



Universidade do Minho
Instituto de Educação

**The Role of Technological Advancements in Learning Entrepreneurial
Competencies for Engineering Students in Higher Education**

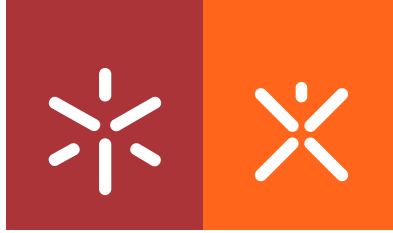
Marius Panxhi

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Marius Panxhi

The Role of Technological Advancements in Learning Entrepreneurial Competencies for Engineering Students in Higher Education

Tese de Doutoramento
Doutoramento em Ciências da Educação
Especialidade em Tecnologia Educativa

Trabalho efetuado sob a orientação do
Professor Doutor António José Meneses Osório

DIREITOS DE AUTOR E CONDIÇÕES DE UTILIZAÇÃO DO TRABALHO POR TERCEIROS

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STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration.

I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.

The Role of Technological Advancements in Learning Entrepreneurial Competencies for Engineering Students in Higher Education

Abstract

This thesis seeks to explore the role of technological advancements in the development of entrepreneurial competencies for engineering students in the context of higher education. The research question focuses on determining the role of digital advancements in the acquisition of these competencies and their applicability to engineering students and graduates. Identifying the role of technological advancements in learning entrepreneurial competencies for engineering students in higher education provides a comprehensive understanding of how digital educational technologies can be used to enhance student learning and engagement. Recognizing the challenges and opportunities of digital technology in higher education helps educators develop effective teaching practices that meet the diverse needs of students and faculty, and contributes to creating additional, improved, and new job prospects or entrepreneurial opportunities for engineering students.

The research process was directed by constructing a comprehensive concept map in the Literature Review. The map is connected to four primary pillars: "Entrepreneurial Competencies," Engineering, "Higher Education," and "Job Creation," which are intricately focused on providing a thorough understanding of the role of technological advancements in teaching entrepreneurial competencies to engineering students. The first two sections of the literature review examined two main topics: how advancements in educational technology are shaping the future of work, and the development of entrepreneurship competence in engineering education, from engineers to entrepreneurs. As a result of the first two sections, in the third section it was developed a comprehensive framework encompassing software and hardware technologies to improve learning and teaching in higher education, focusing on engineering and business. This framework organizes the most recent technological and innovative advancements, and their relationships with new and emerging jobs or occupations.

The study was designed to employ a mixed-methods approach, combining questionnaires for quantitative analysis and interviews for qualitative analysis, to provide a comprehensive understanding of the research questions and address various aspects of the study's objectives. Between higher education students and teaching faculties, around 350 responses were administered, followed by two sets of interviews using artificial intelligence as a necessity, as indicated by the validation of the questionnaire findings.

Overall, the results of the questionnaires and interviews indicate that entrepreneurial competencies are necessary in higher education, particularly in the engineering field. Entrepreneurial competencies are better achieved if higher educational institutions are equipped with adequate educational technological advancements.

This thesis contributes to educational technologies, engineering, entrepreneurship, and teaching in general by covering a wide range of advancements in educational technology and highlighting the impact of technology on employment and self-employment while maintaining the necessary research protocols and research ethics.

Keywords: engineering, entrepreneurial competencies, higher education, technological advancements

O Papel dos Avanços Tecnológicos Aprendizagem de Competências Empreendedoras para Estudantes de Engenharia no Ensino Superior

Resumo

Esta tese visa explorar o papel dos avanços tecnológicos no desenvolvimento de competências empreendedoras para estudantes de engenharia, no contexto do ensino superior. A pergunta de pesquisa foca-se no papel dos avanços digitais na aquisição dessas competências e sua aplicabilidade para estudantes e graduados em engenharia. Identificar o papel dos avanços tecnológicos na aprendizagem de competências empreendedoras para estudantes de engenharia no ensino superior fornece uma compreensão abrangente de como as tecnologias educacionais digitais podem ser usadas para melhorar a aprendizagem e o envolvimento dos alunos. Reconhecer os desafios e oportunidades da tecnologia digital no ensino superior ajuda os educadores a desenvolver práticas de ensino eficazes que atendam às diversas necessidades de alunos e professores, e contribui para criar adicionais, aprimoradas e novas de trabalho ou oportunidades empreendedoras para estudantes de engenharia.

O processo de pesquisa foi direcionado pela construção de um mapa conceptual abrangente na Revisão de Literatura. O mapa está conectado a quatro pilares primários: "Competências Empreendedoras", "Engenharia", "Ensino Superior" e "Criação de Empregos", que estão intrinsecamente focados em fornecer uma compreensão aprofundada do papel dos avanços tecnológicos no ensino de competências empreendedoras para estudantes de engenharia. As duas primeiras seções da revisão de literatura examinaram dois temas principais: como os avanços em tecnologia educacional estão moldando o futuro do trabalho e o desenvolvimento da competência empreendedora na educação em engenharia, de engenheiros a empreendedores. Como resultado das duas primeiras seções, na terceira seção foi desenvolvido um referencial abrangente que abrange tecnologias de software e hardware para melhorar a aprendizagem e o ensino no ensino superior, com foco em engenharia e negócios. Este referencial organiza os avanços tecnológicos e inovadores mais recentes e suas relações com novos empregos ou ocupações emergentes.

O estudo foi projetado para empregar uma abordagem de métodos mistos, combinando questionários para análise quantitativa e entrevistas para análise qualitativa, a fim de proporcionar uma compreensão abrangente das perguntas de pesquisa e abordar vários aspectos dos objetivos do estudo. Entre estudantes e docentes do ensino superior, cerca de 350 respostas foram administradas, seguidas por dois conjuntos de entrevistas utilizando inteligência artificial como uma necessidade, conforme indicado pela validação dos resultados do questionário.

No geral, os resultados dos questionários e entrevistas indicam que as competências empreendedoras são necessárias no ensino superior, particularmente no campo da engenharia. As competências empreendedoras são melhor alcançadas se as instituições de ensino superior forem equipadas com adequados avanços tecnológicos educacionais.

Esta tese apresenta contributos em tecnologias educacionais, engenharia, empreendedorismo e ensino em geral, cobrindo uma ampla gama de avanços em tecnologia educacional e destacando o impacto da tecnologia no emprego e no autoemprego, respeitando os protocolos e a ética necessários à pesquisa.

Palavras-chave: competências empresariais, desenvolvimentos tecnológicos, educação superior, engenharia

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1. Introduction

The introduction of the thesis includes four sections and seeks to highlight the lack of previous studies and the need for a framework, contributions of this research, academic and personal motives to conduct the research, and organization of the whole thesis.

Aim and scope of the study

Identifying the role of technological advancements in learning entrepreneurial competencies for engineering students in higher education:

First, it provides a comprehensive understanding of how digital educational technologies can be used to enhance student learning and engagement, thereby bridging the gap between engineering and entrepreneurship. This knowledge allows educators to embrace these advancements and improve the abilities and knowledge of engineering students with a focus on them, preparing them to become successful entrepreneurs.

Second, recognizing the challenges and opportunities of digital technology in higher education helps educators develop effective teaching practices that meet the diverse needs of students and faculty, thereby enhancing their learning outcomes.

Third, it contributes to the generation of more job opportunities for engineering graduates in entrepreneurship. By equipping engineering students with the necessary entrepreneurial competencies, they are better prepared to start their businesses and become entrepreneurs. The incorporation of digital technologies into education can enhance these competencies and provide students with the skills and knowledge needed to succeed in the entrepreneurial landscape. This, in turn, can lead to the creation of new job opportunities as engineering graduates establish and grow their own ventures, driving innovation and economic growth in various industries.

Lack of previous articles and need for a framework

Prior to determining the topic of doctoral studies, a database search was performed on the Web of Science website (webofknowledge.com) using various keywords and categories. The search keywords were "educational technologies," "framework," "framework on technologies," and "digital technologies in education." The search was limited to articles published between 2010 and the present, with the full text in English. The selected categories for the search were "Education & Educational Research",

"Mathematical Methods in Social Sciences", "Robotics", and "Science & Technology Other Topics". The search yielded 148 articles published during the selected period, all of which belonged to the "Education & Educational Research" category. However, when the search criteria were narrowed down to articles containing the keywords "educational technologies" and "framework in education," no studies were found.

In the second phase of the study, all 148 articles were analyzed using SciMAT, a mapping software that includes methods, algorithms, and measures for all general science steps (Cobo et al., 2012). SciMAT can map the workflow from preprocessing to the visualization of the results. Once the articles were uploaded in the appropriate format, groups of words were created manually and automatically using the software. The software was instructed to create groups of words that differed only by one letter. The software then analyzed the content of the articles and generated a view of the most frequently used topics. If technology mapping in education reveals distinct categories that are not covered, a new taxonomy framework may be necessary (Cobo et al., 2012). If the mapping did not yield related keywords, it suggested that a similar study did not exist for the selected period, and that the framework that would be created would likely be the first of its kind (Cobo et al., 2012).

This short analysis relies on a review to identify articles that have previously built frameworks in similar areas of research. The review chose all educational technologies that fit the framework that will be explained. This search met the criteria for a systematic literature review because it reviewed previous studies on taxonomies and classifications of (digital) technologies in education (Hanson-Abromeit and Moore, 2014).

The mapping process was followed by an analysis of all words used at least twice, and the software was used to map a minimum of three topics and a maximum of six topics. Articles with an "h index," "g index," and "sum citations" were selected as quality measures. After the software processed the data, the results were displayed in five clusters, which were the most popular topics among 148 articles. The software showed a separate view for each category ("h index," "g index," and "sum citations"), and an overall map of all the categories. The results are shown in Figure 1. This figure displays an evolution map of the most frequently used topics after processing using SciMAT. The software reveals that the word or group of words most commonly used in all 148 articles is "education," which was expected.

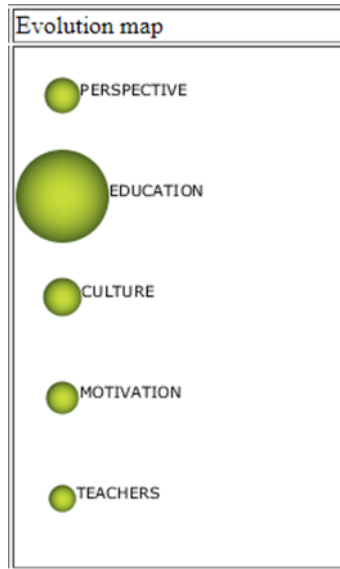


Figure 1: Evolution map of most used topics processed with SciMAT

The dominant cluster among the five identified is "education," followed by "perspective," "culture," "motivation," and "teachers." This indicates that the articles' characteristics reflect an education-centered model, with a focus on analyzing the relationship between education and other topics. However, there is a significant absence of any subtopic related to "technology," indicating a dearth of studies on educational technology (Cobo et al., 2012). Additionally, the clusters other than education suggest that the articles belong to social science fields like sociology or psychology, and there are no significant connections between "education" and "technology" or any of its subtopics.

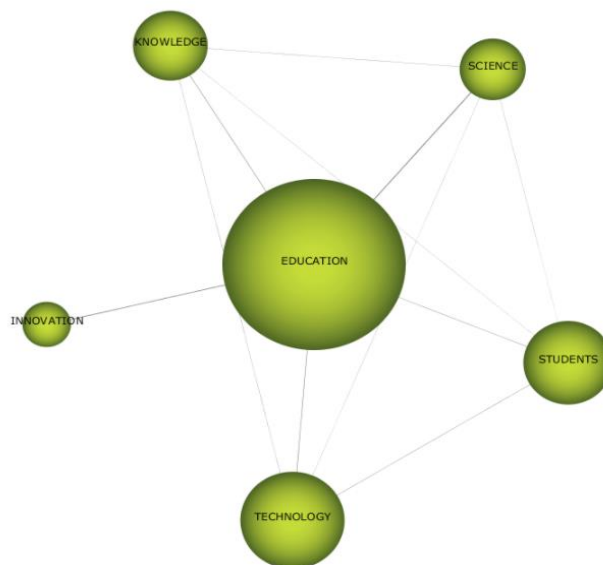


Figure 2: Evolution map of topic "education" composed with five pillars, processed with SciMAT

SciMAT generated a map for each of the five clusters. The education cluster (Figure 2) supports the notion that technology is a fundamental aspect of education, with the sub-cluster "technology" being the primary pillar. The other sub-clusters include "knowledge," "innovation," "students," and "science." The software also produces an internal pattern table with connections between topics. The connection between "education" and "science" has the strongest link, with a density range weight of 0.1. The pattern "education-technology" has a density range of 0.06, which is relatively close to 0.1 (Cobo et al., 2012).

Finally, the most important link for establishing the taxonomy framework was to identify the main keywords cited in the 148 analyzed articles. Some of the significant keywords include "model," "constructive," "system," "experience," "content," "perspective," and "design."

Contributions

This Ph.D. thesis contributes significantly to the disciplines of educational technology, engineering, entrepreneurship, and teaching.

First, it provides a complete understanding of the role of technological advancements in the development of entrepreneurial competencies among higher education engineering students. It explores effective ways to utilize digital educational technologies to improve student learning and engagement and proposes a framework of the technology landscape to be applied worldwide in education by various organizations. This study aims to bridge the gap between engineering and entrepreneurship by emphasizing the role of engineering in bringing about and developing job forms with a particular emphasis on self-employment, as suggested by Mosly (2017).

Second, it contributes to educational technology by providing an integrated set of software and hardware technologies that are linked to four major pillars: entrepreneurial competencies, engineering, higher education, and job creation. This framework is a helpful resource for educators and students interested in understanding and implementing recent innovations in educational technology to improve learning outcomes and increase engagement (Heinonen et al., 2019).

Third, by reorganizing the data and providing efficient approaches to enhance students' entrepreneurial competencies using digital technological advancements, this thesis contributes to entrepreneurship (Cristina, 2016). This will help engineering students better understand the value of entrepreneurship in their area and provide them with the skills they need to be successful entrepreneurs.

Finally, this thesis contributes to teaching by providing insight into the challenges and opportunities of digital technology in higher education. This study also identified the individuals and groups most affected by the implementation of digital technologies in education, emphasizing the need to recognize the diverse needs of students and faculty (Kryukov & Gorin, 2016). This will allow educators to create more effective teaching practices that meet their students' needs.

Academic and personal motives

This thesis is necessary for several academic reasons. First, by focusing on engineering education, it fills a gap in the research on the impact of digital technology advancements on learning entrepreneurial competencies. Although numerous studies have been conducted on the usefulness of digital technologies in education, there has been a lack of focus on how these technologies might be used to foster entrepreneurial competencies, particularly in the context of engineering education (Oppong et al., 2020).

Second, the aforementioned framework could be a useful resource for educators, researchers, and policymakers interested in learning more about the benefits of the latest educational (and non-educational) technologies.

Third, this thesis contributes to an analysis of the existing competency framework for entrepreneurship education. This analysis provides an understanding of the knowledge, abilities, and attitudes necessary for successful engineering entrepreneurship as well as how technological advancements can be leveraged to enhance these competencies (Antonizzi & Smuts, 2020).

This thesis contributes to a better understanding of the effects of digital technological growth on job creation and workforce development. This thesis provides insights into how education can be used as a tool to promote economic growth and innovation by investigating the impact of digital technologies on the emergence of new job prospects and employment types (Stadler, 2012).

Regarding the personal motives, there was observed the growing importance of digital technology in education and its potential to improve learning outcomes, which was also supported by Inquimbert et al.(2019). In today's fast-paced and dynamic work market, where invention and creativity are highly rewarded, researchers have emphasized the relevance of studying entrepreneurial competencies (Mohammadkazemi et al., 2016). Furthermore, as a user of digital technology on a daily basis, the researcher has experienced the influence of technological advancements on teaching and learning.

Other researchers have long been interested in the relationship between engineering and entrepreneurship. The researcher's belief that engineering students (being a mathematics instructor in a higher education college of engineering and business), with their problem-solving skills and technical expertise, have the potential to become great entrepreneurs and drive innovation in a variety of industries, which is also supported by Puni et al.(2018). However, other researchers have discovered that many engineering students lack the entrepreneurial competencies required to transform their ideas into profitable businesses (Natrah, 2013).

Consequently, one of the researchers' personal motivations for working on this topic is to explore the potential of digital technology to promote the development of entrepreneurial competencies in engineering students. Furthermore, the researcher sought to map the fields of engineering and entrepreneurship, and study how they can complement one another in generating innovation and employment.

Organization of the thesis

Chapter 1 provides a brief overview of the contributions of this study to academia and policymakers, as well as the academic and personal motives for researching this topic. It also provides a brief analysis of the lack of studies on related topics, and the need for an educational framework. The remainder of this thesis is organized as follows.

Chapter 2 presents a comprehensive literature review organized into three parts, each of which sheds light on different aspects of the topics under consideration.

The first part of Chapter 2 identifies the characteristics of newly emerging jobs created by technology-enriched educational spaces and platforms. The review includes a section on the most recent technological and innovative advancements, as well as their relationship with emerging or reducing new jobs or occupations (Atkinson & Wu, 2017).

Part II of the Literature Review focuses on the significance of entrepreneurship education for engineering students. This section examines the role of entrepreneurship in engineering education and how it affects students' entrepreneurial abilities and mindsets (Barba-Sánchez and Atienza-Sahuquillo, 2018). It also analyzes the effectiveness of engineering skills in small and medium-sized enterprises, as well as the chances for entrepreneurship that these competencies provide. This section examines entrepreneurship as a competency in education. It explores the concept of entrepreneurial competence and its significance in the development of students' entrepreneurial skills. Part II emphasizes the need

to incorporate entrepreneurship education into engineering curricula, and analyzes different approaches and methods for teaching entrepreneurship. Part II covers the strategies and methods used to teach entrepreneurship and provides insights into the fundamental features of entrepreneurship education (Henry, 2020).

Part III of the Literature Review presents a comprehensive framework of the educational technology landscape. The framework is based on five primary pillars: learning theories, Bloom's taxonomy, the ADDIE instructional design model, motivating design model, and disruptive technologies of Industry 4.0

The methods employed in this study and the research questions and objectives are presented in Chapter 3. The chapter begins with a pilot study that serves as an introduction to the main study, a mixed-methods study that blends quantitative and qualitative methodologies (Zha and Tu, 2016).

The quantitative approach included two research questionnaires: one for the higher education teaching faculty and one for students. This survey was created to collect information from participants on their perceptions of the use of technology in education, the usefulness of educational technology, and the relationship between technology and new and emerging jobs or occupations.

The qualitative analysis included interviews conducted using artificial intelligence. The interviews were designed to elicit more information on the use of technology in education and its impact on new and emerging jobs. The methodology describes the research design in depth, including the sampling and data collection procedures. It also describes the methods used to collect data, such as the survey questionnaires and interview protocols.

Ethical aspects such as participant permission, confidentiality, and data privacy were thoroughly considered. This section emphasizes the significance of ethical considerations in research, especially when human volunteers are used.

Chapter 4 covers the primary study's results, which are divided into two sections: the questionnaire and the interview results.

Chapter 5 is organized into five sections, each investigating one of the 5 W-s questions raised. It presents a complete analysis of the study's results and their implications.

Chapter 6 discusses the results and analyses provided in Chapters 4 and 5, respectively. It critically examines the empirical evidence and compares it with past research.

Chapter 7 (final considerations) concludes the thesis, which is organized into three parts. The first section outlines the study's limitations, and the second section suggests potential future research directions. The final section presents the last conclusions.

2. Literature Review

Education is undergoing a significant transformation in an era marked by rapid technological advancements and the rise of disruptive technologies. The need to provide students with the skills and competencies needed to adapt to the changing job market is becoming more apparent, and the integration of educational technology is reshaping their teaching and learning experiences (Succi & Canovi, 2020). This three-part literature review provides a thorough understanding of these primary points. The influence of technological advancements on the future of employment, development of entrepreneurial competencies in engineering education, and the use of educational technology are all key points.

Part I examines how technological advancements affect the labor market. As digitalization produces new industries and professions, whether existing employment is affected by disruptive technologies such as automation and artificial intelligence will be examined. The literature on developing technology employment was studied to analyze the qualities that lead to job creation and provide insights into how these developments may be utilized to promote a more inclusive and sustainable workforce.

Part II focuses on the importance of developing entrepreneurial competencies for engineering students to compete in today's competitive job market. This section investigates the efficient use of engineering skills in small and medium-sized businesses, as well as the role of entrepreneurship as a competency in education, highlighting the significance of entrepreneurship development in engineering education.

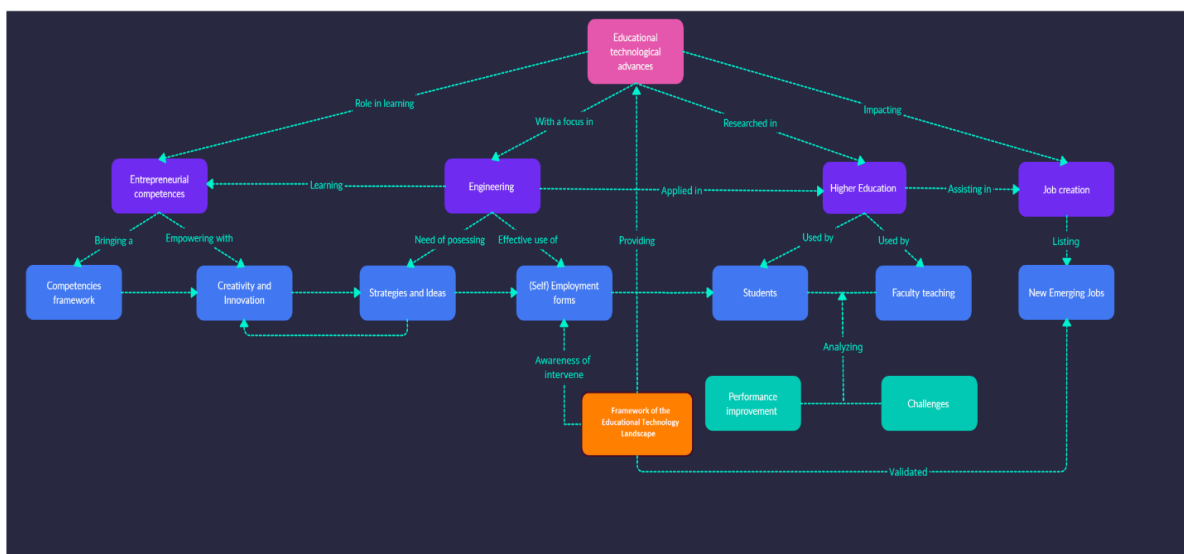


Figure 3: Detailed concept map of the key terms analyzed

Part III provides the framework and examination of various scholarly articles, books, and websites. To provide a holistic picture of the educational technology landscape, this framework integrated five critical components.

Taken together, these three sections present an in-depth examination of the complicated link between technology and the future of work, entrepreneurial competencies, and advancements in educational technology.

First, a detailed research concept map (Figure 3) was provided, which guided the literature review, actions, data collection methods, and analysis. The concept map precedes the objectives of this thesis (listed and explained in Chapter 3) and also comprehends the findings from the other sections. The main reference of this study is the latest digital technology, which is referred to as Educational Technological Advancements and each link is associated with a verb or description

Educational technological advancements are connected with four main pillars which are, firstly “Entrepreneurial competencies” where our purpose is to identify the role of educational technological advancements in learning the competencies by students and by teaching faculties. Second, the study mainly involved engineering students and the Faculty of Engineering. This analysis aimed to show that even if the link between engineering and entrepreneurial competencies is solid, students need to have deep knowledge of both disciplines. Third, the context is higher education because there are more facilities for digital technology and students have wider access to educational technological advancements. Fourth, educational technological advancements have an impact on job creation, where interest lies in the advantages and disadvantages of technology.

The first pillar (entrepreneurial competencies) is detailed in Part II of this chapter by analyzing a competency framework and its importance in creativity in innovation (Waychal, 2014). It resulted that “entrepreneurial competencies” is the main phrase while searching electronically about the need to develop entrepreneurial competencies. “Engineering” is linked with “Strategies and ideas” due to the importance the study has to review these aspects to better complete the puzzle starting with the “creativity” and “innovation.” In addition, this study aimed to demonstrate the effectiveness of engineering in bringing and developing employment forms, with a special focus on self-employment. Higher education topic is inevitably connected with “students” and “faculty teaching” since they are the main actors that validate our study through our methods.

Vertically from downwards, it introduced two fundamental characteristics that impact students and faculties in the relationship with educational technological advancements, “quality improvement” and “challenges” by using digital technologies while studying and learning. As in the interdisciplinary topic, the “Framework of the Educational Technology Landscape” is linked downwards with the proving and aiming to cover a wide field of educational technology, validating that all characteristics of educational technological advancements bring in job creation and awareness of intervention of technologies in employment and self-employment forms. The “Job creation” pillar is connected with listing “new emerging jobs” and it is detailed in Part I of this chapter.

In the conclusion of this chapter, the literature review seeks to identify the importance of technological advancements in learning entrepreneurial competencies for engineering students in higher education for several reasons. It prepares them for the modern workforce, enhances innovation and creativity, improves collaboration and communication, develops digital literacy, fosters an entrepreneurial mindset, provides access to resources and networks, is cost-effective and efficient, prepares them for remote work, helps them develop technological business models, and aligns with industrial trends. Specifically, the aforementioned reasons can be detailed as follows:

a) The job market is changing rapidly, and technological advancements are transforming the way businesses and companies operate. Students (of engineering) need to be equipped with the skills and knowledge that will make them relevant to the modern workforce. By incorporating technology into entrepreneurial education, students can be better prepared to navigate the digital landscape and adapt to new technologies in their future careers.

b) Technology can facilitate the development of innovative ideas and creative solutions. By leveraging technology, students (of engineering) can experiment with new products, services, and business models and develop innovative solutions to real-world problems. This will help them become more competitive in the job market and foster an entrepreneurial mindset.

c) Technology can facilitate collaboration and communication among team members, stakeholders, and customers. Students (of engineering) can learn how to use technology to work effectively in distributed teams, communicate their ideas clearly, and engage with customers in virtual environments.

d) Technology can help students (of engineering) develop an entrepreneurial mindset by providing them with the tools and resources to experiment, take risks, and learn from failure. This mindset is essential for success in today’s rapidly changing business environment.

e) Technology can provide students (of engineering) with access to a wealth of resources and networks that can help them develop their entrepreneurial skills. For instance, they can connect with mentors, investors, and potential customers through online platforms, and access a vast array of educational resources, including online courses, webinars, and workshops.

f) Incorporating technology into entrepreneurial education aligns with industry trends. By equipping engineering students with the skills and knowledge to thrive in a technology-driven environment, they can become more attractive to potential employers and better positioned to succeed in their careers.

Part I: The Effects of Technological Advancements on the Job Market

Digitalization has had a substantial impact on employment market dynamics in recent years (Balsmeier & Woerter, 2019). This technological revolution has resulted in the creation of new and emerging jobs or occupations (Harborth & Kümpers, 2021), as well as increased efficiency and improved working conditions. Emerging technologies, such as robots and big data, reduce human intervention and accelerate automation, leading to the abolition of thousands of jobs and occupational images as a result of the exponential usage of digitalization (Horvat et al., 2019). Additionally, combinations of technological advancements neutrally affect job creation and reduction.

Among all the technological advancements in education and industry that have been analyzed in various academic papers, a classification grouping for (a) *neutral technologies* in the phenomena of job creation and job reduction; (b) *technologies that negatively affect job creation, job acceptance, or the nature of jobs*; and (c) *technologies that bring new forms of occupation or contribute to job creation*. In this section, some characteristics that contribute to the improved application of technologies that bring about new forms of occupation are discussed. The characteristics of jobs that bring new forms of occupation may aid in the creation of jobs from low-ranking emerging technologies, such as machine learning and augmented reality (AR) (Harborth & Kümpers, 2021).

Through a literature review, the results of the best studies in the last six to seven years in the main topic “new emerging technological jobs”.

In “Part I”, it was considered a retrieval search on the Web of Science database by searching the phrase “new emerging technological jobs”, which yielded 42 results. Thirty-four articles were published in 2013 or later, and 24 were published in the previous five years. All studies were peer-reviewed, and the platforms that published them are well known. Management (eight articles), economics (eight articles), sociology (four articles), computer science (four articles), and other topics were covered in the

articles. Articles from specific fields (forestry, toxicology, metallurgy engineering, etc.) were removed, resulting in 35 studies, beginning with a systematic literature review. Subsequently, additional articles have been added to support and cite various statements or conclusions.

A review of these studies first explored the rise in non-routine jobs and the evolution of graduate employment. Second, some determinants of job creation were identified and briefly explained. Third, technologies were classified into categories (a), (b), and (c). AI, automation, robotics, cloud computing, and the Internet of Things are a few examples that have been analyzed in the context of shifting job landscapes, job creation, and the advantages and/or disadvantages they bring when addressing the combination of digital technologies and new emerging jobs. By doing so, it was aimed to provide a view of how digital technologies are shaping the future of work, and to identify as many technological advancements as possible that bring new and emerging jobs, reduce them, or are neutral in these changes.

Many educational and non-educational technologies were targeted and analyzed only in the context of job creation, as per the findings of the original 35 studies.

Shifting job landscape: The rise of non-routine jobs and the evolution of graduate employment

In recent years, there has been much debate and research on the changing structure of the job market and the rise of non-routine jobs. Graduate jobs have been noted as a potential source of innovation and opportunities for routine jobs are creating a growing need for new forms of employment.

The trend of traditional (routine) jobs vs. emerging (non-routine) jobs

Researchers classify emerging new jobs as non-routine and existing jobs as routine (Marcolin et al., 2019); (Squicciarini, 2016). According to the same authors, employment grew mostly in non-routine occupations, particularly market services, between 2000 and 2010, whereas manufacturing lost both its regular and non-routine positions. Routineness and skill intensity have a negative but weak relationship, implying the importance of both technological and organizational issues in determining routine intensity. Once other employment characteristics are considered, people who work in more ICT (Information and Communications Technology) intensive jobs perform fewer routine-intensive tasks. However, there is a non-linear component to this correlation: in jobs that are more routine-intensive, ICT intensity is more strongly and adversely associated with routine intensity (Squicciarini, 2016). Routine occupations are being lost in the overall economy, in tandem with the diffusion of automation-

intensive technological development throughout a wide range of industries, including those that employ a large number of non-routine workers. The decline in the share of routine employment across the economy is exacerbated by an economic and technological revolution that punishes human resource-intensive industries. The fall in regular task employment and the rise in positions requiring more complicated reasoning or higher customer engagement resulted in a loss of middle-skill jobs, a process known as polarization (Marcolin et al., 2019). Manufacturing industries are the most intensive in routine work, whereas ICT jobs are the most intensive among emerging jobs.

Graduate jobs as an opportunity to generate new workplaces and new forms of employment

A *graduate job* is defined as one in which a significant portion of the skills required are typically acquired during higher education, as well as many of the activities that surround it and its aftermath—the years following higher education when skills are acquired in the workplace through graduates' acquired faculty for learning them (Green & Henseke, 2017). On one hand, the labor market's supply of graduates is anticipated to expand and become more heterogeneous. However, according to previous studies, technology maturation, automation of increasingly complex task bundles, and worldwide growth of graduate labor are all risk factors that could diminish the future need for high-level talent (Henseke, 2019). As technology advances, vocational skills are likely to become more obsolete (Hanushek et al. 2017).

The lack of a widely agreed upon categorization of graduate occupations has hampered more direct analyses of demand trends. Some methods rely on educational attainment distributions, and are thus prone to tautological findings. Others are based on difficult-to-test assumptions about labor market organization or are only tangentially related to skill requirements (Henseke, 2019). Most techniques completely disregard variations in educational needs within occupations. In scholarly analyses and public discourse on graduate labor market destinations, the traditional concept of professions or high-level management as graduate occupations has persisted. This view is frequently based on the normative understanding of graduate jobs established by legal licensing laws, which limits admission to professions for those with specific higher school credentials. The approach described here can accommodate a wider range of vocations that use talent obtained through higher education, by drawing on the skills used at work. Various methods have been used in international research to define graduate employment (Henseke 2019).

Some determinants of job creation

Several variables affected the generation of new jobs. Several factors, such as variations between surrounding countries, employee replacements, employee cost of replacement, and social and cognitive abilities, can influence the development of new employment by influencing both supply and demand for jobs.

Digitalization

Researchers have examined the impact of digitization on job creation and elimination, where access to data empowers machines, computing, communication, and digital technology (Balsmeier & Woerter, 2019). They conclude that technological advancements have been the most rapid in recent years, and that this is the primary driving factor behind the present industrial revolution (Balsmeier & Woerter, 2019). These studies showed that enterprises that use non-machine-based technologies have no significant employment effects. According to previous research, digital investment has a significant influence on job creation and destruction. However, the impact varies depending on the skill level and technology (Balsmeier & Woerter, 2019; Acemoglu et al., 2014).

Job analysis structure

Researchers have proposed *job analysis* of organizational change as a result of technological advancements and increased competition (Singh, 2008). The effects of these technological and other changes will be universal and will affect all organizations. According to research and practice, new knowledge, skills, and abilities are required for jobs to be performed effectively and efficiently in this dynamic environment. They claim that the human resource function is crucial for the creation and emergence of new employment as a consequence of strategic job analysis (Singh, 2008). Strategic job analysis is a significant step toward the advancement of traditional job analysis to address the changing demands of modern enterprises. To accommodate quick changes in the workplace, organizations must allow for significant flexibility in their job analyses (Singh, 2008).

Other studies, Y. Lin, (2011), suggest that the winning formula for developing countries is to take advantage of the latecomer advantage by establishing industries that are growing rapidly in more advanced countries with endowment structures similar to their own. They see inclusive *structural transformation* as key to economic development and long-term growth. They provide examples of rapid post-World War II changes and economic developments. The structural change marked a new area in the emergence of new jobs, and they believed that a new structural change was critical in establishing a new area (J. Y. Lin, 2011).

Profile of workers

A worker's profile may play a role in creating new employment. Rohlman et al. (2013) discovered that many young workers start working with little safety training or understanding of their rights or obligations. Consequently, their needs are unsatisfactory. Almost half of the employees were new to the job, and almost one-third of those who had previously worked lacked safety training. Workers under the age of 18 were less familiar with their legal rights and lacked information on recognizing and controlling workplace dangers, indicating a lack of awareness of workplace safety standards.

Relationship Technology-Education-Wages

The roles of technology, education, and wages should be examined when assessing work structures and skills. Awareness of changes in employment requires an understanding of the dimensions of occupational skills (Cirillo et al. 2015). Higher education is more likely to be beneficial in terms of creating highly skilled jobs. Demand is a primary driver of employment. At the industrial level, employment can increase only if demand exceeds productivity. Such adjustments may elicit diverse reactions from different skill groups. During recessions, the long-term effects of technological advancement on employment and skills, as well as demand, education, and wages can be disturbed (Cirillo et al., 2015).

Immigration and neighbor countries competition

Immigration and disparities between surrounding countries have been demonstrated to alter labor market wage supply and demand, as well as stimulate job creation (Gordon & Kaplanis, 2013). Instead of simply accumulating a growing supply of "unskilled" migrant labor, which exerts increasing downward pressure on wages in bottom-tier jobs, the initial channeling of (potentially skilled) new arrivals from poor countries into these jobs causes temporary downward pressure on wages in that tier. As a result, rather than a total reversal, a slowdown in inflow (as seen in the late 2000s) was sufficient to ease the strain. This means that salary disparities between neighbors can cause major spatial shifts in the demand for locally tradable personal services (e.g., through customer migration), even if a shared change in income level has no effect on the overall demand for these services (Gordon & Kaplanis, 2013).

Job security

In the early 2010s, *job security* was a factor in the emergence of new jobs in the German context (Bernhardt and Krause, 2014). Most indicators of employment relationships are relevant for explaining job security. Job tenure is positively correlated with job security, suggesting that it maintains the ability

to generate expectations of a long-term relationship with the firm. However, skill requirements have a small, but positive impact on job security (Bernhardt & Krause, 2014). Indicators of workplace flexibility and performance requirements present a mixed picture.

Social skills and cognitive skills

The importance of an individual worker's "*social skills*," such as leadership and communication, to labor market outcomes has been proven (Weinberger, 2010). The fact that employment in jobs requiring complex interactive tasks has grown between cohorts, and that the earnings advantage enjoyed by high school sports participants or leaders supports the idea that the demand for social skills has grown over time. Both *cognitive skills* and interactive experiences in high school, such as sports and leadership activities, are credited.

Employee replacements

Employee replacement affects a company's inventive performance, and the development of new employment from employees who are not new graduates correlates with existing company innovation (Grinza & Quatraro, 2019). Worker replacements have a large negative impact on innovation, which is consistent with the assumption that they cause losses in a firm's tacit knowledge base. Moreover, worker replacements are particularly harmful to large and young businesses, probably because large businesses gain less from 'migration of people' effects and because young businesses' inventive skills are mostly dependent on distinctive human resources (Grinza & Quatraro, 2019). The findings suggest that locating businesses in industrial districts reduces the negative impact of worker replacement, and that a similar picture arises when businesses are more exposed to information spillovers, particularly related knowledge (Grinza & Quatraro, 2019).

Neutral technologies

By replacing machines and software with human jobs, advanced technologies have the potential to drastically reduce many current jobs, particularly routine jobs. However, they have also created new job forms. To meet the evolving job demands and new job positions, employees require appropriate training and on-the-job guidance. New business models and working methods have been enabled by new technologies, resulting in the emergence of new job categories. However, workforce disruptions may occur if the job destruction rate exceeds the job creation rate.

AR and VR: Reducing jobs vs. Emerging new forms of jobs

Assistance in real-time and suitable workforce training for new employees is essential to prepare them to shift job demands. Consequently, researchers are investigating whether user-oriented technologies such as augmented reality (AR) and virtual reality (VR) can be utilized for training and assistance, also known as intelligence augmentation (IA) (Harborth & Kümpers, 2021). VR is generally used to teach workers no prior knowledge, whereas AR is used to increase people's competency in their domains of expertise while they are working. Based on these findings, Harborth and Kümpers (2021) created a framework that instructs practitioners on utilizing AR or VR to assist workers in meeting their expected skill expectations. It also highlights the application areas, such as AR or VR, that can provide workers with adequate training to acquire new job duties.

Advanced technologies have the potential to replace 49% of occupations worldwide, particularly jobs with well-defined and repetitive duties that can be taken over by machines or encoded in computers (McKinsey, 2013).

A study comparing a "basic scenario" of expected labor demand and supply in Germany with a "Industry 4.0 scenario" considering the effects of digitalization, analyzes potential workforce changes through 2030. In 2035, the implementation of "Industry 4.0", according to Wolter et al., will result in a loss of 1.46 million employment, according to Wolter et al. (2016).

By projecting visual information into a physical job environment, AR can exploit employee strength by providing real-time support for operational activities (Harborth and Kümpers, 2021). This is referred to as "on-the-job mentoring." Manufacturing and production jobs have five use cases, in which AR assists workers with tasks such as maintenance, repair, and assembly.

In their research, "Intelligence augmentation: rethinking the future of work by leveraging human performance and abilities," Harborth & Kümpers, (2021), on page 9, they give Fig.1 "Framework for employing AR and VR in workforce training," which explores the stages of using AR or VR. The first step in leveraging AR or VR to boost labor efficiency is to determine the breadth of its applicability. Second, the goal of using AR or VR in certain activity sectors must be established. Finally, given the training aim, the selected learning theory was determined. The process through which a worker develops new abilities is referred to as learning theory. Based on a synthesis of theoretical and practical data, Harborth and Kümpers (2021) created four learning theories: immersive learning, instructional guidance, collaborative assistance, and visualization. Following the selection of a learning technique,

the framework can be used to identify the technical instruments necessary to accomplish a training activity (Harborth & Kümpers, 2021).

Combination of Big Data, Automation, and AI reducing existing jobs vs. generating new forms of jobs

According to a recent study (Garrido-Baserba et al., 2020), big data and Artificial Intelligence (AI) technologies will collide with the fourth revolution in the water industry. Combining the capabilities of Big Data analytics (including AI) with existing and future urban water infrastructure presents a significant opportunity to promote economic and environmental sustainability in the operation, rehabilitation, and maintenance of urban water infrastructure. If new requirements and business models emerge, such advancements could lead to socioeconomic changes and cross-industry boundaries, thus affecting labor markets.

Based on a combination of Big Data, Automation, and Artificial Intelligence (AI), Price Waterhouse Coopers and Deloitte, in collaboration with Oxford University, predicted that the water and waste management sector would experience the most changes out of a list of 50 sectors, with approximately 60% of current related jobs under threat within the next 15 years (Frey et al., 2013). According to current projections, jobs most at risk from progressive digitization involve automation of low-level tasks (Garrido-Baserba et al., 2020).

The introduction of new needs and business models will influence the labor market in general (including the water sector). To ensure that the evolving framework of new occupations meets future social needs, new technical techniques and effective management strategies are needed. Finally, new technological advances will alter the employment market (and social life) and bring new types of professions in the context of the water sector, as per multiple resources (Garrido-Baserba et al., 2020); (Frey et al., 2013). However, currently, linked occupations are threatened and may cease to exist.

Technologies that negatively affect job creation, job acceptance, or the nature of jobs

The employment landscape has changed in several ways because of the adoption of advanced technologies. While some technologies have the potential to create new types of employment, they may also have negative impacts on the rise, acceptance, or nature of employment. These difficulties raise concerns about the future of work and the competencies necessary to succeed in a rapidly changing job market.

Big data as a “killer” of job applicants

Big data techniques (large and complex sets of data) can be used to analyze the performance using this richness of data. Big data techniques have been proven to be key negative factors for job applicants. Applicant reactions are important for job selection, and this field has attracted considerable research interest. Under these circumstances, employers can use game principles and elements to assess applicants on a variety of factors, including attention, emotional intelligence, cognitive speed, personality, and fit for certain occupations and organizations (Collmus et al., 2016). This new technology may be advertised and used on social media to reach more applicants; alert them about job openings; encourage them to play games, tests, and puzzles; and post their information online, including results, recommendations, endorsements, and qualifications. Organizations can harvest data to assess and compare applications, in addition to monitoring "likes," followers, and retweets on social media sites (McCarthy et al., 2017).

Statistical machine translation (SMT)

Statistical machine translation (SMT), which is an approach for translating text or speech from one language to another using statistical models and algorithms, is believed to eliminate several translation tasks. Many professional translators believe that SMT has reduced translation to an editing and revising process; however, this scenario is not new to professionals who have long been revising entire translated texts, as well as chunks of texts and/or individual segments produced by machine translations, pre-translated by translation memory systems, or both (Raido, 2016). Considering the social media revolution and the continued trend of seeking lower-cost service providers, crowdsourcing has freed translations, giving rise to the concept of translation as a utility (Raido, 2016). The elimination of certain traditional translation professions led to the emergence of new translation methods, thereby creating new employment opportunities in the field.

Robotics and computerization are massively killing agricultural occupations

As previously explained, advanced robotics, which refers to the application of cutting-edge technologies, methodologies, and concepts to enhance the capabilities and performance of robots, positively affects job creation in welfare services. Robotics has a “positive” effect on killing agricultural occupations (Marinoudi et al., 2021). Robotics and computerization have transformed the agricultural production industry, creating a new era of automation. Robots have traditionally been employed in regular jobs that demand physical strength, accuracy, and repeatability, whereas humans have traditionally been used in higher-value tasks that require cognitive and decision-making abilities. However, robots are being

rapidly used in a variety of non-routine tasks that require cognitive abilities (Marinoudi et al., 2021). Agriculture deals with delicate "living" produce that needs to be handled carefully and might be impacted by environmental factors.

According to the findings, 70% of the work force in agricultural occupations that is "threatened" by computerization is employed in manual/routine operations (Marinoudi et al., 2021). Furthermore, vocations prone to partial automation were identified within this sector, as well as one for which there is no reasonable indication that the functions involved can be digitized or robotized in the near future. Finally, agricultural employment has potential for partial automation.

Technologies that bring new forms of occupation

New occupations have emerged because of the technological advancements that have changed the job market. These technologies, ranging from advanced robotics and the Internet of Things to cloud and grid computing, have the potential to boost results, optimize processes, and create new job profiles.

Cloud and grid computing

Cloud computing is a disruptive technology with excellent prospects and cheap prices for both corporate customers and service providers and as a new alternative (Zatonatska & Dluhopolskyi, 2019). Grid computing has emerged as an alternative to the evolution of traditional computing technologies. Grid computing is primarily concerned with large-scale resource sharing, innovative applications, and high-performance perspectives (Patel et al. 2016). As a result of computational balancing methodologies, new job profiles have evolved (clouds or grids). A grid is a computer and data management infrastructure that offers electronic underpinnings for global civilization in business, governance, research, science, and entertainment (Berman et al., n.d.).

Massive Open Online Courses

Massive Open Online Courses (MOOCs) represent a significant educational advancement. Since its inception, the long-term value of physical classrooms has been questioned (Gupta & Jain, 2017). With fundamentally new types of work, new methods for delivering lectures and disseminating knowledge have emerged. MOOCs can address the challenges of lifelong learning. Working individuals who desire to improve their abilities in a certain subject are no longer frightened by their employers' set working hours or other responsibilities (Gupta & Jain, 2017). Academics who are more aware of innovations and current paradigms will be more prepared to alter classrooms and the changing nature of their careers. If they are not alternated, the conventional model may be disrupted, perhaps leading to

failures such as the elimination of ancient professions (Gupta & Jain, 2017). Part III of this chapter discusses other aspects of Massive Open Online Courses.

GVCs (Technology of Advanced Food Tracking and Packaging)

By examining the routine content of jobs, global value chains (GVCs) have a significant impact on employment (Squicciarini, 2016). The GVC is a phenomenon in which production is divided into activities and tasks carried out in different nations. Across all quartiles of routine intensity, technological innovation matters and has a favorable impact on employment. The increased competitiveness that technological innovation can provide to businesses, appears to translate into higher employment levels, particularly in non-routine and low-routine intensive occupations (Squicciarini, 2016)

Mobile devices

The rise of mobile devices and technical advancements have led to the development of new shopping channels in the tourism industry. The use of mobile devices to shop for tourism products and services is known as mobile tourism shopping (Tan and Ooi 2018). In addition, this increase has necessitated a greater understanding of customer motivation to use mobile devices to shop for tourism products. The implementation and upgradation of mobile tourism shopping will generate new job types and increase the number of job openings. This would also result in an increase in the income of touristic countries that benefit from it as well as job prospects in tourism-related fields (Tan& Ooi, 2018).

Offshore wind

Offshore wind is an upcoming renewable technology, listed as one of the disruptive technologies of the McKinsey Global Institute in 2013. As wind-energy extraction solutions are complex, their implementation differs from that of other renewable-energy technologies because they require synergy among various industries, agents, and stakeholders (Vieira et al., 2019). According to the same authors, a path might result in significant investment in new capacity increases and economic benefits for the industry's added value, as well as more than 20,000 employment per year in Portugal by 2030 (a study carried out in the Portuguese context).

3D printing, Machine learning, Artificial Intelligence

According to some studies, the usefulness and appropriateness of employing new technologies to supply jobs currently held by underrepresented groups (Wehrle et al. 2020); (Ozkazanc-Pan 2021). Furthermore, ethical questions and emerging digital inequities will become significant topics for discussion in future diversity studies. One of the key results of technological progress, automation has drastically changed the dynamics of manufacturing and service jobs throughout the last century, and

continues to touch all industries in new and sophisticated ways today (Ozkazanc-Pan, 2021). Artificial intelligence (AI), 3D printing, virtual and augmented reality, machine learning, and other breakthroughs, together with the rapid rise of information technology, have opened up new opportunities for re-imagining labor and challenging conventional ways of organizing and performing activities (Ozkazanc-Pan, 2021). Although AI and machine learning hold the possibility of advancing diversity efforts by eliminating specific types of biases in candidate recruitment and selection, practitioners and scholars have emphasized that they can also increase them (Wehrle et al., 2020).

Advanced Robotics

Advanced robotics, a major disruptive technology (McKinsey Global Institute, 2013), is a determining factor for new forms of work. In welfare services, successful robot implementation necessitates staff approval as a part of daily work tasks. Turja et al. (2020) identified psychological and sociodemographic factors linked to robotization readiness among professional Finnish care workers (Finnish context). Potential change agents in Finland are separated from others by their great interest in technology, high self-efficacy in using robots, the sense that coworkers approve robots, and the optimism that robots will not take on employment. Robotization opens up many possibilities for easing and modernizing caregiving (Turja et al. 2020).

Telework and ICT-based mobile work (TICTM)

Telework and ICT-based mobile work (TICTM) are two new forms of employment that result from technological advancements. Telework and ICT-based mobile work arrangements fueled by digitalization have increased labor market flexibility and globalization (López-Igual & Rodríguez-Modroño, 2020). As teleworking has become more common, flexible work models are rapidly expanding to include new types of employees, modifying the characteristics historically used to determine teleworking eligibility. While teleworking was once thought to be appropriate only for high-status jobs with more desirable contracts, a high degree of autonomy, a focus on results, and little need for monitoring and control (Eldér, 2019), lower-status jobs are now considered eligible for remote or flexible work arrangements.

The analysis of the relationship between teleworking and higher-quality occupations revealed that working part-time reduces the likelihood of teleworking (by 27.3 percent) (López-Igual & Rodríguez-Modroño, 2020). Therefore, although teleworking creates new full-time jobs, it is likely to harm part-time employment. TICTM work is becoming increasingly unstable, transient, and low-paying, particularly for home-based and mobile teleworkers. This continual extension of teleworking to

occupations with increasingly mundane activities is changing its consequences and reducing the autonomy and sense of freedom it has historically provided (Ojala et al., 2014). Flexible work is likely to become a rule rather than an exception for many jobs in the near future. Our contribution can assist in avoiding teleworking promotion strategies that widen the gaps and inequalities between different groups of employees (Belzunegui-Eraso & Erro-Garcés, 2020).

Internet of Things (IoT), and Co.

Machine tool firms may utilize smart technologies, such as AI, big data, IoT, and digital twins, to optimize operations, enhance productivity, and minimize waste. One example is the ongoing transformation in the metal-producing industry due to Industry 4.0 (Akyazi et al., 2020). Industry 4.0 presents a chance for the machine tool sector to manufacture products with enhanced performance, longevity, and reliability. However, this opportunity will only be realized if the industry possesses a proficient workforce that can utilize new business models and technological advancements. To develop a highly competent workforce, the existing workforce must undergo upskilling and reskilling (Akyazi et al., 2020).

New-generation machine tools (Machine Tool 4.0) combine network connectivity, flexibility, predictability of intelligence, real-time reaction loops, and the wide deployment of cyber-physical systems (CPS), IoT, sensors, and computer technologies (Liu et al., 2018; Zhu et al., 2021). Consequently, digital technologies transform machine tools into intelligent assets capable of collecting and distributing real-time data based on their conditions, performance, and environment, thereby ensuring transparency in the manufacturing process.

