A TRANSFORMATIONAL FRAMEWORK FOR THE DEVELOPMENT OF UNDERGRADUATE ENGINEERING EDUCATION PROGRAMS IN SUDAN

ABDELRAHIM MOHAMED MINALLA

UNIVERSITI TEKNOLOGI MALAYSIA

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DECLARATION OF THESIS

Author's full name	:	ABDELRAHIM MOHAMED MINALLA			
Student's Matric No.	:	PLP193009	Academic Session	:	2023/2024-1
Date of Birth	:	April 04, 1957	UTM Email	:	minalla.a@graduate.utm.my
Thesis Title	:	FRAMEWORK FOR TRANSFORMATION DEVELOPMENT OF SUDAN UNDERGRADUATE ENGINEERING EDUCATION PROGRAM			

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Full Name ABDELRAHIM MOHAMED MINALLA
Date: December 31, 2024

Approved by Supervisor(s)

Signature of Supervisor I:

Full Name of Supervisor I
ZAKI YAMANI BIN ZAKARIA
Date: December 31, 2024

Signature of Supervisor II

Full Name of Supervisor II
FATIN ALIAH PHANG BINTI ABDULLAH
Date: December 31, 2024

"We hereby declare that we have read this thesis and in our opinion this thesis is sufficient in term of scope and quality for the award of the degree of Doctor of Philosophy in Engineering Education"

Signature	:	
Name of Supervisor I	:	ZAKI YAMANI BIN ZAKARIA
Date	:	DECEMBER 31, 2024

Signature	:	
Name of Supervisor II	:	FATIN ALIAH PHANG BINTI ABDULLAH
Date	:	DECEMBER 31, 2024

Pengesahan Peperiksaan

Tesis ini telah diperiksa dan diakui oleh:

Nama dan Alamat Pemeriksa Luar 1 :	**Prof. Ir. Dr. Che Maznah Mat Isa** Civil Engineering Studies, Universiti Teknologi MARA Pulau Pinang Branch, Permatang Pauh Campus, 13500 Pulau Pinang
Nama dan Alamat Pemeriksa Luar 2 :	**Prof. Madya. Ts. Dr. Muhd Khaizer Bin Omar** Jabatan Pendidikan Sains dan Teknikal, Fakulti Pengajian Pendidikan, Universiti Putra Malaysia, 43400, Serdang, Selangor
Nama dan Alamat Pemeriksa Dalam :	**Prof. Dr. Muhammad Sukri bin Saud** Sekolah Pendidikan, Fakulti Sains Sosial dan Kemanusiaan, Universiti Teknologi Malaysia, 81310, Johor Bahru, Johor
Disahkan oleh Timbalan Pendaftar di Fakulti :	
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ABDELRAHIM MOHAMED MINALLA

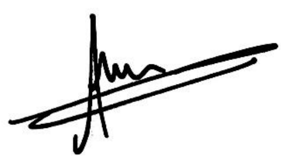
A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Engineering Education)

Malaysia-Japan International Institute of Technology
Universiti Teknologi Malaysia

December 2024

DECLARATION

I declare that this thesis entitled *"A TRANSFORMATIONAL FRAMEWORK FOR THE DEVELOPMENT OF UNDERGRADUATE ENGINEERING EDUCATION PROGRAMS IN SUDAN "* is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



Signature:

Name: ABDELRAHIM MOHAMED MINALLA

Date: December 31, 2024

DEDICATION

This study is dedicated to the youths of Sudan, known colloquially as “Shefoot wa Kandakat” *, who led the popular Sudanese Revolution of December 19th, 2018. That revolution put an end to the most cruel and oppressive ruling regime in the history of modern Sudan. These “Shefoot and Kandaakat” believe in, and deserve, a better Sudan. A modern Sudan led by its knowledgeable and competent youths where science and knowledge are used to develop and prosper their country, rather than old regimes of Myths and Quackery.

At a personal level, this dedication goes to my wife Salma, and to my two daughters Noora and Cindy.

* Note: First, Shefoot is a modern Sudanese slang, referring to male youths. Second, Kandakat is the plural of the word “Kandaka”; which means “Strong woman”. This title “Kandaka” was given to queens and mothers of queens in the ancient Kingdom of Kush, currently Sudan. Amuna Wagner wrote, “… the Sudanese people still honor strong women as Kandakat today. In the Sudanese Uprisings of 2018, women protesters were at the forefront of demanding change and social justice, and the title Kandaka was used to celebrate their courage and strength.” (https://kandaka.blog/startseite/).

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ABSTRACT

The engineering education system in Sudan faces significant challenges, leading to a shortage of qualified engineers necessary for the country's development. This study aims to develop a transformational framework to enhance the quality and effectiveness of undergraduate engineering education in Sudan. The academic and practical importance of this study lies in addressing the critical gap in qualified engineering graduates, which is essential for the socio-economic development of Sudan and can serve as a model for similar contexts globally. The research employs a qualitative methodology, incorporating post-structuralism theory, a case study strategy, and three data collection methods: documentary analysis, semi-structured interviews, and researcher observations. Data was analyzed using thematic analysis to gain in-depth insights. The findings reveal several key issues: an overly content-focused curriculum, inadequately prepared educators, prevalent traditional teaching methods, underprepared students entering engineering programs, and weak links between academic and professional institutions. The study concludes by presenting a transformational framework that addresses these issues, focusing on improving interactions between educational institutions and professional bodies, thereby enhancing the quality of engineering graduates. The practical implications of this framework include providing a structured approach to curriculum reform, educator training, and institutional collaboration, with the potential to modernize engineering education not only in Sudan but also in other regions facing similar challenges. One limitation of this study is the incomplete validation step of the transformational framework. Therefore, future research is needed to validate its functionality and applicability in the modernization of the Sudanese engineering education system and similar ones.

ABSTRAK

Sistem pendidikan kejuruteraan di Sudan sedang menghadapi cabaran besar yang akan menyebabkan kekurangan jurutera berkelayakan yang diperlukan untuk pembangunan negara. Kajian ini bertujuan untuk membangunkan kerangka transformasi untuk meningkatkan kualiti dan keberkesanan pendidikan kejuruteraan sarjana muda di Sudan. Kepentingan kajian ini terletak pada identifikasi dan pengendalian jurang kritikal yang seharusnya ada pada graduan kejuruteraan berkelayakan, yang sememangnya penting untuk pembangunan sosio-ekonomi di Sudan, dan boleh dijadikan model bagi konteks yang sama untuk negara lain. Penyelidikan ini menggunakan metodologi kualitatif, menggabungkan teori pasca strukturalisme, strategi kajian kes, dan tiga kaedah pengumpulan data iaitu analisis dokumen, temu bual separa berstruktur, dan pemerhatian penyelidik. Data dianalisis menggunakan kaedah analisis tematik untuk mendapatkan perspektif mendalam. Kajian ini mendedahkan beberapa isu utama iaitu kurikulum yang terlalu menumpukan pada kandungan, pendidik yang tiada persiapan mencukupi sebagai pengajar, amalan kaedah pengajaran tradisional, pelajar yang kurang bersedia memasuki program kejuruteraan, dan hubungan yang lemah antara institusi akademik dan profesional. Kajian ini disimpulkan dengan pembangunan satu kerangka kerja transformasi yang berupaya menangani isu-isu yang diutarakan, dengan tumpuan kepada penambahbaikan interaksi antara institusi pendidikan dan badan profesional, yang seterusnya dapat meningkatkan kualiti graduan kejuruteraan. Implikasi praktikal kerangka kerja ini termasuk penyediaan pendekatan berstruktur untuk pembaharuan kurikulum, latihan pendidik dan kerjasama institusi, dengan potensi untuk memodenkan pendidikan kejuruteraan bukan sahaja di Sudan tetapi juga di negara lain yang menghadapi cabaran yang sama. Satu kekurangan yang didapati pada kajian ini adalah pengesahan kejayaan kerangka kerja transformasi ini yang masih belum dibuat. Oleh itu, penyelidikan lanjut diperlukan untuk mengesahkan fungsi dan kebolehgunaan kerangka kerja tersebut dalam pemodenan sistem pendidikan kejuruteraan orang Sudan dan yang mirip dengannya.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ABET	Accreditation Board for Engineering and Technology
AEU	Elshaikh Abdulla Elbadri University
AhfU	Ahfad University
ALatU	Abdullateef Alhamd University
AmshU	Almashriq University
AOU	Arabia Open University
AzU	Al-Azhari University
BahU	Bahri University
BCG	British Colonial Government
BkhU	Bakhatalruda University
BNU	Blue Nile University
ButU	Albutana University
DeinU	Eldaein University
DlnjU	Aldalanj University
DngU	Dongula University
EAC	Engineering Accreditation Commission of ABET
EC	Engineering College
EC2000	Developed what is known as Engineering Criteria 2000
EKorU	East Kordofan University
FashU	Al-Fashir University
FutU	Future University
GCU	Garden City University
GECI	Global Sustainable Competitiveness Index
GMC	Gordon Memorial College
GzU	Gazira University
IAENG	International Association of Engineers
ICI	Intellectual Capital Index
IMU	El-Imam El-Mahdi University

JenU	Aljeenena University
KarU	Karari University
KasU	Kasala University
KorU	Kordofan University
KPI	Khartoum Polytechnic Institute
KTI	Khartoum Technical Institute
MoE	Federal Ministry of Education
MoHESR	Ministry of Higher Education and Scientific Research
MugU	Mugtaribeen University
MUST	Managhil Science and Technology University
NU	Al-Neelain University
NyU	Nyala University
OAU	Omdurman Ahlia University
OIU	Omdourman Islamic University
Q&ISU	Qoran and Islamic Studies University
QadU	Qadarif University
QranU	Qoran University
RAE	Royal Academy of Engineering
RibU	Alribat Alwatani University
RSU	Red Sea University
SCI	Sustainability Competitiveness Index
SEC	Sudan Engineering Council
ShndU	Shandi University
SinU	Sinnar University
SIU	Sudan International University
SlmU	Al-Salam University
SOU	Sudan Open University
SSA	Sub-Saharan Africa
STU	Science and Technology University
STU	SudanTechnical University
SUST	Sudan University for Science& Technology

SUST	Sudan University of Science and Technology
UMST	University of Medical Science and Technology
UNSD	United Nations Statistics Division
UofK	Khartoum University
UofK	University of Khartoum
USAS	University of Science and Applied Studies
WEU	Wadi Elneel University
WKorU	West Kordofan University
WMAU	Wad Maddani Ahlia University
WNU	White Nile University
ZalU	Zalinje University

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

This section provides a brief background about the situation of engineering education in Sudan, including related issues, and the lack of research in the area of engineering education.

1.1.1 Engineering Education Research

Extremely complex and integrated global challenges such as globalization, digital transformation, sustainability, climate change, poverty, and social and political conflicts due to limited resources continue to confront modern societies (Kolmos et. al., 2023; Winkens and Leicht-Scholten, 2023; UNESCO 2021; Hadgraft and Kolmos, 2020). Current and future engineers must be ready to deal with these challenges. Therefore, improving the situation of the engineering profession and engineering education, globally, would be a key pillar for preparing engineering graduates and having them ready for addressing these challenges (UNESCO 2019). UNESCO (2021, p28) stated, 'The engineering profession plays a major role not only in the growth and development of a country's economy but also in improving the quality of life for its citizens. The engineering profession is also playing an ever-increasing role in enabling a country to participate in the global economy and the protection of the environment.' This study is about the situation of Sudanese engineering education, and its ultimate goal is to develop a framework for transforming the engineering education system in response to the above-mentioned challenges. UNESCO (2021, p13) added, '…

engineering education is fundamental to building engineering capacity and to meeting the demand for engineers worldwide, both in terms of quantity and quality. It is important to note that engineering capacity-building is a continuous process, starting in school, proceeding through higher learning with formal programmes, and then continuing through the entire professional career of an engineer, technologist, or technician through an optic of ongoing professional development to meet the rapid growth in knowledge and attendant skills.'

Engineering education research (EER) is a relatively new field that started at the beginning of the current century. However, it began to surface in the United States in the mid-1980s (Beddoes, 2014). Since its inception, EER has been essential for improving the overall science, technology, engineering, and mathematics education worldwide. Beddoes (2014) linked the emergence of the EER field to rigor and methodology discourses, rather than descriptive engineering education publications. The following examples illustrate the significant efforts in the area of EER, globally: In 2003, Purdue University- United States, proposed a framework to attract engineering faculties and to have them engaged in the field of EER; Purdue adopted a formal academic program, called the School of Engineering Education Degree (SEED), to offer bachelor, master, and doctorate degrees in engineering education (Katehi et. al., 2014); and the first Cambridge Handbook of EER was published in 2014.

As part of STEM research, EER has been increasing exponentially, between 2007 and 2017. Takeuchi et. al. (2020) stated that the number of STEM publications, in 2017, increased by 20 times compared to the same number in 2007. Published topics included innovation for STEM learning, professional development, and gender gap and career in STEM, respectively (Takeuchi et. al., 2020; Chomphuphra et. al., 2019).

The lack of enough qualified engineers, ready to face the challenges of the century, has been the focus of a vast amount of research. Researchers have attributed this issue to the shortage of graduates with STEM concentration, due to low enrolment and poor retention of STEM students at both high school and tertiary education levels.

