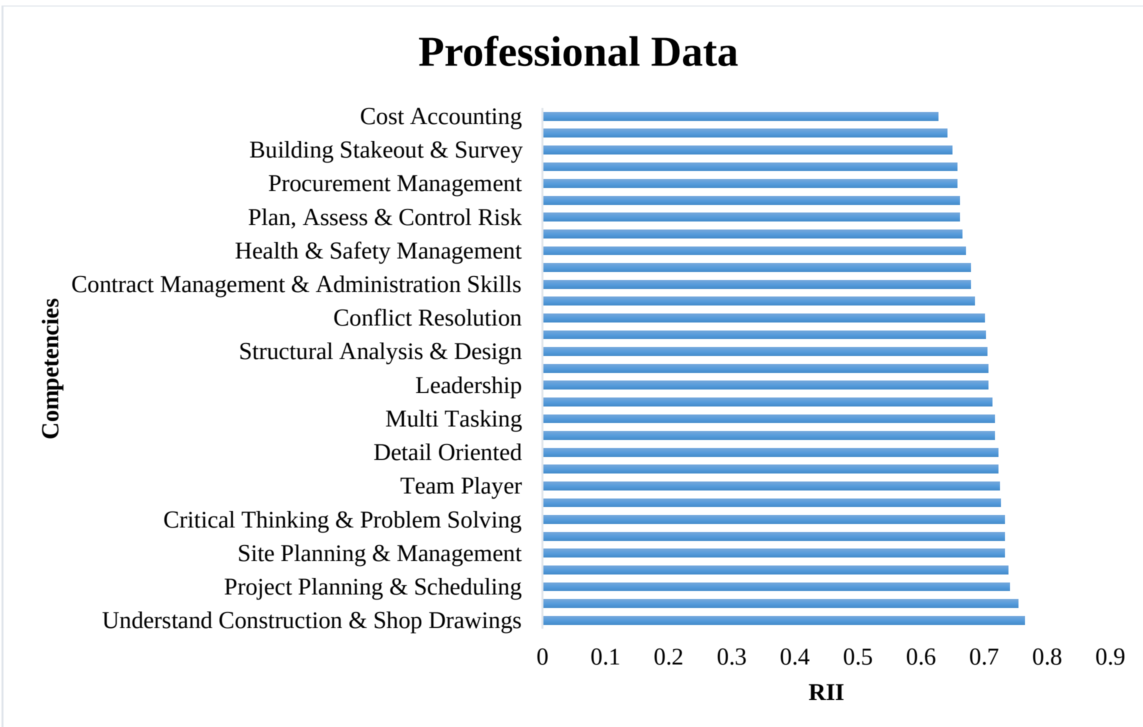

Figure 9: Relatively Importance Index Chart for Students' Data

4.4.Discussions:

A gap exists between the students' perception of important competencies and the skills that are deemed necessary by professionals. The students are rating the professional skills consistently higher than the technical skill. Table 13 highlights the top three skills identified in both categories by students and professionals. Whereas the professionals are taking a more balanced approach between technical and professional aspects while rating the top five skills. This can be interpreted as the existence of a gap between what a student is being taught during their stay at an educational institute during their undergraduate degree and what the industry requires of them in order to be effective and beneficial towards their organization and in enhancing their careers.

Table 13: Top Three Most Important Skills

Skill Type	Students	Professionals
Technical Competencies	Project Planning & Scheduling	Understand Construction & Shop Drawings
	Contract Management & Administration Skills	Project Planning & Scheduling
	Structural Analysis & Design	Site Planning & Management
Professional Competencies	Decision Making	Work Ethics
	Critical Thinking & Problem Solving	Continuous Learning
	Continuous Learning	Critical Thinking & Problem Solving

Industry professionals emphasize that a crucial technical skill for graduate engineers is the ability to comprehend construction and shop drawings effectively. However, there appears to be a discrepancy between the significance attributed to this skill by professionals and how students perceive its importance. Knowledge of construction and shop drawings also came up as an important technical skills by (Ahmed et al., 2014). While industry experts prioritize proficiency in interpreting these drawings due to their central role in construction projects, students seem to undervalue this skill in comparison to other technical competencies.