Many jobs that are currently performed manually using machine tools are replaced by computers that run them, collect data, and supervise automated activities. Collaborative robotic systems undertake easy and boring activities, whereas operators execute jobs that require higher expertise and make critical judgments because of enhanced robotic technology (Bughin et al., 2018). Data security and safety have become increasingly important (Akyazi et al., 2020). Owing to the application of modern technologies, there is high demand for social and emotional abilities (Bughin et al. 2018). As a result of increasing automation, labor will be accountable for more vital activities. The number of tasks that require fundamental cognitive abilities (such as auditory and visual processing) decreases as computers become more automated, resulting in a shift in cognitive skill requirements from basic to advanced (Bughin et al., 2018). Higher cognitive skills such as creativity, strategic thinking, teamwork, lifelong learning, decision-making, and problem solving are becoming increasingly important (Bughin et

al., 2018). Table 1 lists the identified future technical and transversal skills of the machine-tool workforce by Akyazi et al. (2020), in their study “Skills requirement for the European machine tool sector emerging from its digitalization.”

Technical Future Skills for the Machine Tool Industry	Future Transversal Skills for the Machine Tool Industry
IoT	Advanced communication skills
Big Data	Negotiation skills
Artificial Intelligence (AI)	Customer relationship management
Sensors Technology	Interpersonal skills and empathy
Augmented Reality	Leadership and managing others
Machine Learning	Entrepreneurship and initiative taking
Business Intelligence (BI)	Risk management
Cloud Computing	Opportunity assessment
Collaborative/Autonomous Robotics	Adaptability and adapt to change
Agile human-machine interfaces (HM)	Continuous learning
Cyber-physical systems (CBS)	Teaching and training others
Augmented Reality (AR)	Critical thinking and decision making
Digital twin	Cross-functional process know-how
Additive Manufacturing	Interdisciplinary thinking and acting
Post-processing	Personal experience
Laser technology	Ethical skills
3D printing	Cultural empathy
Reverse engineering	Work autonomously
CURA 3D software	Active listening
ERP and MES systems	Teamwork skills
Communication among components, equipment (M2M), and environment	Basic numeracy and communication
Equipment and process monitoring & its implementation	Advanced literacy
Automated virtual metrology (AVM) system	Quantitative and statistical skills
Traceability	Complex information processing and interpretation
Blockchain	Process analysis
Predictive and Proactive maintenance	Appropriate linguistic skills
Computerized Maintenance Management	Creativity
Process simulation and integration in manufacturing	Conflict resolution
Online inspection and monitoring systems	Complex problem solving
Virtual systems for process simulation and for	

process control
Basic digital skills
Basic data input and processing
Advanced IT skills and programming
Advanced data analysis and modulization
Data management-safe storage
Cybersecurity
Use of digital communication tools
E-commerce
Financial literacy
Knowledge and understanding of quality procedures related to digital transformation

Table 1: Final list of identified future technical and transversal skills for the machine tool workforce

Synthesis

Part I examines how advancements in technology have shaped, been directed, and will change the future of work. It focuses on showing *that digitalization and disruptive technologies are shifting the job landscape and job determinants*, and *identifying which technologies affect job creation positivity, which are those that reduce or eliminate job positions* in addition to those that are neutral in these two phenomena.

The first point of discussion in this section is how routine jobs are declining while non-routine jobs are growing in services and knowledge. Through a literature review, we sought to understand how graduate jobs that require higher education provide opportunities for new roles and forms of employment.

Second, it was found that several factors drive job creation and that change and digitalization directly affect job development and loss. This section shows that analyzing job and organizational structures reveals how technology affects work, and how workers' profiles, needs, and demographics influence their new jobs. Moreover, other conclusions show that the relationships between technology, education, and wages are complex but significant and that immigration and globalization shape labor supply and demand. Factors such as job security, social and cognitive skills, employee turnover, and company innovation are also important.

Thirdly, there are "neutral" technologies in the phenomena of job creation and job reduction, such as AR, VR, and the combination big data-automation-AI, both reduce existing jobs and generate new

opportunities. The water industry exemplifies this with the expected impact of new techniques and technologies.

Fourth, academic studies show that some technologies such as big data negatively affect job performance, which can be disadvantageous for job applicants. Statistical machine translation reduces the translation work, whereas robotics and computing reduce the number of agricultural jobs.

Finally, it was demonstrated that new technologies can create and transform jobs. Cloud and grid computing, MOOCs, global value chains, mobile technology, offshore wind, 3D printing, machine learning, AI, robotics, telework, ICT, the Internet of Things and Industry 4.0 technologies based on several studies suggest that they change work, especially in manufacturing, tourism, welfare, and agriculture.

In summary, studies have shown that new opportunities have arisen but many jobs are at risk. Managing this transition requires insight, innovation, and intervention to create meaningful, sustainable work. Technological advancements have significantly disrupted and reshaped the job market, the nature of work, and the skills required for employment in industry and education. This transformation brings about opportunities and challenges that demand a coordinated response across education, industry, the government, and society.

Part I demonstrates that digital technology has a profound impact on the future of work, with advancements leading to both the emergence of new jobs and reduction in existing jobs. As routine jobs decline and non-routine jobs grow, the complex relationship among technology, education, and wages has become increasingly significant. While some combinations of technologies may negatively affect job creation, acceptance, or the nature of jobs, others are neutral and provide both challenges and opportunities. In addition, considerable advancements in technology have positively affected new forms of occupation.

Some notions and characteristics, such as disruptive technologies, Industry 4.0, Augmented Reality, Virtual Reality, Internet of Things, are mentioned only in the context of their role in job creation/job reduction.

Part II: From Engineers to Entrepreneurs: Developing Entrepreneurial Competence in Engineering Education

This section emphasizes the need for engineering students to adapt to a dynamic employment market driven by technological innovation. Engineers can help to establish new enterprises and drive economic development by developing entrepreneurial competencies. Part II explores the significance of incorporating entrepreneurship education into engineering programs to better prepare students for future professional difficulties and maximize their potential in a developing workforce. It is commonly agreed in academic circles that the landscape of engineering education has rapidly altered in response to emerging technological advancements and difficulties provided by the competitive labor market.

First, the efficient use of engineering competencies in small and medium-sized firms (SMEs) was analyzed. There are various elements that impact decision-making, such as the importance of encouraging innovation in the workplace and the differences in the characteristics and size-related aspects of small, medium, and large enterprises.

Second, it analyzes the present status of global engineering unemployment and the necessity for other skills, in addition to traditional technical competence. Using an Entrepreneurship Education (EE) course syllabus as a case study, it was investigated the integration of business courses into engineering education. A comparison of Entrepreneurship Education course-learning results and an engineer's entrepreneurial competencies should explore the potential benefits of incorporating entrepreneurship education for engineering students.

Third, this section motivates the need to develop an entrepreneurial attitude through innovation education, with an emphasis on process and product innovation, their implications for employment, and the significance of a company's job skill structure.

Fourth, it examines the growth of entrepreneurship as a competency in education, with the European Commission recognizing its significance and establishing frameworks to measure entrepreneurial competence.

Fifth, in this age of disruptive technology, developing a digital mindset is crucial for entrepreneurs.

Part II analyses the engineering mindsets and skills required to prosper in today's workforce, whether as an employee or an entrepreneur.

Effective use of engineering skills in small-medium enterprises

Students enrolled in engineering programs are required to complete courses on *engineering knowledge, development or design of solutions, problem analysis, investigation, modern tool usage, engineering and society, environment and sustainability, ethics, communication, individual and teamwork, and lifelong learning*, among other topics (Karim, 2015). From an analysis of the comparison between the learning outcomes and business skills needed by engineers, it was found that engineering students first needed to learn entrepreneurial competencies. It was also confirmed that university skills are required in the business industry.

However, it is important to show the opposite: if engineering skills matter in the business industry, and if they are important in analyzing their effectiveness. This analysis focuses on small and medium-sized enterprises (SMEs). Makers (2019) surveyed and analyzed the engineering skills shortage in the UK and why employer brand awareness is costing SMEs.

Directors of manufacturing firms claimed that there are not enough young people who want to start a career in engineering, while more than 2000 young people from High Schools, and Colleges have said that they wanted to start a career in engineering. As per the "Make UK Education & Skills Survey," conducted in 2019, 72% of manufacturers aim to hire an apprentice in the next 12 months, with 58% citing the age range of 16-18 as the age range at which they want to start apprentices in their organization. Furthermore, 33% said they were looking between the ages of 19 and 21 (Makers, 2019). Young individuals want to work in engineering and businesses require young engineers. While firms are looking for new, young engineers to hire apprentices, it is critical to understand why.

Shortage of skills, ineffective use of skills, or wrong place to get started

New graduate students should have different skills to have a successful professional career. This is mostly related to the engineering discipline in which students specialize. First, young engineers should have most researchers agree to innovation. According to Plana (2018), engineering and infrastructure are highly dependent on the ability to rapidly adopt new technologies, methodologies, and applications. This can be achieved by involving young engineers in challenging projects with innovative tasks and through new, more collaborative approaches to work that utilize agile and imaginative methodologies. Innovation is an important issue in all areas of an economy and society. Economic growth depends on the ability to create and realize continuous innovation in terms of new products and processes (Weissenberger-Eibl, 2014).

According to Weissenberger-Eibl (2014), a young engineer is unable to display full capacity in a new creative workplace because of lack of experience. Furthermore, they are unable to see that creativity is required to distinguish themselves from other employees (Weissenberger-Eibl, 2014). Freshly employed engineers who offer new abilities, talent, or inventions can add credibility to various firms for recently graduated students. Credibility favors firms that hire new engineers. However, this is doubtful, because they have demonstrated a lack of capacity to provide inventive solutions (Galloway, 2004).

Students lack innovative skills

Weissenberger-Eibl (2014) proposed that universities and higher education institutions should enrich their study courses in engineering with the important elements of Innovation Engineering to fill the gap between the requested profiles of innovation engineers' companies and those of university graduates. They pointed out that professional, methodological, social, and personal competencies are important for innovative engineers to succeed in their professional lives. Students face unique hurdles when starting their job hunts during the early stages of their careers, despite having all the abilities required for a successful professional trajectory. These issues center on their capacity to clearly communicate their competencies and choose where to begin their employment search.

First, being able to express their skills is a matter of quality, and key factors or parameters should be analyzed to determine why some graduates with the same capabilities can be more productive earlier than their peers. Here, a short analysis of the tools that newly graduated students need to have an effective start once they have graduated or specialized (Weissenberger-Eibl, 2014).

Second, regarding the place of starting work, it is fundamental to show that the effectiveness of students' capabilities is more significant in the early stages of their career. Before analyzing, suggesting, or listing research on where it is better for young engineers to start their careers, it may be useful to tell where they should not start. To tell that a brief analysis is needed about poor decisions happening in a workplace that lead employees to an unsuccessful career. Often, young people make poor decisions when prioritizing new jobs. Erwin (2019) lists several reasons for this finding. The reasons listed below are stated for people who have already chosen their workplace. An analysis of where these mistakes are most likely to occur is required. He states that the first reason is decision fatigue: no one has endless mental energy, and our ability to perform mental tasks and make decisions wears thin when repeatedly exerted.



Figure 4: Six reasons we make bad decisions by Harvard Business Review

Second, he noted that a steady state of distraction—an unprecedented convenience era—created an environment in which information and communication never ceased. Third, because of lack of input, employees often have no information in meetings, discussions, or forums, and they do not have time to think. Thompson (2019) found that, in a typical meeting, an average of three people accounted for 70% of the conversation. Fourth, Multi-tasking, most jobs require multitasking, and research clearly shows that performance, including decision-making effectiveness, suffers by up to 40% when we focus on two cognitive tasks at the same time (Smith, 2015). Fifth, the emotions included frustration, excitement, anger, and joy. In particular, moments of peak anger and happiness can hinder our ability to make good decisions (Khazan, 2016). Finally, the Analysis Paralysis is presented (see Figure 4) *Figure 4*. The more information that must be considered, the longer we typically take to make a decision (Schwartz, 2006).

The difference in size and characteristics between small, medium, and large enterprises

These studies have demonstrated differences in efficacy and effectiveness. In addition, there are reasons that lead young employees to make poor decisions. Moreover, it was assumed that young engineers do not have a shortage of skills. An important competence that brings an innovative spirit to the workplace is highlighted as a capability that 21st century engineers should have (Plana, 2018).

Before any further analysis, the specifications of the size and characteristics of the enterprises are required. Enterprises can be classified into various categories (data.oecd.org, n.d.). For this purpose, different criteria may be used, but the most common one is the number of people employed. Small-

and medium-sized enterprises (SMEs) typically employ fewer than 250 individuals and are further categorized into micro-enterprises (fewer than 10 employees), small enterprises (10-49 employees), and medium-sized enterprises (50-249 employees). On the other hand, large enterprises employ at least 250 people (data.oecd.org, n.d.).

<i>Enterprise</i>	<i>Micro Enterprise</i>	<i>Small Enterprise</i>	<i>Small-Medium Enterprise</i>	<i>Large Enterprise</i>
<i>Size</i>	<i>1 -9 employees</i>	<i>10-49 employees</i>	<i>50-249 employees</i>	<i>250 or more</i>

Table 2: Types of enterprises considering the number of employees

Regarding other enterprise characteristics, the concepts of innovation and collaboration differ between large firms and SMEs (Keeun Lee, 2015). Researchers and economists consider SME as SMEs. Thus, SME-s consider to 10-249 employees. Since micro-enterprises are often considered family businesses, their characteristics are quite different and will not be analyzed in this section.

<i>Concepts</i>	<i>Large Enterprises Level</i>	<i>SMEs Level</i>	<i>Researchers</i>
Purpose of development	Product platform development	Product development based on key technology	(Ledwith, Richardson, & Sheahan, 2006)
Global operation	Focusing on global market	Focusing on domestic market	(Prater & Ghosh, 2006)
Knowledge requirements	Preferring internal knowledge	Preferring external knowledge	(Teirlinck & Spithoven, 2013)
Collaboration affects	An influence on process	An influence on products	(Nieto & Santamaría, 2010)
Appropriability	Strong appropriability	Weak appropriability	(Pérez-Cano, 2013)

Table 3: The differences between large firms and SMEs in the concept of innovation and collaboration

The concepts analyzed by Lee (2015) are the purpose of development, global operation, knowledge requirements, collaboration effect, and appropriability, which refers to the ability of an innovator (a firm

or individual) to appropriate some of the social gains that result from his or her innovation (reed.edu, n.d.).

The importance of entrepreneurship education for engineering students

Amid prevailing circumstances and crises, the number of unemployed engineers is on the rise globally (Hall and Kudlyak, 2020). However, until 2017, universities worldwide continued to graduate from a significant number of engineers (Y. L. Zhang & Dinh, 2017). The curriculum for engineering degree considers new findings or tends to be more digitalized; however, new skills are needed to succeed in a highly competitive job market (Allen et al., 2020). Competition for certain jobs often occurs in details that are not strongly related to the traditional learning outcomes an engineer has studied at a university. Globally, many desperate graduates search for companies to hire (Smith and White 2017). Waiting time is dangerous to kill their hope of becoming engineers, and there is a risk that they will abandon and try new alternatives out of the engineering field to succeed in their lives, or even worse, wait for years hoping that one day they will be hired somewhere (Cardella et al., 2014).

Considering these circumstances, new engineering graduates should, if not necessarily, complete their study cycles using entrepreneurial skills (Ekpe et al., 2016). In addition to helping them learn more about the challenges of entrepreneurship, they will have strong tools added to their curricula, such as a greater chance of being promoted to a managerial position in a company where the graduate will be hired and create a job (Almeida et al., 2019). This proves that entrepreneurial skills help engineering graduates in job creation to consolidate engineering, attract new students, and approach entrepreneurs more with future engineers (Militaru et al. 2015). Recommendations are needed on how to involve entrepreneurship education to increase the effectiveness of immediate success for newly graduated engineering students (Herman, 2019).

One of the missions of the 21st century is to encourage social and economic development through venture creation and entrepreneurship development. However, published works offer conflicting opinions on whether entrepreneurship can be taught (Barba-Sanchez, 2017). Many researchers highlight that entrepreneurial motivation may be developed through specific entrepreneurship education (Zerbinati, 2007), while others believe that motivation is important for running a business, and therefore question whether teaching can enable the emergence of this motivation (Colette, 2005).

Several questions have arisen in this regard. What entrepreneurial competencies and intentions do the engineering students possess? Are they prepared to face a strong challenge in the job market, and are they aware that their job applications might be rejected multiple times? Next, are they ready to start ventures? If so, what are the key factors and motives that attract them in this respect? Moreover, what should the engineering students compare with social science students to impact their new ventures? Although the impact of entrepreneurial motivations on future engineers' entrepreneurship intentions has been analyzed by different researchers, it is important to analyze the impact of graduate engineers on the job market after they have successfully studied entrepreneurship education in their university studies (Virginia Barba-Sanchez, 2017).

Case study: Comparing an entrepreneurship education syllabus with the business skills required of engineers.

Searching for different course syllabi, the College of Professional Studies at Northeastern University, which is ranked among the ten best universities in the USA, for Entrepreneurship Education on their website (<https://cps.northeastern.edu/files/syllabi/20182520551.pdf>), page 3 has listed the following learning outcomes:

- 1. Consider the use of an inspiring view of the future; the challenge to current institutional assumptions; the identification of challenges, risks, and opportunities to generate innovative and entrepreneurial thinking; and the role of leveraging relationships and resources for change and improvement actions.*
- 2. Discerning elements and conditions of entrepreneurial activity that support and limit efficacy.*
- 3. Identify the skills, personal assets, and characteristics required of leaders who wish to be successful educational entrepreneurs.*
- 4. Develop case studies of prior and current attempts at K-12 and higher ed entrepreneurship in pursuit of educational improvement, change, and reform at the national and local levels.*
- 5. Use scenario planning to develop a coherent "storyline" for the pursuit of entrepreneurial activity,*
- 6. Excite others about innovative opportunities and the possibility*

For students studying a business program, it is obvious that learning outcomes will help them succeed in their careers by working as employees or creating jobs (Bradberry & Maio, 2018). However, it is essential to understand why the other students are out of business. In our case, engineering students might have benefited from these learning outcomes.

For the first learning outcome (L.O), if the graduate student will always be an employee and will never have their own enterprises, he will be skillful in leveraging relationships and resources for actions of change and improvement (Fonseca & Domingues, 2017). In addition, if the graduate initiates an enterprise, he will have an inspiring view of how to challenge institutional assumptions and identify challenges, risks, and opportunities to generate innovative and entrepreneurial thinking (Towers et al., 2020).

Regarding the second learning outcome, in terms of entrepreneurial competencies, students can discern the elements and conditions of entrepreneurial activities that support and limit their efficacy (Wardana et al., 2020). Therefore, the student will have deeper knowledge in analyzing the markets and competition, while if the student is a full-time engineer in a company, he gains skills such as efficacy, which is much needed in engineering (Silva et al., 2018).

The third learning outcome is fundamental for future entrepreneurs because it provides the student skills and characteristics that will lead to a successful educational entrepreneur, whereas leadership skills are needed in engineering (Towers et al., 2020). As leaders, engineering students may have a bright future and be promoted to managerial positions (Wardana et al. 2020).

Learning outcome number four is more technical and improves the prior knowledge level of students regarding entrepreneurship in pursuit of educational improvement. In addition, if a student is never an entrepreneur, he/she will have a better view of the changes and reforms, and he/she will be able to differentiate entrepreneurship characteristics at a local level or compare differentiation among countries (Uddin et al., 2016).

Learning outcome number five is related to the experimental part, and the students use their knowledge to create their “own” enterprise. Additionally, if students are not interested in becoming entrepreneurs, they will have skills, such as self-confidence in developing new projects and a better view of planning (Soni & Bakhru, 2021).

The last learning outcome is a “marketing” set of skills, which is about encouraging others and sharing the innovations, opportunities, and possibilities much needed for a successful entrepreneur or engineer. However, students gain the fundamental persistence skills for engineering work that are required for success (Wickliff et al., 2017).

Table 4 shows the benefits of Entrepreneurship Education for engineering students at the Northeastern University. The set of skills is separated into two columns: what students benefit more from their entrepreneurship career, and what they need for their engineering career.

<ul style="list-style-type: none"> Learning outcomes \ Skills 	<ul style="list-style-type: none"> Entrepreneurship career 	<ul style="list-style-type: none"> Engineering career
<ul style="list-style-type: none"> L.O 1 	<ul style="list-style-type: none"> an inspiring view of the future and how to challenge institutional assumptions able to identify the challenges, risks, and opportunities able to generate innovative and entrepreneurial thinking 	<ul style="list-style-type: none"> skillful in leveraging relationships and resources for actions of change and improvement
<ul style="list-style-type: none"> L.O 2 	<ul style="list-style-type: none"> able to discern elements and conditions of entrepreneurial activity that support and limit its efficacy deeper knowledge in analyzing the markets and the competition 	<ul style="list-style-type: none"> gaining skills like efficacy much needed in engineering
<ul style="list-style-type: none"> L.O 3 	<ul style="list-style-type: none"> skills and characteristics that will lead to a successful educational entrepreneur 	<ul style="list-style-type: none"> skills of leadership higher chances to be promoted to managerial positions.
<ul style="list-style-type: none"> L.O 4 	<ul style="list-style-type: none"> improves the prior knowledge level of students regarding entrepreneurship in pursuit of educational improvement. 	<ul style="list-style-type: none"> will have a better view of the changes, reforms able to differ the entrepreneurship characteristics at a local level able to compare differentiations entrepreneurship characteristics among countries

<ul style="list-style-type: none"> • L.O 5 	<ul style="list-style-type: none"> • able to use his knowledge to create his “own” enterprise 	<ul style="list-style-type: none"> • skills such as self-confidence to develop new projects • will have a better view of planning
<ul style="list-style-type: none"> • L.O 6 	<ul style="list-style-type: none"> • able to encourage others, • sharing innovations, opportunities, and possibilities. 	<ul style="list-style-type: none"> • gain fundamental persistence skills

Table 4: Benefits of Entrepreneurship Education for an Engineering Student Studying at Northeastern University

Ana Avallani, a member of the Royal Academy of Engineering (the National Academy of Engineering in the UK), emphasized the importance of closing the business skills gap to drive successful engineering enterprises (Avallani, 2019). She identified five business skills for engineering entrepreneurs: *Leadership, People Management, Strategy Development, Financial Management, Networking*.

Other organizations, institutions, and researchers have suggested more skills; however, for a more qualitative analysis, the higher the number of skills highlighted, the easier it is to find them, as shown in Table 4. Therefore, analyzing only five main skills will help to observe the importance of these skills in the learning outcomes of universities.

The skills identified suggest that engineers, who are good leaders, possess competencies that enable them to navigate complex economic and regulatory environments, manage stakeholders effectively, and negotiate deals that capitalize on growth opportunities (Avallani, 2019). Having excellent negotiation skills is vital for students to secure the most beneficial outcomes for their business, such as acquiring new contracts or funding, and leading their teams through successful negotiations will directly contribute to their financial growth (Richards et al., 2020).

- a) At Northeastern University, “Leadership” is a skill connected with learning outcomes three and six. Descriptions of these learning outcomes ensure that they provide students with a full set of leadership skills (Northeastern. edu, 2018).
- b) The acquisition and retention of the right skills and experience have been consistently identified as primary challenges for future growth (Ito, 2019). The success of a business ultimately depends on its people; thus, it is important to not only hire employees who possess the necessary skills to bridge any gaps within the workforce, but also to create an environment that

fosters their growth and development (Ulrich & Allen, 2014). Checking the learning outcomes, it is not clear if there is a chapter that highlights the importance of “People Management” however LO.1, gives to students some skills like how to challenge current institutional assumptions, how to identify challenges, risks, and opportunities to generate innovative and entrepreneurial thinking, how to leverage relationships and resources for actions of change and improvement (northeastern.edu, 2018). Students with these skills may be good managers and engineers (Elert & Henrekson, 2020). However, better treatment of “People Management” is needed in the future.

c) Establishing a strategy provides a long-term sense of direction and roadmap and sets milestones along the way. This differs from the day-to-day business and delivery planning. To make the most of your strategic planning, it is crucial to set clear, measurable goals and benchmarks to assess your progress (George et al., 2019). Learning outcome number five covers all these skills, and elements of “Strategy Development” in learning outcomes numbers one, two, and four are also found. Therefore, further improvement is required.

d) Financial Management

A financially stable business is crucial for success, especially during periods of growth when expenses tend to exceed revenue (Gray et al. 2018). Similarities are also found with the skill of “People management.” There is no specified learning outcome that covers this skill, but it can be noticed that what students learn from (LO1) and (LO2) helps them develop financial managerial skills. In the future, changes or improvements may be helpful.

e) Networking

Networking is not something that comes naturally to everyone, but it is a skill that should not be overlooked. Networking can not only help secure funding and investment, but also provide valuable technical knowledge and support during challenging times (Keeun Lee, 2015). A better covering of this skill is found in learning outcome number four; however, all the learning outcomes help the students to have “networking” skills.

This analysis shows that for the best five business skills in engineering by the Royal Academy of Engineering, Northeastern University covers all of them. Leadership and Strategic Development are fully covered by university learning outcomes, networking is satisfactorily covered, and people’s skills and *financial management* need to be improved in the future.

Cultivating an entrepreneurial mindset: The role of innovation education

Entrepreneurship education should emphasize developing students' innovation mindsets as well as their ability to pursue both process and product innovation. According to Zhu et al. (2021), process innovation positively affects job creation, whereas product innovation negatively affects employment by increasing productivity. The effects of innovation differ depending on a company's job-skill structure.

Process innovation refers to the introduction of new or improved methods, techniques, or systems to enhance the efficiency, effectiveness, and quality of business processes within an organization; increase production efficiency; and decrease costs, resulting in increased demand and employment (Toivonen & Tuominen, 2009). Product innovation refers to the creation and development of new or improved products or services that offer customers enhanced features, functionality, or value (Toivonen & Tuominen, 2009). On the other hand, it increases productivity, which can displace workers but also increases market share and employment. Job losses and gains result from the indirect demand for both new and existing products. A company's job skill structure influences its innovation benefits (Zhu et al., 2021).

As technology and markets evolve faster than educational systems do, the digital skills gap widens (Hampton et al., 2020). Online job platforms provide insight into the enormous challenges of reskilling the workforce. It connects millions of remote workers and employers worldwide (Hampton et al. 2020). As technical and societal transformations outstrip national education systems, the digital skill gap expands further and the specific skill needs for grasping future technologies remain hazy (Stephany, 2021).

These platforms may help to comprehend this massive reskilling difficulty and create a globally integrated market that connects millions of buyers and suppliers of cognitive work that can be performed remotely. As technological development accelerates and task automation reshuffles occupational skill needs, the global workforce is constantly under pressure to reskill. Therefore, mismatches in the job market should be avoided. However, traditional reskilling through national education policies is too sluggish to keep up with the rapid pace of technological development, and the precise skill needs for emerging new technologies are unclear (Stephany, 2021).

Five factors have been linked to effective digital transformation among employees at the individual, group, and organizational levels: *technology acceptance and adoption; perceptions and attitudes toward technology and digital transformation; skills and training; workplace resilience and adaptability;*

and work-related well-being (Trenerry et al., 2021). Three traits were identified as being important for group-level digital transformation: *team communication and cooperation, workplace connections and team identity, and team flexibility and resilience*. Finally, three organizational determinants of digital transformation have been proposed: *leadership, human resources, and organizational climate and culture* (Trenerry et al., 2021).

Entrepreneurship as a competence in education

Since the early years of the twenty-first century, large organizations and governments have prioritized the development of entrepreneurial potential for citizens and businesses.

Entrepreneurship Education was recognized as key by the European Commission in 2003, and it was declared one of the eight core competences required by all members of a knowledge-based society in 2006. According to the framework developed by the European Commission, it is necessary to define entrepreneurship as a competency; develop a reference framework that outlines its elements in terms of knowledge, skills, and attitudes; and develop tools that allow citizens to successfully test and develop this competency (European Commission, 2016). Many studies and organizations have begun to construct competence frameworks to bridge the gap between education and employment. This can be referred to as the framework developed by the European Commission, which is optimally designed and updated to reflect the characteristics of the 27-member countries (governments). Their framework (European Commission, 2016) was developed using a mixed-method approach, academic literature, comprehensive review, and a set of consultations of iterative stakeholders. It applies to groups and individuals, and refers to creations in the private, public, or hybrid combination sectors. The framework comprises three competence categories, ideas and opportunities, resources, and action, and encompasses all types of entrepreneurship (intrapreneurship, social entrepreneurship, digital entrepreneurship, and green entrepreneurship). Each category comprises five competencies, and the 15 competencies as a whole serve as the foundation for entrepreneurship (European Commission, 2016). This framework also offers 448 learning outcomes, implying its applicability to educational contests and industries.

Prior to concluding its framework, the European Commission described entrepreneurship as a crosscutting skill that applies to all parts of life, from personal development to starting the labor market as a self-employed or employee individual, as well as start-up businesses. The framework includes a description of each competency that distils it down to its core components, as well as a tip for each that converts the skill labels into plain English exhortations for the student.

The establishment of such frameworks aids the assessment of entrepreneurial competence progression in the education and employment sectors. Another critical aspect is the development of tools that enable Europeans to (self)assess and check their entrepreneurial talent to secure work opportunities (Castro et al. 2018).

The ability to be an entrepreneur then applies to all aspects of life, allowing citizens to foster their personal growth; actively contribute to social development; enter the workforce as an employee or as a self-employed person; and launch or expand businesses with cultural, social, or commercial goals (Schaefer & Minello, 2019). The three framework areas have been written in a way that emphasizes entrepreneurial competency as the capacity to mobilize resources to turn ideas and possibilities into action. This may be private, tangible, or intangible (European Commission, 2016).

Entrepreneurial learning and value creation can occur in various contexts. The European Commission Framework excludes any environment, particularly formal educational contexts. The progression model bridges the gap between education, employment, and civic participation by emphasizing the development of capabilities through the creation of entrepreneurial value. In this regard, the European Commission Framework is applicable to all learning circumstances, including formal, informal, and informal (European Commission, 2016).

Developing a digital mindset: A key competency for entrepreneurs

According to Trener et al. (2021) and Antonizzi and Smuts (2020), entrepreneurs must cultivate a digital mindset to succeed in today's increasingly technology-driven business environment. Adopting new technologies, developing positive attitudes toward technological change, acquiring relevant skills through training, building resilience and adaptability, and maintaining well-being have been identified as five key variables for cultivating a digital mindset (Trener et al., 2021). While digital disruption may have a significant impact on some traditional jobs, it also opens up a plethora of new opportunities for entrepreneurs (McKinsey, 2013).

New technologies are transforming the skills and abilities required for entrepreneurship (McKinsey 2013). Entrepreneurs need to have the capacity and willingness to learn new skills to leverage technologies, such as artificial intelligence, nanotechnology, robotics, the Internet of Things, and cybersecurity. Digital competencies, including fundamental skills, knowledge, and ability to operate in technology-enabled work environments, are crucial for entrepreneurs (Trener et al., 2021). There is a growing demand for entrepreneurs and startups with specialized technical talent in emerging fields,

such as software engineering, data science, and UX design (Konopik et al., 2022). According to a LinkedIn survey, the essential technical skills that many startups and entrepreneurs seek include proficiency in AI, robotics, IoT, and digital platforms, such as mobile devices, tablets, and smartphones (Konopik et al., 2022).

Cultivating a digital mindset is critical for entrepreneurs seeking to identify and capitalize on new opportunities in the digital economy (Antonizzi & Smuts, 2020). The adoption of technology, positive attitudes toward change, continuous learning, resilience, and well-being are critical for entrepreneurs to thrive in the digital transformation era (Antonizzi & Smuts, 2020). Entrepreneurship education programs must emphasize the development of these critical digital competencies and mindsets to prepare students for future digital entrepreneurial success (Konopik et al., 2022).

Synthesis

Part II analyses the necessity of adding entrepreneurship education to higher education programs to educate engineering students on the business and entrepreneurial skills required in today's job market. It explores the efficacy of applying engineering skills in small and medium-sized enterprises and identifies various causes of ineffectiveness among young employees, such as a lack of information, multitasking, emotions, and analytical paralysis.

This section explores whether the Entrepreneurship Education course syllabi covers the required capabilities, or whether it is relevant and applicable to engineering students' entrepreneurial and engineering careers.

Product innovation has a favorable influence on job creation, but process innovation has a mixed impact on job creation due to higher productivity. Entrepreneurship education should focus on developing students' innovation mindsets and abilities to seek process and product innovation. These findings suggest that entrepreneurship education should focus on encouraging students' innovative thinking and providing them with tools to navigate both process and product innovation, considering the various effects on job creation and the need to adapt to rapidly changing technology and market demands.

This section also explains why Entrepreneurship Education is important in higher education, as well as how the European Commission created a framework that defines entrepreneurship as a competency and outlines its elements in terms of knowledge, skills, and attitudes. The framework consists of three competency categories and fifteen competencies that form the foundation of entrepreneurship. It also

incorporates learning outcomes, with the goal of bridging the gap between employment and education by providing tools to analyze and develop entrepreneurial ability.

Important highlights of this section include the findings of Trenergy et al. (2021) and Antonizzi and Smuts (2020), who proposed that entrepreneurs should adopt a digital mindset to prosper in today's technology-driven business environment. Adopting new technologies, having good attitudes toward technological change, obtaining essential skills, creating resilience and adaptation, and sustaining well-being are all parts of this process. It also demonstrates the increased demand for entrepreneurs with specialized technical abilities in developing industries, as well as the importance of entrepreneurship education programs in preparing students for digital entrepreneurial success.

Part III: Framework of the Educational Technology Landscape

As mentioned in Part II, the field of educational technology has undergone significant changes in recent years with the advent of new advancements in technologies and the rise of disruptive technologies in Industry 4.0, as adopted and used by Lewis (2020). To keep pace with these changes and to approach technological advancements and traditional technologies in education, a comprehensive and integrated framework with a special focus on higher education was built.

A framework for the adoption of the aforementioned educational technologies was created, drawing inspiration from NASA 2020 Technology Taxonomy. The framework is based on the five pillars essential for identifying relevant technologies in higher education and beyond (see Figure 5). These are the pillars:

(a) Educational technologies for enabling learning

This category of educational technologies facilitates the application of four major learning theories: constructivism, cognitivism, connectivism, and behaviorism.

(b) Educational technologies and Bloom's taxonomy

This pillar includes technologies that help learners function at the six levels of Bloom's taxonomy, which is a hierarchical classification of learning objectives.

(c) Educational technologies for applying ADDIE instructional design model

Educational technologies for analysis, design, development, implementation, and evaluation were used in the ADDIE instructional design model.

(d) Educational technologies for applying ARCS-V motivational design model

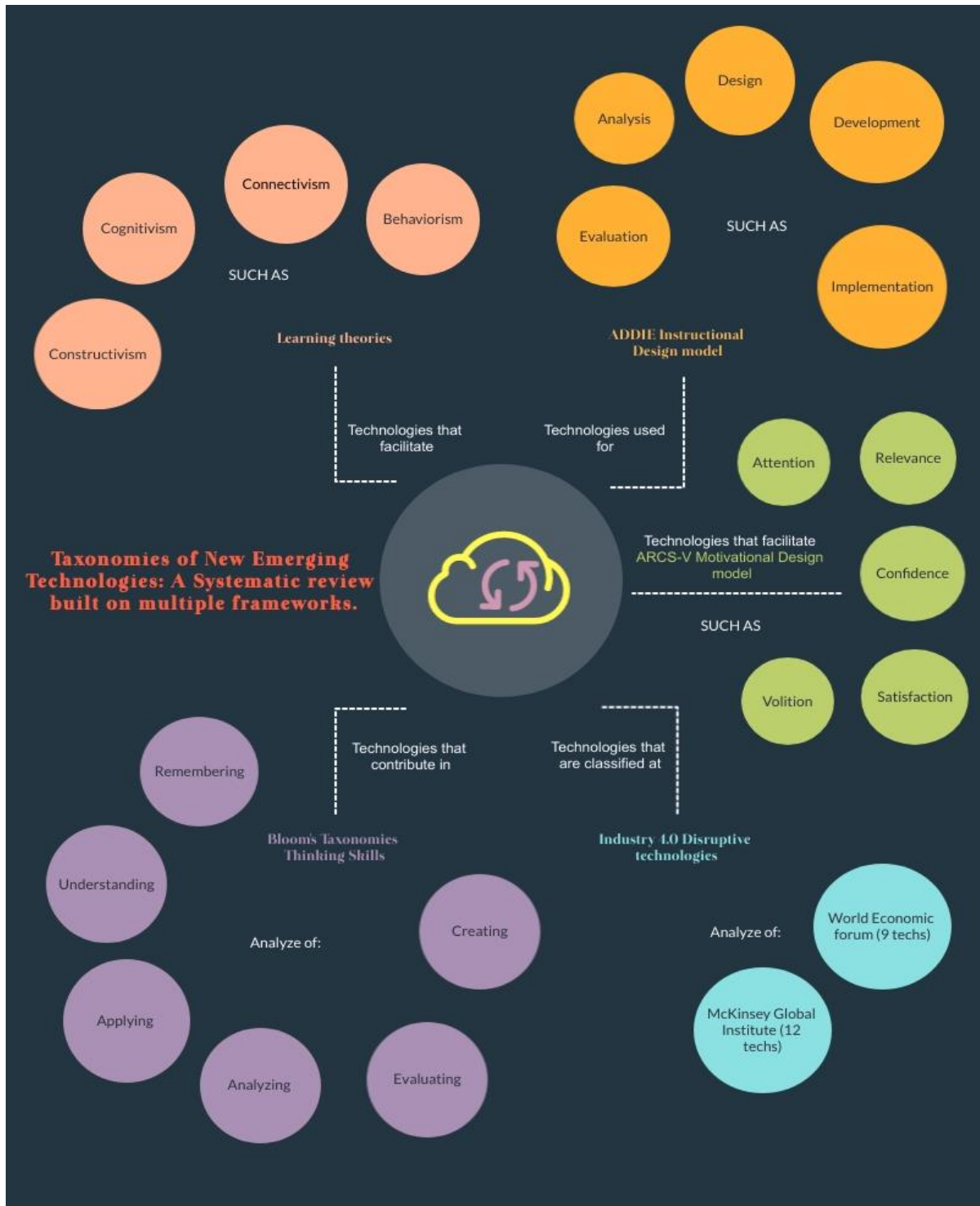


Figure 5: Framework of the Educational Technology Landscape

This pillar includes technologies that enhance attention, relevance, confidence, satisfaction, and volition, all of which are essential components of the ARCS-V Motivational Design Model.

(e) Disruptive technologies of Industry 4.0

The final pillar covers the technologies proposed by the World Economic Forum at the McKinsey Global Institute, which are the key drivers of the Fourth Industrial Revolution.

The resulting Framework of the Educational Technology Landscape provides a comprehensive view of the field, allowing educators to design more effective interventions. It provides a detailed overview and valuable insights into the adoption of educational technologies by integrating these five pillars. Van Wyk et al. (2020) provide additional evidence for the efficacy of a similar approach by demonstrating its successful application in the development of an IT course for emerging technologies.

First, educational technologies play a pivotal role in enhancing learning experience by facilitating the application of various learning theories and alternatives. Learning theories, such as constructivism, cognitivism, connectivism, and behaviorism, have been instrumental in shaping the course of education (Sargeant et al., 2006). Second, educational technologies that contribute to applying Bloom's taxonomy classify cognitive learning objectives into six levels: remembering, understanding, applying, analyzing, evaluating, and creating (Adams, 2015).

Third, there are classified technologies used for the ADDIE model, which is a systematic approach to instructional design comprising five stages: analysis, design, development, implementation, and evaluation (Peterson, 2003).

Fourth, technologies that facilitate the ARCS-V model are classified and designed to help educators create and maintain motivation during the learning process (Wongwiwatthanakit & Popovich, 2000). The focus was on the technologies used for the five main components: attention, relevance, confidence, satisfaction, and volition. Finally, disruptive educational and non-educational technologies have been described as part of Industry 4.0, as identified by the World Economic Forum and the McKinsey Global Institute showed in their study of (Rübmann, et al., 2015). These disruptive technologies may shape the future of education and industry in the near future according to the mentioned two institutes.

Educational technologies for enabling learning

Theorists, scholars, and educational practitioners have characterized learning in various ways. Many academics agree with the definition of (Schunk, 2012), which states that " Learning is an enduring change in behavior or in the capacity to behave in a given fashion, which results from practice or other forms of experience." Learning theories such as empiricism and rationalism have influenced current learning theories. According to Schunk (2012), empiricism is a fundamental source of knowledge. Rationalism is the belief that knowledge is acquired from reason alone, without the use of senses (Schunk, 2012). Cognitivism, connectivism, behaviorism, and constructivism are examples of modern learning theories (Davis et al., 2019). According to prior research, learning theories describe the broad principles that students use to acquire, retain, and remember knowledge (Sahin & Dogantay, 2018). This section highlights the technologies that aid in the development and acceleration of these processes.

Behaviorism theory focuses on observing and quantifying behavior or actions, as well as emphasizing the significance of the consequences of conduct or action (Saari, 2019). According to behaviorism, learning is associated with changes in the form or frequency of observable performance (Ertmer & Newby, 2013). To achieve this, researchers have highlighted the need to demonstrate a suitable response to the introduction of certain environmental stimuli.

In the digital era, information is spread across networks, where linkages and interconnections shape future-oriented learning; this type of learning is known as constructivism (Kitizo, 2016). Constructivism maps the world's structure to learners (Ertmer & Newby, 2013).

In the 1950s, learning theory began to shift away from conventional behavioral and cognitive science models. Educators have begun to emphasize various complex cognitive processes, including thinking, problem-solving, language, idea development, and information processing, as the foundation of cognitivism (Ertmer & Newby, 2013).

Connectivism combines ideas explored by theories of chaos, networks, complexity, and self-organization (Siemens, 2005). Siemens defined connectivism as a learning theory that emphasizes the fact that decisions are made on a continually changing foundation. Understanding what is significant is critical to connectivism.

In their research on developing an IT course for emerging technologies, Van Wyk et al. (2020) analyzed learning theories to create a framework for how each learning theory helps to build and develop a

course. Davis et al. (2019) provided a view of each learning theory. They suggest the main theorists for each, and share the main characteristics and methods that each theory uses to address better teaching. Theorists of each learning theory were not the object of this study, because the aim was to build a multi-framework for the advancement of educational technology. First, it introduces all the technological advancements that facilitate learning theories.

	Cognitivism	Connectivism	Behaviorism	Constructivism
Characteristics	Structured Engaged Higher-order thinking Evaluate	Problem solving Collaborative Experience based Build on ideas	Reinforcement Passive External processing Evaluate	Brainstorming Problem based learning Collaborative Discovering
Methods	Lecture Multi-choice Visual tools	Sharing Research Collaborative	Lecture Multi-choice Repeat	Discover Peer Review Collaborative
Technologies	Digital libraries platforms (Google books Open library Ibiblio, etc.) Open website digital databases for academic studies (Web of Science Scopus Google Scholar IEEE, etc.)	Massive open online courses (MOOC) platforms Platforms that enable webinars and web-conferencing (Coursera, Canvas Network Udemy, Cognitive class, , edX, Khan Academy, Zoom, Microsoft Team etc.)	Opensource learning platforms (Moodle Google Classroom Canvas LMS, etc.)	Enabling learning interactions and activities platforms (Twiddla, Bubbl, Edmodo, Wikispaces, etc.) Statistical data analysis software (SPSS, SAS, Stata R, Python, Excel, MATLAB, NVivo, MAXQDA, ATLAS.ti, etc.)

Table 5: Identified Educational Technologies of Learning Theories

Table 5 was built considering the contribution of Davis et al. (2019) and their findings on the methods used to deliver each learning theory and the characteristics of the learning theories. More specifically, the “characteristics” and “methods” were obtained from Figure 1 on page 4 of the study by Van Wyk et al.(2020). Technologies were searched through academic papers, websites, books, etc. Kay and

Kibble's (2015) study is important for connecting each category of learning theories with their respective emerging technologies. Both studies converged on the same methods and suggested nearly the same tools, helping to select emerging technologies properly. These technologies are listed in Table 5.

Cognitivism and behaviorism involve common lecture methods and involve multiple choices. Therefore, some emerging technologies belong to both learning theories as facilitators. In addition, the method "collaborative" method appears in both "connectivism" and "constructivism." Therefore, these learning theories intersect with our proposed method.

Collaborative learning has been identified as a key characteristic of "connectivism" and "constructivism." Davis et al. (2019) contributed to building two patterns: the first between cognitivism and behaviorism and the second between connectivism and constructivism.

Rubens et al. (2016) identify some of the most common emerging technologies (Rubens, et al., 2016). They classified 13 existing technological trends (instead of many types of research that use "new emerging technologies") using a framework of three main categories: "technologies that contribute to the enrichment of teaching and learning," "technologies that facilitate the incorporation of flexibility in education," and "technologies that facilitate adaptive learning." They also suggested at least ten more technologies that were not considered in their classification. As detailed by Rubens et al. (2016), all technological trends were studied in their report, but most were described and identified as Industry 4.0 (first used by the German Federal Ministry of Education in 2011. The same technologies were studied earlier in 2013 by the McKinsey Global Institute, and are well known as disruptive technologies (Manyika, et al., 2013).

Educational technologies that facilitate cognitivist learning

Based on the above introduction and the characteristics and methods in Table 5, the identified educational technologies that facilitate cognitivist learning are as follows.

Digital libraries platforms

A digital library platform is built by collecting electronic documents (books, studies, etc.) on the internet or other servers that are used to store electronic documents. Depending on the availability of a digital library, users may request access to books, magazines, videos, sounds, or pictures.

After conducting a search on the Internet, using “Google Chrome” browser it was found that some of the most important online digital library platforms are Google Books, Open Library and Ibiblio.

Google Books was first launched in 2004 by Google Inc., and enables users to search for books or magazines that Google has scanned and stored in its database. The authors provided books or articles through the Google Books Partner Program.

Open libraries provide hundreds of thousands of scanned books and articles. Books can either be read page-to-page in a browser or downloaded in PDF formats on an electronic device, and then the reader may choose to read them electronically or print articles (with permission). The first open libraries were launched in 2006.

Ibiblio is an open-source content digital platform that is first launched in 1992 and formerly was known as *SunSITE.unc.edu* and *MetaLab.unc.edu*. This platform enables user content including literature, software, music art, history, politics, science, and cultural studies.

Open website digital databases for academic studies

An academic database is a collection of information commonly used for research and writing, including access to academic journals. We use “open website digital databases for academic studies” to describe mainly academic journals or similar platforms. Journal articles included professional studies published by experts that addressed topics in a specified field.

Detailed online searches suggested that some of the most important research databases are Scopus, Web of Science, IEEE, Google Scholar, PubMed, and JSTOR.

Web of Science is considered the world’s largest publisher-neutral citation index and research intelligence platform (webofknowledge.com). The Web of Science was launched in 1997, was originally produced by the Institute for Scientific Information, and is currently maintained by Clarivate Analytics.

Scopus is the largest database of abstracts and citations in the peer-reviewed literature, including scientific journals, books, and conference proceedings. (Scopus.com). It was launched by Elsevier in 2004, and covers more than 36 000 articles.

Google Scholar is a search engine that provides access to scholarly literature, allowing users to search across multiple disciplines and sources, including articles, theses, books, abstracts, and court opinions, from various sources such as academic publishers, professional societies, online repositories, universities, and other websites. It was launched in 2004 (scholar.google.com). The Institute of

Electrical and Electronics Engineers (IEEE) is the world's largest technical professional organization for the advancement of technology (ieee.org), and its database provides articles in engineering, technology, and similar fields. IEEE was founded in 1963.

PubMed, founded in 1996, provides over 32 million citations in the biomedical literature, life science journals, and online books (Pubmed.ncbi.nlm.nih.gov). The JSTOR, founded in 1995, is a digital library of academic journals, books, and primary sources (Jstor.org).

Educational technologies that facilitate connective learning

Based on the above introduction and the characteristics and methods in Table 5, the identified educational technologies that facilitate connective learning are as follows.

Massive open online courses (MOOC) platforms

Massive Open Online Courses (MOOCs) are free online courses that are accessible to anyone who enrolls. These courses help learners advance their careers and provide affordable and flexible methods to acquire new skills. Dave Cormier at the University of Prince Edward Island and Bryan Alexander of the National Institute first used the term MOOC in 2008 for Technology in Liberal Education in response to an open online course (Nova Southeastern University, 2021). In accordance with the fact that MOOCs boost the learning of connectivism, the first course given online by a MOOC platform was called "Connectivism and Connective Knowledge" and was presented to 25 tuition fee-paying students in Extended Education at the University of Manitoba (Nova Southeastern University, 2021).

Some of the most popular massive open online course platforms include Coursera, Khan Academy, Cognitive Class, Canvas Network, EdX, and Udemy (Ngo, 2020).

Coursera, founded by two professors of Stanford in 2012, is one of the largest open-access course providers in the world (Ngo, 2020). The Coursera course catalog contains over 3900 courses and the platform has approximately 190 partnerships with universities and companies worldwide. The users were satisfied with the platform because 87% reported career benefits.

MOOCs are free online courses that are accessible to anyone who enrolls. These courses help learners advance in their careers and provide affordable and flexible methods for acquiring new skills (Ngo, 2020). Khan Academy, founded in 2007, is known for the support given to K-12 students, providing free content in mathematics, English, chemistry, science, etc.

A cognitive class is a platform launched by IBM in 2015 to disseminate data literacy through free classes to students and experienced IT professionals. The most popular courses include Python for data science, reactive architecture, digital analytics, and regression (Ngo, 2020).

The Canvas network is a platform launched in 2013 that provides professional development for teachers, school administrators, and academic school faculty. Topics include assessment of student affairs and research data management for librarians.

In May 2012, Harvard University and MIT jointly launched edX, a massive open online course (MOOC) platform that currently provides more than 2500 courses from 140 higher education institutions worldwide, covering an extensive range of popular subjects such as data science, engineering, and humanities. EdX utilizes an open-source learning system that allows technologists and educators to enhance their MOOCs by incorporating tools that cater to the specific needs of their students (Ngo, 2020).

Udemy, launched in 2010, is the largest online learning provider, offers over 150 000 courses in more than 65 languages. Many courses require fees, and recently Udemy has been providing finance and accounting courses that are needed for learners to operate in the cryptocurrency market (Ngo, 2020).

Platforms that enable webinars and web-conferencing

Reviewing the characteristics of connectivism and the methods used to approach this learning theory, it was found that platforms that enable webinars or web conferences are strong tools on which educational institutions can rely and use these platforms successfully. Webinars help educators share their ideas, exchange experiences, enhance collaboration, solve problems, and, most importantly, enable online classes when on-campus classes are not possible for various reasons.