Many international organizations have put efforts to investigate and diagnose the shortage of STEM graduates; of them are UNESCO, the Royal Academy of Engineering (RAE), and the National Research Council (NRC), which produced iconic reports on this matter (e.g. UNESCO, 2021 and 2019 reports). Syed et. al. (2022) used a mixed research method to perform document analysis, based on Fairclough's critical discourse analysis (CDA), towards: '1) Identifying the gaps in Malaysian engineering education toward preparing 21st Century educators. 2) Study the transition of engineering educators in their attempt to implement innovative education. 3) Develop a framework for transforming engineering education through the infusion of innovative teaching and learning to support the development of 21st Century Engineers.' Also, Abd Rahman et. al. (2020) investigated educators' transition from traditional teaching to active learning, at one of the universities in Malaysia, by using the (CDA) methodology.

1.1.2 Knowledge Gap in the Engineering Education Field

Although there are vast and diversified scholars' efforts in the area of EER, the researcher has noticed that most of the reviewed research has attributed the lack of success in STEM education to: minority underrepresentation, including gender, race, and ethnicity, (Alam, 2022; Tandrayen-Ragoobur et. al., 2022; García-Holgado et. al. 2018; Saw et. al., 2018; and Niu; 2017; Reilly et. al., 2017; Jamilet. al., 2019); low socioeconomic status (SES): many studies have studied the effect of demographic data on STEM career aspirations in the USA (e.g., Saw et. al., 2018; Betancur et. al., 2018; Niu, 2017; Cribbs, et al., 2021); inappropriate pre-college STEM curricula (Appiah-Castel et. al., 2020; Shahali et. al., 2017; Hulme et. al., 2014); inefficient T&L methods (Abd Rahman et. al., 2020). Nevertheless, all suggested solutions include introducing early STEM curricula (K-12), facilitating early access, for all, to STEM subjects, and adopting efficient T&L methods. In other words, most of the suggested solutions are centered around students and their socio-cultural and socio-economic contexts. Nevertheless, connecting these issues to the broader T&L environment may reveal additional perspectives and a better understanding of these issues. Also, discourse analysis (DA) has been used mainly, within the EER field, to investigate fragmented topics/issues such as the curricular design of engineering disciplines (Noordin et al., 2018: Brundiers and Wiek, 2014) educators' readiness to support engineering students (Syed et. al., 2022); innovative T&L methods (Klassen and Wallace, 2019). As important and interesting as they are, the research community has given little attention to these topics in connection to the broader engineering education field (Berger et al., 2021; Umbach et. al., 2023; Beddoes et al., 2014). Moreover, these groups of researchers have recognized the significance of the organizational structures of colleges on students' outcomes, which have been mostly overlooked by the research community. Berger (2021) wrote, 'Yet less attention has been given to the exploration of the impact of organizational structure at colleges on student learning as an outcome.' These groups of researchers have investigated the attributes of the academic department, specifically class size, gender diversity, departmental research emphasis, and students' contact with faculty, on the students' outcomes.

While searching graduate studies programs at the University of Khartoum (UofK) and Sudan University of Science and Technology (SUST), in addition to Google Scholar, the researcher found a wealth of information about Sudanese general education (K-12). These studies split into: (i) descriptive research, without proper frameworks or models for evaluating general education; and (ii) to a lesser extent, studies based on some learning theories and/or educational frameworks/models. Also, many descriptive studies were found about tertiary education in Sudan; nevertheless, only a limited number of them were based on learning theories and frameworks. Examples are: A business intelligence-based framework to align higher education output with labor market in Sudan (Elhassan, 2020); investigating the success of business intelligence in aligning higher education and labor market (Elhassan, 2020); investigation of the 'Learning Modes' and its learner-centeredness in higher education institutions in Sudan (Arman, 2020); change and development of higher education in Sudan (Salim and Abdul Rahman, 2020); ICT integration in technical and vocational education and training, Sudan (Ramadan et al., 2018); bridging higher education and market dynamics in a business intelligence framework (Elhassan and Klett, 2015); barriers facing English language teachers in applying the learner-centered approach (Suleiman, 2015); challenges of implementing performance measurement systems (PMS), by one of the public Sudanese university (Alboushra et al., 2015); higher education in Sudan- a situational overview (Elhadary, 2018); barriers for implementing ICT for higher education in Sudan (Suliman et al., 2007). However, none of these examples addressed engineering education. In fact, only limited descriptive studies were related to engineering education, which is evident by the low H-index of 34 and 110 in engineering and in all subject areas, respectively. In 2020, Sudan's H-index is based on 138 documents in engineering and 1329 documents in all subject areas (Kenoma.com. World Data Atlas; SCImago Journal and Country Rank). Examples of engineering studies are: biomedical engineering education challenges and opportunities in Sudan (Yassin, 2018); trends in electronic teaching and learning in engineering education (Taha, 2014); engineering education for sustainability and economic growth in developing countries, the Sudan case (Abu-Goukh et al., 2014); the role of technical scientific research education in sustainable development and conservation in Sudan (Omer, 2014). None of them were based on educational theories and/or proper frameworks. Without a proper framework, no one would be able, objectively, to identify factors that, negatively or positively, impact the engineering education in Sudan, and to lay out the foundation for designing a learning environment capable of advancing the engineering education within the context of Sudan.

Clearly, there is a big gap in engineering education research in Sudan. Therefore, there is a need for a lot of research efforts to fill the gap. This study is just a step in bridging this gap, and hence building better engineering programs for prosperous Sudan.

1.1.3 Engineering Education Issues in Sudan

Engineering education in Sudan is provided by higher colleges and universities. These academic institutions must be recognized and accredited by the Ministry of Higher Education and Scientific Research (MoHESR), and all engineering graduates must be licensed and registered by the Sudanese Engineering Council (SEC). The evolution of engineering education in Sudan has gone through three distinctive periods: The first period was during British Colonialism, from the actual start of engineering education in 1939 to 1956; the second period was from the independence of the country, in January 1956 to 1989; and the most recent period lasted for 30 years between 1989 and 2019.

During the last period (1989-2019), the situation of engineering education, as part of the whole higher education, has been affected, to a great extent, by the behavior of the autocratic government that took over in June 1989 (Dafa'Alla et. al., 2017; Elhadary, 2018). This government pledged to resolve the overwhelming problems of higher education, which has been considered the bottleneck in the process of the country's development. The regime has implemented drastic changes in the area of education. Accordingly, the number of universities and other higher academic institutions has been increasing, at a fast-paced. Between 1989 and 2018, this number has increased, by more than 7 times, from only 18 to 132 academic institutions. In addition, the total number of students has increased from 57,600 to 680,000. Engineering students represent about 9% out of the total, or 61,600 students. While the increase in the total number of college students has been estimated to be almost 11 times, during the same period, the jump in engineering students has approached 20 times, or from only 3,000 to 61,600. Table 1.1 shows the elevation of academic institutions, students' enrolment, and graduates between 1989 and 2018 (MoHESR Census Data, www.mohe.edu.sd).

Table 1.1: Increase in academic institutions, enrolment & graduates (MoHESR Census Data, www.mohe.edu.sd)

Indicators	**1989**	**2018**	**The number of times increased**
Number of academic institutions	21	132	6.3
Academic institutions with Eng. Programs	5	62	12.4
Total Students	58,667	680,696	11.6
Engineering students	2,996	61,638	20.6
% of engineering enrolment	5.1%	9.1%	..
Total graduates	7,140	123,887	17.4
Engineering graduates	624	10,047	16.1
% of engineering graduates	8.7%	8.1%	..

Although the number of engineering graduates, during this period, has expanded significantly, from less than 1,000 (in 1989) to more than 10,000 (in 2018), their quality has been compromised (Minalla et. al., 2022 and 2021; Ettridge and Sharma, 2020; World Bank and MoHESR, 2020; Dafa'Alla et. al., 2017; Osman, 2014; Elhadary, 2018). The dilemma of engineering education in Sudan remains the disparity of the quality of graduate engineers. This has been attributed to many reasons, of them are: Expansion in higher education was implemented without consideration of the readiness of education infrastructure (Minalla, 2021); the government has failed to secure reasonable budgets to meet its ambitious education project; the share of the education sector represented only 1.3% of the country's GDP in 2001 and was doubled in 2008, or 2.7% of the GDP; English was replaced with Arabic as a language of instruction; and the general education system was reduced from a 12-year to an 11-year system (Minalla, 2021).

The quality of engineering education depends on the role of academic administration, at the institutional level, in setting and monitoring efficiently the elements of engineering education, namely: curriculum, teaching and learning methods, capacity building, faculty, and engineering environment (Webber, 2016; Osman, 2014). Any effort to improve engineering education in Sudan should start with addressing the inadequate elements of engineering education, namely: Poor funding, outdated engineering curriculum, ineffective traditional teaching and learning methods, inadequate human capacity (academic and non-academic staff), students' under-preparedness for college, inadequate facilities, quality control and accreditation issues, the absence of academic freedom, and poor research and publishing conditions (Minalla et. al., 2022 and 2021).

1.2 Problem Statement

For many decades, the issues of engineering education in Sub-Saharan Africa (SSA) countries have been the focus of many researchers. Moreover, many research papers have proved that the situation is worsening rather than getting any better. Challenges facing engineering education in SSA countries include insufficient funding, outdated curricula, inappropriate facilities, lack of adequate human capacity, brain drain due to the absence of academic freedom and the unattractive working environment within SSA, and lack of quality control and accreditation measures (Ebekozien and Aigbavboa, 2023; Sebola 2023; Sigahi et. al., 2023; Agubos him et. al., 2021; Igbokwe, 2019; UNESCO, 2019; Oloyede et. al., 2017; Mohamedbhai, 2014).

The Royal Academy of Engineering (RAE), London, UK has developed a single Engineering Index (EI), which consists of eight different engineering-related indicators: 1) Employment in engineering-related industries, 2) human capital investment in engineering, 3) number of engineering businesses, 4) the quality of infrastructure, 5) the gender balance of engineers, 6) the quality of digital infrastructure, 7) wages and salaries of engineers, and 8) exports of engineering-related goods (Ettridge and Sharma, 2020). In 2016, about 99 countries were ranked based on the EI; none of the SSA countries was included in this ranking either due to data availability or weak indicators' values (Ettridge and Sharma, 2020).

The state of engineering education in Sudan has been similar to its region; still one may argue that the deterioration rate of engineering education in Sudan has been far exceeding the deterioration in similar countries. The rate of deterioration has been attributed to many profound issues: Poor funding, outdated curricula, ineffective teaching and learning methods, inadequate human capacity, students' preparedness for college, inadequate number and quality of facilities, and issues of quality control and accreditation measures (Minalla et. al., 2022 and 2021; Osman, 2014; Elhadary, 2018). The deterioration was evident by: 1) The country's low number and poor quality of engineering graduates. According to Osman (2014), Sudan has about 188 engineers per 100,000 population. 2) Although the number of engineering graduates increased between 1989 and 2018, by 16 times, or from 624 to 10,047 graduates, respectively, their quality has been compromised; also, as shown in Table 1.1, in 2018 the total number of engineering graduates represented only 8.1% of the total tertiary graduates (MoHESR Census Data, www.mohe.edu.sd). 3) Sudan has never been included in the EI ranking developed by the RAE, and the country is still lagging in all eight above-mentioned engineering indicators (Ettridge and Sharma, 2020).

Accordingly, the main problem of the Sudanese engineering education system is rooted in its inability to graduate enough qualified engineers in terms of Knowledge of theoretical and practical engineering fundamentals, in addition to soft skills and competencies necessary for 21st-century engineers (UNESCO 2021, 2019; Mohamedbhai, 2014). This main problem might be due to one or more of the following four underlying problems:

i. The problem of inappropriate curriculum,

ii. The problem of incapable engineering educators,

iii. The problem associated with T&L philosophy,

iv. Lack of an appropriate approach/framework to resolve the Sudanese engineering education issues.

1.3 Purpose of the Study

Due to many significant challenges, the Sudanese engineering education programs cannot graduate enough qualified engineers necessary for the country's development. Therefore, the study intends to examine and evaluate the existing engineering education system and develop a transformational framework, to equip stakeholders with a structured approach, to reform the teaching and learning environment, including advanced curriculum, qualified educators, and modernized T&L methods. Ultimately, the study aims to achieve the following 4 objectives:

i. To examine the current situation of the engineering curriculum.

ii. To evaluate the situation of engineering educators in terms of qualification and professional development.

iii. To analyze adopted teaching and learning philosophy by engineering programs.

iv. To develop a transformational framework for the Sudanese engineering education programs.

1.4 Research Questions

To achieve the above-mentioned research objectives, the study seeks to address the following four questions:

i. What is the current situation of engineering curricula in Sudan?

ii. What is the situation of engineering educators in Sudan with regard to their teaching effectiveness, qualification, and professional development?

iii. What are the current teaching and learning approaches adopted by the Sudanese engineering education programs?

iv. What is the importance of developing a framework to transform the Sudanese engineering education programs?

1.5 Rationale, Significance, and Contribution of the Study

Constructivism theory has been utilized globally for studying curriculum development of math and science for elementary and secondary education (Thompson, 2020); nursing and medical field (Epp et al., 2021; Cruickshank, 2018); online teaching (Reid-Martinez and Grooms, 2021); adult teaching and teacher preparation (Mayombe, 2020), to name a few.