Project planning and scheduling emerged as one of the top three technical skills identified by both students and professionals, although students regarded it as the most important technical skill. This signifies the importance of this competency and thus necessitates the integration of effective and up to date planning and scheduling components into the curriculum. This alignment in priorities emphasizes the critical role of effective project planning and scheduling in engineering practice and highlights the need for educational institutes to put a greater emphasis on imparting these skills in future engineers.

A disparity exists in the assessment of the importance of professional skills, as evidenced by professionals ranking work ethics as the top professional skill, whereas students rated it significantly lower. Practitioners believe work ethics to be backbone of the getting things done while working in the industry, having good work ethics mean that you are reliable and honest, this builds trust with the team and thus is solid foundation of success. This variance in perception points towards the fact that students highly favors technical skills and lack the conception and training towards professional competence. Both industry professionals and students identified continuous learning as one of the top three professional skills. Professional engineering bodies like Pakistan Engineering Council also puts a great deal of effort in ensuring that there is an ample supply of resource materials available to continued learning. Additionally, (Ahmed et al., 2014) concluded that graduate engineers should possess the capacity to engage in continuous learning throughout their professional journeys. This implies that staying updated with advancements in technology, industry practices, and emerging trends is essential for engineers to remain competitive and effective in their roles over time (Azmi et al., 2018).

Critical thinking and problem solving came up among the top three important professional skills. This highlights the need to emphasize the incorporation of practices to enhance students' critical thinking aptitudes through improvement of undergraduate curriculum. Study of (Wu et al., 2015) also highlights that this is one of the skills that recruiters are desiring in the civil engineering graduates. This highlights the necessity for educational institutions to prioritize the integration of practices that foster critical thinking skills among students, thereby better preparing them for the demands of the engineering profession (ŽivkoviĿ, 2016).

Researches have been conducted on how to best integrate these skills into curriculum to alleviate this gap. Higher learning in students can be inspired through cooperative learning (Schäfer & Richards, 2007). Students responsibility to gain the necessary knowledge of important skills can be emphasized through problem based learning (Perrenet et al., 2000). This approach develops the problem solving and critical thinking capabilities of students, while teachers act as facilitators rather than just instructors (Ahmed et al., 2014). Scenario based learning is another approach which uses real life scenarios to emphasize most desired learning outcomes (Errington, 2010). This will impart students with job relative knowledge (Hill et al., 2010).

4.5.Recommendations:

The significant gap between the acquired skillset of students through academia and the required skillsets of an industry, as identified in this research, requires bridging. Project planning was highlighted as a crucial skill by both students and professionals, corresponding to which, a study from international journal of engineering education (2015) suggests that project planning (technical, contextual and behavioral) can be improved in students by implementing a project based learning methodology. In which a three tiered course approach: Preliminary, final degree and Master's degree, will be suited to generate a pre-work experience, resultantly linking academia and industrial environment (De los Ríos-Carmenado et al., 2015). Another research highlights the significance of infusing project management knowledge in the Engineering project management courses particularly in the undergraduate degree programs (Panuwatwanich et al., 2011). Previous research suggests that by bridging the gap between industry expectations and academic preparation and sharing information and skills needed in the workforce, management and academics may assist increase students' employability (Bae et al., 2022). Real life scenarios are used in order to emphasize the desired learning outcomes in the approach of scenario based learning (Errington, 2010).

Under the professional skillset, critical thinking and problem solving was deemed important by both groups: students and professionals. For ensuring the embedment of Critical thinking in the curriculum of engineering universities, a thorough and well-funded research is essential. Through this, a trial and error methodology needs to be developed and trialed overtime in Higher education programs. In addition, critical thinking theory needs to be thoroughly understood and practically applied by the educators and practitioners (Ahern et al., 2019). Group-based, problem-driven learning makes it easier to integrate technical and non-technical knowledge and abilities, but it also demands more participation from today's students in the curriculum. As students get more adept at regulating their learning, high tutor guidance levels gradually decrease (Duffy & Bowe, 2010).