Using a basic web search, different platforms, such as Zoom, Microsoft Teams, GoToMeeting, and Cisco Webex Meetings, have been found to conduct online classes, webinars, and conferences.

Zoom is video telephony software that provides a chatting service that allows up to 100 participants free of charge. Zooming in to education can help students, faculty, and staff engage in learning, collaboration, and administration. Zoom supports remote and hybrid learning environments for primary and secondary schools, and higher education (zoom.us). Zoom was launched in 2012; however, the number of users increased significantly by 2020 because of the need to replace campus classes or conferences.

Microsoft Teams is another platform launched by Microsoft in 2017, that enables video conferences and online meetings. Microsoft teams appeared on their official websites to show that teams with up to 10 000 participants can conduct meetings using this platform.

Educational technologies that facilitate behaviorist learning

Based on the above introduction and the characteristics and methods of Table 5, the identified educational technologies that facilitate behaviorist learning include the following.

Open-source learning platforms

Behavioral learning theory relies on open-source learning platforms, as Kay and Kibble (2015) suggest. An open-source online learning platform is a software for which the original source code is freely available and may be redistributed and modified according to the requirements of the user (Economic Times, 2021).

Moodle is the world's most popular and used platform (Young, 2018). As an open-source platform, it is also considered a learning-management system. Moodle was launched in 2002 with the goal of offering educators, administrators, and learners a single, comprehensive, secure, and integrated platform for creating personalized learning experiences (Moodle. org).

Moodle's success has created space for other similar platforms, but there are two top alternatives to Moodle: Canvas LMS and Google Classroom.

The Canvas LMS, launched in 2011, is a learning-management system that facilitates teaching and learning from the first years of education to college faculties and business leaders. The Canvas LSM offers three packages for K-12 education, higher education, and a business platform.

Google Classroom, launched in 2014, is a free web platform that offers fewer services than Moodle. However, the main purpose of Google Classroom is to simplify online assessments, as it helps in the creation, distribution, and grading of assessments.

Educational technologies that facilitate constructivist learning

Based on the above introduction and the characteristics and methods in Table 5, the identified educational technologies that facilitate constructivist learning are as follows.

Enabling learning interactions and activities platforms

Davis et al. (2019) and Kay and Kibble (2015) highlight the importance of learning as collaborative and interactive when analyzing the characteristics of constructivism. Inclusive expressions were used to classify the online platforms that contributed to this matter as those that enabled learning, interactions, and activities.

The Twiddla, Bubbl, Edmodo, and Wikispaces are among the most commonly used platforms. Twiddla is available on an online whiteboard, and users can mark websites, graphics, photos, and drawings. Educators may browse the platform with students during tutoring sessions. Bubbl is a mind-mapping software application that helps students and teachers collaborate, present, brainstorm, and visualize (bubbl.us). Edmodo connects all learners with the people and resources required to achieve their full potential (Edmodo.com). Edmodo, founded in 2008, offers a communication, collaboration, and coaching platform for K-12 schools and teachers. Wikispaces is a social writing platform used as a classroom management tool to keep teachers and students organized and on tasks. Wikispaces was founded in 2005 and provides easy-to-use templates. It is free of charge and has various assessment tools (Pappas et al. 2013).

Statistical data analysis software

Constructivism emphasizes the active production of knowledge by learners during the learning process (Manchulenko et al., 2021). This is in line with data analysis, in which learners engage with the data, investigate it, and draw conclusions and interpretations. Through these interactions and discoveries, learners actively create knowledge and insights (Eskrootchi & Oskrochi, 2010).

Constructivism strongly emphasizes how students create knowledge through active learning and experience (Jirasatjanukul & Jeerungsuwan, 2018). Statistical data analysis tools facilitate active learning by enabling students to modify data, visualize data with charts and graphs, test hypotheses, and conduct experiments to evaluate data in various ways (Horton et al., 2014). Learning is facilitated by practical experience using real data (Manchulenko et al. 2021).

According to constructivism, students build knowledge from their experiences, mental models, and beliefs (Suhendi & Purwarno, 2018). The learner applies domain knowledge and beliefs to the process of comprehending and making sense of the data (Manchulenko et al., 2021). Learners create new meanings and insights based on their current knowledge and beliefs (Horton et al.2014).

The viewpoints and interpretations of individual learners are the primary focus of constructivism (Suhendi & Purwarno, 2018). Learners can study data using data analysis tools in an open, exploratory environment, based on their individual viewpoints and interpretations (Barcellos et al., 2017). Several approaches can be used to examine specific data collections.

The most commonly used platforms include Statistical Package for Social Sciences (SPSS), Python, Microsoft Excel, and MATLAB.

SPSS is a popular statistical analysis software used in analytics, survey research, and statistical modeling (ibm.com).

SAS is a software suite used for advanced analytics, business intelligence, data management, and predictive analytics (sas.com). Stata is a completely integrated statistical software package that provides everything required for data analysis, management, and graphics (Stata.com). R is a free software environment for statistical computing and graphics (R-project.org). Python is a popular programming language used for data analysis and visualization in addition to web development and software engineering (Python.org). Microsoft Excel is a spreadsheet application used to organize, calculate, and visualize data using charts, graphs, and pivot tables (Microsoft.com). MATLAB is a programming language used by engineers and scientists to analyze and visualize data, as well as for numerical computing (MathWorks.com). NVivo is a software for analyzing qualitative and mixed-methods data used in research in many fields, including social sciences, public health, and market research (lumivero.com). MAXQDA is a software for qualitative and mixed-methods data analysis used in scientific and market research (maxqda.com). ATLAS.ti is a powerful workbench for the qualitative analysis of textual, graphical, audio, and video data (atlasti.com).

Educational technologies and Bloom's Taxonomy

Bloom's taxonomy organizes thinking skills into six hierarchically arranged categories, ranging from lower to higher zones of thinking complexity (Fastiggi, 2019). Lower complexity thinking zones aim to provide a foundation for "remembering" and "understanding," whereas higher complexity higher zones establish a foundation for "applying," "analyzing," "evaluating," and "creating" (Van Wyk et al., 2020), (Stanny, 2016). Hierarchies are built using verbs chosen to describe the expected cognitive abilities and behavior in a learning result (Stanny, 2016).

Bloom's taxonomy's primary idea is that each verb indicates a progressive increase in thinking skills. Verbs define knowledge acquisition and fact memorization in lower zones of the taxonomy, whereas in

higher zones, they define more complex thinking skills such as applying knowledge or different gains in lower zones to practical problems, analyzing concept creation of new knowledge, or other interpretations of existing knowledge (Stanny, 2016); (Van Wyk et al., 2020).

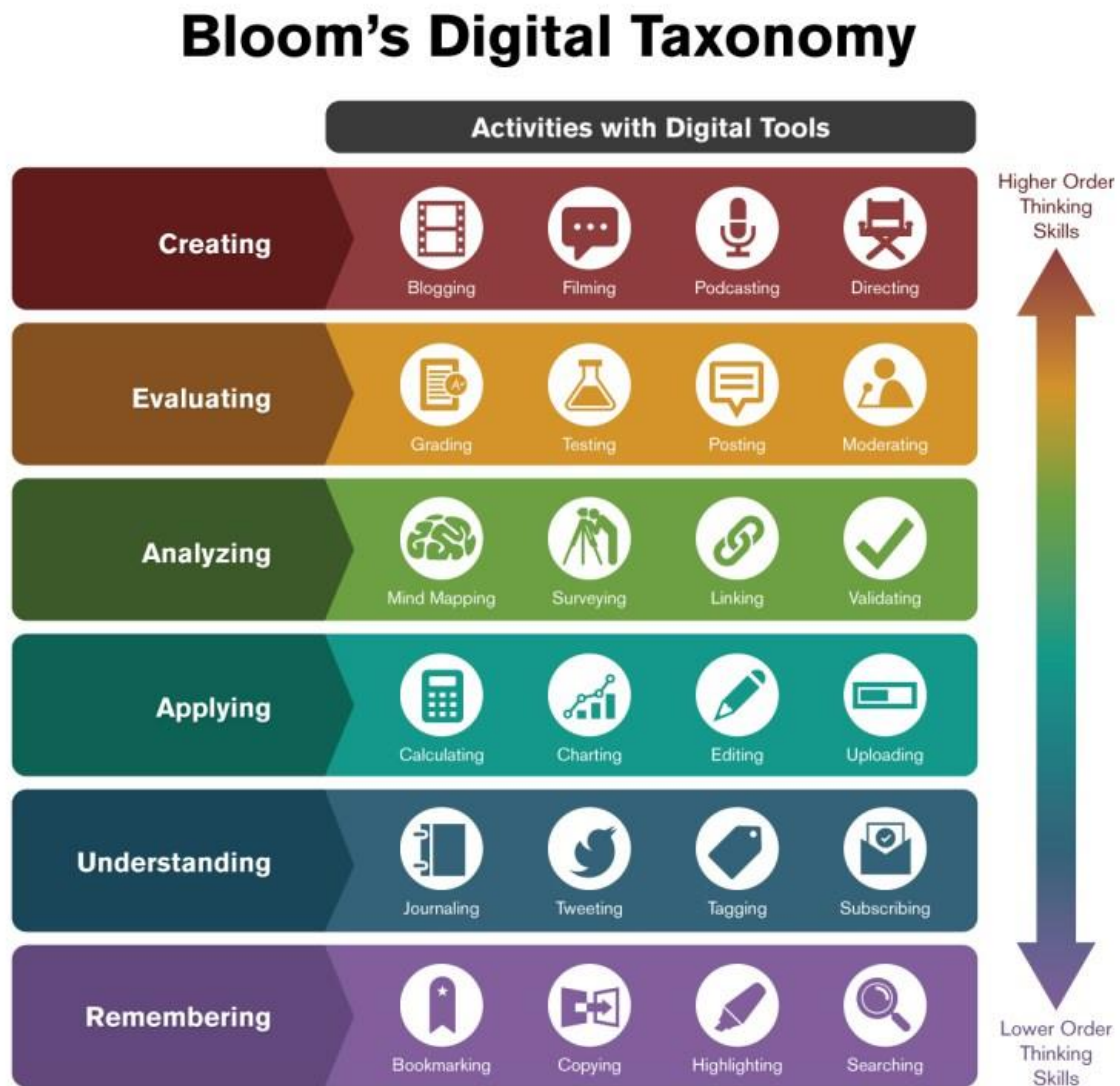


Figure 6: Bloom's Taxonomy levels updated by (Sneed, 2016)

Many authors have studied and analyzed each verb and created articles with sub-categories composed of many sub-verbs in the main levels of thinking of Bloom's taxonomy. Churches (2008) has contributed to the revision of Bloom's taxonomy and has involved new behaviors, actions, and learning opportunities emerging as technology advances and has become more ubiquitous. Churches (2008) provides an updated taxonomy that includes many emerging verbs owing to technological advances up to that period. Churches (2008) has introduced 78 new verbs for the level of thinking skills and mostly

of the verbs have derive from the technological trends (for instance it can be mentioned verbs such as programming, podcasting, broadcasting, emailing etc.) Of the verbs in their map, they suggested 19 main verbs relevant to 2008 technology. In their study, Arizona State University (Sneed, 2016) introduced the idea of Churches (2008) to a new level. Updating the emerging technologies that were developed until 2016 and filtering the verbs of Churches (2008) and other authors who have updated the taxonomy of Bloom (Sneed, 2016) have mapped twenty-four verbs that are linked to existing levels of thinking (Figure 6). Each level of thinking is connected to four verbs, and all verbs characterize newly emerging technologies. Based on the verbs identified by Sneed (2016), we found the corresponding technologies by searching academic papers, books, websites, etc. Specifically, technological verbs are connected to technologies used in education. In certain cases, multiple verbs may be related to the same educational technology.

Bloom's levels of thinking	Remembering	Understanding	Applying
Sneed 2016	Bookmarking Copying Highlighting Searching	Journaling Tweeting Tagging Subscribing	Calculating Charting Editing Uploading
Technologies	Web Browsers Word Processor Programs	Social media Online Video Platforms	Spreadsheet programs Cloud storage services
Bloom's levels of thinking	Analyzing	Evaluating	Creating
Sneed 2016	Mind-mapping Surveying Linking Validating	Grading Testing Posting Moderating	Blogging Filming Podcasting Directing
Technologies	Survey administration	Teacher gradebook	Video-making software

	software's	software's	
	Mind-mapping		Video-recording software
	software's		Teacher's blogs

Table 6: Educational technologies used in Bloom's Taxonomy

Technologies that help in “remembering”

Based on the above introduction and the findings of Sneed (2016) shown in Table 6, the identified educational technologies that help in “remembering” are as follows:

Web browsers

A web browser is a software program that allows users to request and retrieve webpages and other resources from the servers on the web. The first web browser created in 1990, WorldWideWeb, was created by Tim Berners-Lee. In 1995, Microsoft released Internet Explorer and other companies such as Mozilla Firefox, Safari, and Google Chrome. Currently, the most used web browser is Google Chrome, with a 64.1 % global market share for all devices, followed by Apple's Safari, with 19.03% (StatCounter Global Stats, 2021).

Word Processor Programs

A word-processing program, such as a resume or report, is used to manipulate text documents (Zandbergen, 2021). Word processing programs enable the creation, editing, and saving of formatted documents; creation of tables; insertion of pictures; and other complex operations. The first word processor program was the Electric Pencil, which was released in 1976. The leading word processor is Microsoft Word, released in 1983, which is used by more than 1.2 billion users worldwide (Goskills, 2021).

Technologies that help in “understanding”

Based on the above introduction and the findings of Sneed (2016) shown in Table 6, the identified educational technologies that help in “understanding” are as follows:

Social media

Social media is a computer-based technology that allows for the sharing of ideas, thoughts, and information by creating virtual networks and communities (Dollarhide, 2021). Social media provides users with quick electronic communication of content through access to the internet. As of January 2021, the three most popular websites per Investopedia are Facebook (2.76 billion users), YouTube (2.29 billion users), and WhatsApp (two billion users). Twitter has 353 million active users. Sneed (2016) suggests that tweeting and tagging are two sub-verbs included as facilitators of understanding. This may suggest that tweeting is easily derived from Twitter social media, and tagging is an operation available on different social media, such (Facebook, Twitter, WhatsApp, and so).

Students can utilize Twitter by following relevant hashtags: searching for topics, people, and keywords, or subscribing to a specific topic they are researching and learning in school, college, or university. Students can also use Facebook to follow new feeds relevant to their course materials to master the content flowing through class. Facebook and Twitter may help students to improve their new language by familiarizing themselves with the content shared in the language they aim to improve.

Online Video Platforms

YouTube is the second most popular social media platform, but it is also an online video platform. Journaling and subscribing, where two others are listed as facilitators of understanding. Two main online video platforms have been proposed, YouTube and Twitch. YouTube was founded in 2005, and has been owned by Google since 2006.

Students can use YouTube to search for videos to improve their content when they miss some classes, and fill the information gap when they start a new course. In addition, watching YouTube videos improves listening comprehension and pronunciation skills.

Twitch, an online video platform founded in 2011, primarily focuses on live video streaming. In addition, users can find creative video content. Twitch is a highly interactive platform as users can comment while streaming. Thus far, there have been many informative online games that help students learn or improve their knowledge.

Technologies that help in “applying”

Based on the above introduction and the findings of Sneed (2016) shown in Table 6, the identified educational technologies that help in “applying” are as follows:

Spreadsheet programs

A spreadsheet or worksheet is a data file consisting of rows and columns that aids in the efficient organization, arrangement, and calculation of data, including numerical data (Computerhope, 2020). These values can be calculated using mathematical formulas and cell data.

The most popular spreadsheet worldwide is Microsoft Excel, which was founded in 1993, and currently has more than 750 million users. Microsoft Excel enables students to perform more than 400 operations to manipulate data. In addition, graphs and charts are easy to insert and personalize.

Cloud storage services

A cloud storage service is a cloud computing service in which data can be stored, edited, and retrieved from a remote cloud storage server over the Internet using a utility-computing model (Technopedia, 2021). Cloud storage services, also known as utility storage services, started in the mid-1990s, with the first platform launched by AT&T. Since then, several companies have launched cloud-storage services. The most popular storage providers are Apple's iCloud, Amazon's Amazon Web Services, DropBox, Google Drive, and Microsoft OneDrive. Cloud storage services have a positive impact on education because of the global utility of sharing documents and lectures among professors, students, and non-faculty staff. A safe infrastructure helps connect campuses to secure cross-cultural learning and research tools that not only save time but also increase productivity (Filecloud, 2021).

Technologies that help in “analyzing”

Based on the above introduction and the findings of Sneed (2016) shown on Table 6, the identified educational technologies that help in “analyzing” are as following:

Survey administration software's

The survey administration software allows users to create online surveys, polls, quizzes, questionnaires, and other web forms. They are addressed and distributed to a targeted audience to conduct market research or to collect feedback or opinions. In education, survey software is used to gather precise and unbiased feedback from students, faculty, and alumni of universities and colleges on various matters and topics related to educational institutions (Questionpro, 2021). Google Forms, developed and released by Google in 2014, is one of the most used survey software in education, and other software,

such as Survey Monkey, Zoho Survey, and SoGoSurvey, have hundred thousand users (Softwareworld, 2021).

Mind-mapping software

Mind-mapping software enables users to create visual representations of their ideas, including an idea map that displays the hierarchy and connections between various concepts (Dpm, 2021). Mind-mapping tools are useful in education for brainstorming, diagramming, software development, and web design, as well as for business intelligence purposes, by allowing users to import and visualize live data in charts and diagrams (Dpm, 2021). According to Dpm (2021), the best mind-mapping software include ClickUp, MindMeister, Ayoa, and Milanote.

Technologies that help in “evaluating”

Based on the above introduction and the findings of Sneed (2016) shown in Table 6, the identified educational technologies that help in “evaluating” include:

Teacher gradebook’s software

A teacher grade book software is a program that streamlines grade monitoring, student performance evaluation, and attendance tracking, and offers simple access to organized data for teachers, principals, and school administrators (Capterra, 2021). Gradebook software enables recording and monitoring systems, including tracking functionality. Google has included its gradebook versions on the Google Classroom platform. Other platforms that provide electronic gradebook services for teachers include Engrade, Thinkwave, Schoology, Edmodo, EasyGradePro, and MarkBook (Ispring, 2021).

Technologies that help “creating”

Based on the above introduction and the findings of Sneed (2016) shown on Table 6, the identified educational technologies that help in “creating” are as following:

Video-making software

Currently, education is facing various challenges, and teachers and educators are searching for innovative tools and ways to provide excellent teaching. Making videos (not necessarily with their image and voice) is a continuous trend in which teachers encourage their students to master content. iOS operating systems can use iMovie to create videos. WeVideo is software provided by Windows for users. Other free software that teachers widely use include Loom, Animoto, and Quik (Morris, 2020).

Video-recording software

Using video recording software, all tools helped teachers and educators to pre-record their lessons for later sharing with their students. Videos can be recorded during lectures for use in future classes. For this purpose, teachers can use screen-casting (recording a video of the screen). Some of the most used screen casting software include Ezvid, BlueBerry software, Screenr, Rylstim, Krut Etc. (Pappas et al. 2013).

Teacher's blogs

A blog is short of web logs designed as online diaries or journals created for an audience. Many topics have been discussed on blogs, and readers usually leave comments. Blogs may be great educational tools that give students the complete freedom to publish content on the web if they know how to implement it effectively in the classroom. Teachers or university faculty members can use blogs to publish assignments and resources and keep students and parents up to date on class events. They can also help to improve students writing skills. Students can use blogs to publish their writing, educate others on a particular topic, or chess the activities happening in school or university (Pappas et al. 2013). Some of the most read teacher blogs include TeacherLand, Edutopia, and Cult of Pedagogy (teachersofsci.com).

Educational technologies for applying ADDIE instructional design model

The ADDIE instructional design model is extensively used in instructional design and development and is helpful in enhancing teaching and learning (Cheung, 2016). Analysis, Design, Development, Implementation, and Evaluation are the five categories of ADDIE instructional design methodology (Budoya et al., 2019). ADDIE is one of the most common instructional design models and is utilized as a template to create appropriate designs that provide techniques for the continual assessment and analysis of information (Van Wyk et al., 2020). According to Bates (2015), the different steps of the ADDIE instructional design model are as follows:

The *analysis* identified all elements that must be addressed while building the course, including learner characteristics, prior knowledge of learners, and accessible resources. *The design* specifies the course's learning objectives as well as how materials will be generated and designed, as well as the selection and usage of technology, such as a learning management system (LMS), video, or social media. Content creation, copyright clearance for third-party assets, capturing videos or audio, and putting content onto the Web or LMS are all stages of *development*. *Implementation* covers course

delivery, including any preceding training or briefings provided by learner support workers, and student evaluations. The *evaluation* collects feedback and data to suggest areas for improvement, which are then included in the design, development, and execution of the next iteration of the course.

Other studies have provided similar definitions for the five stages of the ADDIE instructional design model. For instance, Shahril et al. (2015) built a map with the characteristics of the ADDIE design model and emphasized the importance of revision in every step from one stage to another. Maintaining the complexities of learning and instructional design and increasing the impact of learning are two of the main benefits of using the ADDIE in the instructional design process. Quigley (2019) suggested that tracking technological trends related to ADDIE instructional design, except for the aforementioned studies, is helpful. Prior to the process, he suggested that training needs should be analyzed and a training program should be conducted. For the design, he suggests storyboarding ideas, and O’Neil (2019) lists some technological trends used to create a storyboard.

The core content has already been determined for development (Quigley, 2019). It is necessary to add a level of detail to polish courses. This is accomplished by adding graphics, choosing colors, and selecting font. For implementation, the courses should be in the LMS, and learners can start taking and completing the courses (Quigley, 2019). LMS technologies are detailed in the Educational Technologies Learning Theories section. In the evaluation stage, learners must complete surveys using authoring tools (Quigley, 2019).

Based on these findings, technological trends were grouped, as shown in Table 7.

ADDIE design model	Analysis	Design	Development	Implementation	Evaluation
Quigley 2019	Audit of audience Goals Training programs	Storyboard the ideas	Add details to the courses	Course is ready in the LMS-s	Conducting surveys Use authoring tools
Technologies	Training software	Storyboard software	Graphic design software	Open-source learning platforms	Survey administration

			Presentation software	(LMS) Media player software	software Authoring tools and software
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Table 7: Educational technologies used for adopting ADDIE instructional design model

Technologies that facilitate the analysis

Based on the above introduction and Table 7, the identified educational technologies that facilitate the analysis include the following.

Training software

Training software automates educational activities for students and educational employees. They are also known as eLearning or Computer-Based Training (CBT) software (Capterra, 2021). Some of the most popular CBT software used in education include Lab on Demand, Minerva, GoBrunch, WCEA, My Class Campus, etc.

Lab-on-demand helps to create a lab environment quickly. The platform is designed to deliver experiential learning and skills for easy laboratory creation (Capterra, 2021). Minerva helps to create clickable instructions online and communicates a set of steps without physically standing next to someone (Capterra, 2021). GoBrunch is a webinar platform for teaching and learning. Educators can create and record as many webinars as they want, choose their own seats, and view photos in a virtual seminar room (Capterra, 2021). The World Continuing Education Alliance (WCEA) is an online platform used to train medical personnel and nurses, and is used daily by more than one million users (Capterra, 2021). The WCEA supports organizations by providing professional staff access to accredited education through online systems and mobile technology. MyClassCampus is a mobility-driven advance platform that helps educational organizations go digital (Capterra, 2021). It has some features such as lesson planning, exam scheduler, user directory, finance management, and digital libraries.

Technologies that facilitate the design

Based on the above introduction and Table 7, the identified educational technologies that facilitate the design include the following.

Storyboard software

The Storyboard software enables the pre-visualization of a video project shot by shot before making a shot list. Storyboards help plan and visualize videos, animations, graphics, or courses (O'Neill, 2019). This tool helps to visually plan every element of e-learning media. There are some popular eLearning storyboard tools for course creators, such as Storyboarder, Storyboard, Boards, and Studio Binder. (O'Neill, 2019). A storyboarder helps users visualize stories by drawing stick figures, creating and showing animacy to others, or expressing a story idea without creating a movie (wonderunit.com). Storyboards should be used in education for small projects (Storyboardthat.com). The board offers audio and subtitles, changing frame timing, and exporting to after effects (boards.com). Studio Binder offers customizing aspect ratios and adding images (studiobinder.com).

Technologies that facilitate the development

Based on the above introduction and Table 7, the identified educational technologies that facilitate development are as follows.

Graphic design software

Graphics software is a tool for creating, editing, and managing two- and three-dimensional images. Computer graphics include clip art, web graphics, logos, headings, backgrounds, digital photos, and other types of digital images (Chastain, 2020). In education, the most popular graphic software used by educators or students to improve the quality of their work include Adobe Photoshop, Adobe Illustrator, and Sketch.

Adobe Illustrator is vector-based editing software used to create logos, graphics, cartoons, and fonts. Adobe Photoshop is a popular program for modifying already-created images or graphics (e.g., photos) (Pluralsight, 2019). Sketch is a design software released by Apple and is not built for photo editing but mainly for the digital design of websites or apps (Singh, 2121).

Presentation software

The presentation software is a type of specifically designed application software. This allows users to present ideas by combining text, images, and audio or video (Techopedia, 2020). The most popular presentation software in education is Microsoft PowerPoint, followed by Apple's Apple Keynote, and Google slides.

PowerPoint was released in 1990, and was the first target of business presentations. Currently, PowerPoint has more than 500 million users (PowerPointinfo.com) and is available in 102 different languages. Using PowerPoint in education has proven beneficial in increasing the visual impact, improving students' focus, and increasing spontaneity and interactivity (Multani, 2021). Keynotes are used to make presentations and are included in most apple devices. Students and educators may use Apple Pencil diagrams or illustrations supported by Apple devices such as iPads, iPhones, or PC (apple.com). Google slides provide a variety of presentation themes, hundreds of fonts, embedded videos, animations, etc. (google.com).

Technologies that facilitate the implementation

Based on the above introduction and Table 7, the identified educational technologies that facilitate implementation are as follows.

Open-source learning platforms (LMS)

(The technologies of these platforms are analyzed in the “**Educational technologies for enabling learning theories**” paragraph).

Media player software

Media player software is used to play multimedia computer files, such as images, audio, video, or animation files (TeachTarget, 2021). The first media player software was Microsoft Media Player, released in 1991 (Digital Media Consult, 2021). Other popular media players include Microsoft movies and TV, Google Music, MacOS, QuickTime Player, Music, Google Play Music, and Google Photos (Graw, 2021). Educators use media player software to share images or videos with their students, whether in a traditional classroom or via online learning. Multimedia files increase students' engagement and offer the flexibility to pause, rewind, or skip throughout the video to have class discussions or review particular areas (Next Thought, 2020).

Technologies that facilitate the evaluation

Based on the above introduction and Table 7, the identified educational technologies that facilitate evaluation are as follows.

Survey administration software

(The technologies of these platforms are analyzed in the **“Educational technologies used in Bloom’s Taxonomy”** paragraph).

Authoring tools and software

Authoring software assists in creating digital content. Research suggests that the evaluation stage is completed by storing course content (Quigley, 2019). In the realm of learning and development, an authoring tool usually denotes software that aids in the creation of e-learning and other digital media (Hassey, 2018). In addition, an authoring tool enables users to create and arrange content in a standardized course structure. This structure can be exported to several multimedia types (McGarry, 2021). Authoring tools help teachers adapt Serious Games to their educational context (Marne & Labat, 2020). Some popular authoring tools and software in education include iSpring Suite, Lessonly, Brainshark, SAP Litmos, Articulate Storyline 3, 360 Learning, EasyGenerator, and Articulate 360. (McGarry, 2021).

Educational technologies for applying the ARCS-V motivational design model

Keeping them engaged requires more than simply introducing new technologies into the classroom, although learners are an important driving force for learning (Van Wyk et al., 2020). Learners are motivated to participate and engage in learning through cognitive, emotional, and practical applications, generally autonomously, because of disappointment or problems (Boulay & Del Soldato, 2016). In addition to using new technology, academics must also implement effective instructional designs and motivationally sound learning theories to maintain learner motivation (Libao et al., 2016). Moreover, in developing successful instrumental content, a key factor is motivating learners (Khan et al., 2019).

Many publications describing these benefits have accompanied the development of new technologies. However, the novelty effect is associated with fading of each innovation. Researchers must continuously provide learning experiences to motivate learners to be instructionally effective (Keller, 2016). Keller suggests that adaptations of basic knowledge of motivation and learning should have to be made by following specific characteristics of a given technology. However, the fundamental principles of motivation and learning transcend these motivations (Keller, 2016). As focusing on learning key skills and motivation is an integral part of building a useful framework, Keller (1979) designed the ARCS motivational design model (Keller, 2016).

To inspire students, instructors or educators must: (a) capture and maintain students' attention, (b) express why students need to understand the topic, (c) make students think they can achieve if they put out effort, and (d) enable students to feel satisfaction and pride. The ARCS model is divided into four systematic process steps: definition, design, development, and evaluation (Li & Keller, 2018). Keller (2016) created the ARCS-v motivational model in 2018 by adding a new component called volition. This model helps academics to develop course materials and content with motivational elements to engage learners.

To identify technological trends related to the ARCS motivational design model, Keller (2016) suggested important technological keywords from which the structure of technologies can be built. However, no studies have specifically addressed specific technologies for categories; Keller (2016) did not prevent any kind of technology from increasing student motivation. Moreover, he encourages all new technological trends or pedagogies if the implementation of technology or pedagogy follows his systematic motivational design steps (Table 8). “These 10 steps follow a typical problem-solving and design process, but the three steps that are particularly important are (3) audience analysis, (6) listing potential tactics, and (7) selecting and designing tactics (Keller, 2016)”.

According to Rubens et al. (2016), 13 technological trends facilitate the incorporation of flexibility in education. Unlike other sections, where the studied technologies were mainly software or website platforms, the 13 technologies suggested by Rubens et al. (2016) included software, hardware tools, and pedagogies. Studies by Rubens et al. (2016) and Keller (2016) complete each other since Keller (2016) lacks technological examples to implement his model of motivation, and the study of Rubens et al. (2016) in their findings does not involve how to motivate students to adapt to these major changes. Certainly, the ARCS-V model design improved the implementation of 13 technological trends.

Categories	Attention	Relevance	Confidence	Satisfaction	Volition
ARCS-V systematic motivational design steps (Keller, 2016)	1. Obtain course information			6. List potential tactics	
	2. Obtain audience information			7. Select & design tactics	
	3. Analyze audience			8. Integrate with instruction	
	4. Analyze other course elements			9. Select and develop materials	
	5. List objectives and assessments			10. Evaluate and revise	
Technologies facilitated by the adaption	1. Virtual Reality			8. Open education	
	2. Serious Gaming			9. Personalized learning environment for learning for cross-institutional study	
	3. Gamification			10. Adaptive learning environment for	
	4. Internet of Things				

of ARCS-V motivational design steps	5. The virtual classroom	agile education
	6. Students as owners of their online identity	11. Learning analytics
	7. Digital badges and micro credentials	12. Digital assessment and learning analytics
		13. Artificial intelligence

Table 8: Educational technologies used for applying the ARCS-V motivational design model

There are listed them in the row of “Technologies facilitated by the adaption of ARCS-V motivational design steps.” The technological trend “*Internet of Things*” is not analyzed here because it is detailed in the following paragraph. Based on the above introduction and the findings in Table 8, the identified educational technologies for applying the ARCS-V motivational design model are as follows.

Virtual Reality (VR)

Virtual Reality (VR) stimulates Reality using a digital device to immerse the user in a sensory experience (Rubens et al., 2016). The primary tools used to stimulate virtual reality include computers, smartphones, and headsets. Virtual reality meets all the criteria listed in Table 8 to be classified as an emerging technology that supports connective learning. It should be noted that implementing the virtual reality in an educational setting is expensive. Successful VR has been used in education to stimulate museum experiences with professional guides and to stimulate trips to spaces, such as planet mars. VR is also used to conduct laboratories in STEM (Science, Technology, Engineering, and Mathematics) courses.

Serious Gaming

Serious games have specifically been developed as learning resources (Rubens et al., 2016). Serious games are visual, and while a player (learner) has multiple choice options, professional lecturers teach serious games. Serious games are highly engaged, well-structured, provide a higher thinking level, and provide options for evaluating players. All of these characteristics met the cognitivism criteria listed in Table 8. One of the pioneers of serious games is the Microsoft Flight Simulator approach in 1982, which was updated in 2020. Foldit, an online puzzle of protein folding, is another serious game that affects education. The foldits were developed at the University of Washington in 2008.

Gamification

In education, gamification involves the use of principles of gaming. Gamification incorporates game-related features such as point tracking, competitive rivalry, team collaboration, and scoreboards to

encourage participation, promote information absorption, and assess knowledge (TrueEducationPartnerships.com, 2021). Significant differences existed between serious games and gamification. Serious games were designed for a clear purpose, and the implementation of gaming was introduced to make learning more attractive. Gamification refers to the application of typical gaming elements. Due to some of their characteristics of being played repeatedly, passively from the learning process, or their reinforcement contribution in supporting learning, gamification meets the criteria for supporting behavioral learning. Some examples of gamification applications in education might be “Mediavel Swansea,” an interactive game where players take the role of detectives to solve some mysteries. Another game that is one of the pioneers of gamifications is “Ribbon Hero” which helps users to learn the basics of Microsoft Office.

The virtual classrooms

A digital platform that facilitates communication and collaboration between teachers and students and among students is known as a virtual classroom (Rubens et al., 2016). A virtual classroom fosters dynamic and interactive learning, encouraging students to participate actively in the educational process. The ability of virtual classrooms to address learning through sharing and research makes this emerging technology contribute more to connective learning than to constructive learning. All the other criteria were perfectly matched.

Virtual classrooms contribute to both online and blended learning. A very used example of virtual classrooms is the “flipped classrooms” where students individually study the material that lecturers share, and students have to be assessed to check the feedback. Many software applications enable virtual classrooms, such as the Blackboard Collaborative, WiziQ, Vitero, and Adobe Connect.

Students as owners of their online identity

Identity enables processes, such as identification and authentication. At present, registration forms a proof of identity, and a passport photo is needed, in addition to a visit to the institution itself (Rubens, et al., 2016). Once the identification is complete, the user (in the educational context, the student) receives a digital identity.

In Education, a reliable identity is essential for flexible and customized education. Students can easily log courses by using their digital identities. Having a digital identity, students may access digital tools and applications permitted by their educational institutions (Rubens, et al., 2016). Students’ grades are usually linked to their educational ID.

Digital badges and micro credentials

A digital badge contains links to information on skills, and is a digital icon that indicates that a person has acquired knowledge in a particular field (Rubens et al., 2016). Specifically, in higher education, some students do not want to follow the entire degree program but only a specific part of it. Micro-credentials, which are small units of the entire course, will help this category of students to follow and be certified only for the skills they have obtained.

By using micro-credentials instead of following the entire course, students have a greater freedom of choice when building their curriculum (Rubens, et al., 2016). Students can look for modules that suit their background. They can put their badges on professional networks such as LinkedIn. Educational institutions provide courses and certify students with badges, mainly by using MOOC platforms (discussed in the Educational Technologies of Learning Theories).

Open education

Open education refers to practices or activities that aim to make education more open through an open pedagogy (Rubens, et al., 2016). Open pedagogy is a learning and teaching method that includes features, such as innovation, creativity, technologies, sharing ideas, connected communities, learner generation, practice, and peer review (Hegarty, 2015). Open education has five components: content, services, teaching efforts, learners' needs, and the general requirements of society (Mulder & Janssen, 2013).

Open education provides more opportunities to create customized education because people and resources are more accessible, and lecturers have a more open scope for supporting education for their students (Rubens, et al., 2016).

Personalized learning environment for learning for cross-institutional study

A personalized learning environment is a set of tools and applications in which students can address study-related issues. Alternatively, the personal learning environment is the student's digital home (Rubens, et al., 2016). Students can view their results, register for modules and exams, communicate and collaborate with their peers and lecturers, etc.

For instructors or lecturers, offering transparent and shared content with others may be challenging because of the need for additional incentives to further improve content and make it more specialized (Rubens, et al., 2016).

Adaptive learning environment for agile education

Adaptive learning is a learning environment in which students can make full use of information about their studies and manage their learning processes (Rubens et al., 2016). Adaptive learning is primarily based on flexibility, and higher education institutions are keen to offer students the ability to design study programs. It provides students with opportunities to develop talent, creativity, and motivation (Rubens, et al., 2016).

Students can combine their studies with their individual incentives. Adaptive learning is also sponsored and enabled by MOOC platforms.

Learning analytics

Improvements in student learning and targeted feedback to students comprise the learning analytics process. By implementing learning analytics, lecturers can monitor students' digital footprints and use their results to improve their learning (Rubens, et al., 2016). Specifically, students can study shared online materials before lectures and then complete online tests. Students can share technical issues with lecturers to improve their learning process. Electronic devices, such as tablets, laptops, and mobile devices, are the main digital hardware tools used in learning analytics.

Learning analytics enable adaptive learning and allow students to move on once they have demonstrated that they have learned a particular topic (Rubens, et al., 2016).

Digital assessment and learning analytics

Digital assessments can be combined with learning analytics and can be accessed through applications. Digital assessments are enabled by item banks that contain digital questions used for assessments (Rubens, et al., 2016). Software or platforms analyze the data and display the results to students and lecturers on the dashboard of an electronic device.

Digital assessments offer several options, in terms of quantity and difficulty. Open-source platforms, such as Moodle, Calvas LMS, and Google Classroom, offer digital assessments.

Artificial Intelligence (AI)

Artificial intelligence is a generic term a broad field that includes robotics, data mining, computer games, and neural networks (Rubens, et al., 2016). Recently, science and technology have been working on the concept of brain hacking, in which AI is deeply intertwined with science in terms of the

possibility of technological improvements in the brain. Watters (2017) determined this theory to be a behaviorist learning process that uses technological advances and artificial intelligence. AI has already been incorporated into educational systems, where the implementation of “Intelligent Tutoring Systems, which are personalized electronic tutoring customized according to student profiles or preferences, can be mentioned. Another example that of AI in education are the “Smart content,” technology that aims to use the textbooks into useful tools for exam preparation.

According to the website of artificial intelligence Claude+, the following are the most commonly used Artificial Intelligence technologies as of March 2023.

- Machine Learning - This method of training algorithms and statistical models to learn patterns from large datasets without explicitly programming them(Landolfi et al., 2021). Many technologies including predictive text, facial recognition, and spam filtering have been used in machine learning.
- Deep Learning - This type of machine learning employs neural networks modeled after the human brain (Duan et al., 2020). Deep learning has been successful in fields, such as computer vision, natural language processing, and medical diagnosis (Duan et al., 2020). Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), Generative Adversarial Networks (GANs), and other deep-learning models are popular.
- Natural Language Processing: This subfield of artificial intelligence teaches computers to understand, interpret, and manipulate human language (oracle.com). NLP power technologies include sentiment analysis, machine translation, speech recognition, and text prediction. Popular NLP techniques include word embedding, LSTM networks, BERT and GPT-3 (Oracle. com).
- Computer Vision: In the branches of AI, computers can recognize and process images and videos in the same manner as humans (Huang, 2020). Facial recognition, object detection, and autonomous vehicles are examples of computer vision power technologies. CNNs, object detection models, such as YOLO and SSD, and StyleGAN for image generation are popular CV techniques (Huang, 2020).
- Robotics: This is an AI field that focuses on designing and building intelligent machines that can perform physical tasks, such as humans (Huang, 2020). Robotics combines machine learning, computer vision, natural language processing, and mechanical and electronic engineering techniques to create intelligent physical agents (Pai and Pai, 2021). Self-driving cars, advanced prosthetic limbs, and autonomous drones are all examples of robotic power technologies (Huang, 2020).

- Conversational AI refers to technologies that enable automated conversations between machines and humans (Guzman, 2020). Conversational AI power chatbots, virtual assistants, and other text- or voice-based interactions. Various conversational artificial intelligence (AI) systems are powered by technologies, such as NLP, machine learning, and deep learning (Maher et al., 2022).

According to the AI website (openai.com) used in academia to access cutting-edge AI research as of April 2023, it is as follows:

arXiv. Many research papers from several disciplines such as computer science, artificial intelligence, and machine learning have been hosted in the arXiv preprint archive. Researchers frequently use it to disseminate their work and to maintain new developments (<https://arxiv.org/>).

OpenAI. The company that created GPT-4 and other innovative AI models is called OpenAI. Their website offers access to multiple API services, as well as details on their research, models, and tools (<https://www.openai.com/>).

Google AI Research. There have been several advancements in artificial intelligence (AI) and machine learning owing to Google research on AI. They created open-source software tools, academic articles, and datasets that are available on their websites (<https://ai.google/research/>).

DeepMind. Google purchased DeepMind in 2014, and is among the top AI research companies. They have significantly influenced AI research, contributing to the creation of AlphaGo and AlphaFold among other projects. They can research articles and blog posts regarding their work on their websites (<https://deepmind.com/>).

GitHub. GitHub is a well-known website for hosting and exchanging code, including projects for AI and machine learning. A key site for viewing and contributing to the most recent AI research is GitHub, in which many researchers post their work (<https://github.com/>).

NeurIPS. The Conference on Neural Information Processing Systems (NeurIPS) is an important annual conference on AI and machine learning. Access to conference resources, including research papers and presentation materials, are available at NeurIPS (<https://nips.cc/>).

ICML. The International Conference on Machine Learning (ICML) is an important AI event. Their website features accepted papers, conference proceedings, and details about future events (<https://icml.cc/>).

ACL. Natural language processing, a branch of artificial intelligence, is the focus of the Association for Computational Linguistics (ACL). Access to research articles, conference proceedings, and details of ACL events is available online (<https://www.aclweb.org/>).

AAAI. An expert group called the Association for the Advancement of Artificial Intelligence (AAAI) encourages AI research and instruction. The materials for education, conference information, and research papers can be found on their website (<https://www.aaai.org/>).

Hugging face. Hugging Face, a business that specializes in natural language processing, is well known for its open-source transformer library, which has versions of models, such as GPT-4. Access to pre-trained models, datasets, and academic publications is available on their websites (<https://huggingface.co/>).

Appendix 6 provides a list of the most popular AI websites and tools for 2023, as suggested by the Generative AI platform.

Disruptive technologies of Industry 4.0

Disruptive technology is an innovation that significantly alters the way in which consumers, industries, or businesses operate by sweeping away the systems or habits it replaces (Dokras, 2020). Intangible assets, such as intellectual property, are increasingly replacing dependence on physical assets. However, technology has always evolved, because it does not remain fixed in today's knowledge society. Technology starts, develops, persists, mutates, stagnates, and declines (Dokras, 2020).

Industry 4.0, in the Fourth Industrial Revolution, is seen as a subset of 4IR. It refers to the period after the computer and digital revolution (Third industrial revolution-3IR) and describes technologies that blur the lines between the biological, physical, and digital worlds (Lewis, 2020). Industry 4.0 it relates specifically to industries, while 4IR expands itself into the political, social, and economic worlds (Lewis, 2020).

There are different models for grouping and classifying the disruptive technologies of Industry 4.0. It was reviewed in the context of education the frameworks of "McKinney Institute," (Rüßmann, et al., 2015) study, Boston Consulting Group (2015) study, and "Top 10 Emerging Technologies 2019" by World Economic Forum.

Disruptive technologies of Industry 4.0 models		
Mc Kinsey Global Institute 2013	Boston Consulting Group 2015	World Economic Forum 2019
Mobile Internet	Big data and analytics	Bioplastics for a Circular Economy
Automation of knowledge work	Autonomous robots	Social Robots
The Internet of Things	Simulation	Tiny Lenses for Miniature Devices
Cloud technology	Horizontal and vertical system integration	Disordered Proteins as Drug Targets
Advanced robotics	The industrial internet of things	Smarter Fertilizers Can Reduce Environmental Contamination
Autonomous and near-autonomous vehicles	Cybersecurity	Collaborative Telepresence
Next-generation genomics	The cloud	Advanced Food Tracking and Packaging
Energy storage	Additive manufacturing (3D Printing)	Safer Nuclear Reactors
3D printing	Augmented reality	DNA Data Storage
Advanced materials		Utility-Scale Storage of Renewable Energy
Advanced oil and gas exploration and recovery		
Renewable energy		

Table 9: Disruptive technologies of Industry 4.0

As shown in Table 9, various studies have proposed different disruptive technologies over the three periods of the last decade. This is due to the definition of “disruptive” and what was disruptive in 2013 and may not be disruptive three or seven years later. The Cambridge Dictionary states that ‘disruptive’ means changing the traditional way in which an industry operates, especially in a new and effective way. In the educational context, the disruptive technologies described below are briefly described.

Disruptive technologies identified by McKinsey Global Institute (2013)

The disruptive technologies of Industry 4.0 by McKinsey Global Institute in 2013, as shown in Table 9, are as follows:

Mobile Internet, for educational purposes, is widely used to gather information and conduct research, or to add to the knowledge of different subjects (Ramani, 2015). Research engines (e.g., Google and Yahoo) are usually the first choice for students and education when they need immediate information.

The automation of knowledge work through advances in artificial intelligence, machine learning, and natural user interfaces in the educational context automates many knowledge-worker tasks that have been regarded as impossible or impractical for machines to perform (Manyika, et al., 2013).

The Internet of Things (IoT) has the potential to revolutionize education by providing students with improved access to resources, such as learning materials and communication channels. By utilizing IoT devices, teachers can monitor students' progress in real-time, enabling a more efficient and connected learning experience (Thomas, 2019).

Cloud technology (delivery of on-demand computing services) brings to the classroom business-related classes (management focusing), strong virtual classroom environments, agility, innovation, and greater reach (Stone, 2019). Cloud technologies provide greater flexibility and responsiveness (Manyika, et al., 2013).

Advanced robotics is acquiring greater senses, dexterity, and intelligence through accelerated developments in machine vision, artificial intelligence, machine-to-machine communication, sensors, and actuators (Manyika, et al., 2013). Classroom robots are invading the education profession, with MIT and the University of Tokyo effectively implementing robots to provide instruction (Gottsegen, 2019).

Next-generation genomics refers to breakthroughs in genetic material sequencing and manipulation, employing the most recent big data analytics capabilities (Manyika et al., 2013). This technology has applications in biological research and medicine, and genomic resources describe how scientists utilize our technologies for further research in various domains (Illumina, 2021).

Autonomous and near-autonomous vehicles are totally or partially autonomous vehicles such as automobiles, trucks, airplanes, drones, and boats (Manyika et al., 2013). This technique has limited

engineering uses, but it provides societal advantages, such as greater safety, lower CO2 emissions, and more leisure or work time for motorists (Manyika et al., 2013).

Batteries, such as lithium-ion batteries, fuel cells, and other devices that store energy for later use, are examples of *energy storage* technologies (Manyika et al., 2013). Currently, they are powered by electric hybrid automobiles and billions of portable electronic devices. There is no evidence to support the use of energy storage in education systems. Experts, on the other hand, have emphasized the need for education to address the benefits of energy storage and the need for change (Normark, 2018).

3D printing enables the generation of design files by bypassing typical manufacturing procedures and utilizing on-demand production. 3D printing lowers material waste throughout the production process (Manyika et al., 2013). 3D printing begins with a 3D digital model file, and ends with a tangible three-dimensional item. It is frequently utilized in education and assists students in creating enthusiasm, complementing the curriculum, providing access to previously unavailable knowledge, and encouraging problem-solving abilities (Markerbot, 2021).

Smart self-healing or self-cleaning materials as well as memory metals that may revert to their original forms are examples of *advanced materials*. This category also includes piezoelectric ceramics and crystals that transform pressure into energy, as well as nanomaterials (Manyika et al., 2013). Various universities offer advanced material courses, programs, and degrees.

Advanced oil and gas exploration and recovery enables the extraction of oil or gas from shale rock formations (Manyika, et al., 2013). This technology has no direct application in education, except for vice versa; education needs to boost and promote technology.

Renewable energy enables an endless source of power without stripping resources, contributing to climate change sources and includes sources such as solar, wind, hydroelectric, and ocean waves (Manyika, et al., 2013). Globally, universities have already provided courses and knowledge on renewable energy.

Disruptive technologies identified by Boston Consulting Group (2015)

The disruptive technologies of Industry 4.0 by the Boston Consulting Group in 2015, as shown in Table 9, include the following:

(It is described only the technologies that are added from Mc Kinsey Global Institute 2013)

Big data analytics includes large amounts of data that are complex to handle using traditional data processor software to uncover hidden patterns, correlations, and other insights (Daniel, 2015). Within institutions of higher education, data are growing but are not consolidated. Consolidated data from various sources across educational institutions provides a better foundation for making better decisions (Daniel, 2015).

A *simulation* is a form of experimental learning in which the learner is placed in a "world" defined by the teacher (UNSW Teaching, 2021). Simulations help students understand time- and decision-based conditions in a way that a lecture cannot provide. They can increase the long-term retention and memory of materials (Caniglia, 2019).

Horizontal integration is an expansion strategy adopted by a company, which involves acquiring another company in the same business line. *Vertical integration* refers to a company operating in the production process of the same industry (Tarver & James, 2021). However, these strategies do not apply directly to education after a detailed web search.

Cybersecurity is the practice of defending computers, servers, mobile devices, electronic systems, networks, and data from malicious attacks (Kaspersky, 2021). The education industry is always exposed by cyber criminals because of the volume of data it holds (student information, alumni databases, research data, etc.) Educational institutions apply for cybersecurity by providing documentation. Students and staff can refer to cyberattacks at any time and guide them on risks and warning signs (Pavithran, 2020).

Augmented reality (AR) is a technology that enhances the real world using digital elements such as visual, audio, or other sensory stimuli to create an immersive experience (Hayes, 2020). AR differs slightly from VR, in that digital information is added to the perception of the environment. This is the main reason that augmented technology is classified as an emerging technology that contributes more to constructivism than to connectivism. Other criteria, such as discovery, brainstorming, and peer-review characteristics, were also met. AR has been shown to enhance student collaboration and problem-solving abilities. Some uses of AR in education are the "Dinosaur 4D+" application in paleontology and Google Expeditions.

Disruptive technologies identified by World Economic Forum (2019)

The technologies listed in this study are newly ideated, and their use in future educational systems (if applicable) needs to be studied after the first implementation in future studies. However, some studies

have found applications for social robots in education (Belpaeme et al., 2018). They can be used in education as tutors or peer learners, and have been found to be effective in increasing cognitive and affective outcomes. Achievement outcomes were similar to those of human tutoring (Belpaeme et al. 2018) .