Also, the literature reveals enormous studies based on either OBE or HPL. For instance, Fisher and Rosa (2021) and Anwar and Menekse (2021), among many other researchers, have studied the influence of HPL learning principles in pedagogy and teaching adaptive expertise. In addition, in the African context, many studies on engineering education have been guided by OBE as a constructive framework (Nguyen et al., 2020; Macayan, 2017; Tshai, 2014).

The lack of coherent research, based on proper theoretical frameworks, in the area of engineering education in Sudan, section 1.1.3, motivates the researcher to examine and evaluate the engineering education programs in Sudan by using post-structuralism and constructivism theories.

The study is expected to have two main contributions: The first is an integrated theoretical framework (IFW) that emerges from the integration of post-structuralism (PST) and constructivism theory, for underpinning the study; and the second one is a transformational framework for developing the Sudanese undergraduate engineering education programs.

1.6 Scope of the Study

The scope of this study is confined to an investigation of the undergraduate engineering program at the University of Khartoum (UofK), recognized as the most prominent and prestigious academic institution in Sudan. The research aims to provide an in-depth understanding of the current state of engineering education at UofK and identify areas for improvement. Data collection will be conducted in two phases. First, secondary data will be gathered from several reputable sources, including the websites of the Ministry of Higher Education and Scientific Research (MoHESR), the Sudan Engineering Council (SEC), the University of Khartoum (UofK), Sudan University of Science and Technology (SUST), and the University of Science and Arts of Sudan (USAS). Site visits to these institutions will complement the data collected from their websites, ensuring a comprehensive understanding of the existing resources and frameworks. In the second phase, primary data will be collected through interviews with key stakeholders involved in the engineering education sector. These stakeholders include academic staff, academic administrators, higher education policymakers, and engineering industry practitioners. Their insights and experiences will provide valuable perspectives on the strengths and weaknesses of the current engineering programs and suggest possible areas for enhancement. While the primary focus of this study is on the engineering program at UofK, the research methodology and findings are designed to be extendable. The insights gained from this investigation can be applied to other engineering programs within Sudan, facilitating broader educational improvements. Moreover, the study's approach and conclusions may also be relevant to engineering education programs in similar African countries, offering a framework for wider application and impact.

1.7 Theoretical Frameworks

As shown in section 1.1.3, up to date there is no coherent, based on a suitable educational framework, evaluation of engineering education in Sudan. Creswell suggested that a proper framework is necessary to guide and shape rigorous research (Creswell, 2016). Framing this study would force the researcher to analyze the data, interpret and generalize the results according to the proposed theoretical perspective; at the same time, a reader and/or evaluator would be informed of the assumptions and approach of the study while, objectively, evaluating the progress and findings of the study.

Looking forward to making this study a valuable addition at the disposal of higher education stakeholders in general and engineering educators specifically, this study will employ both post-structuralism theory (PST) and constructivism as a fundamental theoretical framework, which has been widely used in higher education. In addition, three constructive frameworks, outcome-based education (OBE), constructive alignment (CA), and how people learn (HPL), will guide the study. The following sections will briefly describe PST, constructivism theory, and the three models of OBE, CA, and HPL.

1.7.1 Post-structuralism Theory

The researcher chose post-structuralism theory (PST), as a theoretical perspective for this study, because of its ability to analyze engineering education, as a social practice, which is influenced by many other social, economic, and political factors. This section highlights what is covered in detail about PST, in section 2.4. In addition, at the end of this section, the researcher illustrates the context of the engineering education field.

A literature review, section 2.4, covers Foucault's PST, including his views on certain concepts such as: Discourse, Discourse Analysis (DA), Truth, and Power. Foucault has promoted and developed both 'Discourse' and 'Discourse Analysis' terms, respectively. The review included PST's origin, types, and definition, in addition to the other scholars' views about PST (Crick, 2016; William, 2014; Gaventa, 2021; Fairclough, 2023; and Rabinow, 2022).

For instance, Crick (2016) highlighted thoughts of three poststructuralists as follows: (i) Derrida's PST thought is a critical deconstruction of any discourse that presents itself as completely coherent, centered, and rational; (ii) Barthes's PST refuses to locate any single point of origin of any text that can ground its meaning; and (iii) Foucault's PST invites an inquiry into how discourses, texts, and acts of communication are always implicated in relations of power that act upon possible actions. As well, Williams (2014) critically discussed PST through selected works of five poststructuralists: Derrida, Deleuze, Lyotard, Foucault, and Kristeva. He considers them as the most important figures in the area of PST; in addition, each of them took a stand on key injustices and conflicts (Williams, 2014 p18).

The study employed Foucault's PST, as a theoretical perspective of choice, who had introduced and developed the concept of the archaeology method for discourse analysis (Foucault, 2020, cited in Rabinow, 2022), genealogy approach (Foucault, 2023 cited in Rabinow, 2022), and the concept of biopower, coupled with governmentality, to control individuals' life (Foucault 2021, p.137; Rabinow, 2022 p105), respectively.

Refer to section 2.4 for more details about PST.

The Context for Engineering Education Field: As Brennan (2020) suggested, this study used Clark's model for academic organization analysis. Brennan wrote, 'Starting from a similar proposition to that adopted by Burton Clark in 1983, that is higher education should be examined within a wider context of social science research, …' (Brennan, 2020 p234). Clark's (1983) model consists of three levels: i) Discipline-centered, such as engineering education program; ii) the enterprise, academic institution; and iii) the organization and inter-institutional links. Clark summarized university as an organization, in three features, '(i) the core membership unit in academic systems is discipline-centered; (ii) each disciplinary unit within the enterprise has self-evident and acclaimed primacy in a front-line task; (iii) the characteristics of core membership groups affect everything else of importance in the organization' (Clark 1983, 33–4, cited in Brennan, 2020 p230).

In addition to facilities, teaching and learning environments may include the context where an academic institution, or even a specific discipline such as an engineering program, operates. According to Clark's model, the broader teaching and learning environment is part of an academic system, which consists of three levels: i) Discipline-centered, such as engineering program; ii) the enterprise, academic institution; and iii) the organization and inter-institutional links.

Therefore, utilizing post-structuralism DA, this study is about investigating the power structures within the broader engineering education field, which includes engineering education stakeholders, academic institutions, educational policies, and operational activities. The study chose the engineering program at UofK, Sudan as a case study. Each stakeholder exercises, or not, a certain type of power, called privilege, and is subject to accountability. Rights and accountability operating within the engineering education field form an entangled network of power relationships among stakeholders; see Table 1.2. Academic institutions have power structures, which are exercised by means of competing authority structures; according to Clark, there are four types of authority structures: Academic authority, enterprise-based authority, system-based authority, and charisma.

Table 1.2: Interconnected Power Network among Stakeholders within Discursive Field

Stakeholders	**Rights & Privileges**	**Duties & Responsibilities**
List all stakeholders	For each stakeholder identify manifested powers that are expected to comply with	Identify the responsibilities of the same stakeholder towards the rest of the stakeholders

1.7.2 Constructivism Theory

Section 2.3.1.5 discusses constructivism theory, which is a widespread theory that deals with humans constructing their knowledge through experience and learning through active processes (Newstetter, 2014). Other scholars stated that learners create and store mental models, based on their prior experiences with at-hand situations (Hirst, 2022; Dewey, 2018; Piaget, 1973; Walshe, 2020). As well, the same section explains the three types of constructivism: cognitive constructivism, social constructivism, and radical constructivism (Tan and Ng, 2021), and how its proponents answer the ontology, epistemology, and methodology questions (Lincoln et al., 2018).

Refer to section 2.3.1.5 for more details on constructivism.

1.7.3 Outcome-Based Education (OBE)

Section 2.5.1 covers the literature review of the OBE, which is considered as student-centered learning philosophy measured by ‘outcomes’ (Felder and Brent, 2017). In addition, the section covers OBE’s purpose, requirements, examples, limitations, etc.

OBE has been adopted by many countries, worldwide, to resolve the mismatch between the quality of tertiary education, including engineering education, and the job market requirements in terms of skills and knowledge. In other words, academic institutions have been using OBE to improve the quality of their graduates in terms of knowledge-based competencies and necessary soft skills. Specifically, engineering programs have been utilizing the OBE framework either to improve learning (Biggs et al., 2020) or to meet accreditation requirements (Felder and Brent, 2017). Spady (1994), who is considered by many researchers as the father of the OBE, believed that the purpose of school is to prepare learners for their role in life after school years. This purpose is well-serviced following what is known as transformational OBE rather than traditional OBE (Killen, 2016). Engineering educators and researchers are advocating OBE since it allows engineering students to graduate with the necessary skills and knowledge for the job market.

Refer to section 2.5.1 for more details on OBE.

1.7.4 Constructive Alignment (CA)

Based on Tyler's Curriculum Model (Tyler, 1949 p51), Biggs introduced a constructive alignment (CA) framework to overcome OBE's limitations by integrating all aspects of teaching and assessment for achieving high-level learning. Like OBE, CA requires clear learning outcomes and assessment systems. In addition, CA plans teaching and learning activities that support deep learning and have students master desired learning outcomes by having students engage actively in learning activities. Literature review of CA (e.g. origin, definition, role, etc.) and Tyler's Curriculum Model (Biggs et al., 2020 and 2022) are covered in section 2.5.2.

Refer to section 2.5.2 for more details on constructive alignment (CA).

1.7.5 How People Learn (HPL) Framework

How People Learn (HPL) is a report, which was published in April 1999. The report was a product of 2-year research on the 'Science of Learning'. Two committees carried out the research: The Commission on Behavioral and Social Sciences and Education of the National Research Council (NRC- HPL, 2000).

Section 2.5.3 discusses in detail HPL including its three core learning principles (students come to the classroom with preconceptions about how the world works, the curriculum should include in-depth coverage instead of superficial coverage of subject materials, and a "metacognitive" approach to instruction); HPL's three characteristics (learning with understanding, the process of knowing, and active learning); and HPL's four perspectives on the design of learning environments (learner-centered, knowledge-centered, assessment-centered, and community-centered environments) (NRC- HPL, 1999).

Refer to section 2.5.3 for details on HPL and the design learning environment.

1.7.6 Integrated Theoretical Framework and Operational Framework

As depicted in Figure 1.1, the integrated theoretical framework (IFW), which underpins this study, emerges from the integration of post-structuralism (PST) and constructivism theory. Constructivism, as discussed in sections 2.3.1.5, serves as a philosophical worldview, known as epistemology and ontology, while PST, section 2.4, is utilized as a methodology rather than a philosophy, as suggested by Crick (2016). Both of these theories complement each other. Nevertheless, both see that universal truth does not exist, but it is a construction of discourse, which is under constant change (Rabinow, 2022). As well, both suggest a strong link between the investigator and the participants to construct knowledge. Moreover, PST should question the pre-existing structures, as a set of attitudes, helping investigators to better understand, interpret, and alter any social environment (Crick, 2016), while constructivism theory deals with the construction of new knowledge, based on existing experience and interpretation of a given situation; subsequently, constructed knowledge is refined through a dialectical interchange between and among the investigator and the participants (Lincoln et al., 2018).

PST is a theory of language, discourses, and knowledge, and it is concerned with people's perspectives, values, beliefs, assumptions, and experiences that are socially constructed (Ayaz and Naseem 2022). It can allow researchers to investigate elements of engineering education (e.g. curriculum and pedagogical practices) within social, political, cultural, and historical contexts. Niesche (2020) wrote, 'Poststructuralism has been extensively explored across philosophy, cultural studies, politics, and numerous other fields. It has also received significant attention in education, particularly about education policy…' Moreover, PST allows, among other things, an investigation into relations between the individual and the society in specific sites, and it realizes the complexity of the academic institution with a set of social practices. In addition to providing epistemological consistency and epistemological diversity to the qualitative research (Brennan 2020, p234). The PST is incorporated into the IFW because of its ability to analyze the engineering education field, as a social practice, which is influenced by many other social, economic, and political factors.

PST enables the IFW to investigate the power structures within the broader engineering education field, which includes engineering education stakeholders, academic institutions, educational policies, and operational activities.

The function of the constructivism theory is to ensure validity and reliability of qualitative research; and to provide it with epistemological consistency. The constructivism role in the IFW comes through three constructive models: outcome-based education (OBE), constructive alignment (CA), and how people learn (HPL). Figure 1.1 shows the relationship between the constructivism theory from one side and the HPL, OBE, and CA from the other side. Solid orange line arrows represent a strong connection between constructivism and the HPL/CA, while broken orange line arrow shows a weak relationship between constructivism and the OBE.

In addition, the integrated framework incorporates OBE/CA and HPL models (discussed in sections 2.5.1, 2.5.2, and 2.5.3, respectively) to specifically tie itself to engineering education as a social practice. The commonalities among constructivism, HPL, and OBE/CA are: Active learning- learner in control (metacognitive skills) and educator act as a facilitator; learner constructs and stores models (cognitive) based on learner's prior knowledge; in-depth knowledge (deep understanding); and student-centered learning philosophy. Moreover, the CA framework aligns learning activities and assessment to achieve learning outcomes, in the following order: first, determine the desired learning outcomes (DLOs); then design assessment instruments to ensure achieving DLOs; and finally, establish the teaching and learning activities likely to meet the assessment criteria and lead to the DLOs (Biggs et al., 2022; Biggs 2014).