Using this study and similar further research an undergraduate civil engineering curriculum as an interdisciplinary, and multi-dimensional plan can be developed. Regular audits and updates of the curriculum should be performed to stay up to date with the industry requirements. These audits will prove useful for the educational institutes seeking the improvement in quality and design of the curriculum. The learning approaches discussed above can be implemented to equip the students with necessary skills and emphasize their importance. This research solely focusses on the civil engineering curriculum at an undergraduate level. So further studies on specific fields of civil engineering e.g., structures, construction management, transportation should be conducted at higher education level. Also, the curriculum across the education institutes should be analyzed in order to create a unified curriculum and program learning outcomes tailored to the industry needs.

4.6.Limitations:

The significant skew in our dataset, with 90% male and 10% female respondents, poses a notable constraint on our study. This imbalance highlights the ongoing gender disparities within civil engineering, a field predominantly occupied by men (Naoum et al., 2020). This imbalance may perpetuate existing biases and viewpoints predominantly held by male professionals. To address this limitation, it is imperative for future research to prioritize a more equitable representation of genders in data collection efforts. This approach will ensure that our insights accurately reflect the diverse perspectives within the profession, promoting inclusivity and robustness in our conclusions.

Our study mainly draws data from one academic institute, focusing on batches 2020-2024 and 2021-2025. This narrow focus may limit the generalizability of our findings to other institutions or student groups. Focusing mainly on one school and specific batches of students in our study can actually be a good thing. It allows us to really dive deep into understanding how things work in that particular school and among those specific groups of students. By doing this, we can spot details and patterns that might have been missed if we looked at a bigger, more varied group. Also, studying these batches over a few years helps us see how things change over time. However, we have to remember that because we're just looking at one school and a few batches, our findings might not apply to every school or group of students. Still, what we learn can be really helpful for future studies, giving them a solid starting point to explore more widely.

One significant limitation of our study is the lack of tailoring to specific job titles within the field, such as structural engineers, transportation engineers, or geotechnical engineers. Each of these roles possesses distinct responsibilities, skill sets, and priorities. For instance, a structural engineer might prioritize competencies related to building design and analysis, while a transportation engineer may prioritize skills related to traffic flow management or urban planning. This lack of differentiation can introduce bias into our results, as certain competencies may be rated differently depending on the specific job title. For instance, a structural engineer might rate technical proficiency in structural analysis higher compared to a transportation engineer who might prioritize skills related to traffic modeling. To address this limitation, future studies should aim to tailor their assessments to account for the varied competencies and priorities associated with different job titles within the profession.

4.7.Conclusion:

Our study suggests the existence of a gap between the students and professionals' perception of the level of importance of necessary skills. This means that students might not be learning the practical abilities they need for real-world projects. For instance, things like critical thinking or communication skills might not be emphasized enough. This could be a problem because graduates might struggle when they enter the workforce and need to apply these skills. So, it's important for universities to update their curriculum to ensure students are better prepared for their future careers in construction. In this study, it was noticed that students and professionals have different views. Students see things differently compared to professionals. This means there is a gap between what students learn in their courses and what they'll actually need when they start working. To bridge this gap, it's important to change the students' perception. Because the expectancy value theory suggests that the students will pay more attention to the skills and attributes that they perceive important during their stay at an educational institution. By updating what students learn to match what professionals value, we can help students better prepare for their careers. This way, students' perceptions will align more closely with those of professionals, making the transition from school to work smoother.

The aim of this research was to find out what competencies undergraduate civil engineering students are being taught in the classroom and how important do the students perceive these skills to be. And then to identify the competencies that the industry professionals hiring engineers are looking for in a freshly graduated engineer. This identified gaps between the field and the classroom and can be used as the first step towards updating the curriculum to incorporate the industry necessary skills. The top ranked skills and their ratings by students are different from what professionals think. This identifies the existence of a gap between the curriculum being taught at the educational institutes and the industry. But there was one factor where students and professionals agreed to some extent, and that was the importance of professional skills. At least 5 of the top ranked skills by the students were professional skills. The professionals also ranked the soft skills comparatively higher than the technical skills. This emphasis on importance of professional skills demands the update of curriculum to incorporate them without undermining the technical skills.