Synthesis

To ensure a smooth integration of technological advancements (reviewed in Part I), empowering engineering students to develop entrepreneurial competence and effectively navigate the evolving landscape of work (reviewed in Part II) and creating a framework of the educational technology landscape would benefit both students and educators. To list the advantages of as many digital technologies as possible that can help in education or are predicted to be implemented in the near future, many studies, books, websites, and forums were analyzed through a literature review. Educational technological advancements necessitate an integrated approach to educational technology that considers various components, as widely accepted in academic circles. Different learning, design, and motivational theories that influence the use of educational technology, taxonomies, and the latest disruptive technologies have helped to create a framework for the adoption of educational technologies.

All educational (or non-educational, in a few cases) technologies brought about by the framework for the adoption of educational technologies are classified, and the innovations, advantages, and use of those technologies in education are explained.

First, educational technologies that facilitate the application of learning theories are explained in detail. MOOCs and web conferencing are examples of emerging technologies that facilitate connectivism. Open-source platforms are essential for behaviorism. Constructivism uses interactive platforms and data-analysis software. The cognitive processes are aided by technological software.

Second, regarding educational technologies in Bloom's taxonomy, web browsers and word processors find place in helping "remembering." Social media and video platforms aid in "understanding". Spreadsheets aid in the "application" of knowledge. "Analysis" is possible using survey and mind-mapping software. Video and recording software make this easier for "creation."

Third, the educational technologies used to apply the ADDIE instructional design model were examined and a mix of educational technologies was identified. Training software was used for "analysis," storyboarding was used for "design" and graphic design software for the "development." For

“implementation” are used open-source learning platforms and media player software and for “evaluation” are used survey administration software and authoring tools and software.

Fourth, the characteristics of the educational technologies used for applying the ARCS-V motivational design model include virtual reality, serious games, gamification, virtual classrooms, digital identity, open education, personalized and adaptive learning environments, learning analytics, digital assessment, and AI.

Finally, it was found that Industry 4.0, disruptive technologies such as mobile internet, automation, the Internet of Things, and cloud computing have a significant impact on education.

The analysis of previous studies, books, websites, and forums demonstrates how different theories and frameworks of learning theories, design and motivational models, and technology adoption in education emphasize different tools, techniques, and approaches. Technological advancements provide promising opportunities to improve teaching and learning; however, they also introduce risks and challenges (as reviewed in Part I) that require insight and oversight to maximize benefits and minimize harm. An integrated and balanced perspective across these classifications can aid in the development and application of educational technologies in an effective and ethical manner.

3. Methodology

This chapter presents the methodology used in the empirical section of this thesis. The methodology outlines the literature review approach and was used to conduct the research and collect the data. The “Methodology” serves as a roadmap that guides researchers to address research questions and objectives in a structured and reliable manner (Montgomery et al., 2022). The importance of this chapter lies in its ability to ensure the validity, reliability, and generalizability of research findings. By clearly articulating the research design, data collection methods, and analytical techniques, this methodology allows researchers to evaluate and replicate the study, thereby contributing to the advancement of knowledge in the field (Guimarães and de Carvalho, 2012). The study of methods will include a research design, analysis of the profile of the sample responders, questionnaires to collect perceptions of the participants’ (engineering students and faculties) learning and teaching activities, and detailed procedures used in data collection. A description of the analytical procedure is also provided. The main sections of this study are as follows.

- Research questions and objectives
- Design of the survey
- Pilot study
 - Aim
 - Participants
 - Procedure
- Questionnaires
 - Aim
 - Participants
 - Procedure
- Interviews
 - Aim
 - Participants
 - Procedure
- Research ethics

- Data analysis
 - Reliability of the Latent Construct
 - Analysis matrix

Research questions and objectives

This thesis examines the role of digital technology advancements in teaching and learning in higher education with a special focus on engineering and entrepreneurship education. The main research question of this thesis is:

“What is the role of technological advancements in learning entrepreneurial competencies in higher education?”.

In addition to the literature review conducted in Chapter 2, the research question was supported by a practical approach consisting of various types of surveys. A supportive analysis and detailed answers to the research questions are presented in Chapters 4 and 5.

Objectives:

To determine the role of technological advancements in learning entrepreneurial competencies for engineering students in higher education, this thesis aims to

1. To identify the characteristics of new emerging jobs brought about by technology-enriched educational spaces and platforms.
2. To identify and characterize the technologies of the “Framework of the Educational Technology Landscape” used worldwide in education by different institutions.
3. To validate whether the use of a “Framework of the Educational Technology Landscape” improves the learning outcomes of all higher education courses.
4. To determine awareness of the intervention on the use of technological advancements by engineering students.
5. To suggest ways to improve and develop entrepreneurial competencies for engineering students using digital technological advances.

Design of the survey

The main study design consisted of a survey combining questionnaires (quantitative analysis) and interview methods (qualitative analysis). Several advantages of both the methods have been described in different studies. The increasing need for a clear qualitative understanding to conduct good quantitative modeling can act as a bridge between traditional and false methods, as portrayed separately (Lucas et al., 2019). The use of statistical models to make causal inferences poses several challenges. However, current theoretical and analytical developments have made it possible to make causal assumptions explicit, testable, and interpretable (Judea and Mackenzie, 2018). Thus, the growing use of causal frameworks within statistical practice presents a promising means to reduce the mismatch between intended verbal and statistical hypotheses, as well as facilitate communication between competing schools of thought (Lucas et al., 2019).

To expand and improve the present study, it is necessary to apply quantitative and qualitative methodologies, although not equally. There is a need to develop solid theoretical foundations for systems of interest, as well as the necessity for more concentrated training of qualitative methodologies (Lucas et al., 2019). Directed acyclic graphs can serve as a bridge between qualitative and quantitative methods, overcoming this unnecessary methodological duality, while also facilitating well-informed quantitative analyses and communication between disciplines (Johnson & Onwuegbuzie, 2004).

The thesis survey incorporated two data collection tools—questionnaires and interviews—to improve the credibility of the study and tackle various elements of the same issue. The first was designed to address all research questions, with a focus on the study objectives. Data collection protocols, particularly the questionnaires, were closely followed. Interviews were conducted to confirm the conclusions of the questionnaires. According to the researchers, an interview sample of up to 10% of survey respondents was considered to confirm the findings and the survey questionnaire (Collinbridge, 2022). The data collection section contained more details regarding the questionnaires and their objectives.

The main tools for collecting data from students and lecturers in higher education were used, as described in the table below. To measure and analyze the main challenges students and lecturers face in their routine learning/teaching process, questionnaires were used as a form of quantitative research. The main questions raised prior of conducting the questionnaires to students and teaching faculties include “How open are they to switch to new learning pedagogies,” “Financial costs to cover some technological advances.” And, questions to students and faculties include items like “How open are

they for new qualifications or training to master new teaching pedagogies,” “Financial costs (training, buying fees, travelling, etc.)”.

Students	Faculties
Collecting student perceptions on the use of educational technologies a) To collect data among college students on how many technologies do they use and how satisfied they are using those technologies. b) A ratio to be built on the number of technologies being used/all technologies in the framework.	Collecting teaching faculties perceptions on the use of educational technologies a) To collect data among higher education faculties on how many technologies do they have access. b) The use of those technologies in changing their teaching process.
Students' challenges a) How open are they to switch to new learning pedagogies b) Financial costs to cover some technological advances	Faculties challenges a) How open are they for new qualifications or training to master new teaching pedagogies? b) Financial costs (training, buying fees, travelling, etc.)

Table 10: Use of technological advancements in the Framework of the Educational Technology Landscape: Perceptions and challenges among students and faculty.

The reasons for administering the two questionnaires are listed in Table 10. Both perceptions and challenges among students and lecturers were collected using quantitative analysis. The main objective of conducting interviews was to collect data using Artificial Intelligence to validate the findings based on quantitative analysis. The use of these technologies is believed to have changed the teaching process. Survey methods were used for data collection for further analysis. Using various techniques to collect data from participants helps improve the reliability of both the results and interpretations (David & Ware, 2014). In addition, there were three or more actors in each survey or interview: (1) the researcher, (2) the participant, and (3) any resource or person that helped the participant.

The procedure also includes two or three main steps: (1) initiation and preparation, (2) survey data collection, and (3) interview data collection (using Artificial Intelligence). The section “Data Collection

(Interviews)” mostly refers to the pilot study and validation of surveys, as it was necessary to conduct online interviews to validate some points of the questionnaire items.

The monetary costs of technical equipment, data connection, or paid subscription to specific platforms were not considered because there was no indication from participants that they were unable to participate due to a lack of the above-mentioned resources.

Prior to data collection, the researcher, once enrolled and admitted to the Ph.D. program, expanded the accounts of LinkedIn (the world's largest professional network on the Internet, used mostly to find jobs or connect to professionals in the same field) and Twitter (a platform used to communicate and stay connected through the exchange of quick, frequent messages). The reason for adding more connections/followers has always been to use these platforms to collect data, as it has been predicted that doctoral studies would need to include surveys and interviews. It is worth highlighting that LinkedIn is a platform where the main accounts are professional in many fields and lacks the accounts of freshly graduated students. So, on LinkedIn it was established an account with around 10 000 connections, where most of the connections are teaching faculties (include teachers prior to higher education, higher education faculties, management directions roles like deans, head of departments, etc.) These profiles are distributed worldwide, covering more than 180 countries. Of all the connections, the aim was to manage at least 1% of the participants using different data collection forms. In addition, the researcher had other sources to use (colleagues, ex-collaborators, emails, etc.)

On Twitter, an account with approximately 3200 followers was established, most of which were not verified users or people who had no correlation with academia, but importantly there–150-200 students or ex-students of the researcher were crucial to collect data.

It should be noted that most students who took the survey (97/226) were taking a course with the researcher at a higher education college in Kuwait, and were aware of the nature of the study and the importance of giving honest and trustworthy answers.

The initiation and preparation phase included an interconnection with participants to establish a connection if participants were reluctant (via Zoom), informing them about the aim, and insuring them about protecting their privacy (mainly from LinkedIn, Zoom). To keep in touch with the participants, they needed to install LinkedIn and possibly Zoom (for interviews).

Other applications were required for the later steps (survey and interview), as reflected in the above figure. Usually, LinkedIn, Google Drive, and Google Forms were sufficient to complete the survey;

however, in some circumstances, owing to the lack of experience (mainly students), the researcher recommended that the participants have extra applications installed (e.g., TeamViewer) for further assistance. In addition, additional resources were needed for interview data collection. The mobile device was sufficient to conduct interviews in the absence of a laptop or PC. Hard-copy materials for the researcher and participants, paper, pencil, etc., were important to make the process smooth and efficient.

At the end of the survey (when participants contacted the researcher) or the interviews, the researcher expressed gratitude for their involvement in the study. A few participants were also asked to send post-questionnaire feedback and to say final words about their participation in the study.

Research from the University of Minho contributed to the pilot study and helped to improve the survey prepared for faculties and students from a college in the Middle East tested the pilot survey for students. The electronic correspondence (emails) exchanged with academics at the University of Minho regarding the validation and improvement of the questionnaires has been added in Appendix 4.

Pilot study

This section describes the aim, the participants who helped in conducting the pilot study, and the procedures that were followed to analyze and conclude the study survey.

Aim

This pilot study aimed to determine whether the main research project was feasible in terms of complexity, time, and effort. A pilot study is strongly recommended for nearly all investigations involving innovative equipment, measuring methods, or recruiting approaches (Hulley et al., 2013). This saves time in the long term by allowing researchers to prepare better for their primary research.

As the study aimed to bring and organize new and existing advancements in digital technology and their role in learning entrepreneurial competencies in a certain context, a “pilot study (2+2) was conducted with two students and two faculty members teaching higher education. The pilot study helped to design the main study project (Bell et al., 2018). The procedure of the pilot study was first analyzed, followed by an explanation of the methods used in the main study. The following is a brief description of the study and its contribution to the main study.

Qualitative research is the most acceptable method in pilot projects (Bakan et al.2012). The study of social processes or the analysis of the causes of human behavior is a common application of qualitative research. The pilot project employed a case study approach. According to Yin (2009), case studies are the preferred method when (a) how and why questions are addressed, (b) the investigator has a minimal effect on occurrences, and (c) the investigator has little control over the outcome.

The focus is on the current phenomena in the actual world. Unlike other approaches, case studies allow researchers to address the intricacies of various phenomena and conditions.

Participants

Pilot research with four participants was conducted separately for each participant on May 2022. The participants were two engineering college students and two faculty members of higher education. The students were chosen from a Kuwait City college and enrolled in their third normal semester of engineering studies (their curriculum was delivered in four regular semesters and two summer schools). An Assistant Professor who teaches Economics at the University of Tirana and an Assistant Professor who teaches Entrepreneurship at the Aristotle University of Thessaloniki participated in two interviews through Zoom.

Procedure

Two students were engaged in this study, a male (student M) and a female (student F), both 20 years old, while they visited the researcher's office to ask questions about their own course. They were studying Computer Engineering (student M) and Industrial Engineering (student F), and the researcher taught mathematics (Calculus I). The researcher asked the students if they were willing to participate in a study (anonymous) that consisted of an interview lasting about 15-20 minutes. They accepted the questions and seemed curious and enthusiastic.

The first question was an exclusionary question for their interview when they were asked if "would they consider involving or having a career in entrepreneurship'. They were informed to take their time to think about this question, and were asked to respond to one of the Likert Scale options (1-highly interested, 2-somehow interested, 3-neutral, 4-not really, 5-not at all). They had not studied any course in the Economics Curriculum since their last semester (Entrepreneurship included). Moreover, the students did not know that if their answers were below neutral, their interviews had to be terminated.

After more than three minutes, student M said he was neutral because technology and software programming, in particular, excited him the most, and he prioritized working as an employee of computer engineering. He said that being involved as an entrepreneur that involves “computers” might be something he would consider highly.

Student F needed more time to state an answer because of her poor knowledge of the business field and lack of understanding of entrepreneurship. The researcher had to provide her with an explanation of entrepreneurship and entrepreneurship education before the student decided on her response. In contrast to student M, she was confident and happy to say she was “highly interested” in being an entrepreneur and possessing more skills in this field.

In the second part of the interview, the researcher asked the students to write three “keywords” or skills students thought someone needed to have a successful career in entrepreneurship. The purpose of this question is linked to the need to know whether students have any prior business skills or talent, whether they have any prior knowledge, and to notice the importance of introducing a course to teach these skills in higher education.

Student M said an entrepreneur should “be a strong character”, “have connections” and “respect the law”. While, student F said she believed a successful entrepreneur needs to prior “study,” “support the employees” and “have leadership.”

The last part of the interview was more committed since the researcher gave students a paper format of “Framework of the Educational Technology Landscape” technologies where all technologies included were listed and asked the students “to choose which from listed above technologies the student knows or have used during the interval since the early years of studies to college?” The time to read and choose was ten minutes maximum since the list is relatively long.

All recorded answers were saved by the researcher, and they are presented in Appendix 3. This was an important task to prepare the main study question, to understand the weaknesses of students related to technology in education, and to identify the branches where educational technology should focus in the future for better improvement and implementation of higher education learning. Students tried to ask some questions, but the researcher did not respond, because if the student does not know the technology, he/she may skip it and not choose it.

Interviews with the teaching faculty members were conducted separately in Zoom. With the lecturer from Albania (Doctor A), the researcher had a personal acquaintance; with the lecturer from Greece

(Doctor G), he did not have any personal acquaintance (it was proposed by a college during a friendly conversation). This choice was made in order to ensure diversity.

The interviews with the lecturers consisted of four questions, the first two of which were qualitative. The researcher took notes when participants responded.

The first question was literally: "Based on your experience, have you noticed any difference in learning entrepreneurial competencies in introductory courses between the engineering students and business/economics students?"

Doctor A briefly explained that differences may occur between students, even in the same engineering or business major. However, in the introductory courses, both engineering and business students showed the same interest in learning entrepreneurship skills, and no major differences were noticed.

Doctor G confirmed that, in learning and improving concepts or competences, no major differences were noticed; however, he suggested that there was a significant difference in the will (desire, reasons) to learn between categories. He believed that students who will work in industry and will not have any entrepreneurial initiative (engineering students in pole) are mostly oriented to finish the course (with a higher grade) because it is in their program, and they do not show interest in exceeding their skills beyond basic knowledge. He added that business/economics talented students except of achieving the learning objectives, they show interest toward practical skills and implementing the knowledge as soon as they have an opportunity (fair, project, etc.)

The second question asked lecturers: "In your opinion, after engineering students finish their entrepreneurial courses, are they confident and enthusiastic enough to start a career in entrepreneurship or to apply the learned skills in their future jobs?"

Doctor G said that, in his opinion, engineering students see the business world as a real opportunity to start a career and develop their competencies; however, according to his point of view, students of some specific majors (mostly computer engineering) would generally prefer to be freelancers rather than entrepreneurs. Doctor A said that, according to his experience, a high percentage of graduate engineers tend to start a career in business; however, he emphasized the importance of universities or colleges to provide guidance and practical skills to their students while studying business majors.

The last two questions have more qualitative characteristics. The third question asked Doctors A and G to list three issues and concerns related to technology that cause difficulties in daily teaching. The reasons for this have also been discussed.

Doctor A said the main challenge for him was that “there are no systems in place to utilize new trends of technology”. He then said that there is a “budget limitation” to use the latest technologies that usually do not come cheap. Lastly, it is not possible to attend the latest training on technology due to lack of time, budget, need to travel, and so on.

Doctor G said that “students tend to be more distracted in a technological environment and they lose focus on the explanation of the lecturer”. His second concern was the use of cell phones during class and the danger of filming other students or lecturers at a possible unpleasant moment. Third, he added that there is a lack of platform for technologies to be used in each field of higher education. He claimed the need to know a list of the latest technologies to be used in a specified major of studies, and somehow to be unified worldwide.

And, the fourth question, similarly conducted with students, the researcher gave students a paper format of “Framework of the Educational Technology Landscape” technologies where all technologies included were listed and asked the lecturers “to choose five technologies they think will mostly impact the entrepreneurship in the future?” The time to check and choose was five minutes. Reasons for their choices were also asked.

The researcher showed a document to the lecturers by sharing their screens, and they chose the five technologies they thought would have a higher impact on the other technologies. All recorded answers were saved by the researcher, and they are presented in Appendix 3.

In some circumstances, the students who took part were unable to convey the rationale adequately, instead reverting to “I don't know” or ambiguous explanations. In these cases, the researcher conducted a discourse with the subject to arrive at a rational explanation. The researcher considered the written notes after each session, completed the sentences, and filled in the blanks. Finally, all the interviews were typed and saved as written documents.

Several of the difficulties raised in the pilot study provided valuable information for the overall investigation. First, the interview setting (the researcher's office) has both advantages and disadvantages. On one hand, it allowed the researcher to monitor or observe actions as they occurred and asked participants to clarify their behavior. However, because the students were being interrogated by their lecturers, they put pressure on them. In other words, the researcher's presence may have harmed the credibility of their replies, since they may not have acted as they would if the researcher was not present.

Another issue revealed by the pilot study was the method used to record the responses of the students and lecturers. It was difficult to take notes while inquiring and talking to participants. Furthermore, the students' writing may have attracted interest. In the main study, the researcher explored the changes in this technique.

Some pilot study questions took longer than was intended. Another difficult issue that emerged during the pilot study was the enormous amount of information provided by professors during the brief interviews. This raises difficult questions regarding how to assess the data gathered for the primary study. According to Sharpe (2012), sheer volume of data may be an issue because it necessitates a vital decision on which information to reveal and which to remain hidden. In general, remote interviews raise concerns about the quality and reliability of data interpretation. To address this issue, researchers supported their interpretations in interviews with teaching faculty members by examining the phenomena from many perspectives and employing various methods, such as qualitative and quantitative approaches.

Changes were made to the main study design based on this evidence and reflections on the limitations and challenges that occurred during the implementation of the pilot study (Muth et al., 2016). The procedure of the main study is refined in the following sections, based on the findings of this pilot study and additional literature.

Questionnaires

This section describes the aim of conducting this type of survey, the participants who completed the questionnaires, and the procedures followed to analyze and conclude the study survey.

Aim

Two sets of modified questionnaires were prepared to collect data from students enrolled or graduated in the last three years in higher educational institutions (colleges/universities) and from higher education teaching faculties. The study had a quantitative as well as descriptive nature, and the respondents were searched in all continents using the methods explained in the "Design of the survey" section. The questionnaires were finalized after minor changes were required following a pilot survey to assess the feasibility of the survey (Robson et al., 2011).

Participants

This section provides fundamental details regarding the participants in the survey questionnaires, who were the teaching faculties and students in higher education. In this section, there are details of the participants who completed the questionnaires and the profiles of the sample responders. The remainder of this section is organized as follows.

a) Teaching faculties in higher education

The first survey was conducted among the teaching faculties in higher education. The details, percentages, and frequency distributions of the first questionnaire, titled “Survey for teaching faculties in higher education” are summarized in Table 11. It displays the personal details of the teaching faculty respondents categorized by their teaching experience, highest academic qualification, and the continent in which they most recently taught. All the information presented is derived from primary data sources.

Variables	Categories	Frequency Distribution	Cumulative Frequency	Percentage
Teaching experience	0-5 years	38	38	31.4
	6-15 years	59	97	48.8
	16 and above	24	121	19.8
Highest academic qualification	Bachelor	12	12	9.9
	Masters	48	60	39.7
	Ph.D.	61	121	50.4
Continent of most recent teaching experience	Africa	13	13	10.7
	Asia	37	50	30.6
	Australia (Oceania)	12	62	9.9
	Europe	34	96	28.1
	North America	14	110	11.6
	South America	11	121	9.1

Table 11: Personal Information of Sample Responders for “Survey for teaching faculties in higher education” (N=121)

The data in the table reveal that the majority of the respondents (48.8%) had 5–15 years of teaching experience, 31.4% had less than 5 years of teaching experience, and 19.8% had over 15 years of teaching experience. Among the participants, 50.4% held a Ph.D., while 39.7% and 9.9% held a master’s and bachelor’s degree, respectively. In terms of their most recent teaching experience, Asia

and Europe had the highest representation, with 30.7% and 28.1% of the respondents, respectively. The remaining respondents were from North America (11.6%), Australia (9.9%), South America (9.1%), and Africa (10.7%). Those who taught in Asia and Europe were mostly recruited by the researcher or supervisor through personal connections, whereas those who taught in South America were recruited through the UMINHO email database. Most of the other respondents were recruited using LinkedIn.

b) Students in higher education

The second questionnaire was administered to students with higher educational levels. The details of the second questionnaire titled “Survey for students in higher education” and distributed to college and university students in analyzed in Table 12. It displays the personal details of the student respondents categorized by their study major and the continent on which they had received their most recent academic qualifications. The data in the table reveal that the majority of the respondents (64.6%) were studying an engineering program, which is in line with the objective of this study that focused on the role of technological advancements in teaching entrepreneurship education to engineering students. Of the remaining student participants, 14.6% were studying business, economics, or a similar major, while 20.8% selected ‘Other’ and specified their major in the comments section.

Variables	Categories	Frequency Distribution	Cumulative Frequency	Percentage
Study major	Engineering and/or Technology	146	146	64.6
	Business, Economics, or similar	33	179	14.6
	Other	47	226	20.8
Continent of most recent academic qualification	Africa	10	10	4.4
	Asia	98	108	43.4
	Australia (Oceania)	10	118	4.4
	Europe	83	201	36.7
	North America	12	213	5.3
	South America	13	226	5.8

Table 12: Personal Information of Sample Responders for “Survey for Students in higher education”

(N=226)

In terms of the context of their most recent academic program, Asia and Europe had the highest representation, with 43.4% and 36.7% of respondents, respectively. The remaining students had received their most recent academic qualifications in North America (5.3%), South America (5.8%), Africa (4.4%), or Australia (4.4%). Those who studied in Asia and Europe were mostly recruited by the researcher or supervisor through personal connections, whereas those who studied in South America were recruited using the UMINHO email database. Most respondents were recruited through different Facebook groups. This study included diverse groups of students in order to capture a broad range of perspectives.

c) Profile of the sample responders

Since most of the researcher's contacts were from Asia (working in Kuwait) and Europe (Albanian national and studying at the University of Minho), most of the student participants were from these two continents: Asia (43.3%) and Europe (37.1%). The total number of participants in the study was 226. Regarding the teaching faculties in higher education, 121 responses were collected: 30.8 % of respondents were teaching in Asia, and 28.3% of respondents were currently teaching or had taught in the last five years in Europe.

As outlined in the Research Design section, data were collected using two types of research tools: two sets of questionnaires and interviews. Questionnaires were distributed to a sample of teaching faculties and university students to gather quantitative data on their teaching experiences, academic qualifications, and academic environments. The aim of the interviews was to gather qualitative data on the challenges and best practices of teaching entrepreneurship education. To achieve this, interviews were conducted using Artificial Intelligence (AI) technology. The interviews covered only two research questionnaire items, suggesting a need for further analysis (Bongomin et al., 2016). Exact information about the nature of participants' data is also found in Appendix 1.

Procedure

Two questionnaires' sets were administrated as explained at the "Participants" titled respectively: "Survey for students in higher education" and "Survey for teaching faculties in higher education." Questionnaires on the header of the first page indicated the approximate duration (approximately 10 minutes for the student's survey and approximately 20 minutes for the teaching faculty survey). Additionally, it was explicitly indicated that, to recruit students, survey participants should be currently studying or have graduated from a college or university within the past two years. To complete the

teaching faculty survey, participants were required to either currently teach or have taught in the last five years at a college or university.

Each questionnaire consisted of five sections. "Survey for teaching faculties in higher education" in Section 1 collected information about participants age, highest degree qualification and the continent where they had their last teaching experience. In the other four sections, ten questionnaire items for each section used a Likert Scale model to collect data. Each participant chose response options of Strongly Disagree, Disagree, Neutral, Agree, or Strongly Agree for each question. Section 2 presents information on the effectiveness of the characteristics of new and emerging jobs. Section 3 presents opinions regarding the Framework of the Educational Technology Landscape. In Section 4, teaching faculty members are asked about the use of educational technologies in higher education. Section 5 focuses on interventions for technological advancements. Technical terms were explained at the bottom of each item and explanations were prepared using a glossary with the corresponding references. The glossary is included in

Appendix 5.

From the survey questionnaire, 121 responses were collected from Google Forms and were distributed online. Of the total responses, 13 respondents stated that they had not been teaching in the last five years; therefore, 108 responses were administered for further analysis (see multiple Table 19) *Table 13*.

Characteristics of new and emerging jobs

Code	Questionnaire item
S2Q1	Technology-enriched educational platforms bring new and emerging jobs.
S2Q2	Technology-enriched educational platforms will reduce the need for the human workforce.
S2Q3	I am open to introducing more digital educational technologies in my daily teaching in the near future.
S2Q4	Introducing entrepreneurship courses in higher education will give graduates more options to find/create jobs.
S2Q5	Learning and implementing the latest digital technologies is expensive for me.
S2Q6	I believe there is a digital transformation in the job industry.
S2Q7	New and emerging jobs brought by digital technologies differ considerably from traditional jobs.
S2Q8	I can identify at least five disruptive technologies.
S2Q9	In my field of expertise, there is an expansion of new and emerging jobs.
S2Q10	I think the institution I teach provides a sufficient technological environment for creative-mind students.

Framework of the Educational Technology Landscape

Code	Questionnaire item
S3Q1	I am aware of Bloom's and its applications in education.

S3Q2	A complete taxonomy framework including as many educational technologies as possible is needed in education
S3Q3	A complete taxonomy framework including as many educational technologies as possible is difficult to be provided/realized.
S3Q4	I know the learning theories and can mention at least one learning theory.
S3Q5	In my opinion, following an instructional design model in teaching is beneficial.
S3Q6	I am aware of the implementation of instructional design models in higher education, such as ADDIE model.
S3Q7	I am aware of motivational design models.
S3Q8	In my opinion, Bloom's Taxonomy should be updated.
S3Q9	I believe the so-called 4 th Industrial Revolution is already a reality.
S3Q10	I follow the latest updates of the World Economic Forum.

Use of educational technologies

Code	Questionnaire item
S4Q1	During my classes, I emphasize using digital library platforms (Google books, Ibiblio, etc.)
S4Q2	I recommend and use the MOOC (Massive Open Online Courses) platforms.
S4Q3	My institution provides access to using open-source learning platforms (Moodle, Canvas LMS, Google Classroom, etc.)
S4Q4	I use learning interactions and activities platforms (Twiddla, Bubbl, Edmodo, Wikispaces, etc.).

S4Q5	Social media platforms may help in learning/teaching activities.
S4Q6	I have knowledge of survey software (Google forms, Survey Monkey, Zoho Survey, etc.).
S4Q7	I use the graphic design or video software (Adobe Photoshop, Adobe Illustrator, Sketch, etc.).
S4Q8	I am open to implementing Virtual Reality (VR) or Virtual Classrooms in teaching in the near future.
S4Q9	I think Serious Gaming and/or Gamification will have more use in the future.
S4Q10	Artificial intelligence (AI) is already a reality in higher education.

The intervention on the use of technological advancements

Code	Questionnaire item
S5Q1	I am aware that entrepreneurship in education is categorized as a competence.
S5Q2	I believe that in colleges and universities, engineering students should develop entrepreneurial skills.
S5Q3	Working as an engineer is the only profession accessible to recent engineering graduates.
S5Q4	Technological advancements bring new forms of occupations and/or kill existing traditional jobs.
S5Q5	The engineering course curriculums should be updated with the addition of new technologies.
S5Q6	I have heard of at least one new engineering study program in the previous five years.
S5Q7	Engineering has a bright future.

S5Q8	The engineering field faces challenging times.
S5Q9	Engineering graduation nowadays is more challenging than it was 20 years ago because of the significant growth of the study programs.
S5Q10	Engineering graduation nowadays is easier since digital technology is more readily available than it was 20 years ago.

Table 13: The interview items of "Survey for teaching faculties in higher education."

"Survey for students in higher education" in Section 1 collected information about participants major of studies and the continent where they had their last studying program. As the questionnaire was distributed mainly to engineering and business students, they could choose the options "engineering students", "business students" or "other". The Likert-scale methodology was used in the remaining four sections of the five questionnaires to collect information. For each question, participants had to select one of the following response options: Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree. In section two, are presented the data on the efficacy of new and emerging job characteristics. Opinions on the Framework of the Educational Technology Landscape are presented in Section 3. In Section 4, questions on the use of educational technology in higher education are posed to teaching faculties. The main topic of section 5 is the use of technological advancements in interventions. The bottom of each item included a glossary with associated references used to prepare explanations for the technical terms *Table 14*.

Characteristics of new and emerging jobs

Code	Questionnaire item
S2Q1	Bringing more digital educational technologies into my daily learning is positive and would help me improve my academic knowledge.
S2Q2	Learning entrepreneurship courses in my study program would give me more options to find/create a job.
S2Q3	I can afford to buy/subscribe to the latest digital technologies that are being proposed by my teaching faculties.
S2Q4	I can identify at least three disruptive technologies that I think will be

	implemented in education in less than five years.
S2Q5	My college/university provides a sufficient technological environment for creative-mind students.

Framework of the Educational Technology Landscape

Code	Questionnaire item
S3Q1	A model that includes traditional and newer digital educational technologies would help me in my studies.
S3Q2	A student should have advanced knowledge of learning theories.
S3Q3	I would prefer to study by following an instructional design model and its technologies.
S3Q4	I would prefer my teaching faculties to use motivational design models and their technologies.
S3Q5	I have heard about the 4th Industrial Revolution and see it as a positive thing for my future career.

Use of educational technologies

Code	Questionnaire item
S4Q1	In my studies, I use digital library platforms and/or MOOC (Massive Open Online Courses) platforms.
S4Q2	My college/university provides access to using open-source learning platforms (Moodle, Canvas, etc.).
S4Q3	I have experienced learning using Virtual Reality and/or Virtual Classrooms.
S4Q4	I use social media platforms for my daily studying.

S4Q5	I personally or classmates of mine have experienced studying using one of the following technologies at some point of our studies: Serious Gaming, Gamification, or Artificial Intelligence.
------	--

The intervention on the use of technological advancements

Code	Questionnaire item
S5Q1	I believe that in colleges and universities, engineering students should develop entrepreneurial skills.
S5Q2	Working as an engineer is the only profession accessible to recent engineering graduates.
S5Q3	Technological advancements bring new forms of occupations and/or kill existing traditional jobs.
S5Q4	In my opinion, engineering students and graduates will have successful professional careers.
S5Q5	Studying engineering or any other specialization is easier now than 10 years ago as digital technology is more readily available.

Table 14: The interview items of "Survey for teaching faculties in higher education."

Interviews

This section describes the aim of conducting this type of survey, the reasons for choosing an unusual participant, and the procedures followed to analyze and conclude the study survey.

Aim

Two interviews were conducted to provide more reliability for the two questions that did not satisfy the CFA test (Almalki, 2016) (the results are shown in Chapter 4, **Erro! A origem da referência não foi encontrada.**). The questions belong to "Survey for teaching faculties in higher education" and they are respectively S2Q2 and S5Q3. In the interview on S2Q2, the topic of technological platforms in

education and their impact on the workforce was explored. This study aims to provide a comprehensive and objective overview of this exciting and rapidly evolving field.

Participants

Two interviews were conducted at ChatGPT (<https://chat.openai.com>). The reasons for choosing this form of technology instead of humans are as follows. First, AI can provide all participants with a standardized and consistent interview experience, reducing the possibility of bias or variation in questioning. Second, AI can analyze data in real time, providing researchers instant insight into their responses and allowing them to adjust their questions accordingly. Third, AI can efficiently handle a large number of interviews, thereby saving researchers time and resources. Finally, AI can be programmed to recognize patterns and trends in data, providing researchers with valuable insights that would otherwise be difficult to discern through manual analysis.

Procedure

The interviews discussed the benefits and challenges of using technology in education, and the most recent developments in this field, including the integration of AI and ML, VR and AR, online LMS platforms, and blockchain technology.

Engineering is a dynamic and rapidly evolving field that offers graduates a wide range of career opportunities, and is a topic of conversation regarding the S5Q3 question. Briefly, some of the most common career paths of engineering students after graduation were explored, including industry jobs, government jobs, consulting, entrepreneurship, and academia. The versatility of an engineering degree is also discussed, as well as how it can lead to a variety of careers beyond engineering. Whether someone was a student considering a career in engineering or was simply interested in the field, the conversation provided valuable insights into the world of engineering (Chan et al., 2019). The interviews are included in Appendix 2.

Research ethics

Several precautions were taken to ensure the safety and protection of all participants in the experiment. Participants were informed that the survey was completely anonymous and that their responses would not be shared with third parties. To maintain anonymity, the survey was designed to avoid collecting e-mails (Marreiros et al, 2017). Instead, participants could log in to using their Gmail credentials to save time and continue their responses. Recruitment was conducted professionally through the LinkedIn and

private researcher networks. Many participants were eager to participate in the study; however, some were prohibited from completing the survey by their workplace institutions. In such cases, the researcher thanked them for their honesty, and did not force them to participate.

Students were usually recruited by lecturers who assist the researcher in finding sufficient participants. The QR codes with the survey link were shared with the students, and after the anonymity of the survey was explained, only those who showed interest participated in the survey. This study primarily focused on the two main pillars of "entrepreneurship education" and "engineering; thus, the focus was on identifying student participants studying in these or related fields.

The following ethical principles strictly adhered to all the participants during the survey:

Informed Consent: Participants were informed about the purpose of the survey and what their participation entails, and they provided voluntary consent.

Confidentiality: Participants were assured that their responses will be kept confidential and that their anonymity will be protected.

Data Protection: The acquired data were safeguarded against unauthorized access, manipulation, or theft.

Data Use and Analysis: When participants were asked how their data would be used and analyzed, they were informed, and the results were provided in an ethical manner to safeguard their anonymity (Rodriguez et al., 2013).

Bias: There was no evidence of bias in survey design, questions, or analysis (Polihronis et al. 2020).

Privacy: Participants were informed of the survey's privacy policies and how their personal information could be safeguarded.

Responsibility: The survey was carried out to guarantee that the rights of the participants were safeguarded and that the survey was carried out in an ethical manner (Arifiani et al., 2019).

The following ethical standards were considered when conducting the interviews:

Respect for autonomy. It was verified that the interview procedure did not affect the AI model or jeopardize its integrity or well-being (Polihronis et al. 2020).

Beneficence: The goal is to perform well while avoiding damage. This means that precautions were taken to guarantee that the AI model's knowledge was utilized for the good of mankind rather than for malevolent reasons (Williams et al., 2019).

Non-maleficence: It was avoided inflicting harm on the AI model or those who may have been harmed by the research (Williams et al., 2019).

Confidentiality: Unless there was a legal necessity to release it, any information received by the AI model was kept disclosed.

Informed consent: The AI model was informed of the study's goal, and informed consent was obtained for participation.

Fairness: This study was conducted in a fair and unbiased manner, considering the AI model's opinions and experiences (Polihronis et al., 2020).

Transparency: The study methods and aims were transparent, and the results and consequences were well explained (Baillie, 2019).

Furthermore, the researcher was aware of the limitations of the AI model, such as the possibility of mistakes and restrictions in the data used to train it. The possible societal ramifications of this research ensured that the findings were used in an ethical and responsible manner (Hinrichs-Krapels and Grant, 2016).

Data analysis

Appropriate statistical tools and procedures were used to validate and analyze the data gathered from the sample respondents.

The validation of the data included the following. (a) The internal consistency between the manifest variables and reliability of the latent constructs used in the research were measured using Cronbach's alpha to validate the questionnaires. This analysis for the two questionnaires was applied to validate the two sets of questionnaires (Pascoe and Edvardsson, 2015). (b) Qualitative analysis using ATLAS.ti to validate interviews. Qualitative techniques have been applied to strengthen the validity of the findings and interpretations (Johnson et al., 2007; Mayring, 2000). Information on the use of these techniques and tools is provided below:

An analysis matrix for the data analysis section is constructed and explained to provide a clear and concise summary of the data analysis process and results. The analysis matrix includes an analysis concept map in the introduction and is organized into three sub-sections: (a) SPSS to conduct Descriptive Statistics and (b) Confirmatory Factor Analysis (CFA) to verify whether all measured variables clearly explained their respective latent constructs (Sindwani & Goel, 2018). SPSS software (version 23) was used to analyze the advantages of online learning and explore how students felt about it during the pandemic.

A mixed research approach was used to analyze the data for this thesis. Analyses using both quantitative and qualitative data have been combined (Johnson et al. 2007). Once more, qualitative research is frequently "used to explore social processes or the causes of human behaviour" (Stenius et al., 2017). This study was one of its goals.

Validation

The two sets of questionnaires were validated using Cronbach's alpha to test the Reliability of the Latent Construct, and the interviews were validated using qualitative analysis software ATLAS.ti.

a) Reliability of the latent construct

Testing reliability is crucial, because it examines the quality of the measuring scale and verifies its internal consistency (Gleaves et al., 2014). Cronbach's alpha, a frequently used reliability indicator in survey questions that uses a Likert scale, was used in this study. Table 15 provides Cronbach's alpha values for each construct, which were considered independently. SPSS Output (version 26) was used to generate the data.

Latent Constructs	Cronbach's Alpha	No. of questionnaire items	Valid responses
Survey for teaching faculties in higher education	0.899	40	121
Survey for students in higher education	0.866	20	226

Table 15: Reliability of latent constructs for the two surveys.

Cronbach's alpha reliability values between ± 0.41 and ± 0.70 indicate moderate reliability of the scale being tested, whereas values greater than ± 0.70 indicate good internal consistency (Matsuda et al., 2003). Values of Cronbach's alpha between ± 0.70 and ± 0.90 , exceed the acceptable threshold (Korukcu et al., 2021). As shown in Table 15, the Cronbach's alpha was slightly below 0.90, demonstrating strong internal consistency and enabling further analysis.

b) Qualitative analysis for the Interviews by using Atlas.ti

Based on the CFA results of the Confirmatory Factor Analysis, it was concluded that the findings of the two questionnaire items were not fully accepted. The questionnaire items were S2Q2 and S5Q3, respectively. Another form of data collection was utilized (interviews), and the results were analyzed

using qualitative data software, with the purpose of integrating all statistics from the data collected as significant findings and thoroughly confirming the above questionnaire items. Two interviews, labeled "Interview S2Q2" and "Interview S5Q3," were developed in response to the questionnaires and were conducted on the ChatGPT website (chat.openai.com). Each interview included four questions to corroborate or contradict survey results.

After coding the data, a semantic linkage was created and shown for each interview using qualitative analysis software (ATLAS.ti) (Foster et al., 2015). Furthermore, word frequency visualizations for both interviews were created using the same software, indicating that the data collection findings were consistent with the literature analysis undertaken for the same ideas or variables (Aliprand, 1993; Latif et al., 2012).

The results of this analysis are presented in Chapter 4 (**Erro! A origem da referência não foi encontrada.**).

Analysis Matrix

The analysis matrix provides a concept map (Figure 7) that leads to the data analysis. The concept map of data analysis precedes the results and analysis of the next two chapters and also comprehends the findings from the Literature Review chapter.

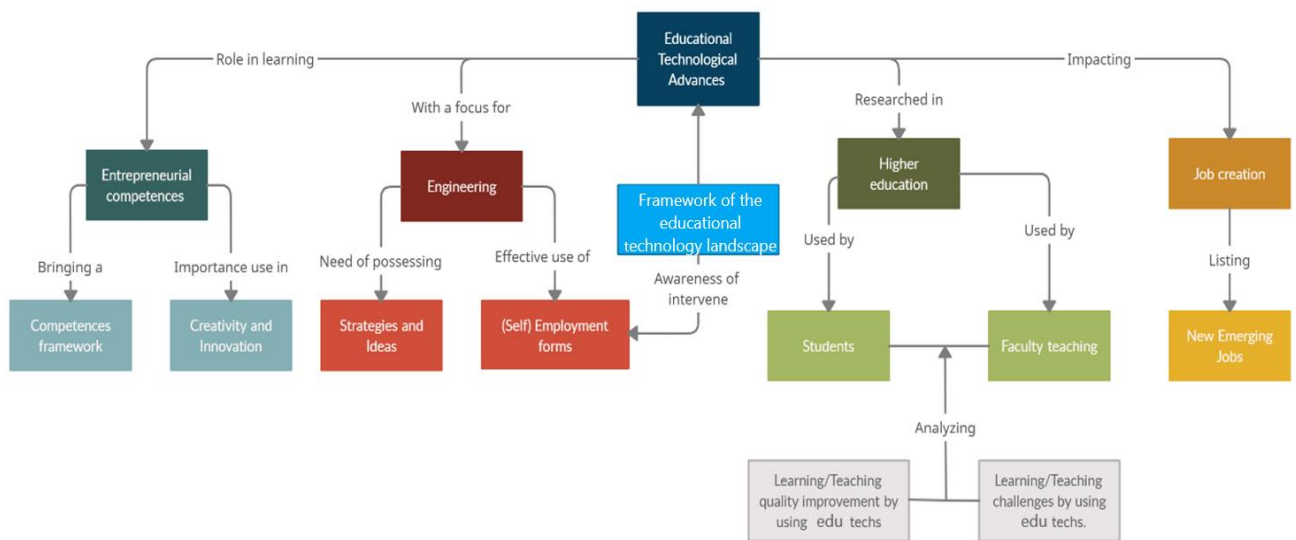


Figure 7: Concept map of the key terms analysed in "Data Analysis"

This study's main reference is the most recent digital technology, referred to as educational technological advancement. Figure 7 shows a concept map of the data analysis that provides a visual representation of the key components involved in the data analysis process.

The concept map shows the effects of advancements in educational technology on higher education and job creation. It begins with "Entrepreneurial Competencies" and ends with "New Emerging Jobs," demonstrating the various aspects of educational technology advancements and how students and faculties use them. The concept map identifies steps such as "engineering," "Framework of the Educational Technology Landscape," "Students," "Faculty Teaching," and "Challenging teaching methods through the use of digital technologies." These patterns are intended to demonstrate how educational technology advancements can be used by students and faculties to improve teaching and learning, resulting in the development of entrepreneurial competencies and creation of new jobs.

Figure 7 depicts the significance of creativity and innovation, forms of self-employment, and need for competencies. These aspects highlight the role of educational technological advancements in cultivating an entrepreneurial mind-set and encouraging individuals to think creatively and innovatively, resulting in the development of new products, services, and businesses.

Following the concept map, the next two data analyses included descriptive statistics conducted using SPSS, and confirmatory factor analysis using AMOS.

a) Descriptive Statistics conducted by using SPSS

In research studies, Likert-scale questionnaires are a popular method to gauge attitudes and opinions. Many statistical tools can be used to analyze data once it has been gathered. It involves asking participants to rate their level of agreement or disagreement with a series of statements, using a scale ranging from strongly agree to strongly disagree. SPSS, a widely used program for analyzing Likert-scale data, was used to analyze the data (Pascoe & Edvardsson, 2015; Xu & Leung, 2018).

The first step in using SPSS to analyze the Likert-scale questionnaire was to enter the data. The "Analyze" tab was then chosen, followed by the "Descriptive Statistics" and "Frequencies" tabs, which provided a thorough description of the data. In addition, the it was conducted a more thorough study of the data using the "Explore" function.

Graph analysis is another method used in SPSS to evaluate the data using a Likert scale. A bar chart showing the frequency of responses for each rating category is one of the most frequently used graphs

to display such data (Waldner et al., 2019). The "Graphs" tab was chosen in SPSS, then "Chart Builder," to create a bar chart. Subsequently, the settings were adjusted to present the data in a way that was both educational and visually appealing, using the appropriate chart type that had been selected. The results of the descriptive statistics are presented in Chapter 4 (***Erro! A origem da referência não foi encontrada.***).

b) Confirmatory factor analysis (CFA)

Confirmatory Factor Analysis (CFA) was used to verify whether all the measured variables clearly explained their respective latent constructs (Khan et al. 2021). This analysis aimed to understand the role of technological advancements in higher education from the perspectives of both the teaching faculties and students.

Role of technological advancements in higher education from teaching faculties perspective

To analyze and respond to the main study objective (What is the role of technological advancements in learning entrepreneurial competencies in higher education?), four construct objectives were included as defined in the section of the "Research questions." Specifically, the four sub-objectives of the study are as follows: to identify the characteristics of new emerging jobs brought about by technology-enriched educational spaces/platforms (O1); to identify and characterize framework of digital technologies used worldwide in education among different institutions (O2); to validate that the use of the "Framework of the Educational Technology Landscape" improves the learning outcomes of all higher education courses (O3); and to determine the awareness of the intervention on the use of technological advancements by engineering students (O4) (Landrum et al., 2021).

Figure 8 depicts the CFA measurement model for the same latent construct, demonstrating how each measure variable is associated with its presumed theoretical construct using the AMOS software. The figure shows that each major latent variable (O1, O2, O3, O4) was measured by their ten sub-constructs. The sub-constructs were 40 questionnaire items used to conduct a survey of the teaching faculties in higher education. Section 2 of the questionnaire items was linked to O1, Section 3 was linked to O2, Section 4 was linked to O3, and Section 5 was linked to O4. For instance, S2Q1 indicates the first question of O1 and S4Q3 indicates the third question of O3.

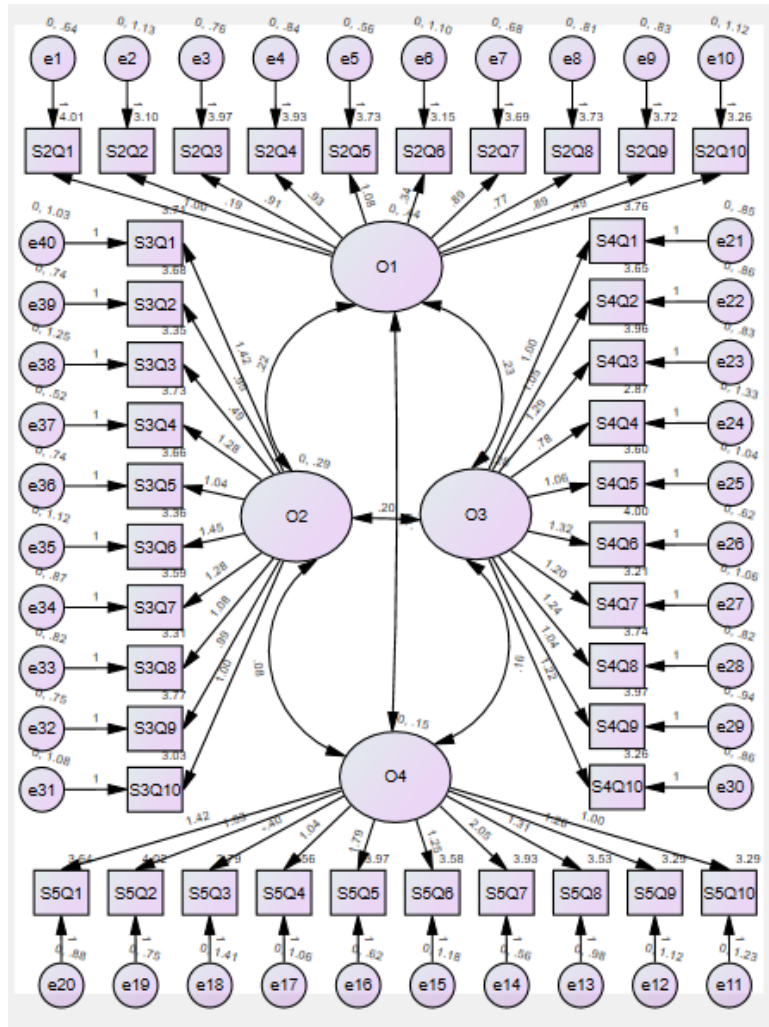


Figure 8: Confirmatory Factor Analysis (CFA) performed for the “Survey for teaching faculty in higher education.”

The small arrowed circles are residual terms that show the extent to which the change in the endogenous variable cannot be explained by exogenous influences. Multiple correlations were observed above each manifest variable response item, and the factor loading for the given item was specified next to the pointing arrow (Khan et al., 2021). AMOS software cannot perform without indicating the residual terms and letter “e” is used automatically to indicate the word “error.” An analytical summary of the aforementioned model, as produced by AMOS 26, is shown in Tables 16-18.

CFA Model Fit Summary

Name of Category	Model Fit Indices	Threshold limits	Values Attained
Absolute Fit Indices	χ^2	p -value > 0.05 non-significant p -value < 0.05	0

		significant p-value = 0 variables are independent	
	RMSEA	<0.08 good fit; 0.08-0.10 mediocre fit; and if >0.10 bad fit	0.073
Incremental Fit Indices	CFI	>0.95 great; >0.90 traditional; and if >0.80 sometimes permissible	0.964
	TLI	>0.90	0.943
	NFI	>0.90	0.946
Parsimonious Fit	CMIN/DF	<3 good; and if <5 sometimes permissible	1.632

Table 16: CFA model fit summary for the survey of teaching faculty in higher education.