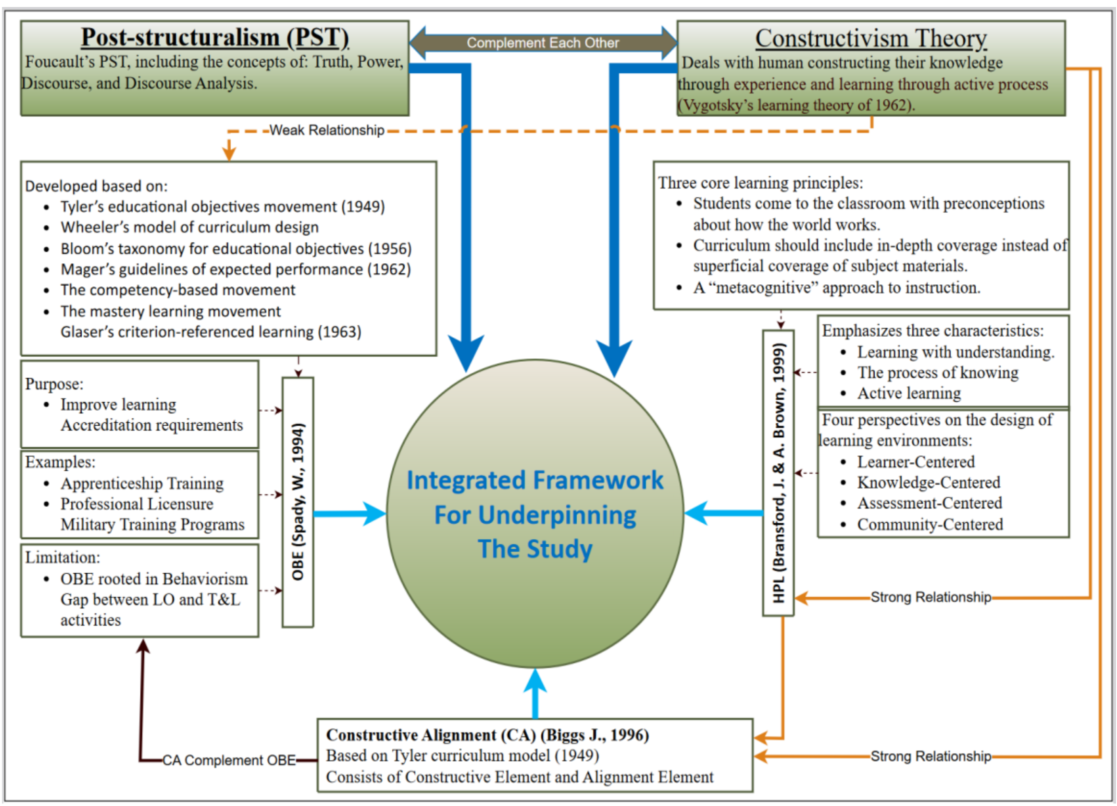

Figure 1.1: Theoretical Framework

Figure 1.2 shows the conceptual (operational) framework, as envisioned by the researcher, to investigate the research questions and to address the objectives of the study. In other words, identify whether any of the teaching and learning elements, of the current engineering programs, are in accordance with the principles of the integrated framework (Figure 1.1): active learning, in-depth coverage of the subject matter, student-centered learning philosophy, etc. Eventually, the operational framework should determine the gap between elements of the current engineering programs and the principles of the integrated framework.

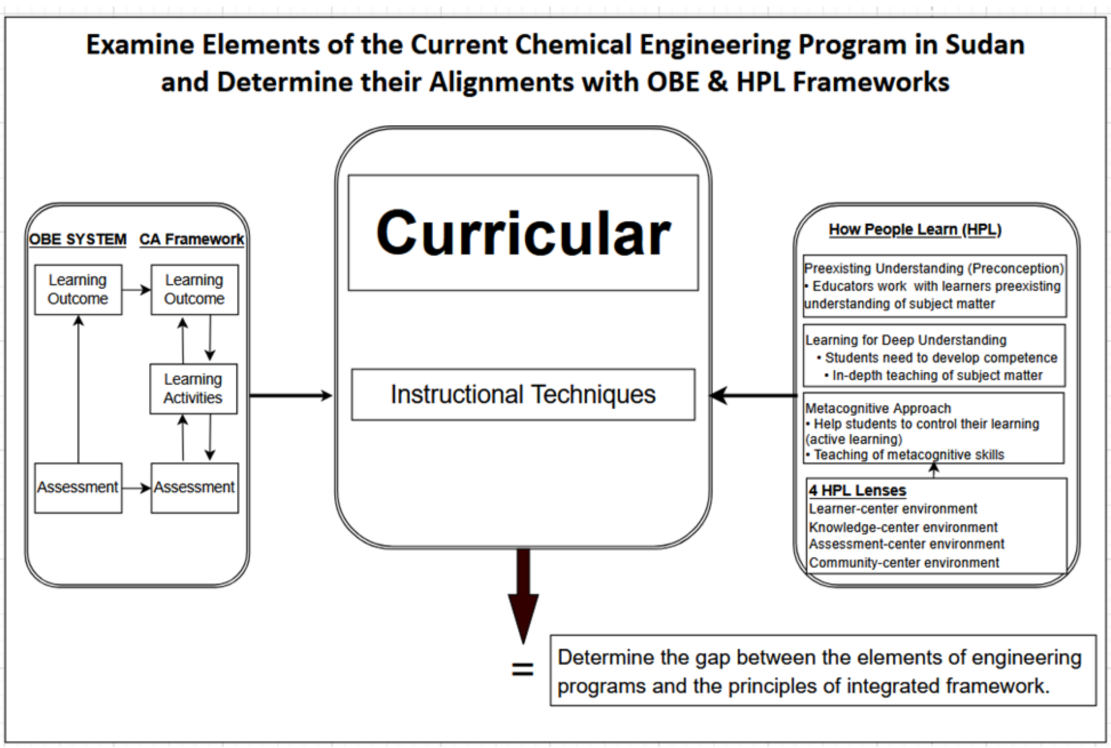

Figure 1.2: Operational Framework

1.8 Limitations of the Study

This study is to investigate engineering education in Sudan. Accordingly, gathered data is supposed to achieve the research objectives. However, the researcher split data collection into two phases: phase 1 is the documentary analysis of the holistic higher education in Sudan, including engineering education. The scope of phase 2 is limited to the engineering program at UofK, a single case study. UofK has different characteristics compared to other academic institutions. It is the oldest and most prestigious public university in the country (https://www.uofk.edu/en/). Its students, graduates, and academic staff believe that they are the best in higher education in the country. This belief comes from the fact that UofK accepts the top high school graduates. On top of that, UofK structure and operation are very rigid and not easily changed. Therefore, this single case study might introduce data collection bias and subsequently, a negative impact on the findings. On the other hand, the single case study would not allow statistical generalization. The researcher believes that this limitation would not adversely influence the study because the researcher constructed validity through multi-level triangulation, internal validity through pattern matching, and external validity through analytic generalization.

1.9 Organization of the Study

This thesis contains six chapters, which are organized as follows:

Chapter 1 includes the following sections: Introduction; Problem Background; Statement of the Problem; Research Objectives; Research Questions; Rationale, significance, and Contribution of the Study; Scope of the Study; Theoretical Perspectives and Frameworks; Limitations of the Study; Organization of the study; definition of terms; and summary.

Chapter 2 discusses literature review. The chapter starts with the background of the study, which covers Sudan's profile and engineering and engineering education, globally and within the context of Sudan. The chapter concludes with learning theories, theoretical perspectives, and additional frameworks.

Chapter 3 discusses the methodology used for the study. The chapter introduces qualitative methods of research. Then the discussion involves the qualitative approach design used in the study, which includes a constructivist worldview, strategy of inquiry, and research method. This is followed by triangulation, the researcher's role, the interview protocol, analysis, and interpretation of gathered data, validity and reliability, ethical issues, the goal of constructing a transformational framework, and chapter summary.

Chapter 4 is divided into three parts: The first part is about the data gathering for this study, through seven semi-structured interviews, documentary analysis, and researcher's observations; followed by the analysis of gathered data; and the final part illustrates findings of the study.

Chapter 5 discusses the findings of the study, as emerged from the analysis of data collected in the previous chapter, in accordance with the formulated research questions. Additionally, the Chapter illustrates the proposed new framework for transformational Sudanese engineering education programs, which represents the main contribution of the study.

Chapter 6 is concerned with the conclusion of the study including findings, contribution, and the limitations of the study; as well, the chapter includes recommendations for stakeholders and recommendations for future work.

1.10 Definition of Terms

Section 1.10 contains terms that were used in this study, and their definitions. The researcher aims to help readers understand these terms within the context of the study. They are organized alphabetically.

Administrators: Refer to managerial (non-academic) staff within educational systems.

Attitude is defined as, ‘A mental and neural state of readiness, organized through experience, exerting a directive or dynamic influence upon an individual's response to all objects and situations with which it is related’ (Allport, 1935, cited in Falk and Lieberman, 2013).

Course Learning Outcomes (CLOs): The Sudan Engineering Council defines CLOs as statements that describe what students can know, perform, or attain after a certain course experience.

Desired Learning Outcomes (DLO): The Sudan Engineering Council defines DLOs as knowledge and skills that students will acquire upon completion of a specific class, course, or program.

Educators: Refer to all academic staff within any higher education institution in Sudan.

Engineering Index (EI) Ranking: The Royal Academy of Engineering (RAE), London, UK has developed a single Engineering Index (EI), which consists of eight different engineering-related indicators: 1) Employment in engineering-related industries, 2) human capital investment in engineering, 3) number of engineering businesses, 4) the quality of infrastructure, 5) the gender balance of engineers, 6) the quality of digital infrastructure, 7) wages and salaries of engineers, and 8) exports of engineering-related goods (Ettridge and Sharma, 2020).

General education: Refer to the K-12 education system, which comprises primary, elementary (middle), and high secondary schools.

Higher Academic Institutions: All academic institutions that are accredited and recognized by MoHESR, including universities, colleges, and technical institutes, and lawfully operate in Sudan and grant academic degrees.

Holistic: The term holistic is used when describing different perspectives inclusively. In this thesis, the term is used when describing the overall engineering education field.

Intellectual Capital Index (ICI): ICI is the capability to generate wealth and jobs through innovation and value-added industries in the globalized markets.

Ministry of Higher Education and Scientific Research (MoHESR): MoHESR was established to oversee higher education and scientific research in Sudan including setting and implementing policies, plans, and programs for all academic and research institutions.

Natural Capital Index (NCI): NCI reflects the country's ability to sustain the population and the economy, now and into the future.

Program Learning Outcomes (PLOs): The Sudan Engineering Council defines PLOs as statements that describe what students are able to know, perform, or attain upon completion of their studies programs.

Stakeholders: In this study, stakeholders refer to an individual or a group of individuals who have an interest in the Sudanese engineering education programs; examples are: undergraduate engineering students, academicians, the university's management, and employers of the engineering industry.

STEM: Refers to the part of education that concentrates specifically on the following four subjects: Science, Technology, Engineering, and Mathematics.

Sudan Engineering Council (SEC): SEC is a governmental agency affiliated with the Council of Ministers of Sudan. SEC was established to oversee the regulation of engineering education and the engineering profession in the country.

Sustainability Competitiveness Index (SCI): SCI is the ability to generate and sustain inclusive wealth without diminishing the future capability of sustaining or increasing current wealth levels.

Technical institutes: All institutes that operate lawfully in Sudan, according to MoHESR policies and regulations, and grant their graduates technical associate degrees upon completion of 2 to 3 academic years.

Vocational Education: Vocational education is education that prepares people to work in a trade, a craft, as a technician, or in professional vocations such as engineering, accountancy, nursing, medicine, architecture, or law. In Sudan, vocational education consists of Grades 9–12, after completion of elementary school.

1.11 Summary

This chapter introduces the study on transforming engineering education in Sudan by outlining the critical challenges faced, such as outdated curricula, insufficiently prepared educators, traditional teaching methods, and weak industry-academia links. It articulates the problem statement, emphasizing the need for a cohesive and modern framework to address these issues. It sets forth the research objectives to examine the current curriculum, evaluate educator qualifications, analyze teaching philosophies, and develop a transformational framework. The chapter also presents the research questions and highlights the academic and practical significance of the study. The scope is defined, focusing on the undergraduate engineering program at the University of Khartoum, with findings applicable to other contexts. Lastly, it provides an overview of the thesis structure, establishing a roadmap for the subsequent chapters.

CHAPTER 2

LITERATURE REVIEW

Chapter two consists of five parts: The first part introduces Sudan, which includes a brief about the country's profile, an overview of the education sector in Sudan, and the overall situation of engineering education as part of tertiary education in the country. The second part is about global engineering education research. The third part includes a historical background of learning theories. The fourth part is a literature review of the theoretical perspectives and frameworks utilized in this study (sections 2.4 and 2.5, respectively). The last part concludes with the taxonomy of educational objectives.

2.1 Background of the Study

This section provides a brief background about Sudan: the country's profile, general education, tertiary education, including engineering education, and global engineering education.