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Appendix

Table A1: Short forms for Competencies

Factors	Variables	Denotions
Technical Competencies (TC)	ProjectPlanningampScheduling	TC1
	ProcurementManagement	TC2
	CostAccounting	TC3
	ContractManagementampAdministrationSkills	TC4
	SitePlanningampManagement	TC5
	ResourceManagement	TC6
	HealthampSafetyManagement	TC7
	PlanAssessampControlRisk	TC8
	StructuralAnalysisampDesign	TC9
	UnderstandConstructionampShopDrawings	TC10
	BuildingStakeoutampSurvey	TC11
	ConstructionMachineryampEquipment	TC12
	QualityAssuranceampControl	TC13
	ConstructionMaterialsampTesting	TC14
	InformationTechnologyITCompetencies	TC15
	BuildingInformationModelling	TC16
Professional Competencies (PC)	Leadership	PC1
	DecisionMaking	PC2
	CriticalThinkingampProblemSolving	PC3

	WrittenampOralCommunicationSkills	PC4
	ConflictResolution	PC5
	WorkEthics	PC6
	DetailOriented	PC7
	Networking	PC8
	TeamPlayer	PC9
	Adaptable	PC10
	ContinuousLearning	PC11
	CulturalCompetence	PC12
	SelfAwareness	PC13
	Persistence	PC14
	MultiTasking	PC15

Students Data

Denotions	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8	TC9	TC10	TC11	TC12	TC13	TC14	TC15	TC16
TC1																
TC2	0.69															
TC3	0.59	0.63														
TC4	0.66	0.58	0.64													
TC5	0.58	0.47	0.63	0.62												
TC6	0.47	0.44	0.51	0.55	0.57											
TC7	0.47	0.51	0.56	0.42	0.58	0.58										
TC8	0.52	0.57	0.56	0.53	0.48	0.56	0.60									
TC9	0.44	0.46	0.43	0.43	0.45	0.47	0.44	0.47								
TC10	0.53	0.54	0.45	0.46	0.46	0.44	0.44	0.42	0.65							
TC11	0.45	0.45	0.43	0.37	0.48	0.39	0.47	0.45	0.54	0.63						
TC12	0.45	0.50	0.43	0.36	0.51	0.44	0.49	0.43	0.51	0.57	0.62					
TC13	0.60	0.60	0.60	0.58	0.55	0.45	0.60	0.60	0.57	0.51	0.52	0.59				
TC14	0.50	0.51	0.45	0.42	0.49	0.42	0.57	0.47	0.59	0.54	0.56	0.68	0.70			
TC15	0.41	0.42	0.38	0.36	0.41	0.45	0.43	0.33	0.50	0.45	0.50	0.50	0.45	0.52		
TC16	0.51	0.49	0.50	0.48	0.35	0.38	0.36	0.40	0.41	0.46	0.42	0.35	0.52	0.41	0.61	

Figure A1: Correlation matrix for Technical Competencies

Denotions	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12	PC13	PC14	PC15
PC1															
PC2	0.77														
PC3	0.62	0.67													
PC4	0.56	0.53	0.59												
PC5	0.58	0.61	0.63	0.61											
PC6	0.45	0.48	0.57	0.53	0.64										
PC7	0.46	0.46	0.54	0.55	0.53	0.69									
PC8	0.46	0.58	0.57	0.54	0.66	0.54	0.48								
PC9	0.53	0.52	0.59	0.56	0.55	0.58	0.58	0.66							
PC10	0.52	0.55	0.54	0.54	0.58	0.60	0.53	0.50	0.62						
PC11	0.44	0.48	0.46	0.49	0.53	0.59	0.54	0.54	0.57	0.63					
PC12	0.39	0.39	0.38	0.46	0.45	0.56	0.53	0.45	0.51	0.62	0.64				
PC13	0.49	0.56	0.53	0.42	0.55	0.50	0.45	0.52	0.51	0.55	0.54	0.54			
PC14	0.58	0.55	0.58	0.53	0.53	0.60	0.54	0.48	0.55	0.67	0.55	0.53	0.62		
PC15	0.54	0.54	0.55	0.53	0.53	0.58	0.47	0.53	0.54	0.50	0.52	0.54	0.57	0.63	