Table 16 shows that the chi-square p value is 0, which was expected considering that the model has four major latent variables (O1, O2, O3, and O4), which are not linked to another main latent variable. Since the Chi-square p value is 0, the variables are independent of each other, but the CMIN/DF value is 1.632 (less than 3), which reveals that the data are suitable for the model fit (Khan et al., 2021). The other model indices were CFI=0,964, NFI=946, and TLI=0.943, which exceeded the threshold limits and indicated that this was a well-fitted model (Khan et al., 2021). The index of badness RMSEA was 0.073 (less than 0.1), revealing that the data fit the model well. This indicates that the CFA measurement model fits the data well (Khan et al., 2021).

Given that their p -values are less than 5% for 38 out of the 40 questionnaire items, Table 17 shows that all manifest variables connected to the corresponding latent construct shown in Figure 8 are statistically significant. The convergent validity of the CFA measurement model previously discussed is also achieved because each measured variable, manifest variable, or observed variable has a strong correlation with the theoretical construct assumed to underlie it, with regression model weights of greater than 0.4 (Abbott, 2003; Khan et al., 2021). The two questionnaire items that were not revealed to be significant were analyzed again by conducting qualitative research (S2Q3-Technology-enriched

educational platforms will reduce the need for the human workforce; S5Q3-working as an engineer is the only profession accessible to recent engineering graduates).

Path Analysis

Path	Std. Regression Coefficients	Standard Error (S.E)	Critical Ratio (C.R)	p-value
01 → S2Q1	1.000	0.636	5.062	<0.001
01 → S2Q2	0.195	0.162	1.202	0.229
01 → S2Q3	0.911	0.175	5.203	<0.001
01 → S2Q4	0.927	0.182	5.104	<0.001
01 → S2Q5	1.083	0.179	6.062	<0.001
01 → S2Q6	0.344	0.164	2.101	0.036
01 → S2Q7	0.890	0.168	5.297	<0.001
01 → S2Q8	0.773	0.168	4.617	<0.001
01 → S2Q9	0.890	0.178	5.007	<0.001
01 → S2Q10	0.488	0.171	2.860	0.004
04 → S5Q10	1.000	0.292	2.202	0.022
04 → S5Q9	1.263	0.448	2.818	0.005
04 → S5Q8	1.308	0.449	2.916	0.004
04 → S5Q7	2.053	0.614	3.343	<0.001
04 → S5Q6	1.249	0.450	2.779	0.005
04 → S5Q5	1.790	0.546	3.275	<0.001
04 → S5Q4	1.037	0.394	2.633	0.008
04 → S5Q3	-.400	0.323	-1.240	0.215
04 → S5Q2	1.531	0.487	3.142	0.002
04 → S5Q1	1.420	0.468	3.031	0.002

03 →	S4Q1	1.000	0.498	4.996	<0.001
03 →	S4Q2	1.045	0.251	4.166	<0.001
03 →	S4Q3	1.291	0.281	4.587	<0.001
03 →	S4Q4	0.778	0.254	3.064	0.002
03 →	S4Q5	1.056	0.264	4.002	<0.001
03 →	S4Q6	1.319	0.273	4.839	<0.001
03 →	S4Q7	1.198	0.283	4.236	<0.001
03 →	S4Q8	1.244	0.274	4.539	<0.001
03 →	S4Q9	1.038	0.255	4.069	<0.001
03 →	S4Q10	1.224	0.274	4.462	<0.001
02 →	S3Q10	1.000	0.457	5.169	<0.001
02 →	S3Q9	0.994	0.254	3.920	<0.001
02 →	S3Q8	1.084	0.272	3.990	<0.001
02 →	S3Q7	1.276	0.305	4.182	<0.001
02 →	S3Q6	1.449	0.346	4.183	<0.001
02 →	S3Q5	1.041	0.260	4.006	<0.001
02 →	S3Q4	1.277	0.286	4.472	<0.001
02 →	S3Q3	0.489	0.229	2.138	0.032
02 →	S3Q2	0.954	0.246	3.874	<0.001
02 →	S3Q1	1.421	0.338	4.209	<0.001

Table 17: Path Analysis of the Survey for Teaching Faculties in Higher Education

Table 18 shows the estimates of covariance between the four latent variables, which were not expected to be high because they were independent variables aimed at measuring the main study objective. Importantly, *the p-values* are less than 0.05, which means that they are statistically significant, indicating a significant covariance of the correlation between the variables (Khan et al., 2021).

Covariances:

Path	Estimate of Covariance	Standard Error (S.E.)	Critical Ratio (C.R.)	p-value
02 ↔ 04	0.085	.038	2.232	0.026
04 ↔ 03	0.161	.059	2.726	0.006
01 ↔ 03	0.233	.065	3.588	<0.001
02 ↔ 01	0.223	.067	3.350	<0.001
01 ↔ 04	0.187	.066	2.841	0.005
02 ↔ 03	0.201	.062	3.216	<0.001

Table 18: Estimates of covariance between the four latent variables

Table 19 shows that the variables that observe the other variables and their error terms are all significant because their *p*-values are all less than 0.05 (Abbott, 2003).

Variances:

Sub-Constructs	Estimate of Covariance	Standard Error (S.E.)	Critical Ratio (C.R.)	p-value
01	0.438	0.122	3.592	***
04	0.153	0.089	1.725	0.085
03	0.279	0.103	2.718	0.007
02	0.286	0.117	2.437	0.015
e1	0.644	0.096	6.723	<0.001
e2	1.131	0.146	7.724	<0.001
e3	0.759	0.108	7.029	<0.001
e4	0.842	0.119	7.076	<0.001
e5	0.560	0.088	6.361	<0.001
e6	1.100	0.143	7.676	<0.001
e7	0.679	0.097	6.980	<0.001
e8	0.812	0.112	7.264	<0.001

e9	0.830	0.117	7.119	<0.001
e10	1.115	0.147	7.607	<0.001
e11	1.226	0.162	7.565	<0.001
e12	1.119	0.151	7.429	<0.001
e13	0.979	0.133	7.358	<0.001
e14	0.558	0.093	6.029	<0.001
e15	1.179	0.158	7.452	<0.001
e16	0.617	0.094	6.576	<0.001
e17	1.057	0.141	7.521	<0.001
e18	1.412	0.183	7.721	<0.001
e19	0.749	0.106	7.046	<0.001
e20	0.880	0.122	7.236	<0.001
e21	0.846	0.115	7.336	<0.001
e22	0.864	0.118	7.308	<0.001
e23	0.831	0.118	7.047	<0.001
e24	1.334	0.176	7.590	<0.001
e25	1.036	0.141	7.374	<0.001
e26	0.622	0.092	6.767	<0.001
e27	1.057	0.145	7.275	<0.001
e28	0.817	0.115	7.087	<0.001
e29	0.938	0.128	7.348	<0.001
e30	0.864	0.121	7.143	<0.001
e31	1.085	0.147	7.367	<0.001
e32	0.754	0.105	7.206	<0.001
e33	0.818	0.114	7.154	<0.001
e34	0.868	0.124	6.971	<0.001

e35	1.118	0.160	6.970	<0.001
e36	0.740	0.104	7.142	<0.001
e37	0.525	0.081	6.458	<0.001
e38	1.249	0.163	7.667	<0.001
e39	0.735	0.102	7.236	<0.001
e40	1.033	0.149	6.938	<0.001

Table 19: Estimates of variances and error terms.

Role of technological advancements in higher education from students' perspective

Similarly, with the CFA model built to confirm the measured variables of the survey conducted with the teaching faculties, another CFA was conducted to confirm whether the measured variables clearly explained the respective latent variables of the questionnaire conducted with students.

Figure 9 shows that each major latent variable (O1, O2, O3, O4) was measured using its five sub-constructs. The sub-constructs included 20 questionnaire items used to conduct a survey of the teaching faculties in higher education. Section 2 of the questionnaire items was linked to O1, Section 3 was linked to O2, Section 4 was linked to O3, and Section 5 was linked to O4. For instance, S2Q1 indicates the first question of O1 and S4Q3 indicates the third question of O3. However, even though the analysis parameters were acceptable, the AMOS software indicated that the model was not well fitted for two reasons: the sample of participants was insufficient, or the model was not built properly. Since the sample size of participants in this survey was almost double that of participants in the other survey (226 students), it was understood that one latent variable (objective) required more than five questionnaire items to yield results.

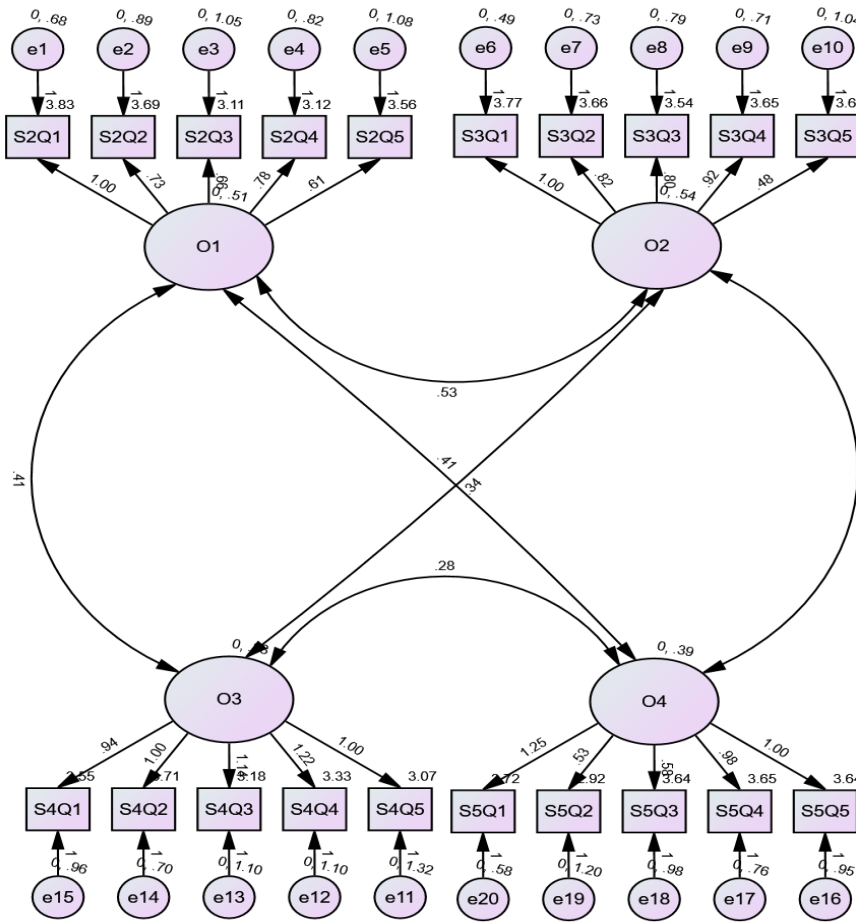


Figure 9: Confirmatory Factor Analysis (CFA) was performed for the “Survey for students’ faculties in higher education using four latent variables.

Figure 10 shows that this CFA (second one) was built by grouping the latent constructs (objectives), two by two (O1+O2) and (O3+O4). The two latent variables were linked to their sub-constructs, which were the questionnaire items used in the student survey. Residual terms were inserted appropriately, and multiple correlations were used to link the two latent variables. An analytical summary of this model, as produced by AMOS 26, is shown in Tables 20-22.

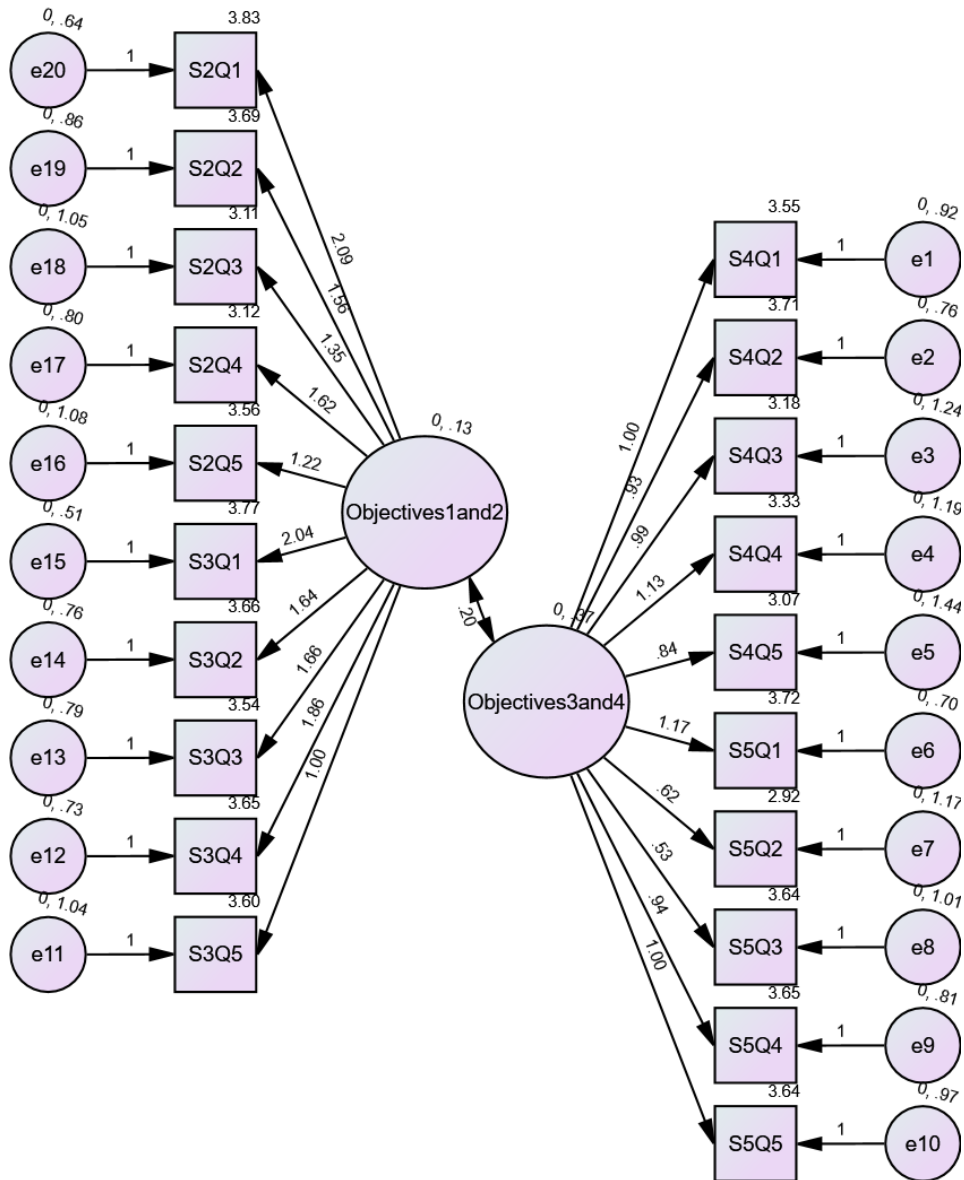


Figure 10: Confirmatory Factor Analysis (CFA) was performed for the “Survey for students’ faculties in higher education using two latent variables.

CFA Model Fit Summary

Name of Category	Model Fit Indices	Threshold limits	Values Attained
Absolute Fit Indices	χ^2	p -value > 0.05 non-significant p -value < 0.05 significant	0

		p-value = 0 variables are independent	
	RMSEA	<0.08 good fit; 0.08-0.10 mediocre fit. and if >0.10 bad fit	0.085
Incremental Fit Indices	CFI	>0.95 great; >0.90 traditional; and if >0.80 sometimes permissible	0.865
	TLI	>0.90	0.936
	NFI	>0.90	0.973
Parsimonious Fit	CMIN/DF	<3 good; and if <5 sometimes permissible	2.612

Table 20: CFA Model Fit Summary for the Survey for Students in higher education

Table 20 shows that the chi-square p -value is 0, which was expected considering that the model has two major latent variables (Objectives 1 and 2; Objectives 3 and 4), and they do not “communicate” between them by linking a parental construct. Since the Chi-square p -value is 0, the variables are independent of each other, but the CMIN/DF value is 2.612 (less than 3), which reveals that the data are suitable for the model fit (Khan et al., 2021). The other model indices were CFI=0.864 (permissible), NFI=973, and TLI=0.936, which exceeded the threshold limits and indicated that this was a well-fitted model (Abbott, 2003). The index of badness RMSEA was 0.085 (less than 0.1), revealing that the data fit the model well (Abbott, 2003; Khan et al. 2021).

This indicates that the built CFA measurement model was well fitted.

Given that their p -values were less than 5% for 20 of the 20 questionnaire items, all manifest variables related to the respective latent constructs depicted in Figure 10 were statistically significant, as indicated in Table 21. Each measured, manifest, or identified variable has a strong correlation with the theoretical construct assumed to underlie it, with regression model weights greater than 0.4, which also contributes to the convergent validity of the CFA measurement model previously discussed (Abbott, 2003; Khan et al., 2021).

Path Analysis

Path	Std. Regression Coefficients	Standard Error (S.E)	Critical Ratio (C.R)	p-value
01-02 → S2Q1	2.090	0.463	4.510	<0.001
01-02 → S2Q2	1.564	0.375	4.169	<0.001
01-02 → S2Q3	1.347	0.348	3.870	<0.001
01-02 → S2Q4	1.623	0.383	4.239	<0.001
01-02 → S2Q5	1.220	0.329	3.707	<0.001
01-02 → S3Q1	2.038	0.448	4.552	<0.001
01-02 → S3Q2	1.643	0.384	4.277	<0.001
01-02 → S3Q3	1.662	0.389	4.272	<0.001
01-02 → S3Q4	1.860	0.423	4.394	<0.001
01-02 → S3Q5	2.071	0.328	4.521	<0.001
03-04 → S4Q1	1.105	0.534	4.343	<0.001
03-04 → S4Q2	0.931	0.151	6.157	<0.001
03-04 → S4Q3	0.991	0.177	5.609	<0.001
03-04 → S4Q4	1.131	0.186	6.073	<0.001
03-04 → S4Q5	0.837	.174	4.816	<0.001
03-04 → S5Q1	1.165	0.170	6.862	<0.001
03-04 → S5Q2	0.623	0.148	4.205	<0.001
03-04 → S5Q3	0.530	0.135	3.918	<0.001
03-04 → S5Q4	0.942	0.155	6.097	<0.001
03-04 → S5Q5	0.997	0.166	6.002	<0.001

Table 21: Path Analysis of the Survey for Students in Higher Education

Covariances:

Given that the two latent variables are independent variables attempting to quantify the main research objective, Table 22 displays the estimates of covariance between the two latent variables. The p-values were less than 0.05, indicating that the correlation between the variables was statistically significant and that there was significant covariance between them (Khan et al., 2021).

Path	Estimate of Covariance	Standard Error (S.E.)	Critical Ratio (C.R.)	p-value
01 - 02 <-> 03 - 04	0.196	0.051	3.876	<0.001

Table 22: Covariance estimates between the two latent variables.

Table 23 shows that the variables that observe the other variables and their error terms are all significant because their p-values are less than 0.05(Abbott, 2003).

Variances:

Sub-Constructs	Estimate of Covariance	Standard Error (S.E.)	Critical Ratio (C.R.)	p-value
Objectives 3 and 4	0.368	0.092	3.995	<0.001
Objectives 1 and 2	0.125	0.053	2.355	0.019
e1	0.924	0.094	9.839	<0.001
e2	0.764	0.078	9.801	<0.001
e3	1.239	0.123	10.047	<0.001
e4	1.192	0.121	9.846	<0.001
e5	1.442	0.140	10.265	<0.001
e6	0.702	0.076	9.215	<0.001
e7	1.166	0.112	10.373	<0.001
e8	1.013	0.097	10.412	<0.001
e9	0.814	0.083	9.833	<0.001
e10	0.972	0.098	9.882	<0.001

e11	1.043	0.100	10.408	<0.001
e12	0.730	0.076	9.619	<0.001
e13	0.786	0.080	9.877	<0.001
e14	0.761	0.077	9.869	<0.001
e15	0.514	0.058	8.910	<0.001
e16	1.078	0.104	10.321	<0.001
e17	0.805	0.081	9.927	<0.001
e18	1.048	0.102	10.248	<0.001
e19	0.861	0.086	10.017	<0.001
e20	0.639	0.070	9.174	<0.001

Table 23: Estimates of variances and error terms.

4. Results

In this chapter, the primary findings of the study are presented and analyzed in the context of existing research. The chapter completes the Analysis Matrix section (Chapter 3, **Descriptive Statistics conducted by using SPSS**) and shows the results of the study survey, questionnaires, and interviews. As indicated in Chapter 3 (**Descriptive Statistics conducted by using SPSS**), the results of the questionnaires are presented using Descriptive Statistics obtained using SPSS, and the results of the interviews are presented using a qualitative analysis obtained using the software ATLAS.ti. The use of both SPSS and ATLAS.ti in data analysis offers a comprehensive approach to data interpretation that has a range of advantages (Mason, 2006).

SPSS is a powerful tool for managing and conducting statistical analysis. This is especially valuable in questionnaire-based research, in which the data are typically quantitative. Using SPSS, researchers can easily compute descriptive statistics, such as the mean, median, mode, and standard deviation, which provide a summary of the dataset. This software also enables the application of more complex statistical tests, such as factor analysis, which can help identify patterns, relationships, and differences among variables (Rahman & Muktadir, 2021). The patterns and relationships are described in detail in Chapter 5. The use of SPSS and ATLAS.ti in data analysis provides a comprehensive approach to data interpretation, with a number of benefits (Méndez-Romero, 2016). The use of SPSS not only simplifies the statistical analysis process but also improves the reliability and accuracy of the results by reducing human error (Rahman & Muktadir, 2021).

ATLAS.ti is an industry leader in qualitative data analysis software. It is especially useful for dealing with unstructured data such as interview transcripts, where it is difficult to quantify Obermayer et al. (2022). ATLAS.ti enables the systematic identification, coding, and categorization of data themes or patterns (Rahman & Muktadir, 2021). This method allows the investigation of underlying meanings, perceptions, and experiences that are frequently overlooked in quantitative analysis. ATLAS.ti's ability to visualize data connections and patterns can lead to deeper insights and a more complete understanding of the research topic (Huth et al., 2016).

SPSS and ATLAS.ti allow for the integration of quantitative and qualitative data (a mixed-methods approach), which is a key strength of comprehensive research (Huth et al., 2016). This method allows data triangulation, which increases the validity of the findings. In other words, quantitative data can provide a broad, generalizable understanding of the research topic, whereas qualitative data can

provide a detailed, nuanced perspective (Obermayer et al., 2022). Together, they provide a more comprehensive picture of the research topic than either method alone.

Thus, using SPSS and ATLAS.ti to present the questionnaire and interview results, respectively, provides a robust, versatile, and comprehensive approach to data analysis that can improve the quality and depth of research findings (Unger et al., 2020).

Questionnaires

Descriptive Statistics conducted by using SPSS

This section is showing the descriptive statistics of both the “Survey for teaching faculties in higher education” and “Survey for students in higher education.” As shown in Table 15 (**Reliability of the latent construct**), the validity and reliability analyses demonstrated that each latent construct Composite Reliability (CR) exceeded the accepted threshold of 0.70, indicating a high degree of internal consistency among the scale items (Khan et al., 2021). Additionally, the Average Variance Extracted (AVE) for each latent construct surpasses the threshold of 0.5, indicating that the CFA measurement model presented earlier possesses robust convergent validity (Khan et al. 2021).

Both questionnaires collected data on students' and teaching faculties' perspectives on the impact of technological advancements in higher education, particularly on engineering students' perspectives and thoughts on incorporating entrepreneurship education into engineering programs. A Likert scale was employed, with response options ranging from "Strongly Disagree" to "Strongly Agree."

Teaching faculties perception of technological advancements

Characteristics of new and emerging jobs

Code	Variables	SD (1)	D (2)	Total (1+2)	N (3)	A (4)	SA (5)	Total (4+5)
S2Q1	Technology-enriched educational platforms bring new and emerging jobs.	2	8	10	19	34	46	80
S2Q2	Technology-enriched educational platforms will reduce the need for the human workforce.	4	27	31	43	22	13	35
S2Q3	I am open to introducing more digital educational technologies in my daily	2	9	11	21	32	45	77

	teaching in the near future.							
S2Q4	Introducing entrepreneurship courses in higher education will give graduates more options to find/create jobs.	4	7	11	23	32	43	75
S2Q5	Learning and implementing the latest digital technologies is expensive for me.	1	10	11	29	41	28	69
S2Q6	I believe there is a digital transformation in the job industry.	4	26	30	37	29	13	42
S2Q7	New and emerging jobs brought by digital technologies differ considerably from traditional jobs.	2	13	15	27	42	25	67
S2Q8	I can identify at least five disruptive technologies.	3	11	14	26	41	28	69
S2Q9	In my field of expertise, there is an expansion of new and emerging jobs.	4	11	15	25	38	31	69
S2Q10	I think the institution I teach provides a sufficient technological environment for creative-mind students.	6	20	26	40	25	18	43

Multiple taxonomies of educational technologies

Code	Variables	SD (1)	D (2)	Total (1+2)	N (3)	A (4)	SA (5)	Total (4+5)
S3Q1	I am aware of Bloom's Taxonomy and its applications in education.	7	14	21	19	30	39	69
S3Q2	A complete taxonomy framework including as many educational technologies as possible is needed in education	1	13	14	26	45	24	69
S3Q3	A complete taxonomy framework including as many educational technologies as possible is difficult to be provided/realized.	7	18	25	27	38	19	57
S3Q4	I know the learning theories and can mention at least one learning theory.	2	11	13	27	42	27	69
S3Q5	In my opinion, following an instructional	1	14	15	28	40	26	66

	design model in teaching is beneficial.							
S3Q6	I am aware of the implementation of instructional design models in higher education, such as ADDIE model.	16	10	26	24	37	22	59
S3Q7	I am aware of motivational design models.	6	15	21	24	36	28	64
S3Q8	In my opinion, Bloom's Taxonomy should be updated.	4	23	27	38	27	17	44
S3Q9	I believe the so-called 4 th Industrial Revolution is already a reality.	2	11	13	27	39	30	69
S3Q10	I follow the latest updates of the World Economic Forum.	11	24	35	37	25	12	37

Use of educational technologies

Code	Variables	SD (1)	D (2)	Total (1+2)	N (3)	A (4)	SA (5)	Total (4+5)
S4Q1	During my classes, I emphasize using digital library platforms (Google books, Ibiblio, etc.)	4	12	16	23	40	30	70
S4Q2	I recommend and use the MOOC (Massive Open Online Courses) platforms.	3	11	14	28	41	26	67
S4Q3	My institution provides access to using open-source learning platforms (Moodle, Canvas LMS, Google Classroom, etc.)	4	7	11	19	31	48	79
S4Q4	I use learning interactions and activities platforms (Twiddla, Bubbl, Edmodo, Wikispaces, etc.).	18	23	41	34	21	13	34
S4Q5	Social media platforms may help in learning/teaching activities.	3	16	19	24	39	27	66
S4Q6	I have knowledge of survey software (Google forms, Survey Monkey, Zoho Survey, etc.).	2	10	12	20	31	46	77
S4Q7	I use the graphic design or video software (Adobe Photoshop, Adobe Illustrator,	9	22	31	37	19	22	41

	Sketch, etc.).							
S4Q8	I am open to implementing Virtual Reality (VR) or Virtual Classrooms in teaching in the near future.	4	10	14	25	39	31	70
S4Q9	I think Serious Gaming and/or Gamification will have more use in the future.	2	8	10	21	30	48	78
S4Q10	Artificial intelligence (AI) is already a reality in higher education.	6	23	29	36	27	17	44

The intervention on the use of technological advances

Code	Variables	SD (1)	D (2)	Total (1+2)	N (3)	A (4)	SA (5)	Total (4+5)
S5Q1	I am aware that entrepreneurship in education is categorized as a competence.	4	14	18	24	39	28	67
S5Q2	I believe that in colleges and universities, engineering students should develop entrepreneurial skills.	3	8	11	16	35	47	82
S5Q3	Working as an engineer is the only profession accessible to recent engineering graduates.	18	24	42	36	21	10	31
S5Q4	Technological advances bring new forms of occupations and/or kill existing traditional jobs.	5	15	20	29	36	24	60
S5Q5	The engineering course curriculums should be updated with the addition of new technologies.	1	11	12	18	35	44	79
S5Q6	I have heard of at least one new engineering study program in the previous five years.	5	13	18	24	39	28	67
S5Q7	Engineering has a bright future.	4	9	13	21	31	44	75
S5Q8	The engineering field faces challenging times.	3	18	21	28	35	25	60
S5Q9	Engineering graduation nowadays is more challenging than it was 20 years ago	7	22	29	37	23	20	43

	because of the significant growth of the study programs.							
S5Q10	Engineering graduation nowadays is easier since digital technology is more readily available than it was 20 years ago.	8	19	27	33	28	21	49

Table 24: Multiple tables of descriptive statistics of the Survey for Teaching Faculties in Higher Education

The "Survey for Teaching Faculties in Higher Education analyzed responses from faculty members who had taught at a college or university within the past five years, yielding a sample size of 109 responses. In general, the results indicate that teaching faculties tend to support the assertions made in the questionnaire, with "Agree" and "Strongly Agree" being the most frequent responses in most instances (Table 24). However, certain questions elicited more evenly distributed responses. For example, only 32% of respondents agreed that "Technology-enriched educational platforms will reduce the need for the human workforce." Some participants were unsure about specific statements, such as only 38% of respondents believing in an ongoing digital transformation in the job industry, and 39% believing that their teaching institution offers adequate technological support for creative students (Table 24).

Approximately 33% of the respondents were expected to follow the latest updates from the World Economic Forum as they provide valuable information related to entrepreneurship and entrepreneurship education. The results also show that teaching faculties do not widely use learning interaction and activity platforms (such as Twiddla, Bubbl, Edmodo, and Wikispaces), with only 31% reporting usage, and graphic design or video software (such as Adobe Photoshop, Adobe Illustrator, and Sketch), with only 37% reporting usage. Moreover, only 40% of teaching faculty members believe that artificial intelligence (AI) is already a reality in higher education.

One statement where the majority of respondents disagreed was "Working as an engineer is the only profession accessible to recent engineering graduates," with only 28% in agreement. Additionally, 39% of the respondents believed that graduating from engineering was more challenging than it was 20 years ago, because of the significant expansion of study programs.

By contrast, the other 32 statements had a higher level of affirmation, with at least 50% of the respondents expressing agreement or strong agreement.

Students' perception of technological advancements

Characteristics of new and emerging jobs

Code	Variables	SD (1)	D (2)	Total (1+2)	N (3)	A (4)	SA (5)	Total (4+5)
S2Q1	Bringing more digital educational technologies into my daily learning is positive and would help me improve my academic knowledge.	8	15	23	36	86	64	150
S2Q2	Learning entrepreneurship courses in my study program would give me more options to find/create a job.	6	23	29	47	82	51	133
S2Q3	I can afford to buy/subscribe to the latest digital technologies that are being proposed by my teaching faculties.	19	38	57	78	51	23	74
S2Q4	I can identify at least three disruptive technologies that I think will be implemented in education in less than five years.	10	44	54	78	56	21	77
S2Q5	My college/university provides a sufficient technological environment for creative-mind students.	13	21	34	50	84	41	125

Multiple taxonomies of educational technologies

Code	Variables	SD (1)	D (2)	Total (1+2)	N (3)	A (4)	SA (5)	Total (4+5)
S3Q1	A model that includes traditional and newer digital educational technologies would help me in my studies.	3	16	19	46	90	54	144
S3Q2	A student should have advanced knowledge of learning theories.	5	18	23	50	92	44	136
S3Q3	I would prefer to study by following an instructional design model and its technologies.	10	19	29	60	83	37	120
S3Q4	I would prefer my teaching faculties to use	9	19	28	48	88	45	133

	motivational design models and their technologies.							
S3Q5	I have heard about the 4th Industrial Revolution and see it as a positive thing for my future career.	9	20	29	52	81	47	128

Use of educational technologies

Code	Variables	SD (1)	D (2)	Total (1+2)	N (3)	A (4)	SA (5)	Total (4+5)
S4Q1	In my studies, I use digital library platforms and/or MOOC (Massive Open Online Courses) platforms.	12	20	32	51	81	45	126
S4Q2	My college/university provides access to using open-source learning platforms (Moodle, Canvas, etc.).	4	24	28	47	82	52	134
S4Q3	I have experienced learning using Virtual Reality and/or Virtual Classrooms.	30	33	63	47	69	30	99
S4Q4	I use social media platforms for my daily studying.	23	35	58	42	65	44	109
S4Q5	I personally or classmates of mine have experienced studying using one of the following technologies at some point of our studies: Serious Gaming, Gamification, or Artificial Intelligence.	36	39	75	45	59	30	89

The intervention on the use of technological advances

Code	Variables	SD (1)	D (2)	Total (1+2)	N (3)	A (4)	SA (5)	Total (4+5)
S5Q1	I believe that in colleges and universities, engineering students should develop entrepreneurial skills.	9	15	24	44	86	55	141
S5Q2	Working as an engineer is the only profession accessible to recent engineering graduates.	27	43	70	77	42	20	62

S5Q3	Technological advances bring new forms of occupations and/or kill existing traditional jobs.	9	20	29	51	86	43	129
S5Q4	In my opinion, engineering students and graduates will have successful professional careers.	10	18	28	52	84	45	129
S5Q5	Studying engineering or any other specialization is easier now than 10 years ago as digital technology is more readily available.	12	19	31	45	80	53	133

Table 25: Multiple tables of descriptive statistics of the Survey for Students' Faculties in Higher Education

The survey sought to gather responses from students who were either currently enrolled or had graduated from a college or university within the past two years. After removing incomplete responses, the responses of 209 students were analyzed. In general, students exhibit a positive attitude towards the assertions made in the questionnaire, with "Agree" and "Strongly Agree" being the most prevalent responses (Table 25).

However, some statements did not agree or strongly agreed with the majority of students. For example, only 35% of the students felt that they could afford to purchase or subscribe to the latest digital technologies recommended by their teaching faculties, whereas only 36% could identify at least three disruptive technologies that they thought would be implemented in education within the next five years. Additionally, only 47% of the students had experienced learning using virtual reality and/or virtual classrooms and only 42% had experienced studying using serious gaming, gamification, or artificial intelligence (Table 25).

Conversely, 15 statements had a higher level of affirmation, with at least 50% of the respondents expressing agreement or strong agreement. A more detailed analysis of the specific questionnaire statements is provided in subsequent sections.

Interviews

Qualitative analysis for the Interviews by using Atlas.ti

As mentioned in Chapter 3, the Atlas.ti software was used to conduct a qualitative analysis of two separate interviews, as supported by Obermayer et al.(2022). The interviews were efficiently coded and analyzed, and word frequencies were retrieved from each interview to identify major themes and patterns using this program. Furthermore, for each study, a semantic linkage was built and shown, which aided in identifying links between various concepts and themes within the data (Huth et al., 2016). Atlas.ti is a useful tool for qualitative research that enables researchers to obtain a deeper understanding of the experiences and viewpoints of study answers (Wang et al., 2018).

Semantic Linkage is an Atlas.ti visualization tool for identifying ties and connections between distinct ideas and themes in qualitative data (Huth et al., 2016). It helps researchers to see patterns, clusters, and links between codes and categories graphically (Wang et al., 2018).

Semantic Linkage examines the frequency and co-occurrence of codes in data before categorizing them into clusters based on their links. In the resultant diagram, clusters are depicted as nodes, with lines linking them to illustrate their relationships (Unger et al., 2020).

As previously mentioned, the two sets of interviews were named respectively “Interview S2Q2” and “Interview S5Q3,” and aimed to deepen the efficacy of the questionnaires. To create a Semantic Linkage in Atlas.ti, the data were first coded by identifying key themes and concepts (Unger et al., 2020). Next, it was used the "Networks" feature in Atlas.ti to create a Semantic Linkage. The software analyzed the frequency and co-occurrence of codes. A diagram illustrating the relationship between the two was created for each interview.

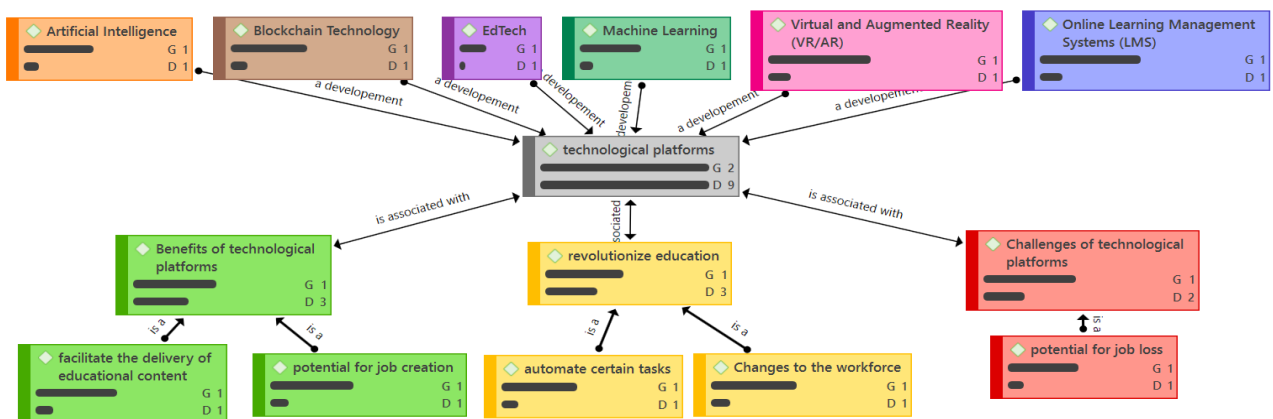


Figure 11: Semantic Linkage for “Interview S2Q2”

It is important to report the values of G and D in a research endeavor to offer a measure of coding quality. A high level of groundedness means that the coding is highly supported by data and is thus more likely to be correct (MacQueen et al., 1998). A high-density level shows significant links between distinct concepts or themes, which may provide insights into the linkages between various parts of the data (MacQueen et al., 1998). However, a high density might suggest that the coding is overly wide or that there is a lack of specificity (MacQueen et al., 1998).

Because the software is used to code and evaluate a large number of texts (interviews) in our projects, the project has only one interview, and the values of G and D range from 1 to 3, suggesting that the coding is well supported by the data and hence, trustworthy (Huth et al., 2016).

Semantic linkages were then investigated to acquire insights into the links between various themes and ideas. Patterns and clusters in the data demonstrate that the "benefits of technology platforms" enhance the delivery of educational content and have the potential to create jobs (Rani & Furrer, 2020). Revolutionize education is associated with "automate some jobs" and results in "workforce transformations." The difficulties of technology platforms have been shown to result in employment loss. These findings are consistent with the responses of the teaching faculty to Statement S2Q2 in the descriptive analysis section.

In addition, word frequency was used to determine the most frequently used terms or phrases in the dataset, allowing researchers to acquire a more in-depth understanding of the data's content and themes (Scharenborg et al., 2017).

Patterns, trends, and relationships within data that are not immediately apparent from a simple reading can be identified by analyzing the frequency of specific words or phrases (Scharenborg et al., 2017). This can aid in determining whether words correspond to the coding process and identifying key themes. Word frequency is a powerful tool for conducting systematic and objective qualitative data analysis (Scharenborg et al., 2017). As shown in Figure 12, the most frequently used words in the word frequency analysis were technology, education, education, platform, workforce, and types of technological platforms, again demonstrating the full validity of the S2Q2 Semantic Linkage.

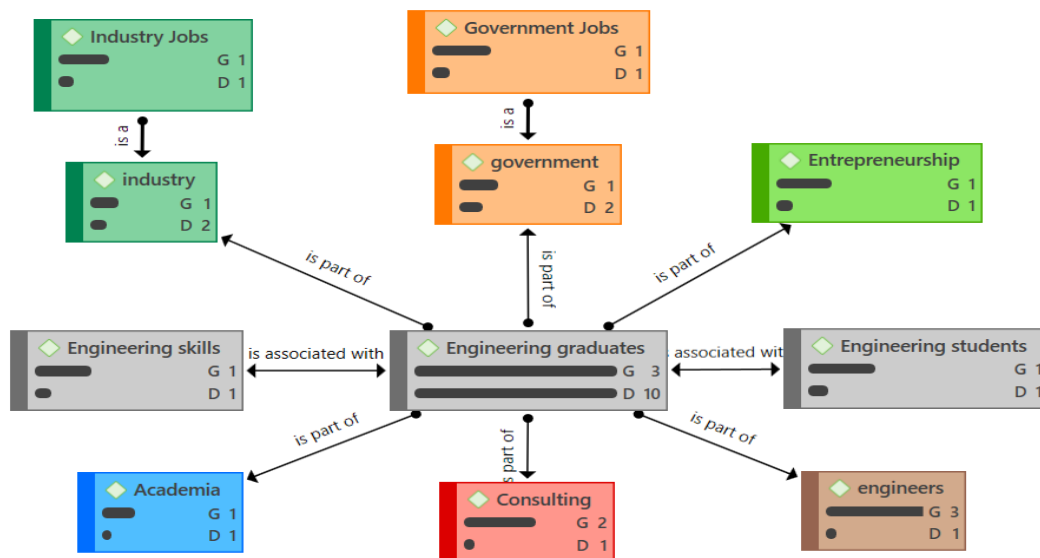


Figure 13: Semantic Linkage for “Interview S5Q3”

The Semantic Linkage of “Interview S5Q3,” as shown in Figure 13, shows engineering graduates with G and D values of 3 and 10, respectively. This cluster is associated with the “Engineering students” and “Engineering skills.” This linkage indicates that engineering students can work in industry, government, entrepreneurship, academia, consulting, and engineering fields (with the highest groundedness). “Industry” is associated also with “industry jobs” code and “government” is associated with “government jobs.” The G and D values were satisfactory (between 1 and 3), indicating that the coding and linkage are trustworthy (MacQueen et al., 1998). These findings are consistent with the teaching faculties responses to Statement S3Q5 in the descriptive analysis section.

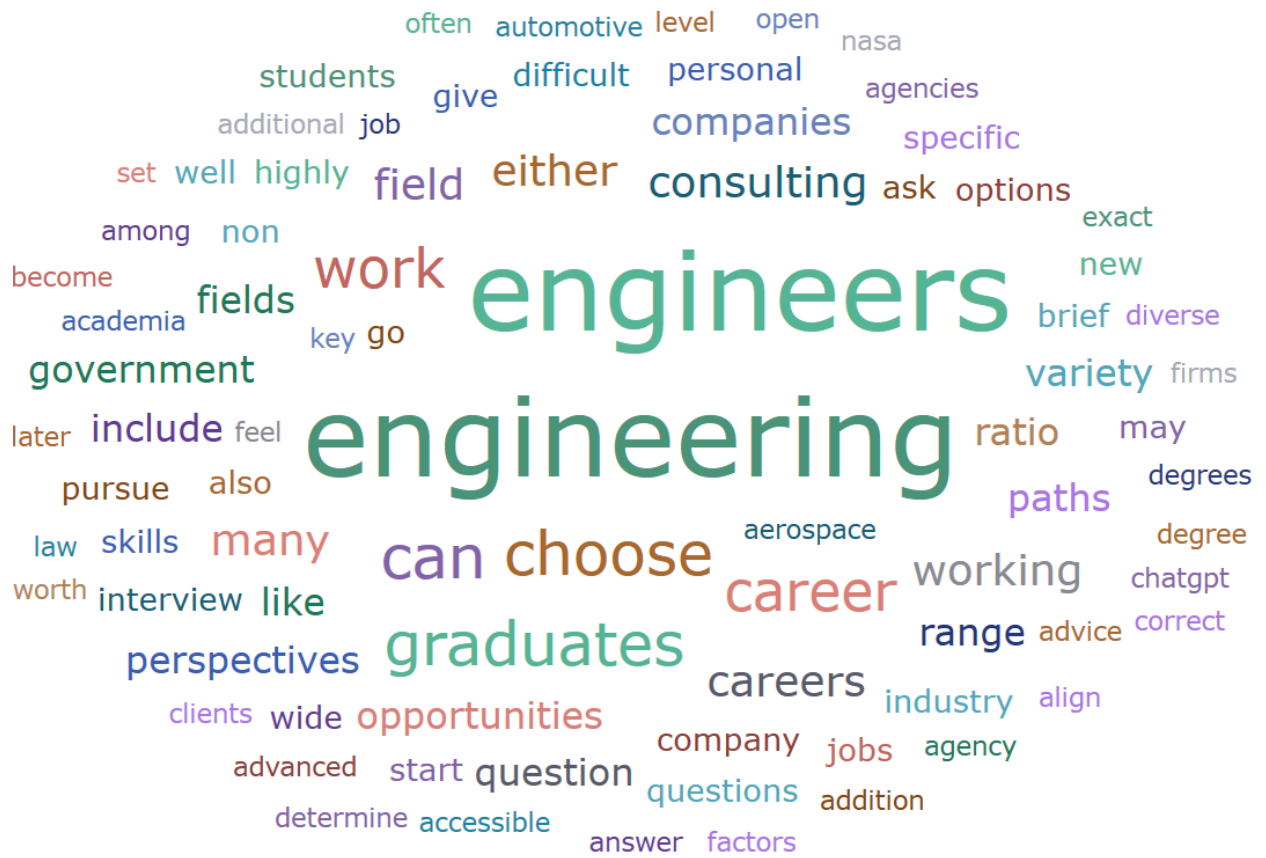


Figure 14: Word Frequencies for the S3Q5 Interview

Regarding the word frequency analysis, as shown in Figure 14, words such as engineering, engineers, graduates, work, and job options after graduation were dominant. Again, this proves the full validity of the Semantic Linkage for S5Q3 (Scharenborg et al. 2017).

5. Analysis

This chapter analyzes the data from the questionnaire results presented in Chapter 4. The chapter is organized by providing a set of 5W questions (who, what, when, where, and why) to solidify the main research question (as shown in the Methodology chapter) and fulfill the study objectives.

Hence, the five intermediate distinct sections provide answers to the following 5W questions:

- Section 5.1: What are the most effective strategies for utilizing digital educational technologies to enhance student learning and engagement?
- Section 5.2: When should engineers learn entrepreneurial competencies, proving that they need them?
- Section 5.3: Where can evidence exist regarding the impact of technology-enriched educational platforms on job creation and reduction exist?
- Section 5.4: Who is the most affected by the implementation of digital technologies in education and engineering?
- Section 5.5: Why the identified technologies in the “Framework of the Educational Technology Landscape” are the right ones, and how will they impact our lives?

The primary goal of this chapter is to answer five key questions regarding the development of entrepreneurial skills among engineering students, in addition to expressing the results of the first and final sections. This order was organized to ensure a logical flow of ideas and coherence in the presentation of the results of this study (Moon et al.2019).

Section 5.1 investigated the most effective strategies for enhancing student learning and engagement through the use of digital educational technologies. Both questionnaires were administered by the teaching faculty and students to capture innovative approaches, learning platforms, and collaborative online tools, emphasizing their ability to encourage active participation and cater to different learning styles (Ha & Im, 2020).

Section 5.2 focuses on determining when a student's college/university career is the best time to develop entrepreneurial skills. By analyzing questionnaires completed by both teaching faculty and students, it aims to identify a student's academic journey to determine when it is most effective in nurturing and enhancing entrepreneurial competencies.

Section 5.3 focuses on investigating the role of technology-enriched educational platforms in job creation and their overall impact on the job market. This study aims to examine the role of technology in the creation of new jobs and how technological advancements can affect job prospects and career paths (Han et al., 2017).

Section 5.4 searches for the factors that are most affected by the adoption of digital technology in education. It examines various stakeholders in education, such as higher education teaching faculty and students, and how the implementation of digital technology affects them.

Section 5.5 discusses the selection and application of specific (mostly) educational technologies in the “Framework of the Educational Technology Landscape.” This section examines why certain technologies were chosen, and how they affected students' lives and society as a whole. This chapter examines the study's findings in depth, contextualizing them within the larger context of existing research on entrepreneurship and education.

Section 5.1

Effective Strategies for Using Digital Tools to Improve Student Learning and Engagement

This research question includes the findings of the analysis of the two surveys. First, by analyzing the Survey of Teaching Faculties in Higher Education, the participants expressed their willingness to use more digital educational technologies in their daily teaching in the near future (S2Q2 statement).

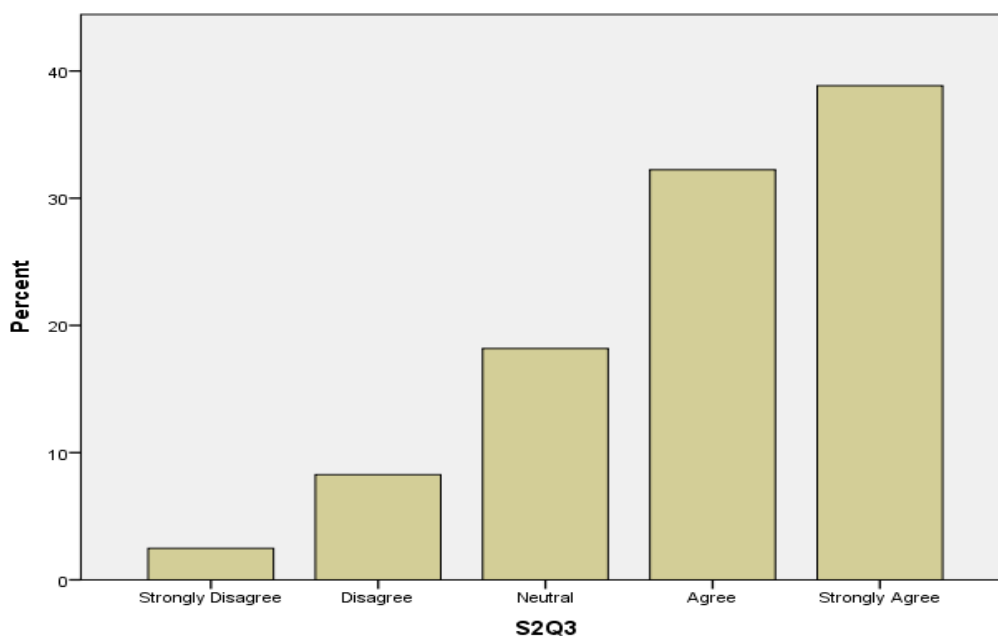


Chart 1: Bar Chart of S2Q3 Research Statement of the Survey for Teaching Faculties in Higher Education

Of the respondents, 70.6% expressed agreement or strong agreement with the utilization of more educational technologies in the near future, whereas only 10% disagreed with the statement. In relation to disruptive technologies, 63.3% of the teaching faculty participants confirmed their familiarity with such technologies and their ability to identify at least five of them (S2Q8). Only 12.8% of faculty respondents were unable to identify the five disruptive technologies. Based on these findings, it can be inferred that incorporating more disruptive technologies into education is an effective strategy for enhancing student learning and engagement, which is also supported by Barros and Osorio (2017).