2.1.1 Sudan Profile

Sudan is located in Northeast Africa. Once it was the biggest country in Africa with one million square miles. Sudan used to have borders with eight neighboring countries (Egypt, Libya, Chad, Central African Republic, Congo, Uganda, Ethiopia, and Eritrea) and the Red Sea from the Northeast of Sudan. The UN divides, geographically, all 54 African countries into two parts: Sub-Sahara Africa, which includes 48 countries that are located south of the Sahara; the other 6 countries are known as North African/Arab countries (Egypt, Libya, Tunisia, Algeria, Morocco, and Mauritania). According to this UN classification and the African Union classification, Sudan is considered part of SSA. However, the UN geoscheme classification, which classifies Africa into 5 subregions: Northern, Eastern, Middle, Southern, and Western Africa, considers Sudan part of North Africa. The United Nations Statistics Division (UNSD) uses the geoscheme classification for statistical purposes (https://unstats.un.org/unsd/methodology/m49/). As shown in Figure 2.1 (Map of Africa), Sudan is located, geographically and ethnoculturally, midway between North Africa/Arab and the SSA countries (africaguide.com). Therefore, this study will compare Sudan partially to the North Africa/Arab world and partially to the SSA countries.

Figure 2.1: Sudan Location (in Green) within Map of Africa (africaguide.com)

Sudan lies between latitudes of 12° N and longitude of 30° E, and its climate ranges from arid in the north to wet/dry in the far southwest of the country. The rainfall increases and the wet season gets longer as moving deep into the south. Sudan is colder during the short winter season and very hot during the long summer season. The average temperatures range between 10 0C, in the northern part during the winter, to 42 0C during the summer in the south of the country. Other than low mountains in the Northeast, West, and Southwest, most of Sudan's topology consists of plateaus and plains. The Nile River, which is the longest in the world, has two main tributaries: The White Nile, which flows north from Lake Victoria in Uganda and Central African highlands, and the Blue Nile which flows west from Lake Tana in Ethiopia. Both of them meet in Khartoum, the capital of Sudan, and then the Nile River continues its journey north, into the Mediterranean, through Northern Sudan and Egypt (Garcea, 2020).

Sudan's population is estimated at around 48 million, and the country is very diverse in terms of ethnicity, with almost 600 ethnic groups, and linguistically, more than 400 languages. Arabic is the official language of the country. English used to be the second language and the main language of instruction in higher education. However, the quality of the English language has been deteriorating due to the central government policies of Arabization of the school system since the early 1990s. Sudanese are mixed of Arab and non-Arab, who are of pure African descent. Arab term has been used in a very loose and confusing way by most Sudanese people with a wide complexion range, from very light to very dark skin. Religion in Sudan is a way of social identity. Islam is the religion of the majority, between 65-75%, and Christianity is a religion of less than 10% Sudanese. Up to 20% of the Sudanese are affiliated with indigenous religions of their ancestry. However, there is no consensus on these percentages (UNDP Report, 2020; Sudan: A Country Study, 2015).

Sudan is considered one of the low-middle-income countries. The country is very rich in natural resources, which include water, land, agriculture, forestry, livestock, crude oil, and minerals. In 2020, Sudan ranked 78 out of 180 countries in Natural

Capital (NC), which reflects the country's ability to sustain the population and the economy, now and in the future. The country's NC score is 49.3%, which is above the average of 46.7%, knowing that the highest score is 74.8%. At the same time, Sudan ranked very low in both the Sustainability Competitiveness Index (SCI) and Intellectual Capital Index (ICI). The country's rank, out of 180 countries, is 163 and 145, respectively. Sudan's SCI score is 39%; the SCI average score is 45.6%, and the best score is 62.8%. While the country's ICI score is only 25.7%, which is way below the average score of 41.2%, knowing that the best score is 74.8%; (Table 2.1). Sustainable competitiveness is the ability to generate and sustain inclusive wealth without diminishing the future capability of sustaining or increasing current wealth levels. While intellectual capital is the capability to generate wealth and jobs through innovation and value-added industries in the globalized markets (Sudan GSCI, 2020).

Table 2.1: The Global Sustainable Competitiveness Index (Sudan GSCI, 2020)

Indicator	**Sudan**		**Global**	
	Rank out of 180 Countries	**Score**	**Average**	**Best**
Natural Capital	78	49.3	46.7	72.8
Sustainable Competitiveness	163	39.0	45.6	62.1
Intellectual Capital	145	25.7	41.2	74.8

However, the distressed economy of Sudan, to a great extent, has been caused by corrupt politicians and disastrous political practices since the country's independence in January 1956. Sudan's political system has been engaging in what is known as a 'Vicious Cycle', which consisted of three cycles: multi-party democracy, followed by a military coup, and ended with a transitional period due to people uprising 'Intifada' against the military regimes. The sum of all democratic ruling, including transitional periods, was only 13 years, while military regimes ruled the country, with an iron fist, for more than 53 years. The result of this disastrous political practice led to the country's significant social instability, civil war, and great economic depression, despite the country's abundant natural resources. Since its independence in January of 1956, Sudan has been torn by many civil wars, which eventually led to the country's secession into two countries, Sudan and South Sudan, in 2011. Now Sudan is about 725 thousand square miles. It is worth mentioning that the deterioration of all aspects of life in the country- socially, economically, politically, etc.- has been attributed primarily to the last military regime, which lasted for 30 years since June 30th, 1989. During this period, the devaluation of the Sudanese currency represents a good economic indicator for the depth of the deterioration: A US dollar used to be around 12 Sudanese Pounds, in 1989, compared to more than 50 thousand Sudanese Pounds, in 2019-, or 4166 times devaluation (Ibrahim et al., 2023). Fortunately, the Sudanese "December 2018 Revolution", which was a significant political movement, started as peaceful anti-government street protests and continued until overthrowing this vicious dictatorship regime in April of 2019. Figure 2.2 shows two iconic images: (a) Alaa Salah, a 22-year-old student demonstrator, known as "Woman in White" and "Lady Liberty of the Sudanese Revolution". The photograph was taken by Lana Haroun using a smartphone (https://kandaka.blog/startseite). (b) Residents of Khartoum, the capital of Sudan, welcoming the "Train of Freedom" carrying more protesters from the city of Atbara, the headquarters of the Sudanese Railways (https://www.middleeasteye.net). The hope is high on the current transitional civilian government to lead the country into a proper democratic system, and hence, a prosperous country (UNDP Report, 2020; Sudan: A Country Study, 2015).

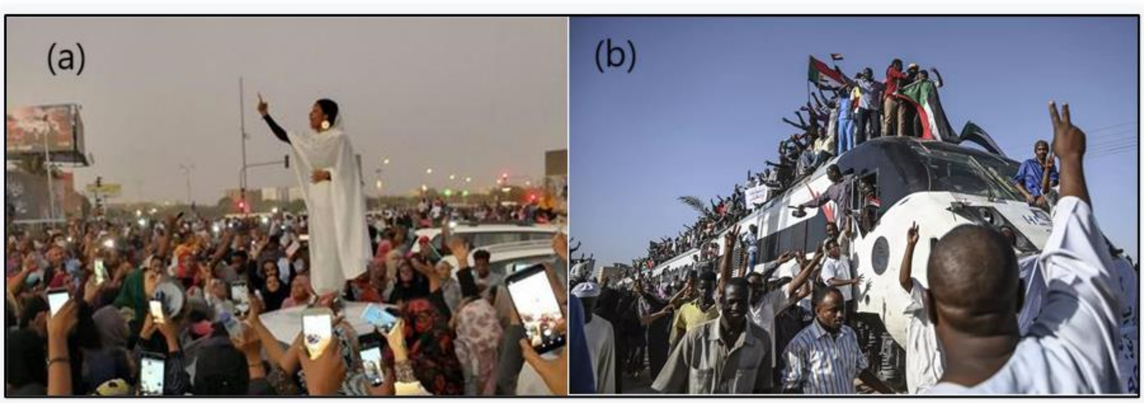

Figure 2.2: (a) Kandake of the Sudanese Revolution and (b) the Freedom Train

2.1.2 Engineering and Engineering Education

There are many definitions of engineering: According to the Cambridge dictionary engineering definition is, ‘engineering is the use of scientific principles to design and build machines, structures, and other items, including bridges, tunnels, roads, vehicles, and buildings.’ The International Association of Engineers (IAENG) defines engineering as, ‘The word "engineering" is derived from the Latin "Ingenium", meaning something like a brilliant idea, the flash of genius. It was created in the 16th century and originally described a profession that we would probably call an artistic inventor. Engineers apply the knowledge of the mathematical and natural sciences (biological and physical), with judgment and creativity to develop ways to utilize the materials and forces of nature for the benefit of mankind. The subjects are diverse and include names like bioengineering, computer engineering, electrical and electronics engineering, financial engineering, industrial engineering, internet engineering and systems engineering, etc.’ (IAENG, 2016). A more comprehensive one is given by UNESCO (2021, p24), ‘Engineering is the field or discipline, practice, profession, and art that relates to the development, acquisition and application of technical, scientific and mathematical knowledge about the understanding, design, development, invention, innovation, and use of materials, machines, structures, systems, and processes for specific purposes.’

Engineering is as old as the history of civilization, and it is a global profession. For more than two centuries engineering has gone through six waves of innovation. As illustrated by Figure 2.3, these six innovation waves are: First wave (1785-1845): Iron, Waterpower, Mechanization, Textiles, and Commerce. Second wave (1845-1900): Steam power, Railroad, Steel, Cotton. Third wave (1900-1950): Electricity, Chemicals, Internal combustion engine. Fourth wave (1950-1990): Petrochemicals, Electronics, Aviation, Space. Fifth wave (1990-2020): Digital Networks, Biotechnology, Software, Information technology. Sixth wave- current: Sustainability, radical resource productivity, whole system design, biomimicry, green chemistry, industrial ecology, renewable energy, green nanotechnology. (Silva et al., 2016; ; Hargroves et al, 2023).

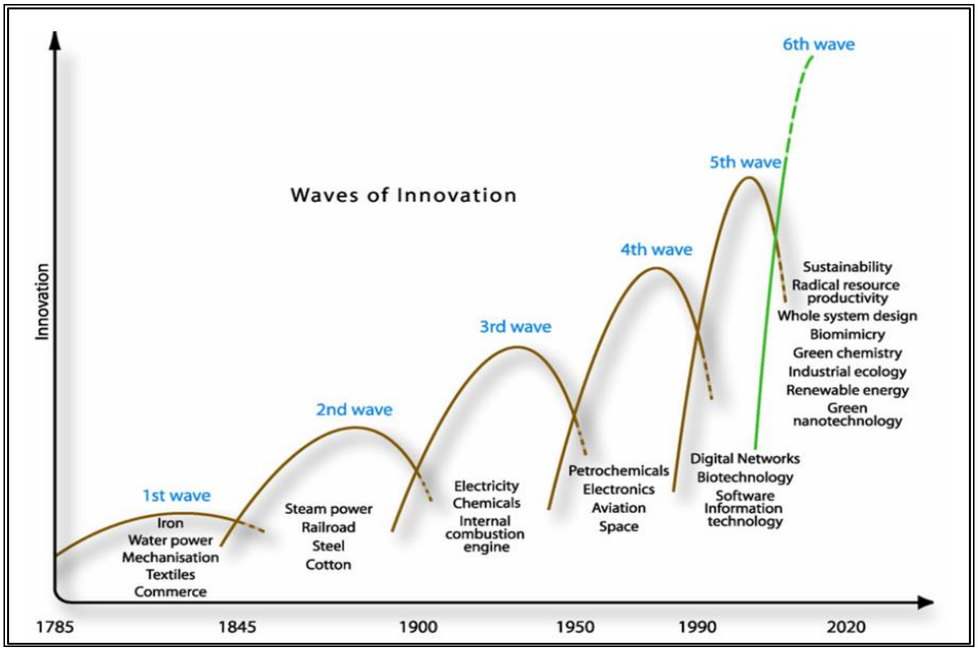

Figure 2.3: Waves of Innovation Diagram (Hargroves et al., 2023)

All these waves of innovation are overlapping, and each one of them takes longer time than its successor. The sixth wave has been progressing since the beginning of the current century, and it has been influenced by many factors, which are globalization, emerging technologies, climate change, and inequality. Future engineering must consider dealing with the arising issues of poverty and climate change (UNESCO, 2021, 2020). UNESCO (2020, p32) states, 'For the future of engineering, an obvious goal is the need to focus specifically on the important role engineering will play in addressing the UN Millennium Development Goals, especially poverty reduction and sustainable development, and the vital role of engineering in climate change mitigation and adaptation in the development of sustainable, green, eco-engineering and associated design, technology, production and distribution systems and infrastructure.'

Engineering evolution has been following global technology growth. Figure 2.4 illustrates the exponential technology growth within the last 20 years related to incremental growth within the prior 600 years (Komerath, 2021).