Figure A2: Correlation Matrix for Professional Competencies

Denotions	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8	TC9	TC10	TC11	TC12	TC13	TC14	TC15	TC16
PC1	0.52	0.51	0.50	0.48	0.52	0.53	0.44	0.41	0.44	0.47	0.37	0.40	0.47	0.40	0.40	0.34
PC2	0.52	0.47	0.52	0.58	0.59	0.53	0.52	0.44	0.48	0.48	0.39	0.43	0.56	0.49	0.38	0.34
PC3	0.61	0.51	0.57	0.51	0.58	0.44	0.42	0.48	0.47	0.44	0.36	0.40	0.54	0.48	0.36	0.40
PC4	0.57	0.48	0.45	0.49	0.48	0.39	0.40	0.42	0.35	0.42	0.36	0.44	0.47	0.40	0.34	0.36
PC5	0.53	0.52	0.57	0.51	0.52	0.47	0.52	0.47	0.50	0.50	0.46	0.51	0.57	0.53	0.42	0.38
PC6	0.51	0.46	0.52	0.47	0.53	0.47	0.53	0.43	0.41	0.43	0.40	0.47	0.57	0.53	0.36	0.37
PC7	0.47	0.42	0.47	0.42	0.44	0.43	0.42	0.41	0.36	0.38	0.39	0.39	0.47	0.45	0.32	0.36
PC8	0.48	0.44	0.53	0.48	0.48	0.41	0.45	0.44	0.38	0.32	0.46	0.45	0.53	0.46	0.44	0.37
PC9	0.53	0.49	0.54	0.41	0.48	0.42	0.46	0.45	0.37	0.42	0.44	0.45	0.53	0.45	0.35	0.32
PC10	0.52	0.44	0.46	0.51	0.50	0.45	0.44	0.38	0.38	0.49	0.41	0.37	0.46	0.43	0.30	0.22
PC11	0.48	0.40	0.47	0.45	0.44	0.47	0.47	0.40	0.37	0.44	0.45	0.45	0.53	0.48	0.41	0.37
PC12	0.38	0.37	0.40	0.38	0.34	0.45	0.40	0.37	0.33	0.36	0.43	0.36	0.36	0.39	0.33	0.35
PC13	0.42	0.39	0.45	0.38	0.40	0.40	0.41	0.34	0.38	0.40	0.39	0.42	0.45	0.41	0.36	0.32
PC14	0.47	0.46	0.54	0.53	0.52	0.51	0.44	0.43	0.40	0.44	0.35	0.36	0.48	0.39	0.35	0.33
PC15	0.47	0.42	0.47	0.42	0.47	0.39	0.37	0.37	0.28	0.33	0.36	0.35	0.39	0.35	0.36	0.35

Figure A3: Correlations Matrix Values for Heterotrait Correlations

Industry Professionals Data

Denotions	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8	TC9	TC10	TC11	TC12	TC13	TC14	TC15	TC16
TC1																
TC2	0.56															
TC3	0.66	0.70														
TC4	0.67	0.69	0.69													
TC5	0.66	0.51	0.45	0.64												
TC6	0.61	0.59	0.55	0.61	0.71											
TC7	0.45	0.53	0.50	0.49	0.47	0.60										
TC8	0.49	0.64	0.53	0.62	0.50	0.62	0.52									
TC9	0.55	0.44	0.40	0.42	0.58	0.54	0.38	0.50								
TC10	0.59	0.38	0.40	0.48	0.67	0.54	0.45	0.49	0.62							
TC11	0.54	0.52	0.49	0.41	0.54	0.54	0.50	0.50	0.59	0.67						
TC12	0.52	0.52	0.50	0.60	0.46	0.54	0.51	0.57	0.50	0.53	0.63					
TC13	0.48	0.43	0.33	0.48	0.63	0.51	0.38	0.52	0.57	0.58	0.55	0.55				
TC14	0.54	0.44	0.42	0.44	0.58	0.59	0.51	0.48	0.66	0.69	0.64	0.54	0.65			
TC15	0.39	0.35	0.30	0.43	0.40	0.50	0.45	0.42	0.45	0.47	0.41	0.47	0.39	0.54		
TC16	0.42	0.47	0.38	0.49	0.54	0.61	0.37	0.67	0.58	0.45	0.39	0.44	0.51	0.52	0.51	