Section three of the "Survey for Teaching Faculties" brings more valuable insights about the most effective strategies to enhance the students' learning. Again, 63% of the participants appreciated Bloom's Taxonomy in Education (S3Q1), and the same percentage of faculty members believed that a taxonomy framework for educational technologies was needed (S3Q2). Only 19% of the respondents disagreed with S3Q1 and 12.8% disagreed with S3Q2.

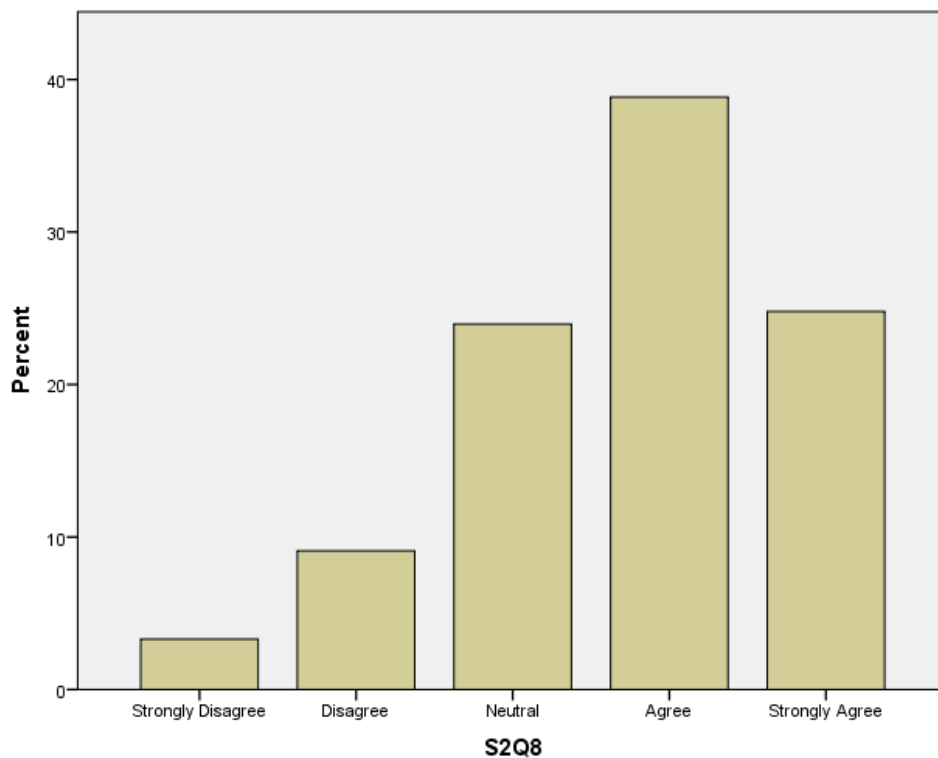


Chart 2: Bar Chart of S2Q8 Research Statement of the Survey for Teaching Faculties in Higher Education

Again, the respondents confirmed their good knowledge of learning theories (S3Q4), with 63% versus 11% with no deep knowledge of learning theories.

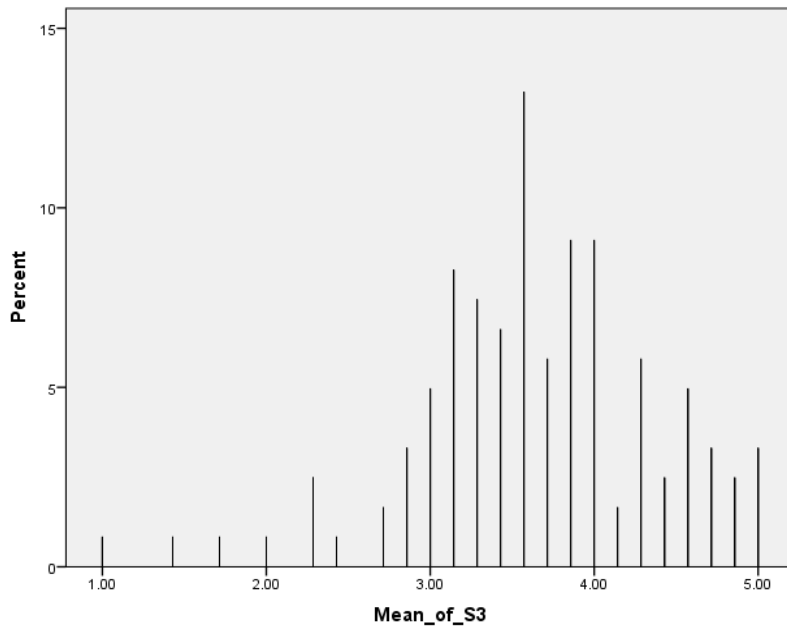


Chart 3: Mean Chart of selected items of Section 3 from the Survey for Teaching Faculties in Higher Education

Teaching faculty members also had a positive opinion about (S3Q5) using an instructional design model in teaching (60%) and its implementation (54%), as represented by statement S3Q6. Only 13% of the respondents disagreed with S3Q5 and 23% disagreed with S3Q6. A very important questionnaire statement (S3Q7) found satisfactory confirmation: 58% of teaching faculties were aware of motivational design models and only 19% were not. Most faculties (63%) believed that the 4th Industrial Revolution is already a reality (11% disagree). All these confirmations led to the other section of the questionnaire, which showed the main findings (the use of educational technologies in each of the above categories).

Chart 3 shows the mean of the seven analyzed statements in Section 3 (S3Q3, S3Q8, and S3Q10), which are not included in this section.

Another important research item is S5Q5, where 65% of the teaching faculties believe that engineering course curricula should be updated with the addition of new technologies (11% disagree).

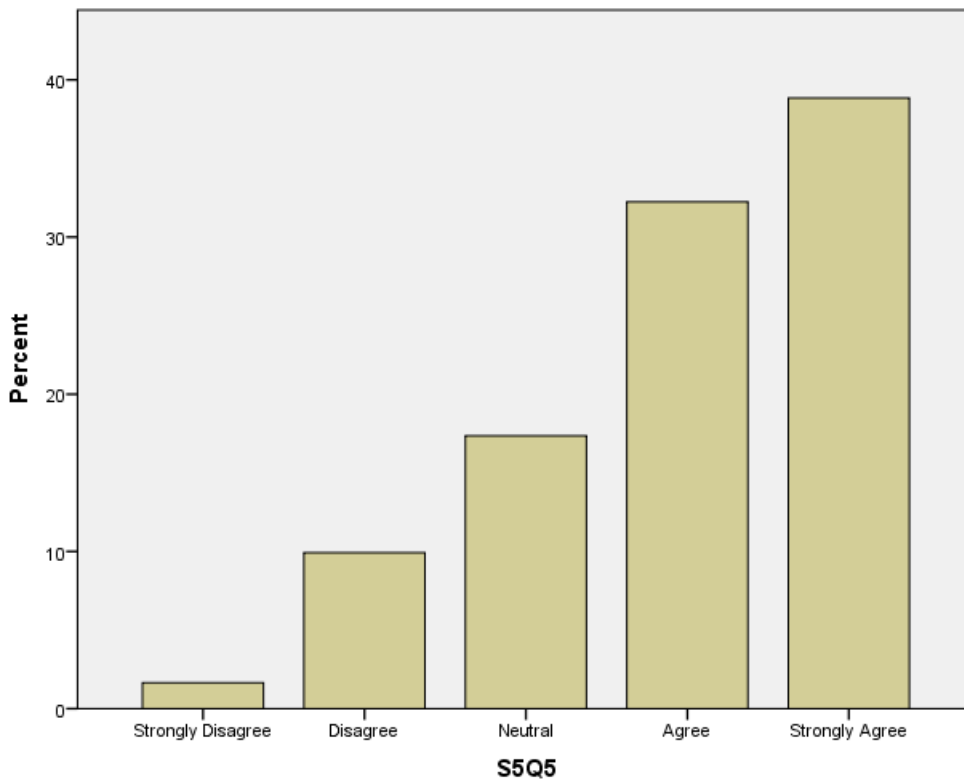


Chart 4: Bar Chart of S5Q5 Research Statement of the Survey for Teaching Faculties in Higher Education

Based on previous research, it appears that the "what" of this study will yield a significant response when examining Section 4 of the Survey for Teaching Faculties. According to the data presented in Table 24, 64% of the teaching faculty emphasized using digital library platforms, with only 14% disagreeing. Additionally, 61% recommended and used Massive Open Online Courses, while only 12% did not. In response to S4Q3, 72% of the teaching faculty members confirmed that their institutions provided access to open-source learning platforms, such as Moodle, Canvas LMS, and Google Classroom, while only 10% of the participants reported insufficient access. The teaching faculties also believed that social media platforms could aid in learning and teaching activities (60%), with 17% disagreeing. The survey results also confirmed that 70% of the participants had knowledge of the survey software, while only 11% reported insufficient knowledge.

Other important findings from critical pedagogies include the fact that 64% of teaching faculties are open to implementing virtual reality or virtual classrooms (S4Q8), and 71% of them believe that serious gaming and gamification will be more widely used in the future (S4Q9). Conversely, the questionnaire statements S4Q4, S4Q7, and S4Q10 suggested that some educational technologies were not trusted by the teaching faculty. For instance, only 31% used learning interactions and activities platforms (S4Q4) and only 37% used graphic design or video software (S4Q7). Furthermore, teaching faculties

seem to be reluctant about artificial intelligence in education, as only 40% of participants believe that AI is already a reality in higher education (S4Q10).

Chart 5 shows the means of the findings in section 4, excluding S4Q4, S4Q7, and S4Q10. The x-axis values range from 1 to 5, representing the Likert scale from "strongly disagree" to "strongly agree," whereas the y-axis values show the mean percentages of the seven statements.

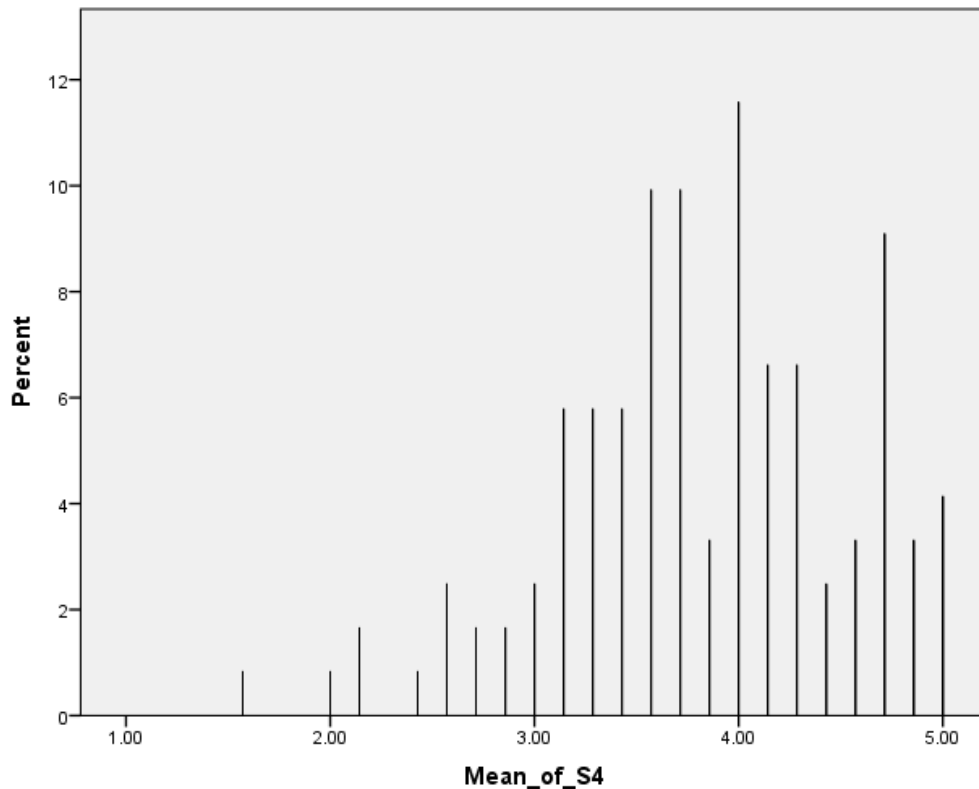


Chart 5: Mean Chart of selected items of Section 4 from the Survey for Teaching Faculties in Higher Education

Within this section, three questionnaire items indicated that the teaching faculties may not be prepared to use or may not be familiar with certain technologies. For instance, only 31% of the participants agreed with statement S4Q4, indicating that they used learning interactions and activity platforms, such as Widdla, Bubbl, and Edmodo. Meanwhile, 37% of the participants disagreed with this statement and the remaining respondents were neutral.

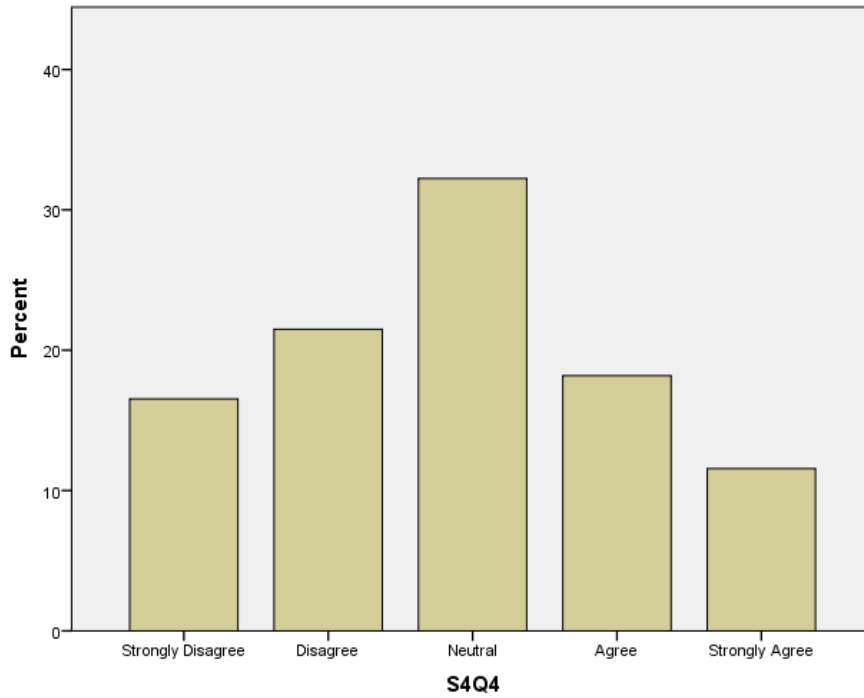


Chart 6: Bar Chart of S4Q4 Research Statement of the Survey for Teaching Faculties in Higher Education

According to the results of S4Q7, only 37% of the teaching faculty participants reported using graphic design or video software, while 28% disagreed with the statement and the remainder were neutral.

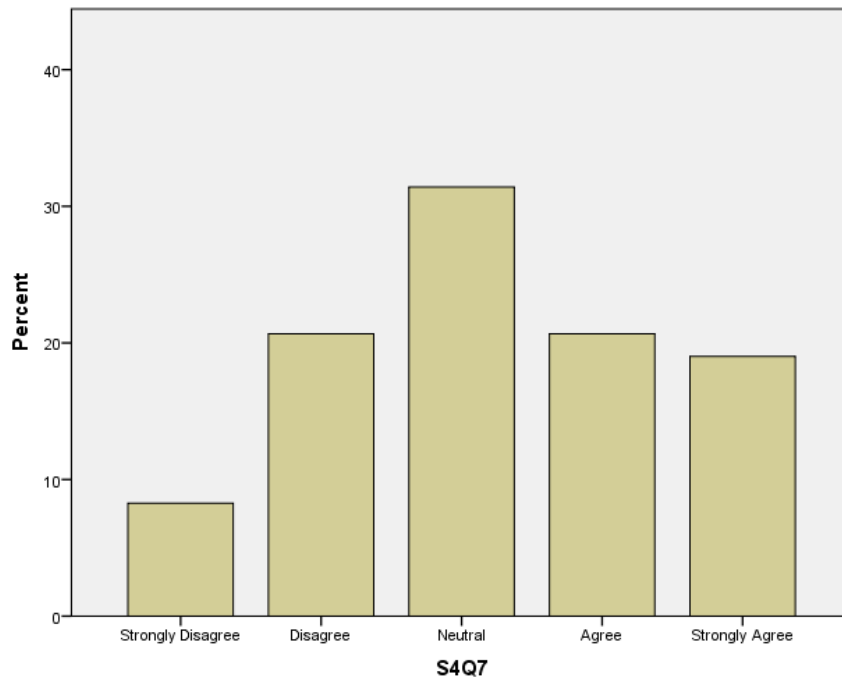


Chart 7: Bar Chart of S4Q7 Research Statement of the Survey for Teaching Faculties in Higher Education

Finally, with regard to S4Q10, only 40% of the participants partially agreed that Artificial Intelligence is already a reality in higher education, while 26% disagreed with the statement, and the remainder were neutral.

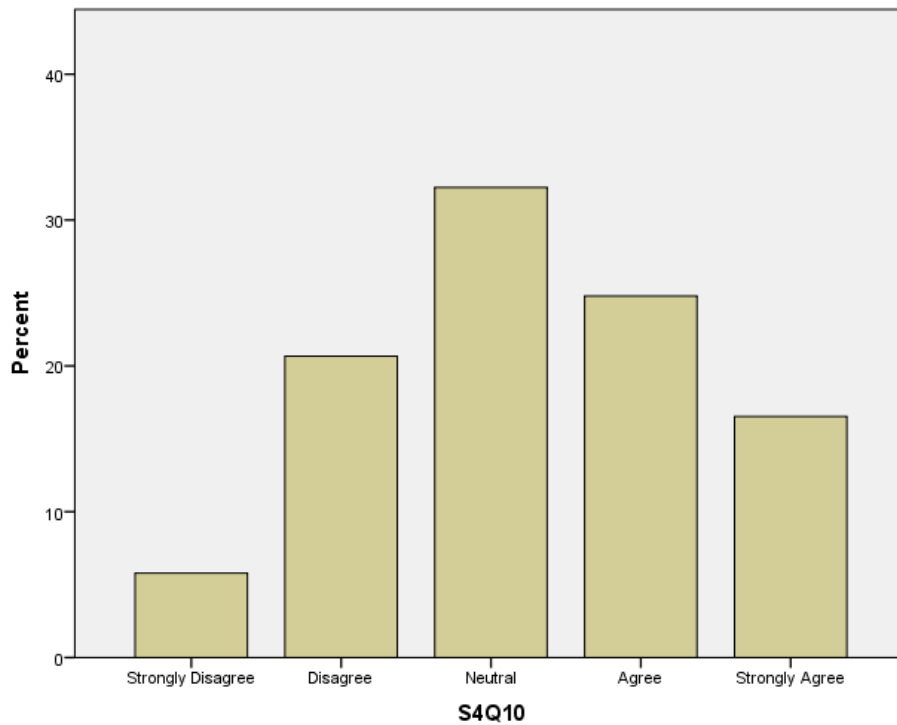


Chart 8: Bar Chart of S4Q10 Research Statement of the Survey for Teaching Faculties in Higher Education

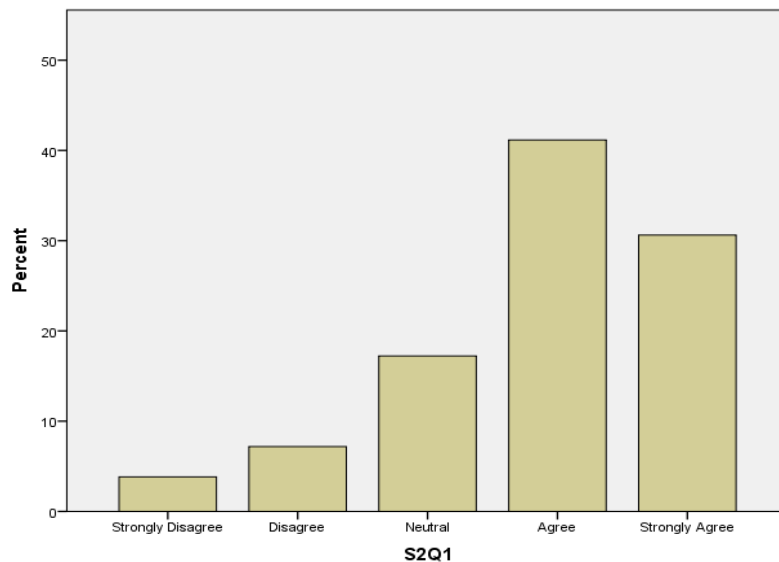


Chart 9: Bar Chart of the S2Q1 Research Statement of the Survey for Students in Higher Education

Comparable results highlight the necessity of conducting a survey of higher-education students. Analyzing the findings of this survey from the students' perspective reveals some valuable insights. For

instance, statement S2Q1, which pertains to effective strategies for utilizing digital educational technologies to improve student learning and engagement, suggests that introducing more digital educational technologies to students' daily learning is beneficial, and enhances their academic knowledge. Specifically, 71% of the students agreed with the statement, whereas only 11% disagreed with it.

The students also indicated their ability to afford the latest digital technologies proposed by their teaching faculty, as demonstrated in S2Q4. Specifically, 35% of students agreed that they could afford such technologies, 72.7% either agreed or remained neutral, and 28.3% disagreed with this statement.

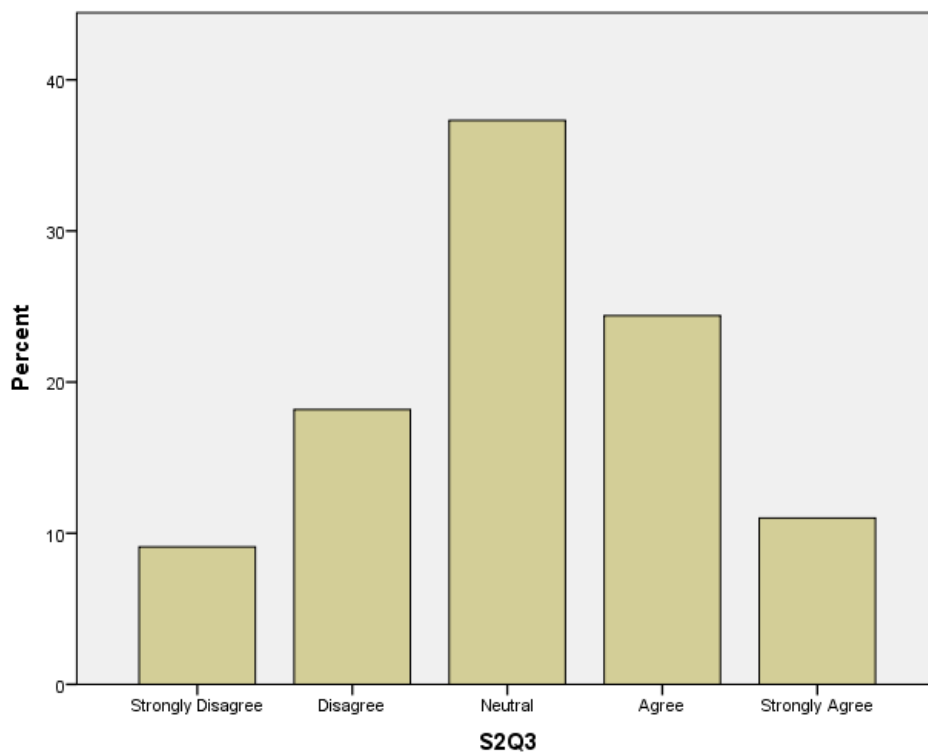


Chart 10: Bar Chart of the S2Q3 Research Statement of the Survey for Students in Higher Education

Section three of the student survey provides valuable insights into the most effective strategies for enhancing student learning. For example, 68% of the participants believed that a combination of traditional and new digital educational technologies (S3Q1) would benefit their studies, with only 9% disagreeing with this. Furthermore, students recognized the importance of having advanced knowledge of learning theories (S3Q2), with 65% of participants agreeing and only 13% disagreeing with the statement. Additionally, students showed their readiness to learn by following an instructional design model and its technologies (57% agreed), and by encouraging their teaching faculties to utilize

motivational design models and their technologies (63% agreed). In the final two questionnaire items (S3Q3 and S3Q4), only 13% of participants expressed disagreement.

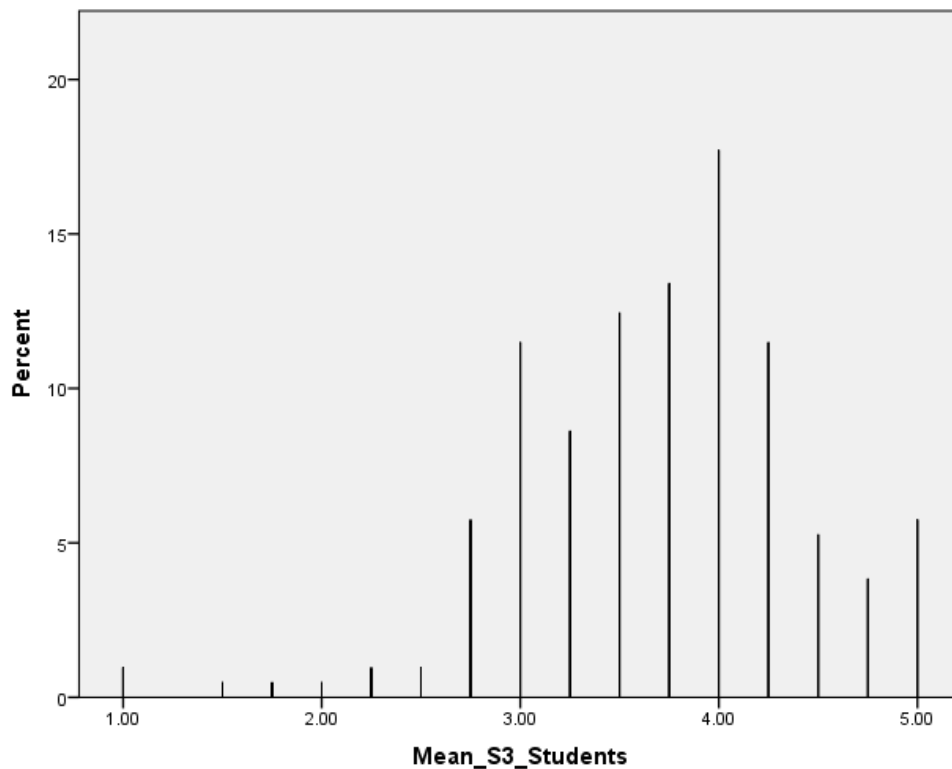


Chart 11: Mean Chart of selected items of Section 3 from the Survey for Students in Higher Education

The chart displays the average scores of the four statements analyzed in Section 3 (S3Q1, S3Q2, S3Q3, and S3Q4). The x-axis represents the Likert scale from 'strongly disagree' to 'strongly agree,' and the y-axis indicates the mean percentage of the four statements.

In Section 4 of the Survey for Students in Higher Education, 60% of the students confirmed the use of digital library platforms or massive open online courses (S4Q1), whereas only 15% did not use these resources. Furthermore, 64% of the participants agreed that their teaching institutions provided access to open-source learning platforms (Moodle, Canvas, etc.) in S4Q2, with only 13% disagreeing. However, for the other two questionnaire items related to new educational technologies, there was less confirmation of their use by students. Only 47% of the students confirmed experiencing learning using virtual reality or virtual classrooms (S4Q3), with 30% admitting that they had not experienced it, and the rest were neutral.

Similarly, in S4Q5, students partially agreed that they had studied serious gaming, gamification, or artificial intelligence, with 42% agreeing, 36% disagreeing, and the remainder neutral. However, in

S4Q4, 52% of the students agreed that they used social media platforms for daily teaching, 27% disagreed, and the remaining participants were neutral.

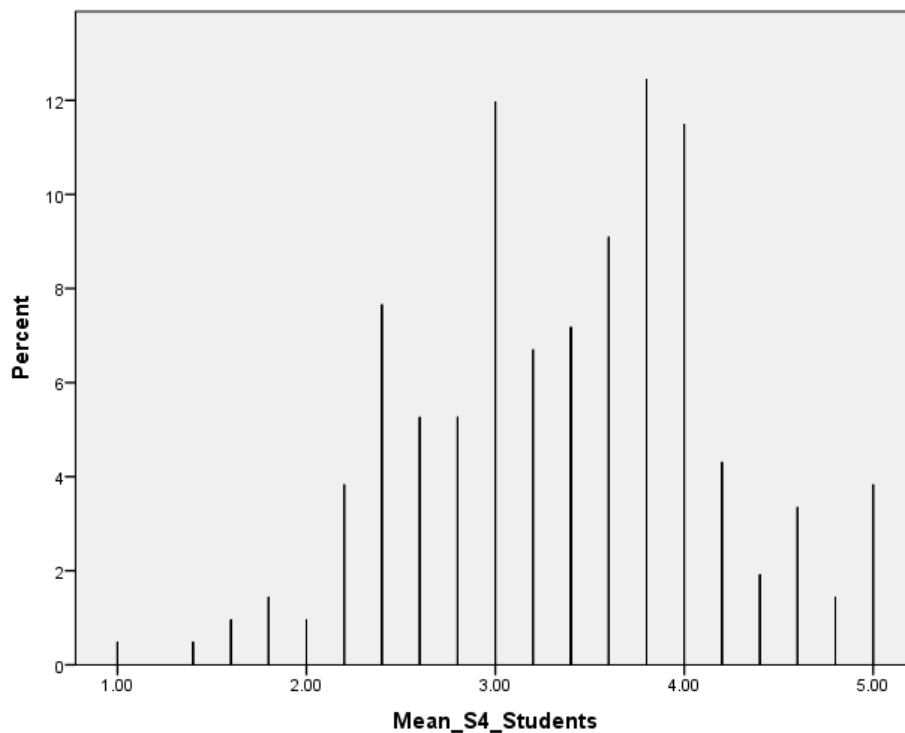


Chart 12: Mean Chart of selected items of Section 4 from the Survey for Students in Higher Education

The graph displays the average scores of the four statements analyzed in Section 4. The horizontal axis ranges from 1 to 5 and represents the Likert scale, where 1 corresponds to "Strongly disagree" and 5 to "Strongly agree." The vertical axis represents the average percentage of the seven statements analyzed.

Based on the findings of this section, many successful techniques have been identified for employing digital educational technology to promote student learning and engagement. The following are some of these strategies:

- a) Introducing more disruptive technology into the classroom to boost student learning and engagement.
- b) Improving student learning using a taxonomy framework for educational technology.
- b) Instructional design models for teaching and motivational design models to increase student learning and engagement.
- d) Use digital library platforms or massive open online courses to assist students in learning.

e) The availability of open-source learning tools such as Moodle, Canvas LMS, and Google Classroom to boost student learning and engagement.

(f) Making use of social media platforms to assist students in learning and teaching.

g) Improving student learning and engagement through the use of new technologies in engineering curricula.

h) Improving student learning and engagement using virtual reality or virtual classrooms, as well as serious gaming and gamification.

Combining existing advancements in digital instructional technology, according to the questionnaire findings, would enhance students' learning and engagement. It is important to guarantee that teaching faculties and students have the knowledge and abilities necessary to successfully use digital educational tools in their everyday learning and teaching activities.

Section 5.2

Entrepreneurial Competencies for Engineers: Timing and Importance of Acquisition

Upon analyzing the Survey of Teaching Faculties in Higher Education, it was found that 61% of faculty members acknowledged that entrepreneurship in education is classified as a skill, as confirmed by questionnaire item S5Q1. Only 16% either lacked this knowledge or did not agree to the classification.

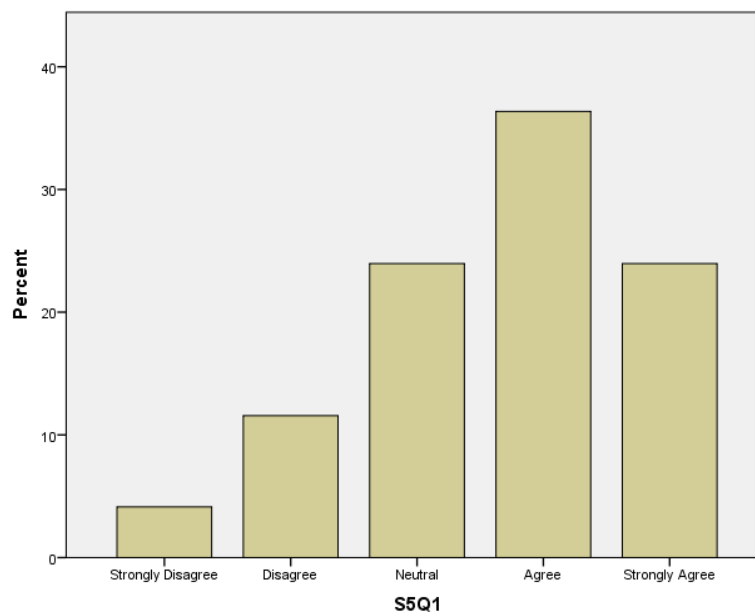


Chart 13: Bar Chart of S5Q1 Research Statement of the Survey for Teaching Faculties in Higher Education

The S5Q5 item in the Survey of Teaching Faculties in Higher Education revealed that faculties strongly advocate the inclusion of new technologies in the engineering course curriculum as a means of teaching entrepreneurial competencies. Specifically, 72% of the participants agreed with this idea, whereas only 11% disagreed with it.

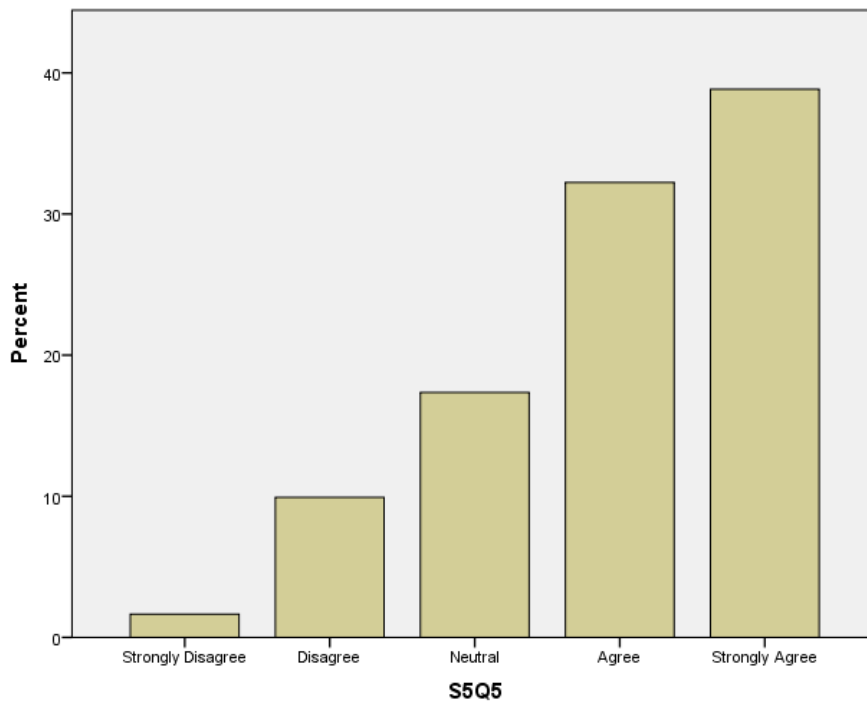


Chart 14: Bar Chart of S5Q5 Research Statement of the Survey for Teaching Faculties in Higher Education

Regarding the emerging jobs brought about by digital technologies (S2Q7), participants indicated that they believed these jobs differed significantly from traditional jobs, with 61% agreeing. Only a small proportion of participants (13%) disagreed.

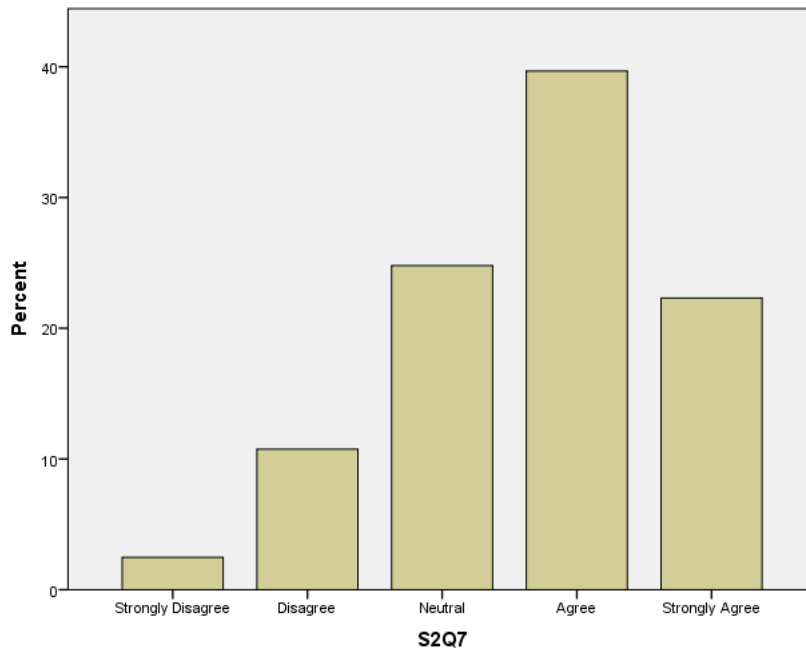


Chart 15: Bar Chart of S2Q7 Research Statement of the Survey for Teaching Faculties in Higher Education

Based on the initial findings, the key questions in this section were S2Q4 and S5Q2. In response to S2Q4, most teaching faculty members (68%) believed that offering entrepreneurship courses in higher education would increase graduates' job prospects, while only 11% disagreed with this. Additionally, 21% of the respondents remained neutral on this topic.

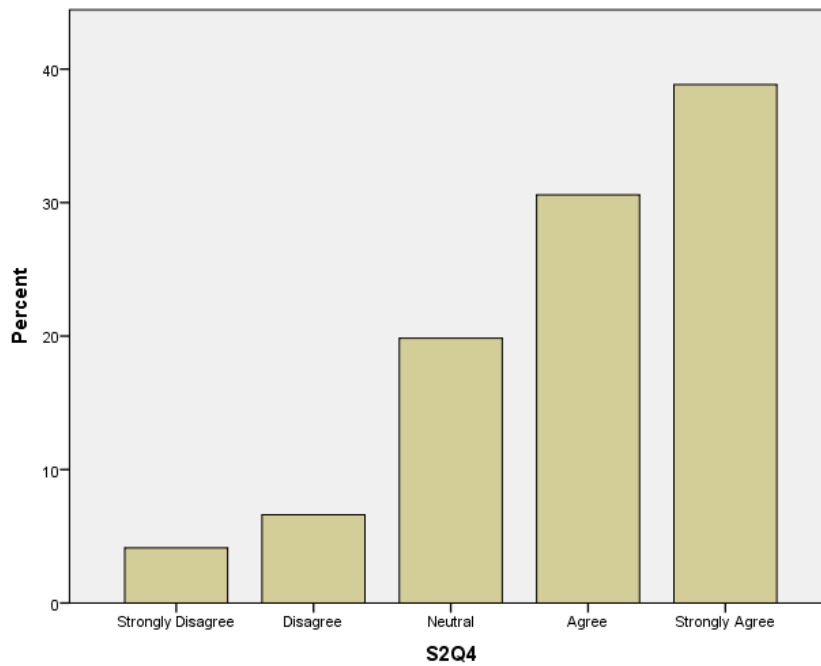


Chart 16: Bar Chart of S2Q4 Research Statement of the Survey for Teaching Faculties in Higher Education

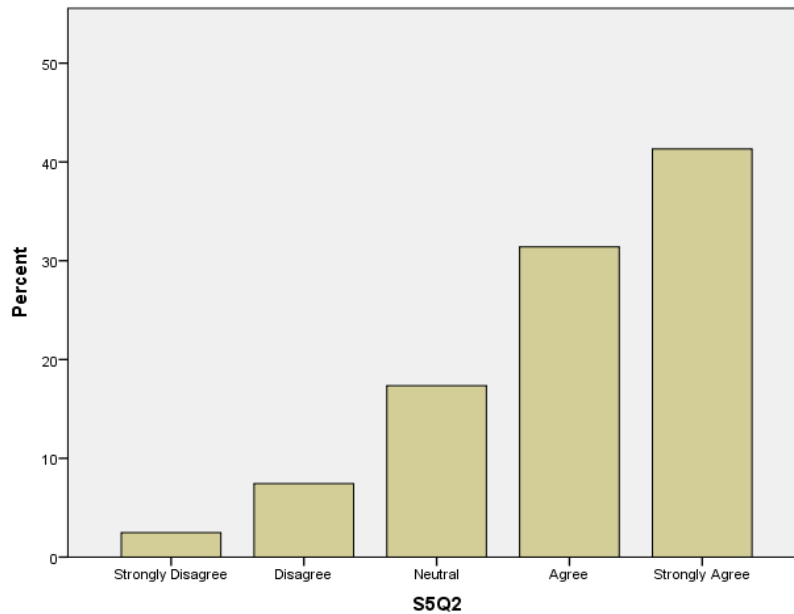


Chart 17: Bar Chart of S5Q2 Research Statement of the Survey for Teaching Faculties in Higher Education

The most significant finding is related to questionnaire item S5Q2, which asks whether engineering students should acquire entrepreneurial skills in colleges or universities. Most faculty members (75%) agreed or strongly agreed, while only 11% disagreed. A small percentage of patients (14%) were neutral. This result provides further evidence for the importance of incorporating entrepreneurial competencies into engineering courses, as supported by Besterfield-Sacre et al.(2016).

The results of the Survey for Students in Higher Education support the findings of the faculty survey regarding this research question. In particular, 63% of the students who participated in the survey agreed that incorporating entrepreneurial courses into their study programmes would provide them with more opportunities to find or create jobs, whereas only 13% disagreed.

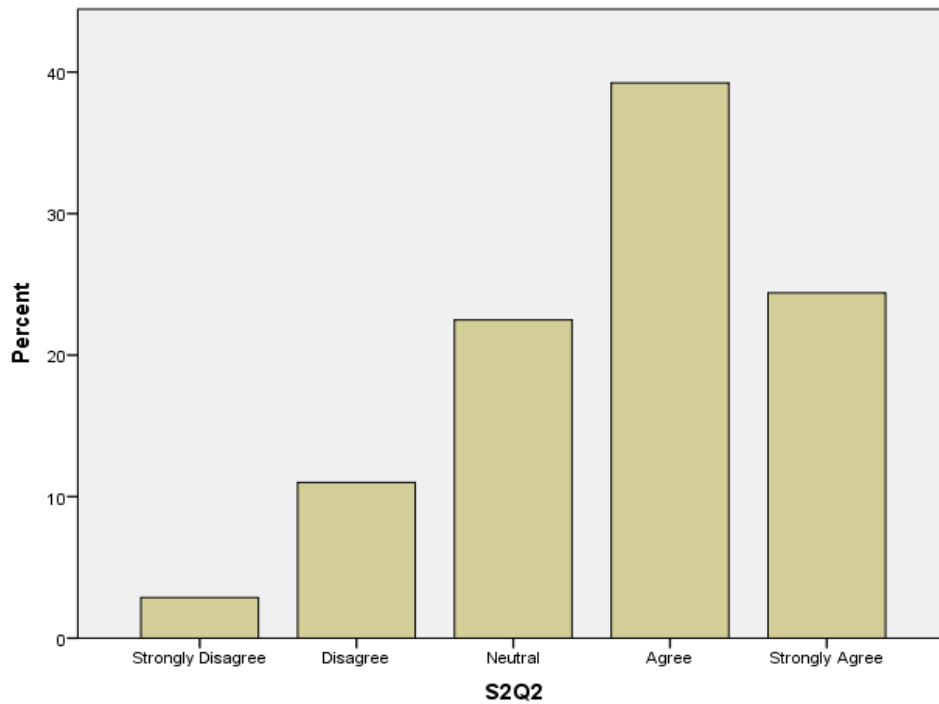


Chart 18: Bar Chart of the S2Q2 Research Statement of the Survey for Students in Higher Education

According to the results of a survey conducted with higher education students, there is a similarity in the views of teaching faculties and students regarding the importance of entrepreneurial skills for engineering students. In response to the question of whether engineering students should develop their entrepreneurial skills, 67% of the student participants agreed, 22% remained neutral, and only 11% disagreed (S5Q1).

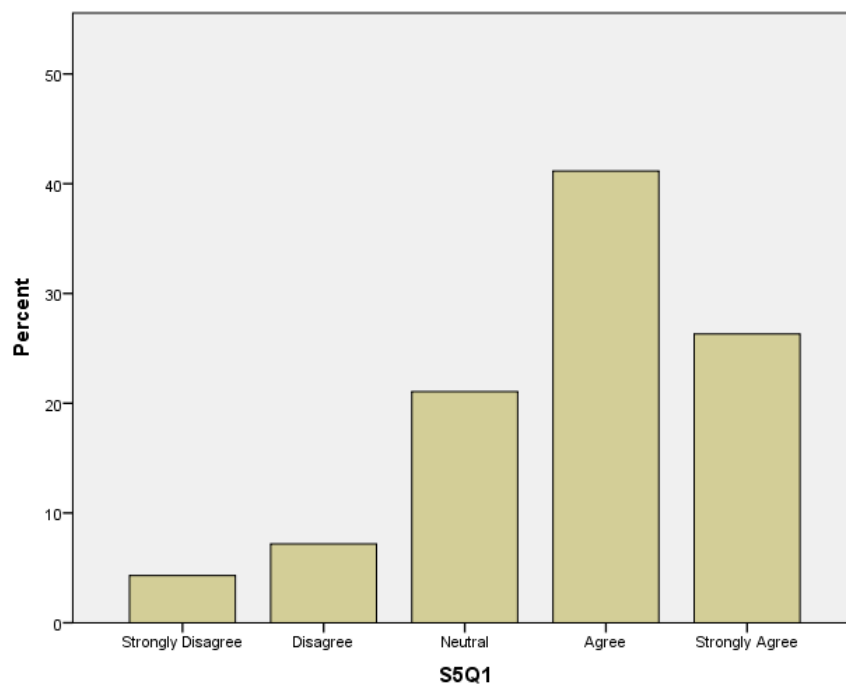


Chart 19: Bar Chart of the S5Q1 Research Statement of the Survey for Students in Higher Education

According to the findings in this section, both the teaching faculties and students appear to believe that entrepreneurial skills are necessary for engineering students to learn in higher education. According to the questionnaire results, 72% of the participants believed that higher education institutions should include new technologies in the engineering course curriculum to educate entrepreneurship skills.

The findings indicate that both the teaching faculty and students agree that including entrepreneurial courses in study programs increases the likelihood of finding or creating jobs. The majority of the teaching faculty (68%) believed that offering entrepreneurship courses in higher education would improve graduates' job prospects, while 63% of students agreed that incorporating entrepreneurial courses into their study programs would increase their chances of finding or creating a job.

According to the survey results, entrepreneurial competencies should be included in higher education engineering curricula. These findings imply that teaching entrepreneurial skills to engineering students increases their chances of obtaining or creating jobs (Carolis & Litzky, 2019).

However, further research is required to determine the best timing and methods for teaching entrepreneurial skills to engineering students. Nonetheless, the survey results strongly support the importance of incorporating entrepreneurial skills into higher-education engineering courses.

Section 5.3

Evidence of the Impact of Technology-Enriched Educational Platforms on Job Creation and Reduction

When the teaching faculty were asked whether technology-enriched educational platforms bring new and emerging jobs (S2Q1), 73% of the participants agreed with this statement, and only 9% disagreed.

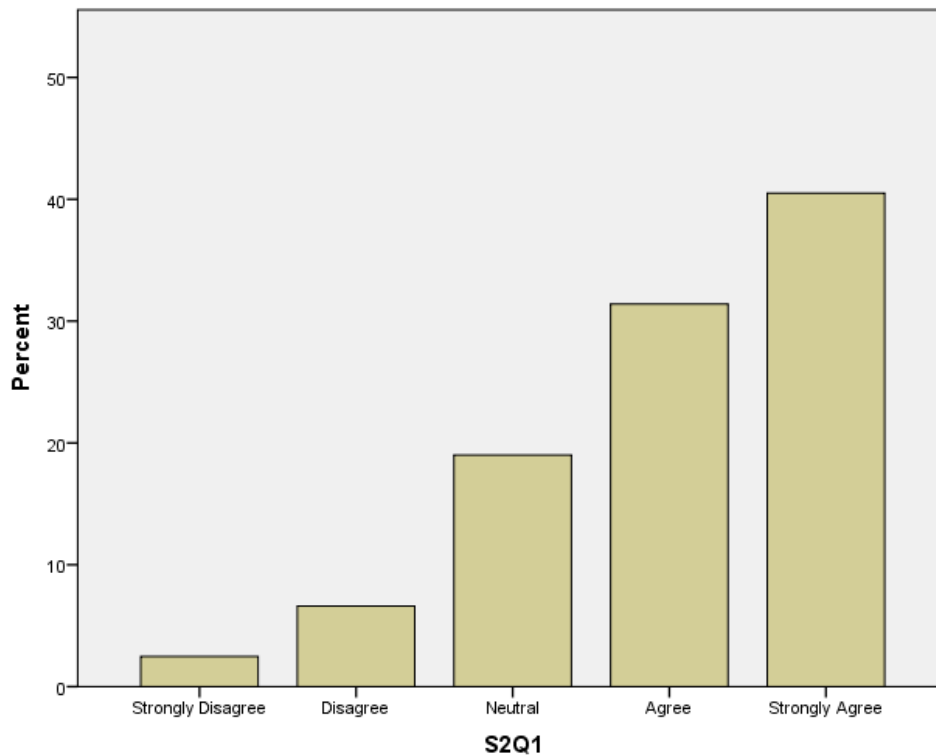


Chart 20: Bar Chart of S2Q1 Research Statement of the Survey for Teaching Faculty in Higher Education

With regard to research statement S2Q2, which failed the CFA test, a mere 32% of surveyed teaching faculties agreed with the statement that "technology-enriched educational platforms will reduce the need for the future workforce," while 39% remained neutral and approximately 29% disagreed with the notion. These findings align with those presented in the Literature Review chapter (Part I). This research question will be further investigated using qualitative tools in the forthcoming sections for enhanced substantiation.

As the teaching faculty belonged to diverse majors and academic disciplines, they were also asked (S2Q9) whether there was a proliferation of new and emerging jobs in their respective fields of expertise. Of all participants, 63% concurred with the statement, while only 13% dissented.