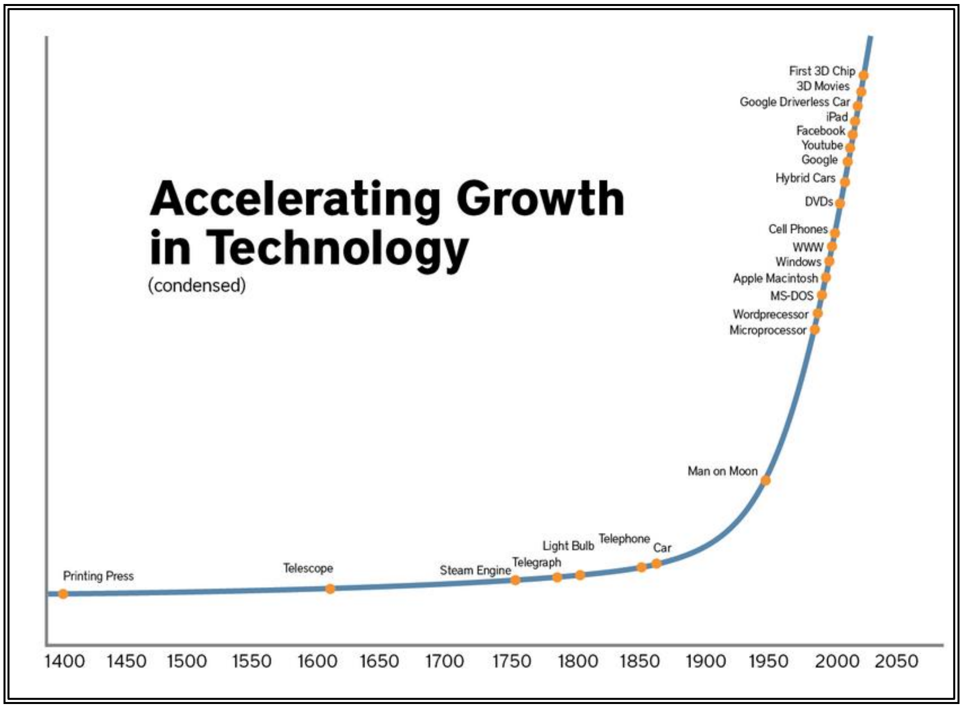

Figure 2.4: Accelerating Growth in Technology- (Komerath, 2021)

In line with the same engineering evolution, the 21st century is characterized by a very fast-paced and rapidly changing reality, which leads to the constant emergence of unexpected challenges (Pushkina, 2020). These challenges include proliferating information, multidisciplinary technological development, globalized market, endangered environment, emerging social responsibility (poverty, inequality, and peace and justice), and issues in sustainability (Ling et al., 2022; Chursin et al., 2020; Meyer, 2020; Mohd-Yusof et al., 2015).

The Purpose of engineering education is to prepare most of the engineering graduates for employment as a professional engineer in various industries. However, a small portion of engineering graduates may seek other options, like research and/or graduate studies. Also, it is worth mentioning that the potential employers of engineering graduates are considerably diverse; nevertheless, all employers look for the same set of skills in an engineering graduate. This means employable engineering graduates should be acquainted with a set of certain skills, such as: problem-solving and strong analytical skills, excellent communication and leadership skills, teamwork skills, and a desire for lifelong learning.

On the other hand, the evolution of engineering innovation waves influences the history of engineering education. As shown in Table 2.2, there have been five major shifts in US engineering education since the second decade of the twentieth century (de la Peña et al., 2016).

Table 2.2: Major Engineering Education Shifts Over 100 Years*

Shift Number	**Description of the Five Major Shifts**
1	A shift from hands-on and practical emphasis to engineering science and analytical emphasis
2	A shift to outcomes-based education and accreditation
3	A shift to emphasizing engineering design
4	A shift to applying education, learning, and social behavioral sciences research
5	A shift to integrating information, computational, and communications technology in education

* Adopted from (de la Peña et al., 2016)

The first shift was established in Europe; then, immigrants' European engineers and engineering faculties introduced this engineering education approach, into US engineering programs, between 1935 and 1965. The second shift provided quality control for engineering education in the USA, as required by accreditation agencies, like ABET. Always ABET has intended to ensure that accredited engineering programs graduate professional engineers ready to practice. On the contrary, many engineering educators have viewed the implementation of accreditation requirements as too bureaucratic and representing a great deal of obstacles to innovations within engineering programs. Major engineering schools and ABET have agreed on changes that bring a quality-oriented environment and prevent rigid implementation of accreditation requirements. Accordingly, the Engineering Accreditation Commission (EAC) of ABET developed what is known as Engineering Criteria 2000 (EC 2000), which has a very positive impact on engineering education (ABET, 2018). Arguably, many researchers believe that the engineering curriculum has been focusing more on science and mathematics than on design. This belief led the way for the third shift in US engineering education, which focuses on design. Since the mid-nineties of the last century, the emphasis on design has greatly improved and has led engineering students to become more knowledgeable and skillful about design. This progress has been attributed to design courses introduced as part of the first-, middle-, and senior-year curriculum. Examples are design thinking, sophomore design project, junior design project, and capstone senior design project. The fourth shift has been evident by the fact that engineering education has become part of engineering programs, and more engineering researchers have been involved in engineering education research. In addition, engineering educators have been participating in professional development programs related to many practices developed by psychology and social science researchers. See learning theories section 2.3. Lately, technology utilization in education has been progressing very fast. Not to mention, the post-covid19-era would accelerate even more technology usage in education.

Although the first two of these five shifts have already been completed, still they have a lasting impact on engineering education. The latter three shifts are proceeding with potential implications for the practice of engineering education. They should be regarded with respect to the sixth wave of engineering innovation, which will continue evolving at an even faster pace (Nelson et al., 2021; Froyd et al., 2017; de la Peña et al., 2016). Accordingly, completely different challenges will be faced today and by future engineers. Hence, engineering education must change, at a similar pace, to match respective changes within the engineering profession, and to train engineers with the right sets of knowledge, skills, and attitudes.

2.1.3 Education in Sudan

Contemporary education in Sudan has been developed during the colonialism period. Back then, the goal of education was to help the colonial administration meet their needs for civil servants and municipality professionals from the local job market. The philosophy of education and the design of the Western curriculum were to achieve the goal of the colonial administration rather than to promote education for the Sudanese people. Most schools were concentrated around urban centers, and not around rural areas, where most of the Sudanese population lives. Education in Sudan is divided into general education and higher (tertiary) education; they are regulated and administered by the Ministry of General Education (MOE), and the Ministry of Higher Education and Scientific Research (MOHESR), respectively.

2.1.3.1 General Education

The general education ladder in Sudan used to consist of 6, 3, and 3 years for primary, middle, and secondary high school, respectively. 2-year preschool is also mandatory for 4-6 years old children. Otherwise, kids are not eligible to enter primary school. In 1992, the education ladder was replaced with 8-year basic and 3-year secondary school. Thus, the duration of general education has been reduced to 11 years instead of a 12-year system, which is a standard and globally recognized system. The 11-year general education system has a serious negative impact on students' preparation for college. General education is compulsory for children between the ages of 6- and 14 years old, with the caveat that students must pass a national exam, to be eligible for secondary high school admission. The researcher believes that the way these national exams are designed and administered would not allow a high rate of student success, which results in a significant student dropout before even the completion of general education. To put this in perspective, the success rate on these exams for the last three academic years was 71%, 75%, and 73%. On top of that, students must score high to be admitted to good high schools (MOE, 2014). As viewed by the researcher, this policy resulted in the segregation between high and low academic achievers and prevented diversity among students.

Based on courses offered, there are many branches of high schools: Academic high schools, which include scientific and liberal arts courses. Academic high schools with science concentration courses may allow students to apply for medical, engineering, and other science-related colleges, while liberal arts courses would allow students the opportunity to major in liberal arts and all other unrelated natural science colleges. In addition to academic branches, there are vocational high schools, which grant attendees industrial, agricultural, or trading certificates. The researcher believes that the main issue with this strict classification is that students have no chance to change their majors after graduating from high school.

The capacity of general education in Sudan is far less than the demand for schooling of Sudanese children. As of 2010, the number of basic schools reached about 20,000, with a student enrollment of 6.3 million; for the same year, there were only 3,000 secondary schools with about 461,000 students. These numbers are well below corresponding numbers for similar countries within low-income SSA countries and North African and Middle Eastern countries. The capacity and the quality of general education in Sudan have been significantly influenced by many reasons, of them are: instability around war zones and inhabitants' displacement; level of poverty, which prevents children from going to school; schools are mostly distributed in urban centers, and not around rural areas where the majority of Sudanese live; lack of enough teacher, and proper school facilities. Moreover, the 11-year general education system, combined with an anemic education budget, inadequate curriculum, obsolete teaching methods, and insufficiently qualified schoolteachers, led to under-prepared high school graduates for college in general, and for engineering colleges in particular (Osman, 2014; MOE, 2014).

To reflect on the overall situation of general education in Sudan, one may use the Human Capital Index (HCI), which is a report prepared by the World Bank. HCI (2018) measures countries' potential losses due to a lack of adequate health and education. The highest HCI is the best, which ranges between 0 and 1. Sudan ranked 139 out of 157, with HCI equal to 0.38. This value is among the lowest worldwide. According to an HCI report (2018), Sudanese children, who attend preschool at age 4, are anticipated to complete 7.3 years by age 18. However, considering the actual quality of learning, this number of 7.3 years is equivalent to only 4.4 years (GSCI, 2018).

2.1.3.2 Tertiary Education in Sudan

In 1902 Gordon Memorial College (GMC) was established as part of the secondary education, named after the British army officer, Charles George Gordon. GMC represented the nucleus of higher education in Sudan. In 1937, GMC linked to the University of London and started awarding its graduates a bachelor's degree. Other academic institutions include: the Higher Islamic Institute, which was established in 1912 and 1921 became Omdurman Islamic University. Kitchener School of Medicine (KSM) was established in 1924. In 1951 GMC and KSM merged as the University College of Khartoum, which became the University of Khartoum (UofK), with independence. The goal of tertiary education, during British colonialism, was to secure the colonial administration's needs for civil servants and municipality professionals from within Sudan. Since its inception, tertiary education has gone through three distinctive stages of transformation: Stage 1, during the British Colonialism, from 1902 to 1956: During this period, there were only four academic institutions, GMC, Omdurman Islamic University, Cairo University-Khartoum Branch, and Khartoum Institute of Technology (KIT). These institutions used to have very limited programs with low numbers of enrolments and graduates, respectively. Stage 2, after the independence of the country, from January 1956, until 1989: During this period two additional universities were established, the University of Juba and Jazeera University, in 1975. Both of them are located outside of Khartoum province. The University of Juba is in the south of Sudan, and Jazeera University is located in Jazeera province, central Sudan (Sudan: A Country Study, 2015). As well, there was a gradual improvement in tertiary education in terms of college programs, number of enrolments, and number of graduates. Stage 3 lasted for 30 years between 1989 and 2019: During this period, tertiary education was affected greatly by the country's ruling system that took over in June of 1989 via a military coup. To achieve quick political, social, and economic success, the regime started addressing various issues facing the country, within all sectors. In the area of education, the regime showed its desire and willingness to address well profound education issues and immediately pledged to double the number of universities and their capacities. An education conference was organized, which ended with what was called the 'Education Revolution'. Soon after, the regime started implementation of dramatic and fast changes within the education sector. Accordingly, the number of universities and other higher academic institutions has been increasing, at a fast-paced, from only 6 public and 2 private universities in 1989 to 10 public and 7 private universities in 1991, and to 12 public and 11 private universities in 1992. By 1995 the number of academic institutions jumped to 21 public and 11 private universities; or within six years the number of both public and private universities increased by more than 5 times (Elhadary, 2018).

As shown by Table 2.3 by 2018 the number of universities has become 36 public and 13 private universities, which represents, between 1989 and 2018, an increase of 6 times and 6.5 times for public and private universities, respectively. During the same period, technical institutes have increased from 12 to 83 institutes, an increase of almost 7 times. In addition, since 1989 the number of students enrolled in higher education has been increasing exponentially. The total number has increased by almost 12 times between 1989 and 2018, or from 57,600 to 680,000, see Table 2.3 (MoHESR Census Data, www.mohe.edu.sd).

Table 2.3: Higher Academic Universities- Number and Enrolment of Students (MoHESR Census Data, www.mohe.edu.sd)

Year	**Academic Institutions**		**Number of Students**	
	Type	**Number**	**Enrolled**	**Graduate**
1980	Public Academic Institution	_	_	_
	Private Academic Institution	_	_	_
	Special Colleges (Diploma Graduate)	_	_	_
	Total	_	_	_
1990	Public Academic Institution	6	45,399	6,272
	Private Academic Institution	2	1,027	233
	Special Colleges (Diploma Graduate)	12	4,555	635
	Total	18	50,981	7,140
2018	Public Academic Institution	36	623,424	_
	Private Academic Institution	13	57,272	_
	Special Colleges (Diploma Graduate)	83	_	_
	Total	132	680,696	_

2.1.4 Engineering Education in Sudan

In Sudan, engineering education is provided by higher colleges and universities, and regulated by two governmental entities: the Ministry of Higher Education and Scientific Research (MoHESR), and the Sudanese Engineering Council (SEC). The evolution of Sudanese engineering education has gone through three distinctive periods: the colonialism period, the post-independence period, and the 1989-2019 period.