Figure A4: Correlation matrix for Technical Competencies

Denotions	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12	PC13	PC14	PC15
PC1															
PC2	0.82														
PC3	0.72	0.75													
PC4	0.70	0.65	0.78												
PC5	0.72	0.69	0.70	0.62											
PC6	0.53	0.54	0.60	0.66	0.63										
PC7	0.63	0.68	0.66	0.70	0.62	0.76									
PC8	0.51	0.57	0.51	0.53	0.55	0.51	0.58								
PC9	0.56	0.57	0.67	0.67	0.61	0.70	0.62	0.59							
PC10	0.69	0.65	0.64	0.70	0.64	0.63	0.70	0.59	0.71						
PC11	0.57	0.53	0.62	0.72	0.53	0.73	0.66	0.53	0.71	0.74					
PC12	0.61	0.50	0.56	0.57	0.57	0.68	0.60	0.60	0.67	0.66	0.61				
PC13	0.56	0.59	0.62	0.68	0.62	0.67	0.71	0.53	0.70	0.70	0.65	0.65			
PC14	0.61	0.65	0.67	0.67	0.57	0.59	0.64	0.56	0.64	0.70	0.62	0.57	0.76		
PC15	0.48	0.56	0.56	0.59	0.55	0.54	0.51	0.45	0.57	0.58	0.50	0.53	0.69	0.60	

Figure A5: Correlation Matrix for Professional Competencies

Denotions	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8	TC9	TC10	TC11	TC12	TC13	TC14	TC15	TC16
PC1	0.61	0.52	0.47	0.57	0.62	0.60	0.45	0.51	0.49	0.56	0.54	0.48	0.60	0.48	0.41	0.56
PC2	0.71	0.50	0.52	0.61	0.64	0.63	0.42	0.54	0.54	0.60	0.57	0.48	0.56	0.54	0.36	0.50
PC3	0.67	0.52	0.50	0.58	0.68	0.65	0.50	0.51	0.47	0.62	0.50	0.48	0.47	0.51	0.44	0.49
PC4	0.55	0.43	0.39	0.51	0.58	0.56	0.44	0.49	0.54	0.66	0.47	0.51	0.46	0.51	0.62	0.52
PC5	0.56	0.61	0.49	0.60	0.69	0.67	0.57	0.60	0.61	0.57	0.58	0.52	0.66	0.60	0.42	0.59
PC6	0.45	0.32	0.31	0.44	0.53	0.41	0.49	0.31	0.41	0.61	0.46	0.38	0.43	0.49	0.41	0.36
PC7	0.52	0.40	0.41	0.57	0.50	0.50	0.50	0.49	0.37	0.60	0.49	0.50	0.49	0.53	0.45	0.39
PC8	0.46	0.44	0.44	0.49	0.47	0.49	0.38	0.41	0.38	0.52	0.44	0.51	0.56	0.57	0.40	0.41
PC9	0.49	0.29	0.26	0.32	0.59	0.48	0.40	0.31	0.43	0.65	0.50	0.37	0.52	0.51	0.53	0.33
PC10	0.50	0.37	0.28	0.46	0.56	0.59	0.45	0.48	0.40	0.59	0.50	0.47	0.56	0.51	0.46	0.45
PC11	0.50	0.31	0.32	0.41	0.54	0.49	0.53	0.30	0.41	0.62	0.44	0.40	0.41	0.45	0.46	0.30
PC12	0.37	0.38	0.30	0.47	0.51	0.47	0.43	0.39	0.31	0.53	0.42	0.44	0.48	0.40	0.38	0.34
PC13	0.52	0.41	0.41	0.51	0.53	0.60	0.42	0.49	0.40	0.60	0.42	0.42	0.53	0.53	0.49	0.44
PC14	0.48	0.36	0.33	0.43	0.48	0.57	0.45	0.38	0.41	0.55	0.40	0.43	0.42	0.49	0.48	0.42
PC15	0.51	0.36	0.31	0.55	0.57	0.52	0.31	0.39	0.41	0.45	0.28	0.36	0.51	0.40	0.37	0.41

Figure A6: Correlations Matrix Values for Heterotrait Correlations