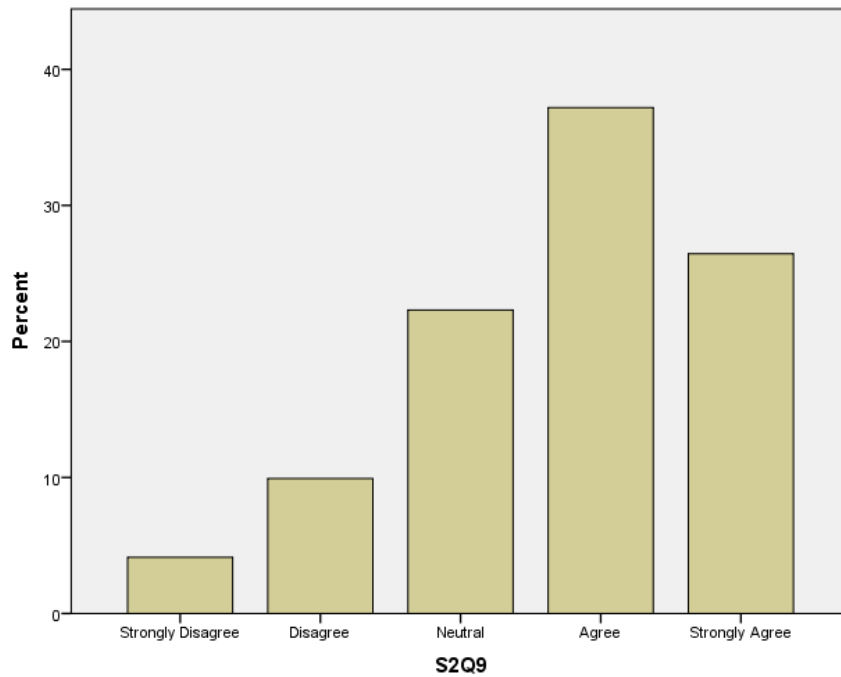


Chart 21: Bar Chart of S2Q9 Research Statement of the Survey for Teaching Faculties in Higher Education

According to the research statement S5Q4, teaching faculties believe that conventional progress leads to the emergence of fresh job opportunities and/or the obsolescence of existing traditional jobs, with 55% agreeing and 18% disagreeing. This finding substantiates the results outlined in Part I of the Literature Review chapter (Part I).

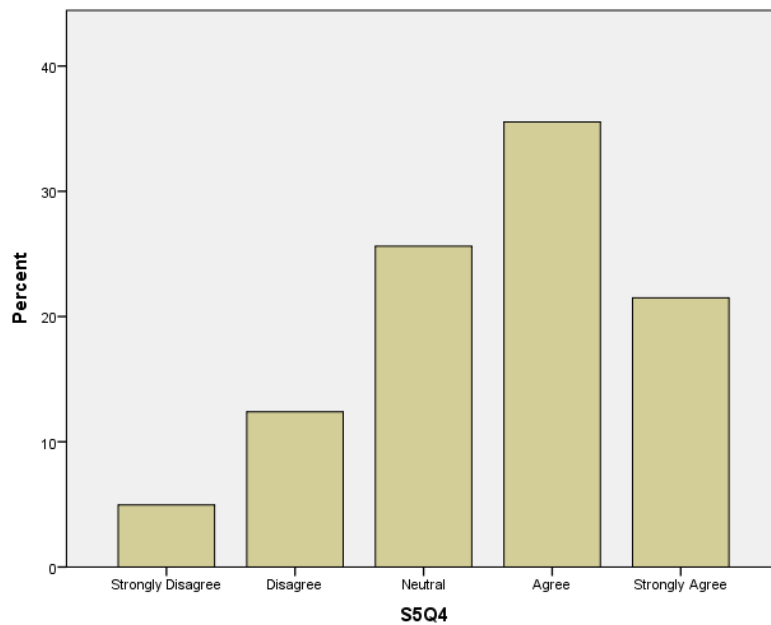


Chart 22: Bar Chart of S5Q4 Research Statement of the Survey for Teaching Faculties in Higher Education

Of note is the fact that when queried (S5Q10), 44% of the teaching faculties believed that engineering graduates today have it easier because of the widespread availability of digital technology compared to two decades ago. Meanwhile, around 24% of the respondents disagreed and 32% remained neutral.

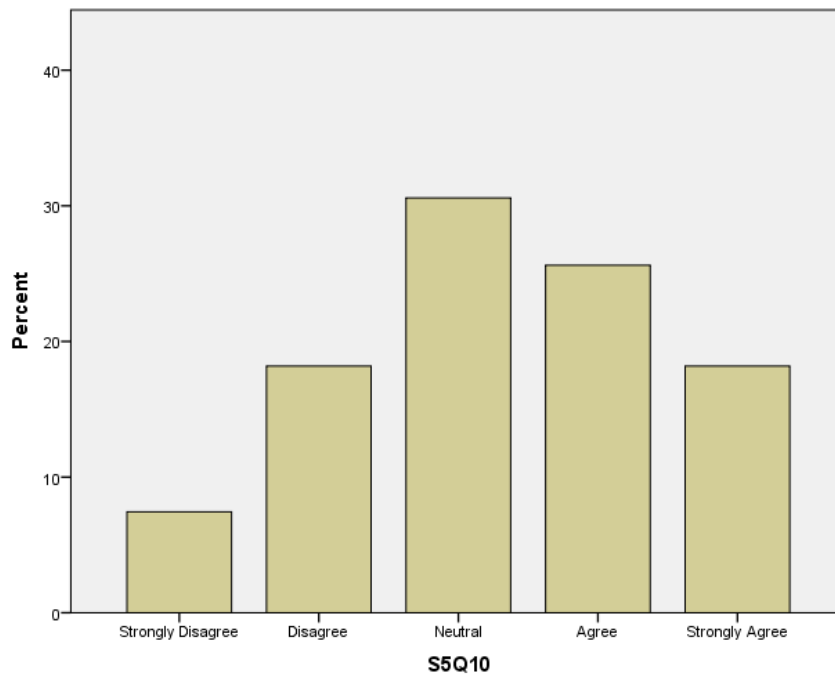


Chart 23: Bar Chart of S5Q10 Research Statement of the Survey for Teaching Faculties in Higher Education

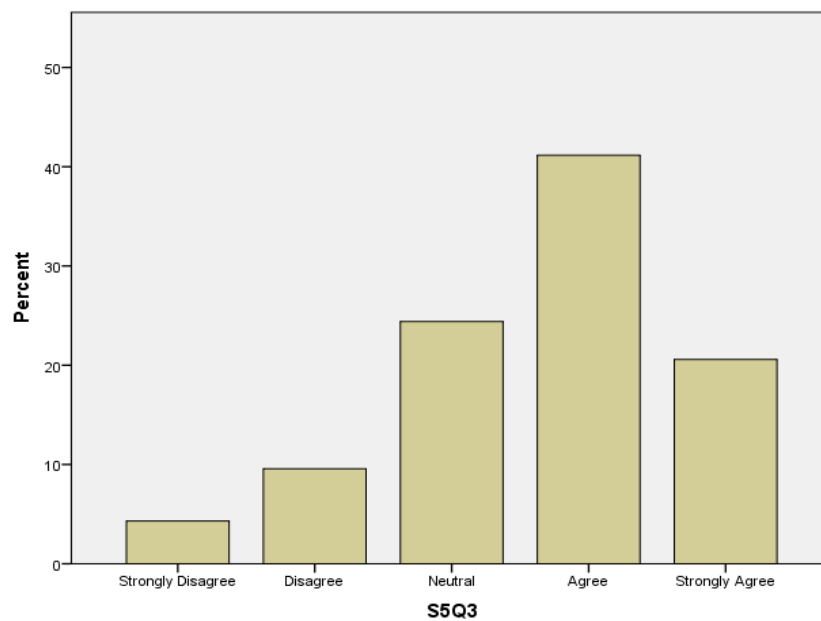


Chart 24: Bar Chart of the S5Q3 Research Statement of the Survey for Students in Higher Education

According to the Survey for Students in Higher Education, 61% of participants concur with the idea that teaching faculties believe that traditional advancements give rise to new occupations and/or lead to the demise of existing traditional jobs, while 13% hold the opposite view. It is worth noting that the students were 6% more convinced about this research item than the teaching faculty members. Conversely, teaching faculties disagree with this notion by 5% more than students. This disparity is further examined in the Discussion chapter.

Regarding research item S5Q5, it was discovered that 63% of the surveyed students agreed with the notion that studying engineering or any other specialization is now easier than it was a decade ago, thanks to the widespread availability of digital technology. Conversely, approximately 15% of students disagreed with this statement.

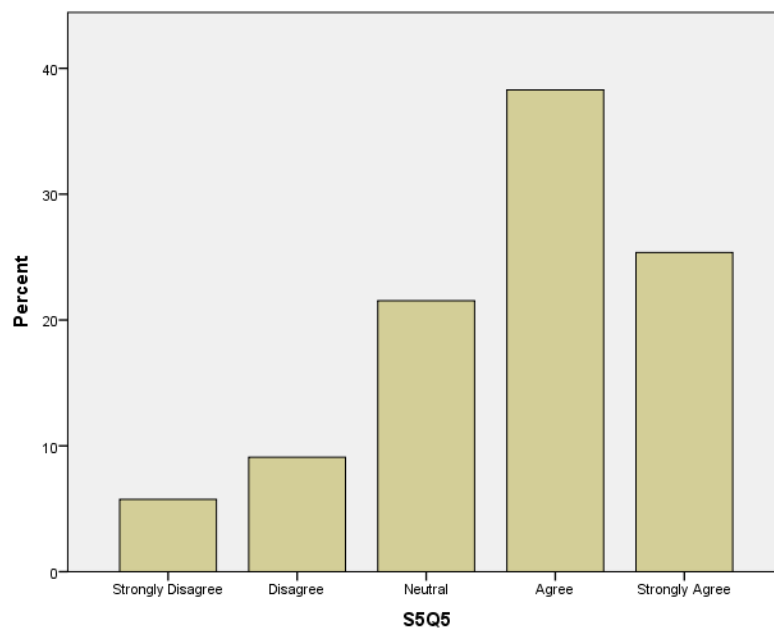


Chart 25: Bar Chart of the S5Q5 Research Statement of the Survey for Students in Higher Education

There are various aspects and reasons why students assign greater weight to digital technology than to teaching faculties when it comes to the questionnaire items of the survey, as will be explained in the discussion chapter. Notably, there is a 19% difference in the percentage of students and teaching faculties who say that studying is easier nowadays because of technological advancements. Interestingly, after completing the questionnaire, one student approached the researcher and expressed his gratitude for the questionnaire, emphatically confirming that technology has definitely made studying simpler nowadays. Nonetheless, given the relative youth and inexperience of students, such emotive assertions should be approached with caution.

The replies of the teaching faculty and students to survey questions S2Q1, S2Q2, S5Q4, S5Q5, S5Q10, and S2Q9 provide evidence of the influence of technology-enriched educational platforms on job creation/reduction and workforce addition/reduction. According to the survey findings, the majority of teaching faculty and students believe that technologically enhanced educational platforms can lead to the creation of new and emerging jobs, whereas traditional progress leads to the creation of new job opportunities and/or the obsolescence of existing traditional jobs. Furthermore, the questionnaire findings suggest that students are more convinced than professors, who study is simpler now that technology is available. However, given the relative youth and inexperience of the students, such emotional claims should be approached with caution.

Section 5.4

Impact of Digital Technologies in Education and Engineering: Identifying the Most Affected Stakeholders

To gain a better understanding of this question, it was examined in section 5 of the Survey of Teaching Faculties. As described in Section 5.3, there is consensus among teaching faculties that technological advancements give rise to novel forms and occupations (S5Q4), while their opinions diverge on S5Q10 (whether studying engineering today is easier because of the widespread availability of digital technology).

Upon analyzing the questionnaire items in this section, it was discovered that 61% of the teaching faculty agreed (S5Q6) that they had heard of at least one new engineering study program in the past five years, whereas 16% had not heard of any.

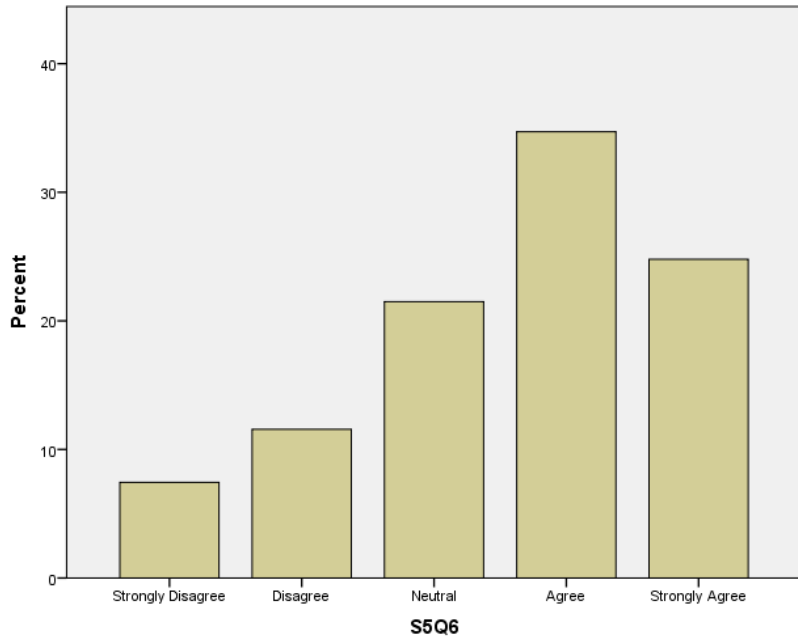


Chart 26: Bar Chart of S5Q6 Research Statement of the Survey for Teaching Faculties in Higher Education

When asked specifically about the engineering discipline, the teaching faculties believed that engineering had a bright future (68%), and only 11% disagreed with this statement (S5Q7).

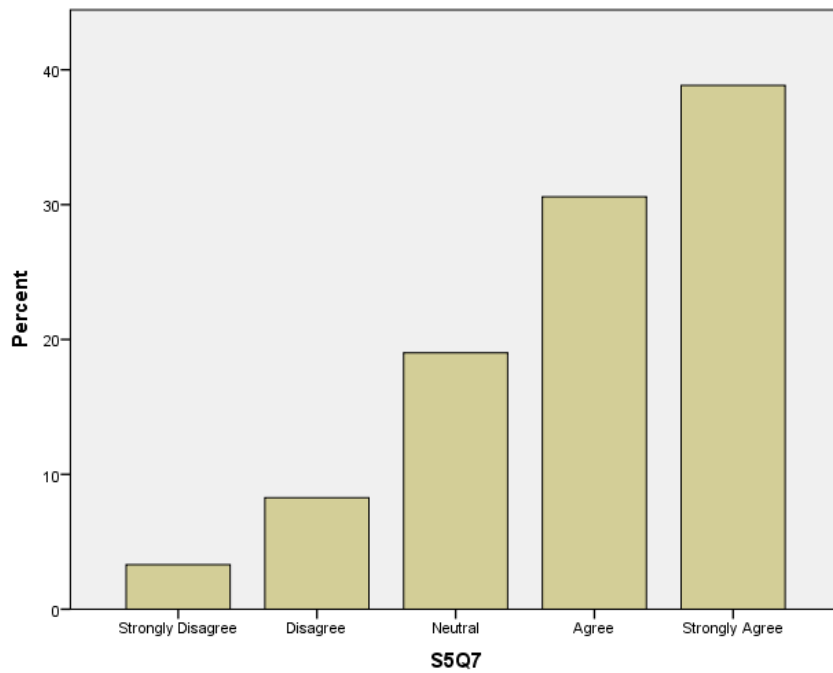


Chart 27: Bar Chart of S5Q7 Research Statement of the Survey for Teaching Faculties in Higher Education

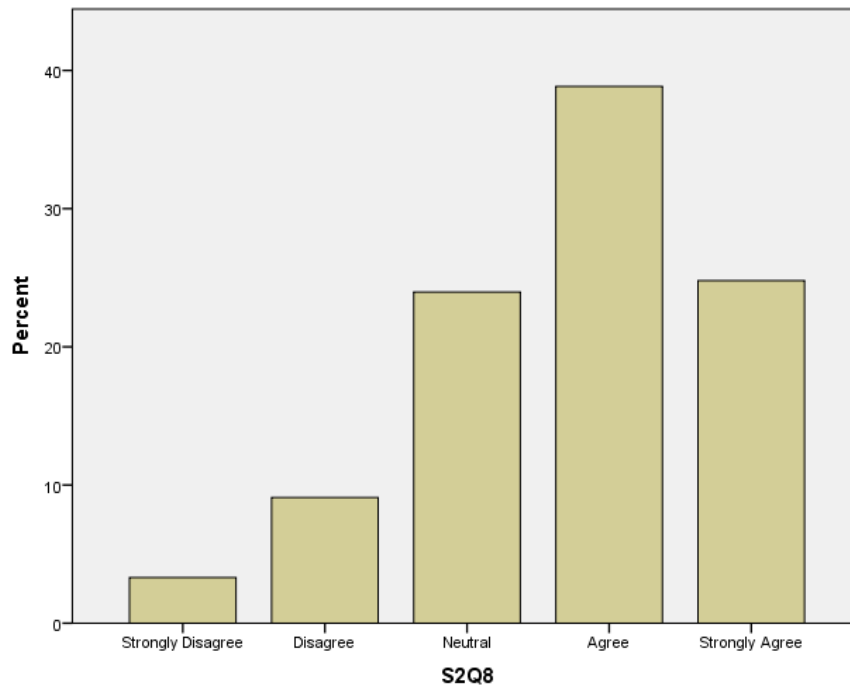


Chart 28: Bar Chart of S2Q8 Research Statement of the Survey for Teaching Faculties in Higher Education

When asked about their current opinions on engineering (S5Q8), 55% agreed that the engineering field faced challenges at times. 26% of participants did not agree to participate.

Another questionnaire item (S5Q9) was included to verify participants' honesty by comparing it with the S5Q10. The participants were asked if engineering today was more challenging than it was 20 years ago because of the substantial expansion of study programs, and their responses varied similarly to S5Q10. Specifically, 39% of participants agreed, 34% were neutral, and 27% disagreed.

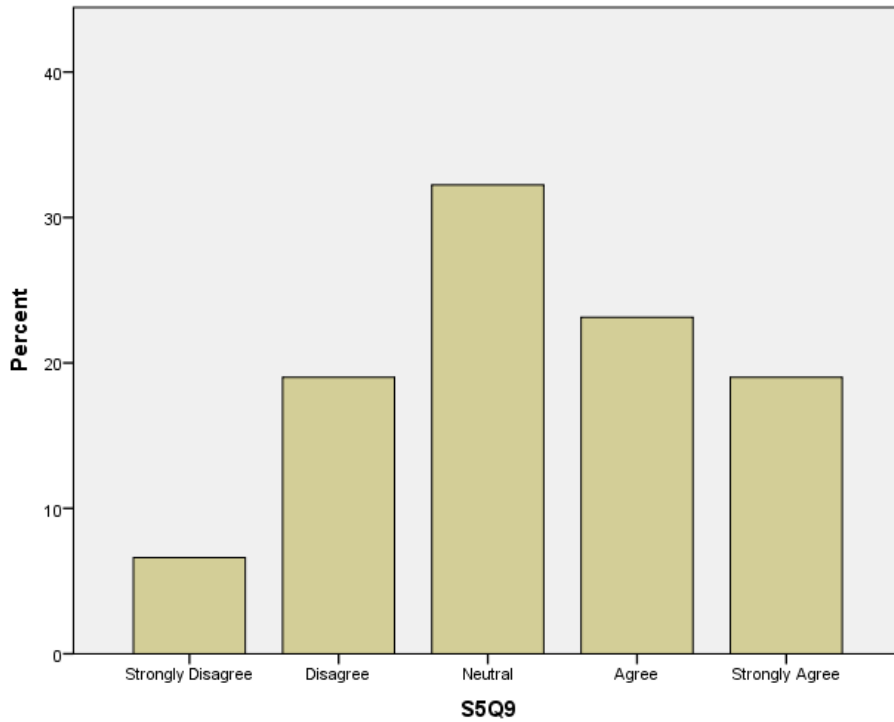


Chart 29: Bar Chart of S5Q9 Research Statement of the Survey for Teaching Faculties in Higher Education

However, Section 1 of the survey yielded the most significant findings for this research question. Specifically, 63% of the faculties agreed that learning and implementing the latest digital technologies was costly for them (S2Q5). Only 10% did not consider it expensive to purchase or subscribe to the latest technological advancements, whereas the remaining respondents were neutral.

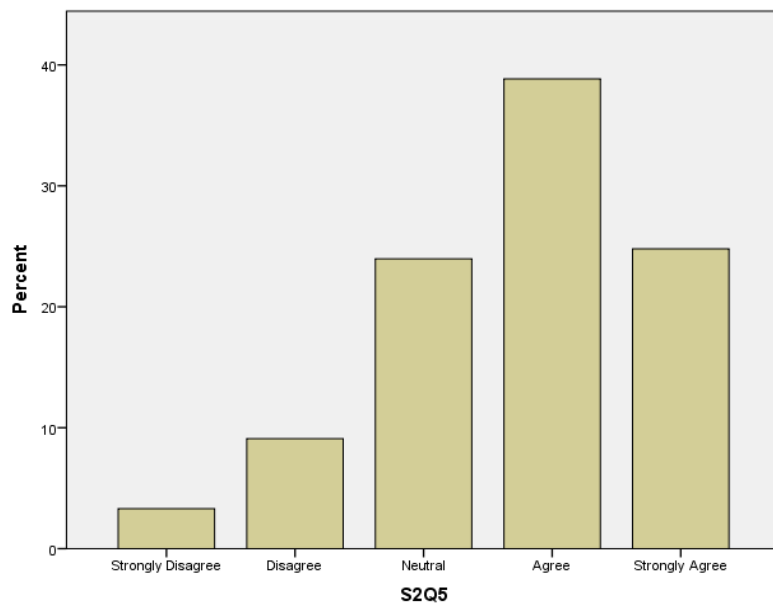


Chart 30: Bar Chart of S2Q5 Research Statement of the Survey for Teaching Faculties in Higher Education

Another crucial finding arises from S2Q10, which asks whether faculties believe that their institutions offer an adequate technological environment for creative-minded students. The results indicate that 40% agreed that their institutions met this requirement, 36% were neutral, and 24% believed that their colleges or universities should enhance their efforts in this area.

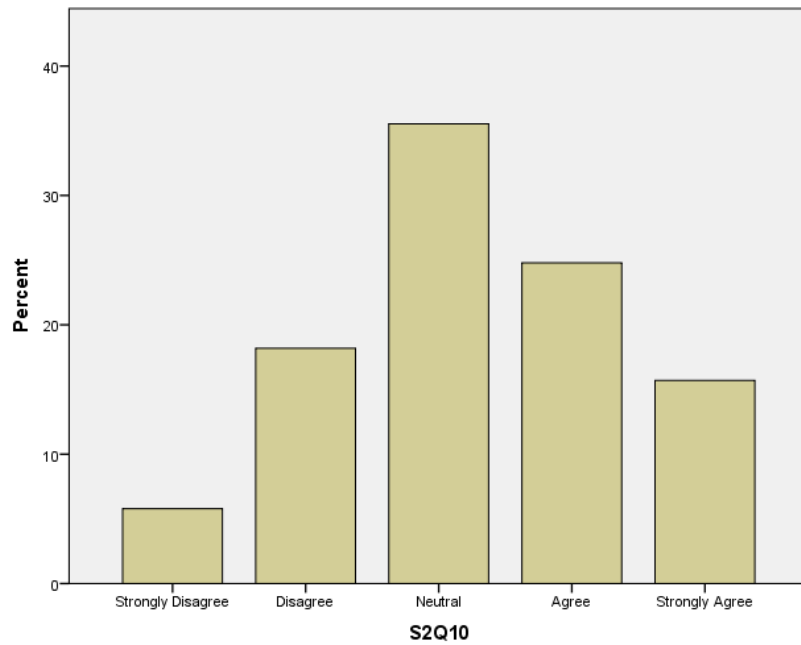


Chart 31: Bar Chart of S2Q10 Research Statement of the Survey for Teaching Faculties in Higher Education

The analysis in Section 5 of the Survey for Students in Higher Education confirms the findings of the previous research question regarding the impact of technological advances on occupations and studying. Specifically, 61% of the students agreed with S5Q3, which stated that technological advances bring about new forms of occupation. Similarly, 63% of the students agreed with S5Q5, which suggests that studying engineering or other specializations has become easier than a decade ago because of digital technology. Additionally, S5Q4 revealed that 62% of engineering students and students in general who participated in the survey agreed that engineering graduates would have a successful professional career, while only 13% disagreed, and 25% were neutral.

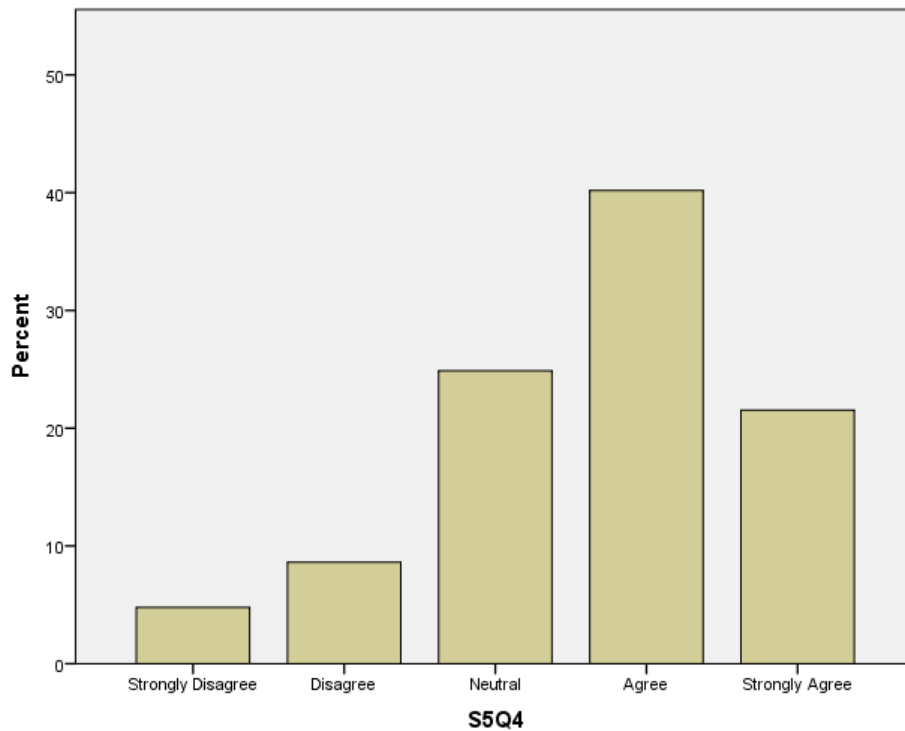


Chart 32: Bar Chart of S5Q4 Research Statement of the Survey for Students in Higher Education

As previously discussed in the first research question, section 2 of the Survey for Students provides additional insights. Regarding the affordability of the latest digital technologies proposed by their teaching faculties (S2Q3), only 36% of students agreed that they could afford them, 37% were neutral, and 27% disagreed. Furthermore, the survey revealed that many students were unfamiliar with the latest disruptive technologies in education (S2Q4). When asked whether they could name at least three disruptive technologies that they believed would be implemented in education within five years, only 37% agreed that they could, 26% said they could not, and the remainder were neutral.

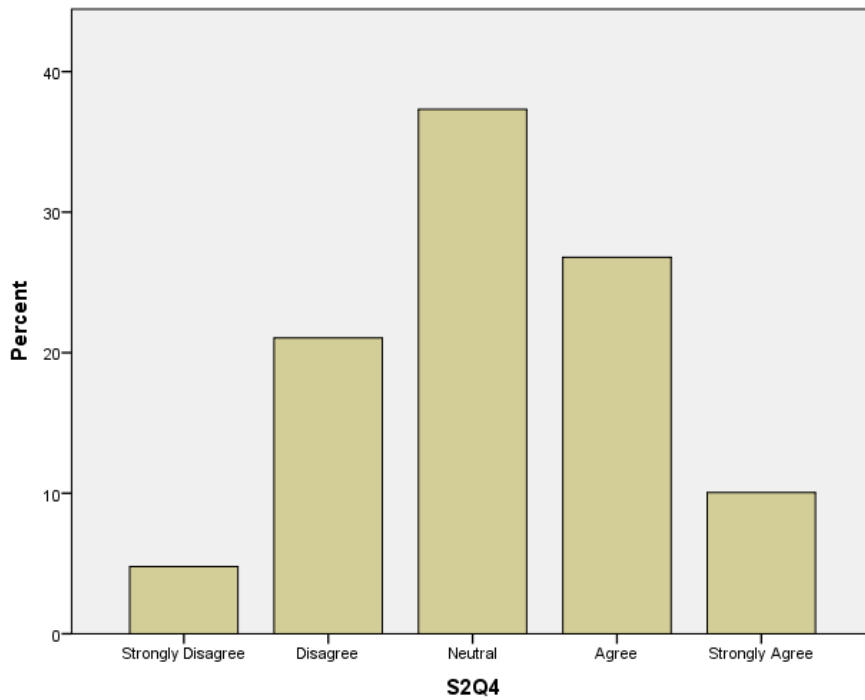


Chart 33: Bar Chart of S2Q4 Research Statement of the Survey for Students in Higher Education

Finally, it is surprising that 60% of students believed that their institutions offered an environment that catered to creative-minded students (S2Q5). While 24% of students remained neutral, only 16% disagreed. In contrast, teaching faculties differ in their opinions, with only 20% agreeing that their institutions provide a sufficient technological environment. The reasons for these divergent views will be discussed in the next chapter.

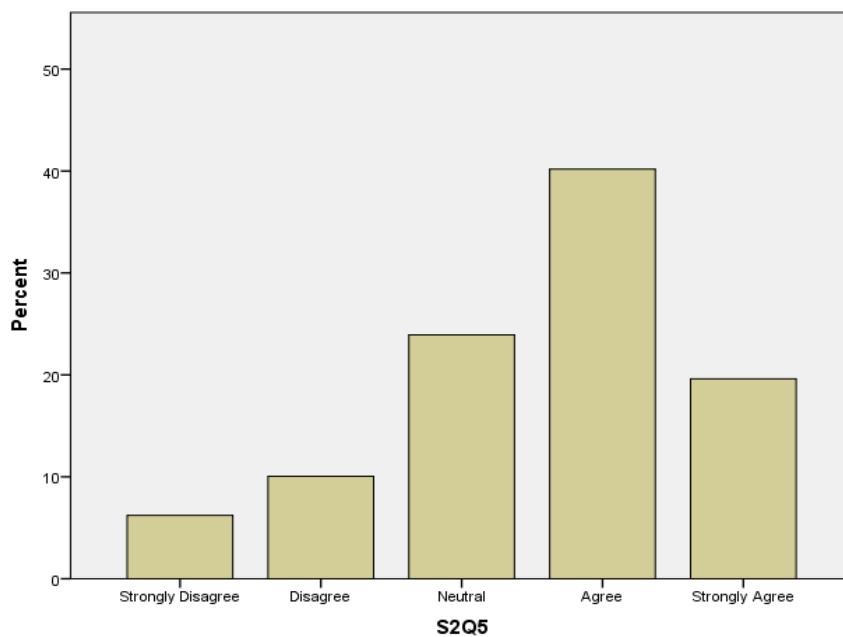


Chart 34: Bar Chart of S2Q5 Research Statement of the Survey for Students in Higher Education

Several findings in this section indicate that using digital technology in education poses obstacles for both the teaching faculties and students. According to the study findings, 63% of the teaching faculty members thought that learning and applying cutting-edge digital technology was costly. Furthermore, only 40% of faculty members think that their universities provide a suitable technical environment for creative students. Because of the financial expenditures and technical obstacles connected with implementing these technologies in their teaching practices, these findings show that the introduction of digital technologies in education may have an influence on teaching staff.

Similarly, the poll results suggest that students may face challenges as a result of the introduction of digital technology in educational institutions. For example, only 36% of the students agreed that they could afford the latest digital recommended by their faculties, and many students were unfamiliar with the most disruptive educational innovations.

According to the survey results, the use of digital technology in education may influence both the teaching faculty and students. However, further research is needed to identify the specific groups or individuals most affected by the use of digital technologies in education and engineering.

Section 5.5

Exploring the Framework of Educational Technology Landscape: Their Impact on Our Lives

In Section 5.1, item S3Q2 of the teaching faculty questionnaire was already analyzed, where they expressed the need to have a taxonomy including as many technologies as possible in education. This statement suggests that most faculty participants believe that a taxonomy framework for educational technologies is required, which is also supported by Kemp et al.(2019). A taxonomy framework is a classification system that groups technologies according to their functions and characteristics (Muras et al., 2006).

The fact that 63% of faculty participants agreed on the importance of a taxonomy framework in education indicates that they believe such a framework would be useful in organizing and comprehending various available educational technologies (Kemp et al., 2019). A taxonomy framework could assist educators in selecting appropriate technologies for their teaching and learning needs as well as in evaluating the efficacy of these technologies (Kemp et al., 2019).

However, the low percentage of respondents who disagreed with the statement suggests that the concept of a framework for educational technologies is not widely opposed. This could be because many educators recognize the growing importance of technology in education and see the potential benefits of having a classification system for educational technology (Savov et al., 2017).

This statement highlights the faculty members' views on the significance of a framework for educational technology. However, it is important to note that respondents' opinions may not always reflect those of a broader educational community. Furthermore, the implementation and effectiveness of a taxonomy framework depend on a variety of factors, including the quality of the framework system and educators' ability to use it effectively (Polani et al., 2010).

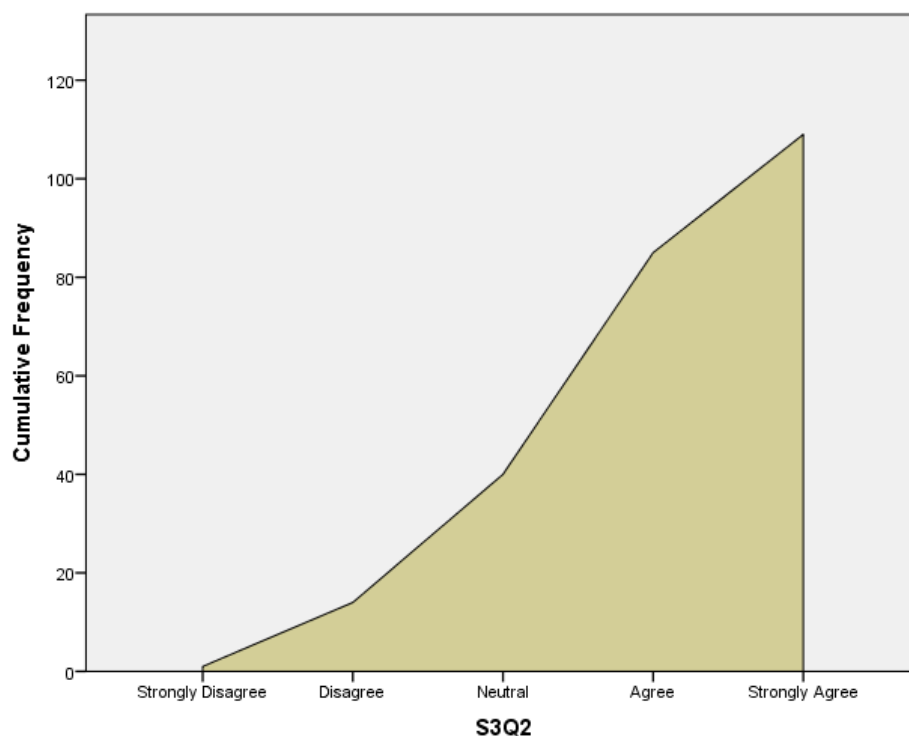


Chart 35: Bar Chart of S3Q2 Research Statement of the Survey for Teaching Faculties in Higher Education

The distribution of the results for item S3Q2 is presented in Section 5.1. In Chart 35, the x-axis shows the Likert scale ranging from "strongly disagree" to "strongly agree," whereas the y-axis shows the cumulative frequency of each option.

Section 4 of The Survey of Teaching Faculty in Higher Education presents several findings concerning the use of digital technologies in education. According to the findings, a large majority of faculty participants agreed on the importance of using digital library platforms, Massive Open Online Courses (MOOCs), open-source learning platforms, social media platforms, survey software, and virtual reality or

virtual classrooms in their classrooms. Additionally, a large proportion of participants believed that Serious Gaming and Gamification would be used more frequently in the future, as supported by Rapp et al.(2019).

These findings highlight the importance of digital technologies in modern education and the willingness of faculty members to adopt them. This was particularly evident in the large number of participants who agreed to use various digital technologies for teaching and learning. Findings indicate that digital technology has the potential to improve educational quality and make it accessible to a wider audience (Inquimbert et al., 2019).

However, it should be noted that some participants expressed reservations about certain technologies such as social media platforms. This suggests that, while there is widespread support for digital technologies in education, careful consideration and evaluation of their potential benefits and drawbacks are required (Schmidt & Tang, 2020).

These findings indicate that digital technologies play an important role in education, and institutions and educators must remain up-to-date on the latest developments in this field.

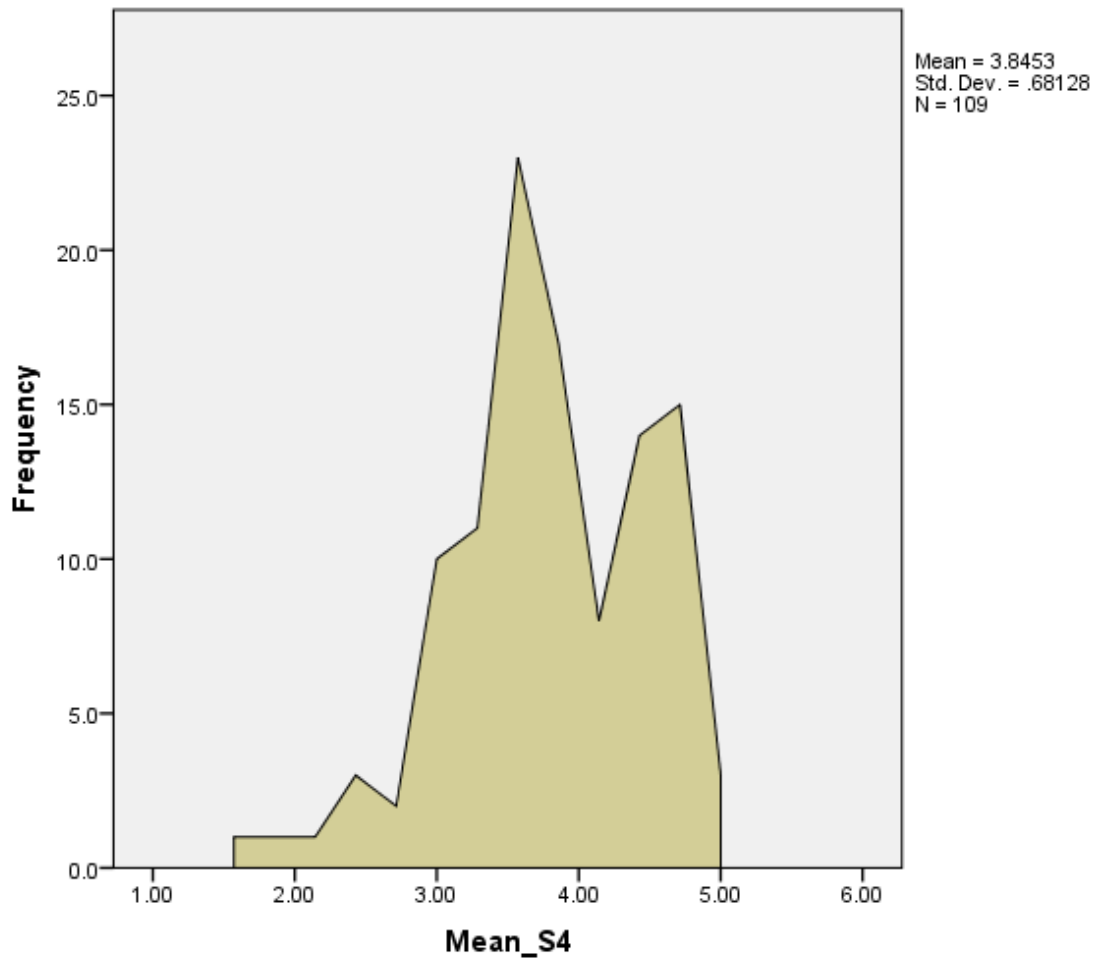


Chart 36: Mean-Frequency Chart of selected items of Section 4 of the Survey for Teaching Faculties in Higher Education

Chart 36 shows the results of the mean of Section 4 of the faculty survey. The x-axis shows the mean of the questionnaire items and the y-axis shows the frequency of each answer.

Section 3 of the students' questionnaire produced several findings regarding the role of educational technologies in student learning. Most participants agreed that a combination of traditional and new digital educational technologies would benefit the students. Furthermore, a sizable proportion of the participants believed that students should have advanced knowledge of learning theories.

Furthermore, the findings indicate that students are willing to participate in instructional and motivational design models as well as the technologies that support them. This shows that students recognize the potential benefits of these models and are willing to use digital technologies to enhance their learning experiences, supported by (Pinto & Leite, 2020), too,

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The findings indicate that students are willing to participate in instructional and motivational design models as well as the technologies that support them. This shows that students recognize the potential benefits of these models and are willing to use digital technologies to enhance their learning experiences, which again confirms the findings of Pinto and Leite (2020).

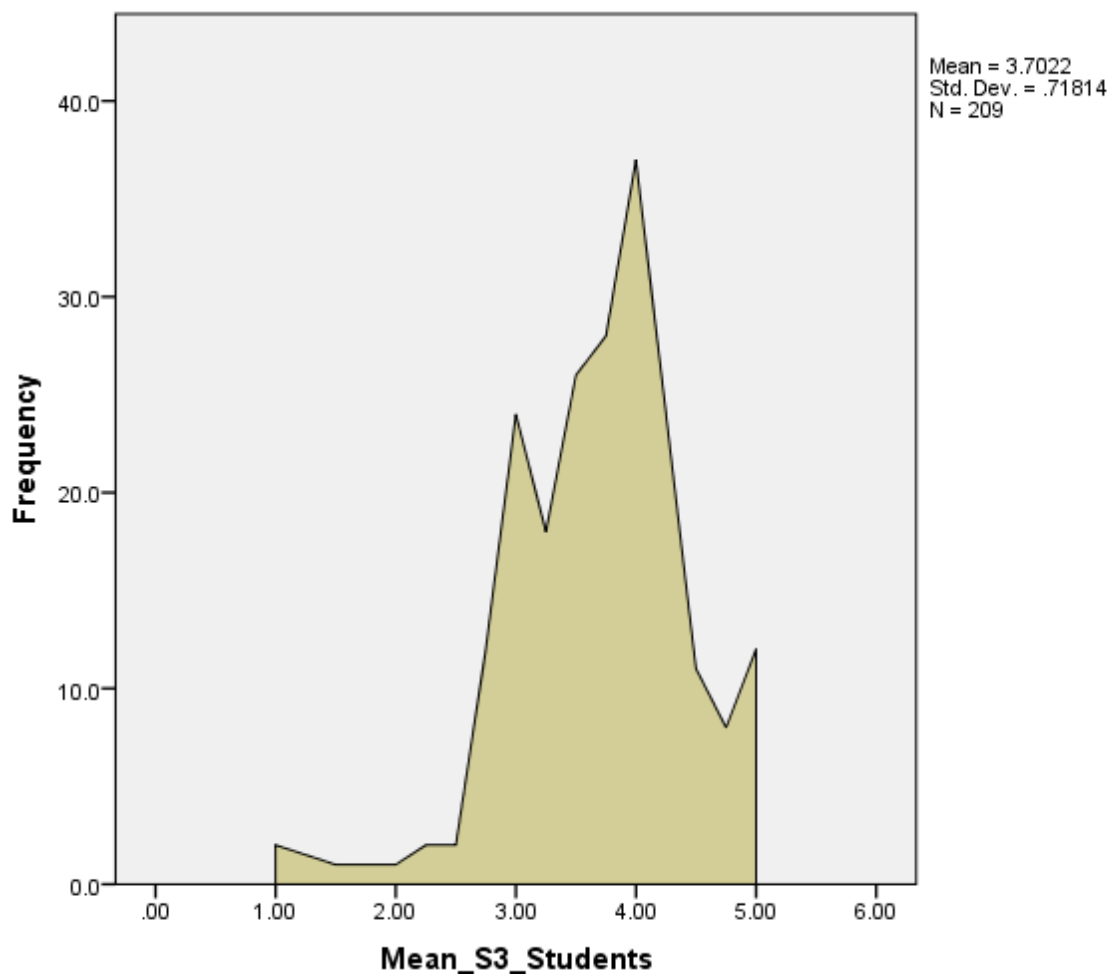


Chart 37: Mean-Frequency Chart of selected items from Section 3 of the Survey for Students in Higher Education

Chart 37 illustrates the mean values of the questionnaire items in section 3 of the students' survey. The x-axis indicates the mean score for each item, and the y-axis represents the frequency of each response.

Section 4 of the survey results on students' usage of digital resources in higher education discusses many findings on the use of digital technology by students. According to statistics, the majority of students utilized digital library platforms, massive open online courses, and open-source learning

platforms. These technologies have become an integral element of modern education, and it is natural that students have embraced them, as supported by Onyema et al.(2021).

However, the findings suggest that students are not as widely using advancements in digital educational tools such as virtual reality, virtual classrooms, serious gaming, gamification, and artificial intelligence. Although these technologies were utilized by a large number of students, they were not used by a major proportion of students.

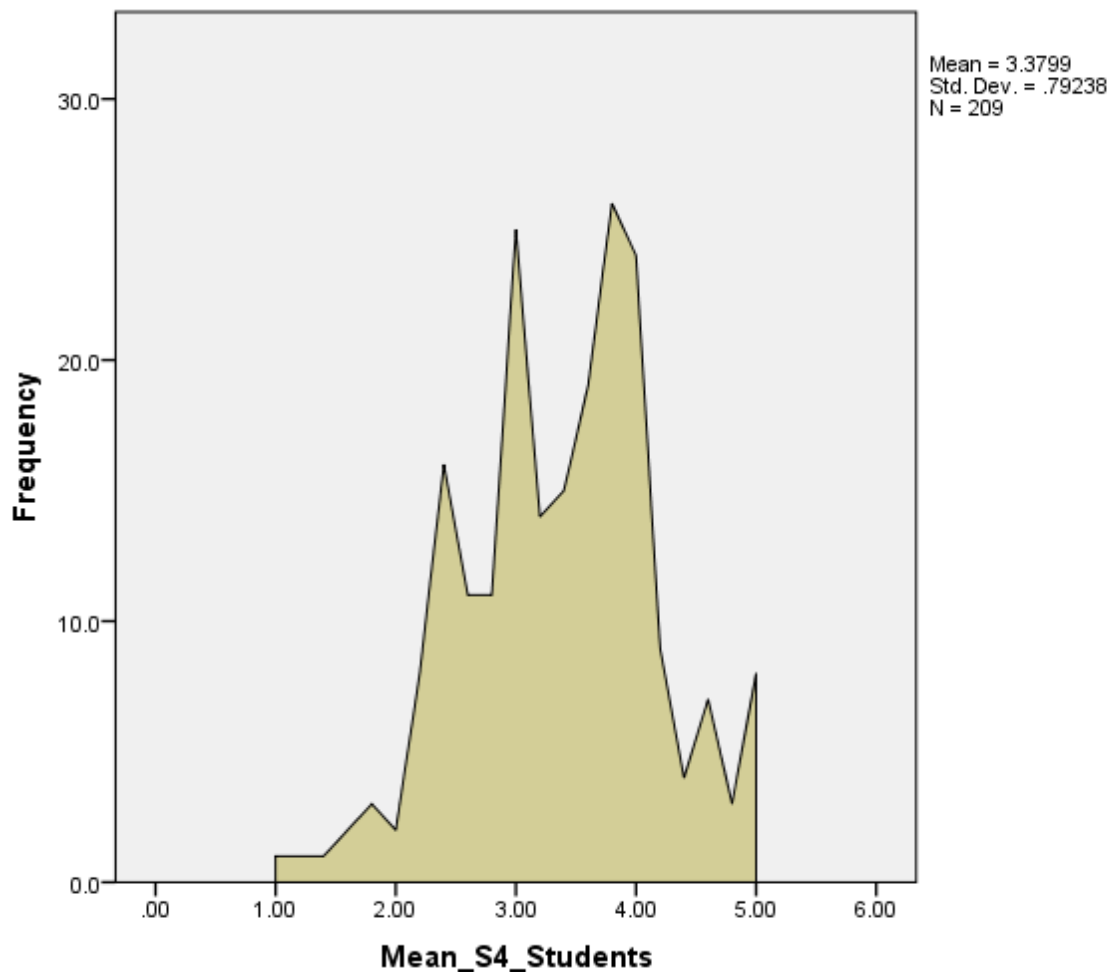


Chart 38: Mean-Frequency Chart of selected items from Section 4 of the Survey for Students in Higher Education

This might be attributed to several variables, including the availability of these technologies, the quality of their implementation, and the degree of assistance offered to students to use them properly (Ibañez-Etxebarria et al., 2020). These findings suggest that institutions should evaluate the challenges of adopting these newer technologies and seek to overcome them so that students can benefit from them.

Furthermore, the findings suggest that students continue to use social media platforms in their everyday classroom education. While there are certain benefits to utilizing social media sites, it is

equally crucial to recognize possible disadvantages, such as distraction and information overload (Zhang et al., 2020).

The findings highlight the significance of providing students with access to and assistance with a variety of digital instructional technologies. It is also vital to regularly assess the efficacy of these technologies and make appropriate improvements to ensure that they satisfy the requirements of both the students and faculties (Jaiswal, 2020).

Chart 38 shows the results of the mean of section 4 of the students' survey. The x-axis shows the mean of the questionnaire items and the y-axis shows the frequency of each answer.

As a result of this section, identified technologies, such as digital library platforms, Massive Open Online Courses (MOOCs), open-source learning platforms, social media platforms, survey software, virtual reality or virtual classrooms, Serious Gaming, Gamification, and artificial intelligence, are recognized as useful and effective tools for teaching and learning in higher education. According to the survey results, these technologies have become an integral part of current education, and their implementation is critical for boosting educational quality and accessibility (Ibañez-Etxeberria et al., 2020).

6. Discussion

Prior to discussing the results and analysis, the study findings suggest that the role of technological advancements in learning entrepreneurial competencies for engineering students in higher education contributes to preparing them for the modern workforce by enhancing their innovation and creativity, improving their collaboration and communication skills, fostering an entrepreneurial mindset, providing access to resources and networks, and aligning with industry trends. Specifically, the aforementioned roles can be detailed as follows:

a) Preparation for the modern workforce: Engineering students need to be equipped with skills and knowledge that will make them relevant to the modern workforce, which is rapidly changing owing to technological advancements. This finding was also supported by Vorhach (2020).

b) Enhancing innovation and creativity: Technology can facilitate the development of innovative ideas and creative solutions, enabling students to experiment with new products, services, and business models and develop innovative solutions, as supported by Distanont and Khongmalai (2020).

c) Improved collaboration and communication: Technology can facilitate collaboration and communication among team members, stakeholders, and customers; teach students how to work effectively in distributed teams; communicate their ideas clearly; and engage with customers in virtual environments, as supported by Hao and Mislevy (2019).

d) Fostering an entrepreneurial mindset: Technology can help students develop an entrepreneurial mindset by providing them with tools and resources to experiment, take risks, and learn from failure, which is essential for success in today's rapidly changing business environment, as supported by Zhang et al. (2022).

e) Access to resources and networks: Technology can provide students with access to a wealth of resources and networks that can help them develop entrepreneurial skills, including online courses, webinars, workshops, mentors, investors, and potential customers, as supported by Zhang et al. (2022).

f) Alignment with industry trends: Incorporating technology into entrepreneurial education aligns with industry trends, making engineering students more attractive to potential employers and better positioned to succeed in their careers, as supported by Holzmann et al. (2018).