2.1.4.1 Engineering Education during Colonialism Period

In the first period, the start of engineering education was based on the need for apprentices to help the British Colonial Government (BCG) with municipality functions. To meet the demand for technical skills, engineering education during this period started as part of the high school programs (Khojali, 2014). Soon after, in 1939, the first school of engineering was established as part of Gordon Memorial College (GMC), which was established in 1902. Later GMC became the University of Khartoum (UofK). The school of engineering used to grant its graduates engineering certificates upon completion of a five-year duration of study after high school. Since 1947 the School of Engineering has become a university college, associated with the University of London, and the duration of study has increased from five to six years. The college graduates have been awarded a degree in mechanical and civil engineering after completing the duration of the study (Sudan: A Country Study, 2015; Khojali, 2014; Osman, 2014). In 1950 Khartoum Technical Institute (KTI) was established to grant its graduates engineering diplomas after completion of a 4-year duration of study. KTI used to provide the local job market with well-trained technicians and applied engineers. KTI's mission was to keep a reasonable balance between diploma graduates from KTI and bachelor graduates from the engineering college; this balance was necessary, back then, for the development of the country. In 1990 KTI became the Sudan University for Science and Technology (SUST). In short, engineering education during this period started as a high-school program; then it has been developed into two academic institutions, Engineering College-GMC and KTI. Both have been located in Khartoum, the capital of Sudan, and they used to offer engineering degrees and engineering diplomas, respectively. Their capacities, the intake of students, and the number of graduates have been very limited, and barely fulfilling the country’s need for engineers. However, the quality of graduated diplomas and bachelor engineers has been comparable to known standards, at least in the UK since EC has been associated with London University (Khojali 2014; Osman 2014).

2.1.4.2 Engineering Education Post-Independent Period

After the independence of the country, in January 1956 (the second period), the College of Engineering became part of the University of Khartoum (UofK), which was known as GMC. In addition to mechanical and civil engineering programs, the College of Engineering expanded its programs to include: Architecture engineering in 1957, electrical engineering in 1959, and chemical engineering in 1964. At a later phase, two more programs came into existence as part of the engineering college: surveying and agricultural engineering programs in 1975 and 1976, respectively. KTI has expanded its capacity and programs, and it has been renamed to Khartoum Polytechnic Institute (KPI). KPI diploma programs included: electrical, electronics, mechanical, surveying, textile, and civil engineering. In addition to diploma programs, KPI has added applied bachelor programs in electrical, mechanical, textile, and civil engineering (MoHESR Census Data, www.mohe.edu.sd; Sudan: A Country Study, 2015; Khojali, 2014; Osman, 2014).

During this period, engineering education in Sudan has been improving incrementally in terms of engineering programs, the capacity of these programs, and the number and quality of engineering graduates. As shown by Table 2.4, the total number of engineering students reached a little over 5,000 by 1988, which represented only 6% of the total students enrolled in tertiary education. In the same year, the engineering graduates numbered only 624. Table 2.5 shows an additional 12 technical institutes as part of higher academic institutions in Sudan. The total number of students enrolled in these institutes was about 2878; only 143 students, or 5%, out of the total number enrolled in engineering programs (MoHESR Census Data, www.mohe.edu.sd).

The high quality of engineering graduates was due to two reasons: first, engineering colleges were well-equipped; and they used to admit into their programs only top-tier high school graduates in the country. However, the number of engineering graduates was relatively small, in order of hundreds, due to the limited capacity of the engineering colleges. To mitigate this problem the government of Sudan used to send Sudanese students to study abroad.

Table 2.4: Engineering Graduates and Enrolled Students in all Academic Institutions (MoHESR Census Data, www.mohe.edu.sd)

Academic Institution	**No. of Students**			**No. of Graduates (1987-88)**		
	Total	**Engineering**	**%**	**Total**	**Engineering**	**%**
Khartoum Polytechnic	3,753	1,459	39%	773	337	44%
Khartoum University	9,269	1,050	11%	1,541	203	13%
Gazira University	1,018	253	25%	167	44	26%
Colleges and Higher Institutes	4,555	234	5%	635	40	6%
Cairo University-Khartoum Branch	35,225	0	0%	2,354	0	0%
Omdurman Islamic University	2,561	0	0%	623	0	0%
Juba University	1,259	0	0%	179	0	0%
Abroad Students	19,512	1,950	10%	N/A	N/A	
Total	77,152	4,946	6%	6272	624	10%

Table 2.5: Enrolled Students in Technical Institutes (www.mohe.edu.sd)

Number of Technical Institutes			**Students in Technical Institutes**		
Total	**Engineering**	**%**	**Total**	**Engineering**	**%**
12	1	8%	2,878	143	5%

2.1.4.3 Engineering Education during 1989-2019 Period

During this last period, the total number of public and private universities has increased by more than 6 times, or from 8 to 49 universities. Similarly, the number of technical institutes has increased from 13 to 83 institutes. The increase in the number of universities and other technical institutes has been accompanied by an increase in engineering programs offered by these academic institutions. Table 2.6 shows universities that offer engineering programs, as of 2018, relative to the total number of public and private universities: 26 out of 36 public universities (or 72%), 11 out of 13 private universities (or 84.5%), and 25 out of 83 institutes (or 30%) (MoHESR Census Data, www.mohe.edu.sd).

Table 2.6: Number of Engineering Programs out of all Academic Institutions (MoHESR Census Data, www.mohe.edu.sd)

Academic Institutions	**Total**	**Number with Engineering Programs**		**Number without Engineering Programs**	
	Number	**Number**	**% of the Total**	**Number**	**% of the Total**
Public Academic Institution	36	26	72.2%	10	27.8%
Private Academic Institution	13	11	84.6%	2	15.4%
Technical Institutes	83	25	30.1%	58	69.9%

In addition, since 1989 the number of students enrolled in higher education has been increasing exponentially. Table 2.7 shows the number of engineering students out of the total number of students. Engineering students represent about 9% of the total number of college students or 61,638 out of 680,696; they enrolled in 26 public and 11 private engineering colleges. While the increase in the total number of college students has been estimated to be 12 times, during the same period, the jump in engineering students has exceeded 20 times, or from only 3,000 to 61,638 (MoHESR Census Data, www.mohe.edu.sd).

Table 2.7: Engineering and Total Number of Students (MoHESR Census Data, www.mohe.edu.sd)

Type of Academic Institution	**Total Number of Students**			**Number of Engineering Students**			**Engineering (%) out of Total Students**
	Bachelor Degree	**Diploma**	**Total**	**Bachelor Degree**	**Diploma**	**Total**	
Public Academic Institution	532,557	90,867	623,424	44,800	3,689	48,489	8%
Private Academic Institution	53,426	3,846	57,272	12,849	300	13,149	23%
Total	585,983	94,713	680,696	57,649	3,989	61,638	9.1%

This period showed a huge reduction in the number of technicians and applied engineers, compared to bachelor graduates, because many engineering institutes have replaced their diploma programs with bachelor ones. This reduction resulted in an imbalance between diploma graduates and bachelor graduates from engineering colleges. The researcher believes that a reduction in diploma graduates is not healthy for the hierarchy of the engineering sector to operate effectively. It is worth mentioning that only 4,000, out of the total engineering students 61,600, were enrolled in engineering diploma programs, which represents about 6.5%; the rest of 57,600 thousand, or 93.5%, were enrolled in Bachelor of Engineering programs. As well, engineering graduates have been increasing substantially from only 624 in 1989 to around 13,000 in 2018 (MoHESR Census Data, www.mohe.edu.sd).

During this period, the situation of engineering education, as part of the whole higher education, has been affected, to a great extent, by the behavior of the autocratic government that took over in June 1989 (Elhadary, 2018). The government pledged to resolve the overwhelming problems of higher education, which has been considered the bottleneck in the process of the country's development.

Although the number of engineering graduates has expanded significantly, during this period, their quality has been compromised; both the number of engineering students and the number of engineering graduates have increased by more than 20 times, from 3,000 to 61,638 and from only 624 to 13,000, respectively (Ettridge and Sharma, 2020; World Bank and MoHESR, 2020; Elhadary, 2018; Osman, 2014). However, the dilemma of engineering education in Sudan remains the disparity of the quality of graduate engineers. This has been attributed to many reasons, of them are:

i. Expansion in higher education was implemented without consideration of the readiness of education infrastructure, which includes: buildings, libraries, laboratories, equipment, academic and supporting staff, etc. (Minalla, 2021).

ii. The government has failed to secure reasonable budgets to meet its ambitious education project. Not only that but also, since 1990, the government has gradually started reducing the already anemic education budget; by 2001 the education sector received only 1.3% of the country's GDP; however, by 2008 the education sector share was doubled to 2.7% of the GDP (Minalla, 2021). Still, Sudan spends far less on the education sector relative to similar countries in Africa and the Middle East; see Table 2.8.

iii. At a later stage, the government considered education in general and higher education in particular, an area of investment for both public and private sectors. Accordingly: The government started to use public universities as a source of income by loosening the admission criteria; instead of solely based on the academic achievement of high school graduates; prestigious universities, in the country, have been admitting wealthy students at premium tuition fees. Furthermore, the government has allowed the private sector to invest in higher education, and even licensed private academic institutions without adhering to the rugged and well-established governmental requirements that govern higher education (World Bank and MoHESR, 2020).

iv. The general education system was reduced to an 11-year instead of a 12-year system, which had a negative impact on the preparation of high school graduates for engineering colleges (MOE, 2014).

2.1.4.4 Benchmarking the Situation of Engineering Education in Sudan

To better evaluate the situation of Sudan's engineering education, the researcher benchmarks it with the situation of engineering education in several countries, namely: Algeria, Egypt, Jordan, and Saudi Arabia, from Middle Eastern/North African territory; Ethiopia, Kenya, Rwanda, and South Africa from SSA; and Malaysia as an example from Southeast Asia. Many indicators may be used to benchmark the situation of engineering education in Sudan, with the situation in those countries; are the following indicators: tertiary enrolment ratio, tertiary enrolment per 100,000 population, percentage of engineering graduates, the number of engineers per 100,000 population, the number of academic institutions, and public spending on education sector % of GDP (World Bank, 2018).

i. Tertiary Enrolment Ratio: This indicator represents the total enrolment in tertiary education as a percentage of the total population of the five-year age group following on from high school graduation (18-23-year age group). Sudan's tertiary enrolment ratio is about 17%, which is better than the enrolment ratio in SSA countries, with an average of 9.4%; however, the same number is far lower than the average enrolment ratio of 40.6% in Middle Eastern and North African countries. In Malaysia, this indicator is more than 45%, see Table 2.8.

ii. Tertiary Enrolment per 100,000 Population: Another indicator to benchmark the education situation is the number of students enrolled in higher education per 100,000 population. As shown in Table 2.8, the value of this indicator, in Sudan, is more than 1500 students per 100,000 population. This value is almost double the average value from SSA countries, only 825 students. However, the same value is less than half the average value of the Middle East/North Africa countries, which is 3259 students per 100,000 population. In the same year, Malaysia has more than 4,000 tertiary enrolments per 100,000 population.

iii. Percentage of Engineering Graduates: Engineering graduates in Sudan represent about 10.7% of the total tertiary graduates, which is better than the percentage of engineering graduates in all benchmarking countries, except Jordan, Algeria, and Malaysia, with engineering graduates' percentages of 16.4%, 22%, and 30.1%, respectively.

iv. Education Sector Share (%) of GDP: With its GDP per capita of $1990, Sudan is considered one of the lower-middle-income countries. This per capita GDP of Sudan is higher than most of its neighboring countries, and higher than some of the countries in SSA, but still, Sudan's per capita GDP is significantly lower than countries in North Africa. On top of that Sudan spends less on education than all these countries.

In 2008 Sudan's education sector share was about 2.7% of GDP, which is less than neighboring countries (3 to 7% of GDP); far less than lower-middle-income countries in SSA (4.4 to 13.1% of GDP); and less than lower-middle-income countries in North Africa (3.7 to 7.1% of GDP) (Minalla, 2021). Since 2008, the share of the education sector of GDP has been dramatically decreasing, and by 2014, it reached about 1.4% of the GDP (World Bank and MoHESR, 2020). As shown in Table 2.8, this government's extremely poor expenditure on education, relative to all benchmarking countries, requires special attention from education sector stakeholders.

Table 2.8: Benchmarking the Situation of Engineering Education in Sudan.

Country Name	**Indicators**			
	Tertiary Enrolment Ratio (%)	**Enrolment per 100K Population**	**% of Engineering Graduates**	**Education % Share of GDP**
Sudan	17	1,562	10.7	..
Algeria	51.4	3,791	22.0	..
Egypt, Arab Rep.	35.2	2,961	6.2	..
Jordan	34.4	3,223	16.4	3.03
Saudi Arabia	68.0	4,809	7.9	..
Middle East/North Africa	40.6	3,259	..	..
Ethiopia	8.1	693	..	4.74
Kenya	11.5	1,095	4.2	5.27
Rwanda	6.7	615	5.8	3.07
South Africa	23.8	2,038	8.0	6.16
Sub-Saharan Africa	9.4	825	..	4.5
Malaysia	45.1	4,075	30.1	4.48

Considering these four benchmarking indicators, Figure 2.5 shows that the situation of Sudanese engineering education looks slightly better than the situation in most Sub-Saharan African countries, except South Africa. However, the situation is too poor compared to the situation in the rest of the benchmarking countries.