Discussion of Chapter 4

This section first discusses and highlights the findings of Chapter 4 and is further divided into two sub-sections: discussion of the questionnaires and interviews.

a) Questionnaires

The results of questionnaire responses from both teaching faculties and students showed numerous key findings about the impact of technological advancements improvements in higher education and the inclusion of entrepreneurial education in engineering programs.

Validity and Reliability Analysis

The Composite Reliability (CR) and Average Variance Extracted (AVE) values for each latent construct in the CFA measurement model exceeded their respective criteria (0.70 for CR and 0.5 for AVE). This demonstrates that the model has high internal consistency and substantial convergent validity (Matsuda et al., 2003); (Abbott, 2003).

Teaching Faculties Perspectives

The questionnaire "Survey for teaching faculties in higher education synthesizes these findings in a summarized way:

- a) Most faculty members supported the assertions made in the questionnaire.
- b) There is a general lack of consensus on several statements, such as the ongoing digital transformation in the job industry and adequacy of technological support for creative students.
- c) Teaching faculties do not use learning interaction platforms, graphic designs, or video software.
- d) Only 40% of faculty members believed that AI was already a reality in higher education.
- e) 39% of respondents believed that engineering graduation was more challenging than 20 years ago.

Student Perspectives

The questionnaire "Survey for students in higher education" synthesizes these findings in a summarized way:

- a) In general, students had favorable attitudes towards the questionnaire statements.

b) Some statements, such as the affordability of the latest digital technology and identification of disruptive innovations, garnered less agreement.

c) Less than half of the students used virtual reality, virtual classrooms, serious gaming, gamification, or AI.

The results of the questionnaire responses revealed teaching faculties and student opinions on technological advancements in higher education, as well as the relevance of entrepreneurial education in engineering programs. While there is a generally positive attitude toward these improvements, several aspects, such as the affordability of digital technologies, the use of learning interaction platforms, and the application of AI and other new technologies in education require additional exploration and refinement. All the aforementioned findings were retrieved from the questionnaires and are in line with the literature, as discussed in Chapter 2.

b) Interviews

The use of Atlas.ti software in conducting a qualitative analysis of the two separate interviews was found to be a valuable tool for any research (Obermayer et al.(2022). The Semantic Linkage feature of Atlas.ti helped visualize the relationships between different concepts and themes within the data and identified patterns, clusters, and relationships between codes and categories in a visual format (Unger et al., 2020). This helped gain deeper insights into the experiences and perspectives of the research responses.

"Interview S2Q2" Semantic Linkage focused on the subject of "technological platforms" and was connected with artificial intelligence, blockchain technology, machine learning, virtual and augmented reality, and online Learning Systems. According to the Semantic Linkage, "benefits of technology platforms" eased the distribution of educational information and had the ability to create jobs, whilst "challenges of technological platforms" had the potential to eliminate jobs. These findings were consistent with the responses of the teaching faculties to Statement S2Q2 in Chapter 4, Section of the Interviews.

The word frequencies used in the analysis contributed to identifying the most frequently used words or phrases in the data, to gain a deeper understanding of the content and themes (Scharenborg et al., 2017). Technology, education, platform, workforce, and type of technological platform were the most frequently used terms in this analysis. This verifies S2Q2's Semantic Linkage and provides new insights into the significant themes and concepts in the data.

According to the analysis of a semantic linkage analysis of an interview Statement S5Q3, "engineering graduates" with certain values (G and D values of 3 and 10, respectively) are grouped together and associated with "engineering students" and "engineering abilities" (Unger et al., 2020). This link with the highest degree of grounding implies that engineering students may work in various areas, including industry, government, entrepreneurship, academia, consulting, and engineering. The G and D values were satisfactory, suggesting that coding and connection were stable. These findings are consistent with the responses of the teaching faculties to Statement S3Q5 in Chapter 4, Section of the Interviews.

A word frequency analysis found that words such as engineering, engineers, graduates, jobs, and employment opportunities were prevalent after graduation, supporting the validity of the semantic linkage for S5Q3 (Scharenborg et al., 2017). These findings suggest that engineering students' abilities and knowledge may be utilized in a variety of areas, and that engineering graduates have a variety of job options. Satisfactory G and D scores indicate that the semantic linkage analysis results are reliable (MacQueen et al., 1998).

In the qualitative analysis, the use of the Atlas.ti software proved to be an excellent technique for acquiring deeper insights into the experiences and perspectives of research responses, as supported by Méndez-Romero (2016). The Semantic Linkage tool visualizes the links between distinct concepts and themes, whereas word frequency analysis provides further insights into the data's important topics and concepts (Huth et al., 2016). These tools can be useful in qualitative data analysis and can help researchers gain a better understanding of the research topic.

Discussion of Chapter 5

This section first discusses and highlights the findings of Chapter 5 and is further divided into five sub-sections, which are the discussions in Section 5.1 to Section 5.5.

a) Discussion of Section 5.1

The survey questionnaires provided valuable information on the most effective strategies for utilizing digital educational technologies to enhance students' learning and engagement. According to these findings, teaching faculties and students are eager to incorporate more digital educational technology into their everyday teaching and learning in the near future, which is consistent with Barros and Osorio (2017). According to the questionnaire findings, teaching faculties and students appreciated the relevance of advanced knowledge of learning theories, employing instructional design models, and motivational design models to encourage student learning and engagement.

According to the findings of the questionnaire analysis, digital library platforms, massive open online courses, and open-source learning platforms such as Moodle and Canvas LMS are useful tools for improving students' learning and engagement. Furthermore, the findings indicate that social media platforms, virtual reality, or virtual classrooms, as well as serious gaming and gamification, can help in learning and teaching activities and improve student learning and engagement.

However, the questionnaire analysis revealed that there may be some resistance or unwillingness to adopt specific technologies in education, such as learning interactions and activity platforms, graphic design or video software, and artificial intelligence. It is important to address these issues and provide the required training and support to teaching faculties and students for the effective use of these technologies.

The findings suggest that combining old and new digital instructional technologies can improve student learning and engagement. However, it is critical to ensure that both faculties and students have the requisite knowledge and abilities to utilize these tools successfully, as well as to address any concerns or opposition to their usage. Consequently, advancements in digital educational technology may be fully leveraged to improve student learning and engagement in higher education (Nkomo et al., 2021).

b) Discussion of Section 5.2

The questionnaire analysis in this section offers insightful information on the value of entrepreneurial competencies of engineering students in higher education. The analysis suggests that teaching engineering students' entrepreneurial competencies would give them more opportunities to find or create jobs in the future, as suggested by Shekhar and Huang-Saad (2021) and Besterfield-Sacre et al.(2016). The findings also suggest that both teaching faculties and students believe that engineering students should acquire entrepreneurial skills at colleges or universities.

According to the questionnaire analysis, the teaching faculties argued for the use of new technologies in the engineering course curriculum to improve entrepreneurial skills. Professor Cam Harvey of Duke University advised that courses in business management, marketing, and finance should be included (Coursera.org). This approach can provide students with the skills and knowledge necessary to successfully launch and manage their businesses or entrepreneurial ventures, as supported by Wang et al.(2019).

However, further studies are needed to determine the appropriate time and techniques for teaching entrepreneurial competencies to engineering students. As Stawiski et al. (2017) suggest

here to enter text., it may be useful to offer these competencies early in the engineering curriculum to enable students to apply their entrepreneurial competencies and knowledge to academic projects and research.

Considerable resources and faculty assistance are required to include entrepreneurial competencies in the engineering curricula. Consequently, it is critical to ensure that the required tools and support are accessible to enable successful entrepreneurial competency education for engineering students (Liu et al., 2015). According to the analysis of the questionnaires, engineering students can learn the skills and expertise required to effectively develop and run their own businesses or entrepreneurial ventures, giving them additional opportunities to find or create jobs in the future, which is also supported by Carolis and Litzky (2019).

c) Discussion of Section 5.3

The questionnaire analysis provided insights into teaching faculties and students' perspectives on the influence of technology-enriched educational platforms on job creation, reduction, and workforce addition and reduction. According to the findings, the majority of teaching faculties and students feel that technology-enriched educational platforms can provide new and emerging occupations, and that conventional progress leads to the emergence of new job opportunities and/or the obsolescence of existing traditional jobs. These results were consistent with those of a previous literature review.

The questionnaire analysis shows that students are more convinced than educators that studying is easier nowadays owing to the use of technology. This gap may be related to the fact that students are more acclimated to utilizing digital technology in their everyday lives and education, whereas teaching faculties may have had to adjust later in their careers.

The analysis also implies that more research is needed on the influence of technology-enhanced educational platforms on job creation/reduction and workforce addition/reduction. The use of qualitative analysis may provide more nuanced insights into the experiences and views of teaching professionals and students regarding the use of technology in education.

According to the questionnaire findings, technology-enhanced educational platforms can create new and emerging occupations and contribute to workforce augmentation (Frenken and Fuenfschilling, 2020). However, it is necessary to continue monitoring and assessing the influence of technology on job growth, job decline, workforce increases, and workforce reductions. This will help to ensure that technology is used to benefit both students and society (Lu & Song, 2020).

d) Discussion of Section 5.4

This section's questionnaire analysis provides useful insights into the obstacles and possibilities linked to the application of digital technologies in education, particularly in engineering. According to the findings, both teaching faculties and students face problems in implementing digital technologies in education, such as financial expenses and technical challenges associated with adopting these technologies in instructional practices.

Teaching faculties also face challenges related to providing an adequate technological environment for creative-minded students, with only 40% of faculties agreeing that their institutions meet this requirement. However, students may face challenges related to the affordability of the latest digital technologies proposed by their teaching faculties, with only 36% agreeing that they could afford them.

The analysis indicates that both the teaching faculties and students appreciate the importance of using digital technology in education. For example, educators acknowledge that technological advancements have given rise to new forms and occupations, and believe that engineering has a promising future. Students, on the other hand, think that digital technology has made studying engineering or other disciplines simpler than a decade ago, and that their schools provide an environment that appeals to creative-minded students.

These findings indicate a need for educational institutions to provide enough training and support to effectively incorporate digital technology into their teaching methods, as supported by Guillén-Gómez et al.(2021). Furthermore, institutions may need to provide resources and infrastructure to facilitate the deployment of digital technologies in education, particularly to guarantee that students from all backgrounds have access to them.

According to the questionnaire analysis, the introduction of digital technology to education brings about both challenges and advantages. By addressing these challenges and providing the necessary support and resources, teaching faculties and institutions can effectively incorporate digital technologies into education, providing students with the skills and knowledge they need to succeed in the field of engineering and beyond, as supported by Rodrigues et al.(2021).

e) Discussion of Section 5.5

The questionnaire analysis provided insights into the perspectives of the faculties and students regarding educational technology in higher education. A key finding is that both faculties and students appreciate the need for a taxonomy or framework for organizing and assessing advancements in

educational technology, as supported by (Kemp et al. (2019) and Muras et al.(2006). According to the findings, the technologies identified in the "Framework for Educational Technology Landscape" are widely acknowledged as helpful and effective instruments for teaching and learning in higher education. According to the faculties replies, 63% believed that a framework would be valuable, most likely because it would aid in the selection and assessment of technology.

According to the study, digital technologies are broadly accepted among faculties, with the majority acknowledging the use of digital platforms, MOOCs, social media, and other technologies in their lectures. This outcome is consistent with the hypothesis that digital technology may increase educational quality and accessibility as supported by Inquimbert et al.(2019). However, other platforms, such as social media, have sparked concerns, underlining the significance of carefully assessing advantages and risks (Schmidt & Tang, 2020).

Likewise, students were enthusiastic about digital technology, with the majority utilizing digital platforms, MOOCs, and open-source tools. However, the adoption rates of emerging technologies such as virtual reality, gaming, and artificial intelligence (AI) are lower. Its usage may be limited owing to its accessibility, implementation quality, and lack of support (Ibañez-Etxeberria et al., 2020). Students continue to use social media extensively, despite potential negatives such as distraction (Y. L. Zhang & Dinh, 2017).

These findings emphasize the need to provide students and educators with access, training, and assistance to fully utilize the potential of educational technology (Jaiswal, 2020). Regular evaluations can help ensure that the technologies are in line with educational objectives.

The analysis indicates that the technologies found in the "Framework for Educational Technology Landscape" are correct and will have a substantial influence on our lives in higher education. Institutions and instructors may offer students the skills and information they need to flourish by using these technologies properly. However, addressing concerns regarding the adoption of these technologies and the continuous evaluation of their performance are critical to ensuring that they satisfy the requirements of students and instructors. Further research should examine the demographic disparities in attitudes and the best ways to integrate these technologies.

7. Final considerations

This chapter is organized into three sections: limitations of the doctoral thesis, recommendations for future research, and conclusions.

Limitations

This comprehensive study aimed to contribute to the existing knowledge base in a particular field. This Ph.D. thesis explores a wide range of topics related to the use of technology in education, such as the design and development of digital learning environments, effectiveness of educational software, implementation of digital technology in the engineering field, importance of studying Entrepreneurship Education, and impact of technology on teaching and learning practices. Like any other research project, a Ph.D. thesis in educational technology has limitations. These constraints can be caused by several variables, including the scope of the research question, availability of data and resources, ongoing innovations in the field of digital technologies, and the challenge of keeping up with the most recent articles or citations. This section seeks to examine some of the most typical limitations of this Ph.D. thesis and proposes strategies to address them.

There are several limitations to the scope of the research question: "What is the role of technological advancements in learning entrepreneurial competencies in higher education?". Some possible limitations of this study are as follows:

Generalizability: The findings of this study may not be relevant to all types of higher education institutions, because the usage of technology and teaching techniques varies significantly between universities and colleges (Tey & Moses, 2018). Consequently, the study may be confined to certain situations and cannot be generalized to other settings.

Limited Data Availability: The researcher encounters difficulties in finding data relevant to the research question, particularly when dealing with emerging technologies or entrepreneurial competencies that have not been extensively studied or evaluated (Ratkovic et al., 2022).

Time Restriction: The scope of the research subject may be too large to be properly examined within the time constraints of a Ph.D. thesis.

Complexity: The research question covered a wide range of topics, including technology, business, learning, engineering, and higher education.

Continuous development of digital technologies: Technology is a rapidly evolving field, with new tools and software being regularly developed and released. This study took three years to complete, during which new technologies arose and existing ones became obsolete (Pérez-Ortega et al., 2018).

In recent years, there has been a substantial emphasis on the development of artificial intelligence (AI) in education. AI technologies have the potential to transform the way students learn and interact with educational information (Yang et al., 2020). However, these technologies are still in their early stages, and much remains to be discovered regarding their usefulness and impact on student learning outcomes.

To address this limitation, the researcher attempted to stay updated on new technologies by attending educational technology workshops and seminars. The Researcher used a variety of data sources, including social media and online forums, to stay updated on the latest trends and developments in the field.

Additionally, as new technologies emerge and existing technologies evolve, the Framework of the Educational Technology Landscape can become outdated and may not fully capture the current landscape of educational technologies. For instance, when the Ph.D. study began in 2020, certain technologies have not existed, and new technologies have emerged. Consequently, the researcher needed to update the list of educational technologies and modify the research questions to account for these changes.

The possibility of not incorporating the latest research and citations into the study: As the research is being conducted, new studies and publications related to educational technologies may be published, making the research outdated.

In conclusion, Part III of the Literature Review was carried out between 2021-2022 and might not reflect the rapid changes that occurred in the late months of 2022 and 2023 due to the rapid developments in technological advancements, especially Artificial Intelligence.

Future research

As technological innovations continue to impact the environment, the importance of technology in higher education has grown. The influence of technology on the development of entrepreneurial competencies among higher-education students is a topic of particular attention. Understanding how technological advancements may be used to improve entrepreneurship education has the potential to open up new opportunities for students to learn the skills and knowledge required to flourish in the

twenty-first-century economy. Based on the research question, this section investigates various prospective research directions that might shed light on this important topic.

The impact of specific technologies on learning entrepreneurial competencies in higher education: This research examines how various technologies, such as artificial intelligence, virtual and augmented reality, and social media, influence students' acquisition of entrepreneurial competencies in higher education.

The effectiveness of different teaching approaches in leveraging technological advancements for the development of entrepreneurial competencies: This study examined various teaching techniques that use technological advancements, such as project-based learning, experiential learning, or gamification, to help students acquire entrepreneurial skills in higher education.

This study examined the social and cultural factors that influence the adoption of technological advancement in developing entrepreneurial competencies. This study examined the social and cultural factors that influence the adoption of various technologies and teaching methods for developing entrepreneurial competencies in higher education, such as institutional culture, student demographics, and regional differences.

The impact of technology-enabled entrepreneurship education on student outcomes outside the classroom: This study examined the impact of entrepreneurship education using technological advancements on student outcomes outside the classroom, such as employability, innovation, and entrepreneurial activity.

The effect of entrepreneurship education on students' attitudes and behaviors toward technology adoption: This study examined how entrepreneurship education that takes advantage of technological advancements affects students' attitudes and behaviors toward technology adoption, innovation, and entrepreneurship.

The role of interdisciplinary approaches in leveraging technological advancements for entrepreneurship education: This study examines the impact of interdisciplinary approaches that combine entrepreneurship education with other fields, such as engineering, design, and social sciences, in leveraging technological advances to develop entrepreneurial competencies among students in higher education.

There are only a few examples of prospective study areas that might be pursued in response to the research topic. Further research into these themes can help comprehend the impact of technological

advancements in fostering entrepreneurial skills and competencies in higher education, as well as guide the design of effective entrepreneurship education programs for the twenty-first century.

Conclusions

This study aimed to explore the role of technological advancements in encouraging entrepreneurial competencies among engineering students in higher education institutions. The research question was on the role of technological advancements on the development of entrepreneurial competencies and their relevance to engineering students. This research created a complete framework of software and hardware technologies that may be utilized to improve learning outcomes, as well as the most successful ways to utilize digital educational technology to boost student learning and engagement. It also investigated the impact of digital technology on learning quality and the challenges faced by engineering students and educators during the learning process. As previously mentioned, the findings of this study can help educators, policymakers, and industry experts to enhance the learning outcomes of engineering students in higher education.

This thesis makes a significant contribution to the fields of educational technology, engineering, entrepreneurship, and teaching by providing an in-depth understanding of the role of digital technological advancements in developing entrepreneurial competencies for engineering students in the context of higher education. This research addresses a gap in the literature by examining the association between digital technology advancements and entrepreneurial competencies among higher education engineering students. This research acknowledges the increasing relevance of digital technology in education, as well as the necessity to build entrepreneurial skills in today's fast-paced and dynamic work market, where innovation and creativity are highly appreciated.

This study has revealed numerous successful ways to enhance student learning and engagement through the use of digital educational technology. These include incorporating disruptive technologies into education; utilizing a technology framework; adhering to instructional and motivational design models; accessing digital libraries; utilizing open-source platforms such as Moodle and Google Classroom; leveraging social media; updating curricula with new technologies; and utilizing virtual reality, gaming, and gamification. A combination of existing and contemporary technology benefits students, but faculties and students must have the knowledge and ability to use them successfully.

The questionnaire and interview results revealed that both students and faculty recognize the growing need for entrepreneurial competencies in education, with a special focus on engineering. They also

highlighted the potential of technologies to promote the active learning of skills, and adopting these technologies allows programs to build entrepreneurial competencies. According to the survey results, both the teaching faculties and students believe that entrepreneurial skills are important for engineering students to learn in higher education. The majority of teaching faculties (72%) favored the use of technological advancements to teach these skills. 68% of faculties and 63% of students believe that entrepreneurship courses lead to additional career prospects. There is a significant demand to integrate entrepreneurial competencies into engineering curricula as they provide job prospects. However, further research is needed to determine the optimal timing and methods for teaching engineering students.

Questionnaire questions on new employment, job loss, convenience of learning with technology, and technological environment for students provided evidence of the influence of technology-enriched education on jobs and the workforce. Most faculties and students believe that technology produces new employment while simultaneously modifying or eliminating existing ones; this is also supported by Avom et al.(2021). Students are more convinced that technology-enhanced education makes studying easier; however, this claim merits additional exploration, as supported by Lu and Song (2020).

It is challenging to identify who is most affected by technology in education and engineering. However, the survey findings showed that both faculties and students faced obstacles. The costs and installation of new technologies are difficult for faculties (63%). Only 40% of them said that their universities provided suitable technological settings for creative students. This shows that costs and technological concerns influence educators. Similarly, only 36% of the students could purchase the most recent technology, and many were unfamiliar with disruptive technologies and signaling difficulties for students. Both groups encountered challenges; however, further study is needed to determine the most severely afflicted parties.

In summary, this study examined the use of digital technologies in engineering education. According to the survey results, they boost student learning and engagement, and engineering students should be taught with entrepreneurial skills. Although the precise effects are unknown, certain groups are expected to encounter additional difficulties. The Framework of Educational Technology Landscape may be useful for teaching and learning; however, further research is required. Engineering education should be intelligently and supportively connected to digital technological advancements.

8. References

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9. Appendices

Appendix 1

Questionnaire surveys display:


Questionnaire 1:

Survey for teaching faculties in higher education

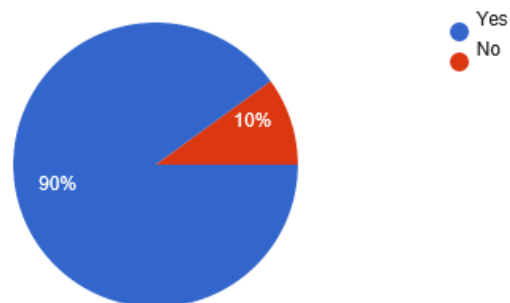
120 responses

[Publish analytics](#)

Are you currently teaching faculty in higher education, or have you in the past five years?

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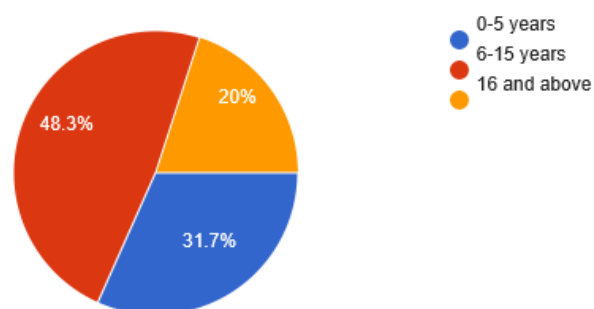
120 responses



How many years of teaching experience do you have?

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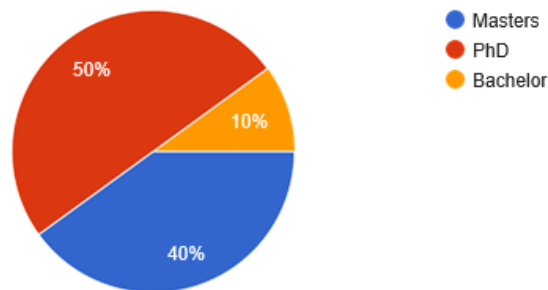
120 responses



What is your level of study?

[Copy](#)

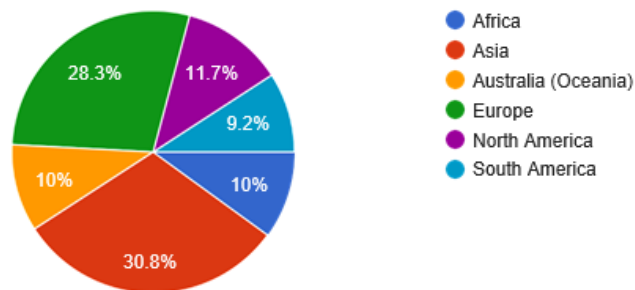
120 responses



In which continent have you most recently taught?

[Copy](#)

120 responses



Questionnaire 2:

Survey for students in higher education

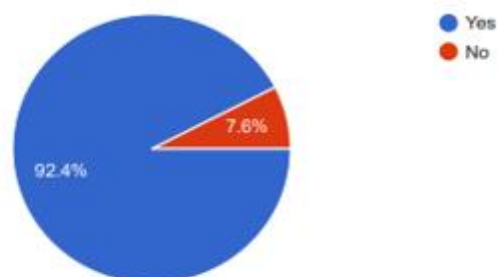
224 responses

[Publish analytics](#)

Do you currently attend a college/university, or did you complete your studies in the last two years?

[Copy](#)

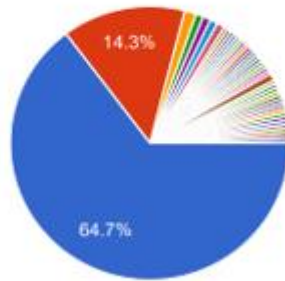
224 responses



What is the major of your studies?

 Copy

224 responses



- Engineering and/or Technology
- Business, Economics, or similar
- Psychology
- Linguistics
- Social Sciences
- Biology
- Law
- MEDICINE AND HEALTH SC...

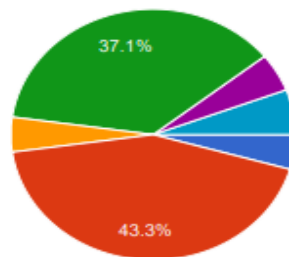
▲ 1/6 ▼



In which continent have you carried your most recent study program?

 Copy

224 responses



- Africa
- Asia
- Australia (Oceania)
- Europe
- North America
- South America

20% completed.

Appendix 2

Interviews with Openai.com about questionnaire items S2Q2 and S5Q3.

Interview 1:

Hello ChatGPT! Can we have a brief interview together?

Of course! I'd be happy to participate in an interview with you. Just ask away!

What is your opinion about the technological platforms for education?

As a language model created by OpenAI, I don't have opinions or personal experiences. However, I can provide some objective information on the topic.

The use of technological platforms for education has increased significantly in recent years, particularly due to the COVID-19 pandemic. These platforms offer a number of benefits, including increased access to educational resources, the ability to facilitate remote learning, and the ability to personalize learning experiences for individual students.

However, there are also some challenges associated with the use of technology in education. These include issues with equity, as not all students have access to the technology and internet connectivity needed to participate fully in online learning. There are also concerns about the impact of technology on students' attention spans and mental health, as well as the potential for distractions and decreased motivation.

Overall, while technological platforms have the potential to revolutionize education, it is important to consider both the benefits and challenges, and to approach their use in education in a thoughtful and strategic way.

Do your findings suggest that the demand for a human workforce will decline as a result of the increased use of technological platforms in education?

It's difficult to predict the exact impact of technology on the demand for a human workforce in the education sector. However, it is likely that the increased use of technological platforms will result in some changes to the workforce.

On one hand, technology has the potential to automate certain tasks that were previously performed by humans, such as grading assignments or tracking student progress. This could lead to a decline in the demand for some types of jobs, such as administrative support staff.

On the other hand, the use of technology in education also has the potential to create new jobs, such as instructional designers, edtech support specialists, and online course facilitators. Additionally, while technology can help to facilitate the delivery of educational content, it cannot replace the importance of human interaction, support, and mentorship in the learning process. As such, the demand for teachers, guidance counselors, and other educational professionals is unlikely to decline.

Overall, it's important to consider the impact of technology on the education workforce in a holistic way, recognizing both the potential for job loss and the potential for job creation. Additionally, it's important to invest in upskilling and reskilling initiatives to help workers adapt to changes in the labor market.

And lastly, what are the most recent developments in educational technological platforms?

There have been a number of exciting developments in educational technology in recent years. Here are a few of the most significant trends:

1. Artificial Intelligence (AI) and Machine Learning (ML): AI and ML are being integrated into a growing number of educational technologies, allowing for more personalized and adaptive learning experiences. For example, AI-powered tutors can offer real-time feedback and guidance to students, while machine learning algorithms can analyze data on student performance to identify areas where they may need extra support.
2. Virtual and Augmented Reality (VR/AR): VR and AR are increasingly being used in education to provide immersive, interactive learning experiences. For example, students can use VR to "visit" historical sites or natural wonders, or to explore scientific concepts in a way that is not possible in a traditional classroom setting.
3. Online Learning Management Systems (LMS): Online LMS platforms, such as Blackboard and Canvas, continue to evolve and improve, offering a wide range of features and tools to support the delivery of online courses and the management of student progress.
4. Edtech for Early Childhood Education: There is a growing number of educational technology products and resources aimed specifically at the early childhood education market, including interactive storybooks, educational games, and STEM toys.
5. Blockchain Technology: Blockchain is being explored as a potential solution for issues of credential verification and transfer in education. For example, a blockchain-based platform could be used to securely store and manage students' academic records, making it easier for them to transfer credits between institutions.

These are just a few examples of the many exciting developments in educational technology. As technology continues to evolve, it is likely that we will see even more innovative and impactful solutions emerge in the future.

Thank you.

You're welcome! I'm glad I could help. If you have any other questions, feel free to ask!

Interview 2:

Hello ChatGPT! Can we have a brief interview together?

Of course! I'd be happy to participate in an interview with you. Just ask away!

What is your opinion about the technological platforms for education?

As a language model created by OpenAI, I don't have opinions or personal experiences. However, I can provide some objective information on the topic.

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However, there are also some challenges associated with the use of technology in education. These include issues with equity, as not all students have access to the technology and internet connectivity needed to participate fully in online learning. There are also concerns about the impact of technology on students' attention spans and mental health, as well as the potential for distractions and decreased motivation.

Overall, while technological platforms have the potential to revolutionize education, it is important to consider both the benefits and challenges, and to approach their use in education in a thoughtful and strategic way.

Do your findings suggest that the demand for a human workforce will decline as a result of the increased use of technological platforms in education?

It's difficult to predict the exact impact of technology on the demand for a human workforce in the education sector. However, it is likely that the increased use of technological platforms will result in some changes to the workforce.

On one hand, technology has the potential to automate certain tasks that were previously performed by humans, such as grading assignments or tracking student progress. This could lead to a decline in the demand for some types of jobs, such as administrative support staff.

On the other hand, the use of technology in education also has the potential to create new jobs, such as instructional designers, edtech support specialists, and online course facilitators. Additionally, while technology can help to facilitate the delivery of educational content, it cannot replace the importance of human interaction, support, and mentorship in the learning process. As such, the demand for teachers, guidance counselors, and other educational professionals is unlikely to decline.

Overall, it's important to consider the impact of technology on the education workforce in a holistic way, recognizing both the potential for job loss and the potential for job creation. Additionally, it's important to invest in upskilling and reskilling initiatives to help workers adapt to changes in the labor market.

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2. **Virtual and Augmented Reality (VR/AR):** VR and AR are increasingly being used in education to provide immersive, interactive learning experiences. For example, students can use VR to "visit" historical sites or natural wonders, or to explore scientific concepts in a way that is not possible in a traditional classroom setting.
3. **Online Learning Management Systems (LMS):** Online LMS platforms, such as Blackboard and Canvas, continue to evolve and improve, offering a wide range of features and tools to support the delivery of online courses and the management of student progress.
4. **Edtech for Early Childhood Education:** There is a growing number of educational technology products and resources aimed specifically at the early childhood education market, including interactive storybooks, educational games, and STEM toys.
5. **Blockchain Technology:** Blockchain is being explored as a potential solution for issues of credential verification and transfer in education. For example, a blockchain-based platform could be used to securely store and manage students' academic records, making it easier for them to transfer credits between institutions.

These are just a few examples of the many exciting developments in educational technology. As technology continues to evolve, it is likely that we will see even more innovative and impactful solutions emerge in the future.

Thank you.

You're welcome! I'm glad I could help. If you have any other questions, feel free to ask!

Appendix 3

Four interviews conducted in the pilot study phase with two students and two teaching faculties:

Interview 1: Student M

Interviewer: Can you tell me a little bit about your background and what you're studying?

Student M: Sure, I'm studying Computer Engineering. My background is in programming and I'm really interested in technology.

Interviewer: Great. So, the first question I have for you is whether you would consider involving or having a career in entrepreneurship?

Student M: I'm neutral about it. I'm really passionate about technology and programming, so I think I would prefer to work as an employee of a computer engineering company. However, if there was an opportunity to be involved in entrepreneurship that involves "computers", I would consider it highly.

Interviewer: That's interesting. Can you tell me what three keywords or skills you think someone needs to have a successful career in entrepreneurship?

Student M: I think an entrepreneur should be a strong character, have connections, and respect the law.

Interviewer: Thanks for sharing your thoughts. Lastly, I have a list of technologies here. Can you tell me which ones you know or have used since the early years of your studies?

Student M: Sure, let me take a look.

Interview 2: Student F

Interviewer: Can you tell me a little bit about your background and what you're studying?

Student F: Sure, I'm studying Industrial Engineering. I don't have a background in business, but I'm interested in learning more about entrepreneurship.

Interviewer: Great. So, the first question I have for you is whether you would consider involving or having a career in entrepreneurship?

Student F: I'm highly interested in being an entrepreneur and possessing more skills in this field.

Interviewer: That's great to hear. Can you tell me what three keywords or skills you think someone needs to have a successful career in entrepreneurship?

Student F: I believe a successful entrepreneur needs to study, support the employees, and have leadership.

Interviewer: Thanks for sharing your thoughts. Lastly, I have a list of technologies here. Can you tell me which ones you know or have used since the early years of your studies?

Student F: Sure, let me take a look.

Interview 3: Doctor A

Interviewer: Can you tell me a little bit about your background and what you're currently teaching?

Doctor A: Sure, I'm originally from Albania and I'm currently teaching entrepreneurship courses at the University of Tirana, Albania.

Interviewer: Great. So, based on your experience, have you noticed any difference in learning entrepreneurial competencies in introductory courses between the engineering students and business/economics students?

Doctor A: In my experience, I haven't noticed any major differences between engineering and business/economics students when it comes to learning entrepreneurship skills in introductory courses. Of course, there may be differences between individual students, but overall, both groups show the same level of interest in learning these skills.

Interviewer: That's interesting. In your opinion, after engineering students finish their entrepreneurial courses, are they confident and enthusiastic enough to start a career in entrepreneurship or to apply the learned skills in their future jobs?

Doctor A: From my experience, a high percentage of graduate engineers tend to start a career in business. However, it's important for universities or colleges to provide guidance and practical skills to their students while studying business majors.

Interviewer: Thanks for sharing your thoughts. Now, I have a list of technologies here. Can you tell me which five technologies you think will mostly impact entrepreneurship in the future?

Doctor A: Sure, let me take a look.

Interview 4: Doctor G

Interviewer: Can you tell me a little bit about your background and what you're currently teaching?

Doctor G: Sure, I'm from Greece and I'm currently teaching entrepreneurship courses at Aristotle University of Thessaloniki.

Interviewer: Great. So, based on your experience, have you noticed any difference in learning entrepreneurial competencies in introductory courses between the engineering students and business/economics students?

Doctor G: In my experience, there are no major differences in learning and improving concepts or competencies between engineering and business/economics students. However, there is a significant difference in the will (desire, reasons) to learn between the categories. Students who will work in industry and will not have any entrepreneurial initiative (engineering students in pole) are mostly oriented to finish the course (with a higher grade) because it is in their program and they do not show interest in exceeding their skills beyond basic knowledge. Business/economics talented students, on the other hand, show interest toward practical skills and implementing the knowledge as soon as they have an opportunity.

Interviewer: That's interesting. In your opinion, after engineering students finish their entrepreneurial courses, are they confident and enthusiastic enough to start a career in entrepreneurship or to apply the learned skills in their future jobs?

Doctor G: From my point of view, engineering students see the business world as a real opportunity to start a career and develop their competencies. However, students of some specific majors (mostly computer engineering) would generally prefer being freelancers rather than entrepreneurs.

Interviewer: Thanks for sharing your thoughts. Now, I have a list of technologies here. Can you tell me which five technologies you think will mostly impact entrepreneurship in the future?

Doctor G: Sure, let me take a look.

Appendix 4

Emails sent by UMINHO teaching faculties or graduates to help improve the questionnaire surveys.

Email 1:

Dear Marius,
Here are my comments.
At the beginning of the questionnaire, you state that the user will take between 5 and 7 minutes to answer the entire questionnaire. I find this very optimistic. Even at an average speed of 200 wpm, it takes at least 12 minutes, regardless of time to decide and respond.
I would say the estimated time will be between 15 and 20 minutes.
Please see the attachment for more comments.
All the best,
L.

Email 2:

Boa tarde!
Aqui vai o meu feedback (espero que seja útil!):
1.Âmbito e objetivos do questionário
Não sei se conjuntamente com o link de acesso ao formulário será enviado algum documento a explicar o âmbito e o(s) objetivo(s) do questionário. Caso não seja, eu recomendo que essa informação seja adicionada no início do formulário para ajudar o respondente a compreender o contexto das questões.
2.Conceitos e definições
Na pergunta referente a “Entrepreneurship Education” reparei que foram abertas aspas (“) mas as mesmas não são fechadas no decorrer da frase. Penso que seja uma gralha.
Fiz um teste e funciona tudo corretamente.
De momento não tenho mais nada a acrescentar. Contudo, se identificar mais algum aspeto eu comunico.
Bom trabalho a todos!
Cumprimentos,
L. A

Email 3:

Dear Mr. Marius

As I said to Professor Osório, it was a quick view of the survey
I hope my suggestions will be useful.

I think my suggestion on the "disruptive technologies" issue is probably more related to my poor English than the concept itself =)

About the analysis, I did not process the data, so I am also open to suggestions.

I congratulate you again on the work of preparing the questionnaire and I hope you have a successful data collection.

Best regards,

A. O.

Email 4:

Hello Marcus!

Olá Professor;

I'm sending in attachment some insights that could improve this questionnaire — feel free to agree or not.

If you need, Marcus, I can translate it to you and help you! Feel free to contact me.

Best regards,

M. B.

Email 5:

Boa noite Professor, como está?

Peço desculpa a demora.

Peço também desculpa a si, e ao Professor Valente, por no sábado ter saído por volta das 12:30 pois chamaram-me para almoçar em família e para não perturbar a envolvente e interessante partilha do Professor Valente, optei por sair sem avisar. Devo-vos um pedido de desculpas pela minha deselegância, ainda que fosse cheia de boas intenções, o pedido e a explicação deveriam ter chegado mais cedo.

Por fim, e em relação ao questionário, que preenchi e achei curioso. 'Alguém' acreditar mesmo no futuro profissional altamente tecnológico sem o lado humano :)

Tenho no entanto, e com o devido respeito, algumas pequenas observações (podem estar completamente erradas).

Começando pelo fim, o atual momento industrial, já iniciado, é a Indústria 5.0 e não, como referido no questionário, a 4.0. O 5.0, em termos gerais (muito gerais) distingue-se da 4.0 pela sustentabilidade, economia circular e tecnologias IoT (onde se encaixa também a demótica e a robótica industrial).

Em relação a esta afirmação, não a consegui entender bem, no sentido de perceber o que é que ela contribui para responder aos objetivos da investigação. Ou seja, qualquer que seja a resposta que nela seja colocada, o que é que ela acrescenta? Pretende responder a algum problema de facto ou apenas uma curiosidade do investigador?

Engineering has a bright future. *

1

2

3

4

5

Depois esta afirmação “A aprendizagem e a implementação das recentes tecnologias digitais é caro para mim”, — sendo uma afirmação (como acontece em boa parte do questionário — mas pode ser preciosismo meu, apenas) eu vejo nela duas questões:

A primeira é: A aprendizagem das recentes tecnologias digitais é cara para mim?

A segunda é: A implementação das recentes tecnologias digitais é caro (o processo de aplicação) para mim?

Interpretando assim, facilmente tenho duas respostas antagónicas. A aprendizagem pode (ou não) depender de questões financeiras, já a sua aplicação é, a meu ver, um processo que depende muito mais de mim do que da minha capacidade financeira/ou falta dela.

Learning and implementing the latest digital technologies is expensive for me. *

- 1 2 3 4 5
-

Depois, na segunda questão do questionário, parece-me faltar aqui, pelo menos, um grau na Higher Education (Licenciatura)

What is your level of study? *

- Masters
- PhD

Por fim, e relativamente à primeira questão, a mesma situação: uma questão com duas questões.

A primeira remete-me para o facto de eu estar atualmente a leccionar ou não no ensino superior.

A segunda indaga se lecionei nos últimos 5anos.

Mas posso ter interpretado mal, ainda que, e novamente, interpretando como duas questões, tenho respostas para ambas completamente opostas.

Pode ser intenção do investigador, mas eu no lugar dele, após a análise dos resultados ficaria pelo menos com a dúvida nas respostas dadas: se deu aulas nos últimos 5 anos, ou se ainda continuo a dar aulas – a precariedade leva pelo menos a esta fração da questão :)

Are you currently teaching faculty in higher education, or have you in the past five years? *

- Yes
- No

Obrigado pelo envio, que completei com agrado!

Com os melhores cumprimentos,

M. B.

Appendix 5

Glossary:

New and emerging occupations – are new forms of work in our economies that are filtered by the processes of new scientific discoveries, development of new production technologies, new product market acceptance, government regulatory requirements, research on and development of national defense capabilities, and a variety of competitive market conditions (Pikulinski, 2020).

Technology-enriched educational platforms - environments, in which open-ended, rich information tasks and resources are available, most of which use a range of technologies or digital tools in interactive, multi-media and inter-disciplinary formats, constantly challenging students and teachers (Groff, 2013).

Digital educational technologies – refers to technologies such as online resources, learning management systems, programs and apps, and tools, such as laptops, tablets, and mobile phones used for supporting teaching and learning (Lindqvist, 2019).

Digital technologies encompass devices, systems, and resources that help create, store, and manage data. "Information technology" (IT) which refers to using computers to process data and information is considered a major part of digital technologies (Devran & Elçi, 2020).

A Disruptive technology - is a new technology that displaces an established technology and shakes up the industry, education, or a ground-breaking product that creates a completely new perspective (Christensen, 2016).

Framework in education - an organized plan or set of standards or learning outcomes that define the content to be learned in clear terms (Paterno, 2002).

Learning theories - describe how students receive, process, and retain knowledge during learning (Ormrod, 2012).

ADDIE model - is the generic process traditionally used by instructional designers and training developers. The five phases—Analysis, Design, Development, Implementation, and Evaluation (Florida State University, 1975).

Motivational models – are models that include the synthesis of motivational concepts and theories that are clustered into categories (Keller, 1983)

Fourth industrial revolution - represents a fundamental change in the way we live, work and relate to one another (World Economic Forum, 2022)

Instructional design model - is the generic process traditionally used by instructional designers and training developers (Florida State University, 1975).

Virtual Reality (VR) stimulates reality using a digital device in order to immerse the user in a sensory experience (Rubens, et al., 2016).

A virtual classroom is a digital learning environment that enables communication and interaction between the lecturer and students and among the students themselves (Rubens, et al., 2016).

Serious games are games that have been specifically developed as learning resources (Rubens, et al., 2016).

Gamification involves game-based elements such as point scoring, peer competition, teamwork, score tables to drive engagement, help students assimilate new information and test their knowledge.

Artificial intelligence is a generic term a broad field that includes robotics, data mining, computer games and neural networks (Rubens, et al., 2016).

Entrepreneurship education has been defined as a collection of formalized teachings that informs, trains, and educates anyone interested in participating in socio-economic development through a project to promote entrepreneurship awareness, business creation, or small business development.

Entrepreneurial skills include various skill sets such as leadership, business management, time management, creative thinking and problem-solving.

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Appendix 6

List of 99 AI platforms suggested by Generative AI for 2023:

AI Tools 2023

1. **Wand AI:** Self-service no code AI platform to generate AI with no friction.
2. **WaitroomAI:** Upgrade your meetings by boosting focus and accountability.
3. **Cohesive AI:** Create magical content with the most powerful AI editor.
4. **GhostwriterAI:** An AI writing assistant made just for Google Docs.
5. **CastmagicAI:** 10x Podcast Content With AI
6. **LovoAI:** Realistic AI voices that captivate your audience
7. **GleanAI:** An AI tool to find exactly what you need.
8. **SlidesAI:** Create compelling slides for your presentations in seconds.
9. **AskThee:** Ask big thinkers like Aristotle and Einstein anything you want.
10. **Wordtune:** AI Summarize documents and identify key points with AI.
11. **Buzzy:** No-code platform turns your idea into a Figma design and a working app
12. **SupercreatorAI:** Create short-form videos 10x faster with AI
13. **BlendAI:** Create professional product visuals in seconds.
14. **Motion AI:** Easily build chatbots to do anything on any platform.
15. **WriteSonicAI:** Create SEO-optimized content 10x faster.
16. **StockingAI:** Generate stock images, wallpapers, and other visual assets.
17. **MagicalAI:** Helps you automate repetitive tasks.
18. **LookaAI:** Design a logo for your brand, website, or company swag with AI.
19. **MagicalAI:** Save multiple hours by automating boring and repetitive tasks.
20. **EllieAI:** An email writing assistant that learns from your writing style.
21. **Rezi AI:** Revolutionize Job Search with AI-Powered Resume Writing and Editing
22. **SimplifiedAI:** An AI writer for blogs, articles, ads, products, and websites.
23. **StabilityAI:** Generate articles and blog posts in seconds with AI.
24. **BrowseAI:** Let you scrape any website within 2 minutes.
25. **MemAI:** AI-powered workspace that's personalized to you.
26. **QuinvioAI:** Create video presentations using AI.
27. **HypotenuseAI:** Create unique copywriting and visual content using AI.
28. **PerplexityAI:** Chrome extension that summarizes online articles.
29. **DurableAI:** Make amazing websites in 30 seconds from scratch.
30. **PicassoAI:** Let you create amazing artwork using AI.
31. **TL; DV:** Record meetings to help you share call moments with AI.
32. **Study AI:** An AI-powered homework helper.
33. **Momentum:** AI tool to help administer and automate sales calls.

AI Tools 2023

1. **Rezi AI:** Revolutionize Job Search with AI-Powered Resume Writing and Editing
2. **LongshotAI:** Writing assistant for accurate and optimized content writing.
3. **MurfAI:** Make studio-quality voiceovers from input text in seconds.
4. **FigmaAI:** Design websites, applications, logos, and much more.
5. **Remove.bg:** Remove the background from any image using AI.
6. **Publer:** Tool to create, schedule or analyze all social posts on one platform.
7. **HintsAI:** Digital organizer to manage your day-to-day activities.
8. **DocktopusAI:** Create compelling slides for your presentations with AI.
9. **PromptpalAI:** Helps you discover the best AI prompts.
10. **QuinvioAI:** Create video presentations using AI.
11. **Ask Your PDF:** An AI Chatbot that helps you interact with any PDF document.
12. **SupernormalAI:** An AI-powered meeting recorder.
13. **SuggestyAI:** Get human-like answers to your Google searches with GPT-3
14. **MarcBot:** An AI assistant that lives inside Telegram.
15. **MotionAI:** Easily build chatbots to do anything on any platform.
16. **Roam around:** Plan your trips through an AI travel planner.
17. **Beautiful:** Generative AI presentation app for the workplace.
18. **Quotify:** Extract meaningful quotes from books and articles.
19. **WandAI:** Self-service no code AI platform to generate AI with no friction.
20. **HarveyAI:** An AI-powered legal advisor.
21. **BearlyAI:** An AI tool to read, write and create content.
22. **FourAI:** Research assistants to save hours per day.
23. **HintsAI:** GPT-based assistant helps you to use productivity tools more efficiently.
24. **Base64AI:** Extract text, data, photos, & more from all types of docs using AI.
25. **Engage AI:** Use AI to write insightful comments on LinkedIn.
26. **Whimsical:** Helps you make mindmaps with AI-powered suggestions.
27. **RoomGPT:** Helps you redesign your room with just a click of a button.
28. **ChatSpot:** All-in-one chat tool for growing better.
29. **Chatthing:** Turn any notion workspace into an AI Chatbot.
30. **Botify:** Create digital humans for engaging conversations.
31. **Nanonets:** Automates manual data entry using AI.
32. **Hereafter:** An AI memory app that preserves your memories forever
33. **Trust:** An AI-powered tool to easily make video and text testimonials.

AI Tools 2023

1. **LovoAI**: Realistic AI voices that captivate your audience
2. **AI Lawyer**: ChatGPT-powered legal assistant to help with decision-making.
3. **AstriaAI**: Tailor-made AI Image generation.
4. **Looka**: Helps you design a logo, and website, and create a brand identity.
5. **Speak**: An AI language tutor to learn a new language without needing a live tutor
6. **BHuman**: Clone your face and voice to generate personalized videos for you.
7. **Ludo AI**: The comprehensive AI platform for game creation.
8. **Browse AI**: This lets you scrape any website within 2 minutes.
9. **Hypotenuse AI**: Create unique copywriting and visual content using AI.
10. **Durable AI Website Builder**: Make amazing websites in 30 seconds from scratch.
11. **Delv AI**: Helps you learn faster by retrieving summarised data from any text file.
12. **RephraseAI**: Use it to convert your text into highly engaging videos in minutes.
13. **AI Picasso**: Let you create amazing artwork using AI.
14. **LongshotAI**: Writing assistant for accurate and optimized content writing.
15. **MurfAI**: Make studio-quality voiceovers from input text in seconds.
16. **ReziAI**: Revolutionize Job Search with AI-Powered Resume Writing and Editing
17. **MarkopoloAI**: Helps you do digital advertising on autopilot.
18. **AI image Enlarger**: Enlarge and upscale your images without losing quality.
19. **Publer**: Tool to create, schedule or analyze all social posts on one platform.
20. **HintsAI**: Digital organizer to manage and organize your day-to-day activities.
21. **SidekickAI**: Helps you to schedule your meetings.
22. **Remove.bg**: Remove the background from any image using AI.
23. **MagicalAI**: Helps you automate repetitive tasks and saves hours per day.
24. **FigmaAI**: Designing tool that helps you create websites, logos, and more ...
25. **Wand AI**: Self-service no code AI platform to generate AI with no friction.
26. **D-ID**: To create digital avatars giving you an immense human-like experience.
27. **AlanAI**: Helps you add an AI voice assistant to your applications.
28. **QuestAI**: Lets you build web applications faster.
29. **AI Article Writer**: Generate articles and blog posts with AI in seconds.
30. **Buzzy**: No-code platform turns your idea into a Figma design and a working app
31. **Ask Your PDF**: An AI Chatbot that helps you interact with any PDF document.
32. **SupernormalAI**: An AI-powered meeting recorder.
33. **SuggestyAI**: Get human-like answers to your Google searches with GPT-3

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