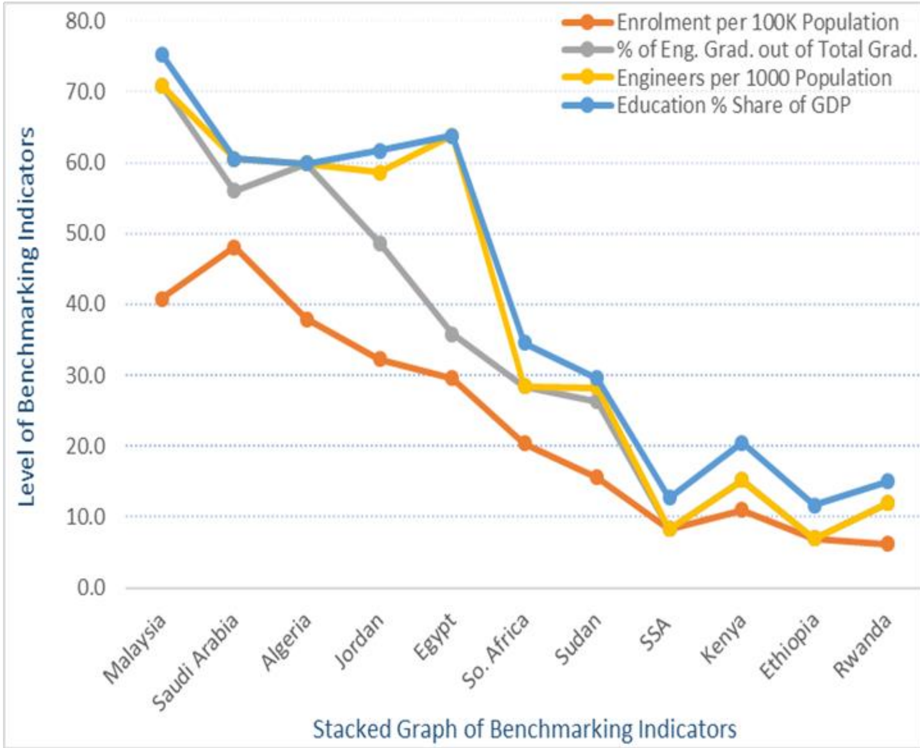

Figure 2.5: EE in Sudan versus Benchmarking Countries (UNESCO, 2018)

Aside from the above table, there are two more important benchmarking indicators: One, the number of engineers per 100,000 population represents a good indicator of the situation of engineering education. Osman (2014) compared this indicator in Sudan, which is around 188 engineers per 100,000 population, with a few countries, from the Middle East/North Africa region, namely: Egypt, Jordan, and Saudi Arabia with 2800, 1000, and 460 engineers per 100,000 population, respectively (Osman, 2014). This indicator is extremely crucial for any efforts to revamp the situation of engineering education in Sudan. Another indicator is the number of academic institutions. According to Teffra (2013), Sudan ranked second in Africa in terms of the number of universities. Teffra stated that all 54 African countries have only 300 universities; he wrote, ‘Africa, a continent with fifty-four countries, has no more than 300 institutions that fit the definition of a university.’ He added, ‘Nigeria, Sudan, South Africa, and Egypt each have 45, 26, 21, and 17 universities, respectively, and each country has many additional postsecondary institutions as well.’

2.1.4.5 Issues of Engineering Education in Sudan

As discussed in section 1.1.2, the state of Sudanese engineering education is similar to the awful engineering education systems in most SSA countries. This situation, which has been evident by the inability of the SSA engineering education programs to graduate enough competent engineers, has been deteriorating due to many challenges facing these programs (Elhadary, 2018). Many researchers were investigating challenges facing engineering education in Africa, such as insufficient funding, inappropriate facilities, lack of adequate human capacity, brain drain due to unattractive working environment in SSA, and missing of quality control and accreditation measures (UNESCO, 2021 and 2020; Nwogbo, 2017; Tarusikirwa et al., 2017; Mohamedbhai, 2014).

Osman (2014) split the Sudanese engineering education problem into: First, the failure of the engineering education capacity to accommodate the increasing number of students who want to study engineering. Second, the inability of engineering graduates to compete for the job market whether locally or globally, due to their improper level of training. Table 2.9 summarizes issues of engineering education in Sudan during three distinctive periods.

Table 2.9: Summary of Engineering Education Issues in Sudan

Stages of Eng. Education	Issues	Comments
(a) Colonialism Period	i. Western model of academic institutions ii. Limited enrolment, limited graduates, limited programs, limited curriculum, and limited freedom.	Only two engineering programs
(b) Post-Independence 1956-1989	i. Poor Funding. ii. Low number of academic institutions. iii. Limited capacity in terms of enrolment and the number of graduates.	The national government kept the same Western education model.
(c) The Latest Period 1989-2019	i. Poor Funding ii. Outdated curricula iii. Ineffective teaching and learning methods iv. Inadequate human capacity v. Students under preparedness for college vi. Inadequate number and quality of facilities vii. Issues of quality control and accreditation measures viii. Other Issues: o Absence of academic freedom o poor research/publishing condition o inadequate educational technology and ICT environment, o weak university/industry relationship	In addition to academic freedom, poor funding is the leading cause for all other issues.

Below is a brief about each one of the engineering education issues, in Sudan, during the latest period that has lasted for more than 30 years, between 1989 and 2019.

(i) Poor funding: For decades, most African countries have been facing severe financial problems, which are mainly due to the state of the economic situation of these countries and their misallocation of scarce financial resources. According to Teferra (2013), the expenditure of higher education in Africa ranged between 4 to 5 billion dollars. He added, ‘The total yearly expenditure for higher education in Africa does not even come close to the endowments of some of the richest universities in the United States’ (Teferra, 2014). Likewise, Higher education in Sudan, including engineering education, has been facing a similar financial crisis.

In Sudan, all public academic institutions are owned by the government, and the government used to meet the financial needs of these institutions. However, since the drastic expansion of tertiary education in 1990, the government not only has failed to secure the budget of its ambitious education programs, but also has started to reduce the education sector expenditure (World Bank and MoHESR, 2020). With its GDP per capita of $1990, Sudan is considered one of the lower-middle-income countries. This per capita GDP of Sudan is higher than most of its neighboring countries and higher than some of the countries in SSA; still, Sudan's per capita GDP is significantly lower than countries in North Africa. On top of that Sudan spends less on education than all these countries. As above-mentioned, benchmarking section, since 2008 Sudan’s education sector share has been decreasing, and between 2008 and 2014, the education sector share has decreased to 1.4% of GDP (World Bank and MoHESR, 2020).

(ii) Outdated Engineering Education Curriculum: One of the main engineering education issues in the country is the outdated curriculum. According to the two engineering education regulatory bodies, MoHESR and SEC, the curriculum for a Bachelor of Science in engineering must contain four categories of courses: Math and Science, Engineering Science, Applied and Design Engineering, and Humanities and Social Science courses. Below Table 2.10 shows these 4 categories and associated percentages (Osman, 2014). Although the overall categories of the curriculum are somehow reasonable, the details of the curriculum demonstrate its inability to graduate engineers capable of competing neither in the local nor in the global job market. This is evident by the high rate of unemployed engineers; the increasing number of foreign engineers and technicians for the local demand for engineering jobs; and irrelevant low-paying jobs for Sudanese engineers (World Bank and MoHESR, 2020).

The curriculum to obtain a bachelor’s degree, in chemical engineering, from UofK, which is considered the top university in Sudan, with international recognition, consists mostly of theoretical courses; even applied and design courses represent less than 10% due to inadequate facilities (UofK website). These theoretical courses are not related to industry. They are far from graduating employable engineers with the right sets of technical and soft skills required by industries.

Table 2.10: Categories of Courses for Bachelor of Science in Engineering

Courses	**Percentage (%)**	**Examples**
Math and Science	25-30%	Math, Physics, Chemistry, Programming
Engineering Science	25-35%	Major-dependent
Applied and Design Engineering	25-35%	Major-dependent
Humanities and Social Science	10-15%	Languages, literature, philosophy, economics, history, geography, law, politics, religion, management, ...etc.

(iii) Ineffective Traditional Teaching and Learning Methods: Traditionally, educators in Sudan have adopted lecture methods as a way of teaching. Yet most, if not all, engineering colleges employ the same teaching methods (Osman, 2014). Prince and Felder (2020) described this traditional teaching method as deductive instruction, which implies that: the lecturer explains, to his/her students, general principles, and applications of a certain topic; and allows students to practice these principles by solving a set of homework problems; and finally assesses students' abilities to resolve similar problems. This ineffective teaching method does not consider the various learning styles of engineering students. Nevertheless, many researchers suggested alternative approaches where students are allowed to work in small groups, using different learning tools (Felder, 2021, 2020, and 2017; Prince et al., 2020).

(iv) Inadequate Human Capacity- Academic and non-Academic Staff: For so long engineering education in Sudan has been suffering greatly from the scarcity of well-qualified academic staff and by low instructor-to-student ratio. On average, in 2019 the instructor-to-student ratio was estimated to be 1:34, which was far below the 1:15 required ratio by regulatory agencies to recognize and accredit engineering programs. On top of that, the required ratio of professorial rank should be around 1:100 and 1:65 for professor-to-student and associate professor-to-student ratio, respectively. These numbers show that most engineering programs do not satisfy the requirement of instructor-to-student ratio to be recognized or granted accreditation (Osman, 2014).

Gasim (2014) stated that more than two-thirds of all academic staff, from teaching assistant to professorial ranks, did not hold PhD degrees in their field.

Another issue with academic staffing is the gender disparity of higher academic positions in tertiary education. In 2018, females represented about 48% of the total lecturer and teaching assistant positions, while females accounted for only 29% of the total professorial rank positions. When it comes to engineering academic positions, the male-to-female ratio is almost 1.9:1 (MoHESR Census Data, www.mohe.edu.sd).

The unattractive teaching environment and poor financial compensation led highly qualified faculties to leave the country looking for a prosperous, satisfying career elsewhere. Therefore, local engineering colleges are left with only under-qualified faculties, retiree professors, and others who are awaiting their opportunities to leave. On top of that, the promotion of academic staff is not linked to professional development programs (Khojali, 2014; Gasim, 2014).

(v) Students' Under Preparedness for College: The duration of general education was reduced to an 11-year instead of a 12-year system, which is a standard and globally recognized system (World Bank and MoHESR, 2020; MOE, 2014). The 11-year general education system, combined with an anemic education budget, inadequate curriculum, obsolete teaching methods, and insufficiently qualified schoolteachers, led to under-prepared high school graduates for college in general, and for engineering colleges in particular (Osman, 2014; World Bank and MoHESR, 2020; MOE, 2014). Although engineering freshmen have a good knowledge of math and science, they still lack meaningful scientific concepts. This is due to missing components of technology and engineering within pre-college education (World Bank and MoHESR, 2020).

(vi) Inadequate Facilities for Engineering Education: Insufficient funding for the education sector has left education in general, and engineering education in particular, without appropriate facilities. Most engineering colleges have been facing devastating shortages of libraries, laboratories, equipment, instruments, and supplies necessary for teaching and training engineering students. It is worth noting that available laboratories and equipment are outdated without enough supplies and consumables. The woeful situation of engineering colleges' facilities is due to spiteful budgets that have been assigned to both public and private engineering colleges. The insufficient funding has been evident in the education sector's low share of the GDP, which was 2.7% of the GDP in 2008, and has become less than 1.4% in the following years (World Bank and MoHESR, 2020).

(vii) Issues of quality control and accreditation measures: As mentioned in section 2.1.4, engineering education, as part of tertiary education, is regulated and administered by the MoHESR. All engineering programs must be recognized and accredited by the MoHESR, based on rigorous accreditation procedures, and all engineering graduates must be licensed and registered by the Sudanese Engineering Council (SEC). Moreover, in 2003 MoHESR formed an academic, technical, and administrative accreditation and evaluation unit; its goal is to improve the quality and the performance of higher academic institutions, establish self-evaluation units within academic institutions, upskilling the human resources, and adopt and disseminate a culture of quality (World Bank and MoHESR, 2020). Nevertheless, none of the engineering programs has earned any-, but not even applied for, international academic accreditation, ABET for instance. This fact requires revision of the implementation of the quality control and accreditation measures from international accreditation perspectives.

(viii) Other issues: Freedom of expression and freedom of educators to teach, research, or pursue knowledge, wherever it may lead, have been completely missing from the Sudanese academic institutions, between 1989 and 2019. Lack of academic freedom was one of the main reasons that had led qualified academicians to leave the country. Fortunately, due to the 'December 2018 Revolution', academic institutions have started claiming their academic freedom (World Bank and MoHESR, 2020). Also, the research and publishing activities, in Sudan, are very low. This fact is evident by the low H-index of 110, in all subject areas, which is below all H-index from all other benchmarking countries except Rwanda. While, in engineering, the H-index is even too low, only 34. According to Scimago Journal and Country Ranking, in 2020, Sudan's H-index is based on 1329 documents in all subject areas, and only 138 documents in engineering (Kenoma.com. World Data Atlas; SCImago Journal and Country Rank). Needless to say, the issue of research and publishing conditions, in addition to poor funding, is due to brain drain, obsolete facilities, inadequate educational technology and ICT environment, and weak university/industry relationships.

2.2 Global Engineering Education Research

This section, which discusses global engineering education research (EER), is divided into three sub-sections: the first one gives an overview of global EER; followed by existing EER as part of a broader field, known as STEM, which stands for Science, Technology, Engineering, and Math; then, the third sub-section is about EER as standalone field. Each sub-section includes various examples from around the world, namely the United States, Europe, Africa, Malaysia, and Australia.

2.2.1 Overview of Engineering Education Research

EER is a relatively new field, which started a little over two decades ago, although its history goes back to the 80s of the last century. Beddoes (2014) quoted Jamieson et. al. (2009), 'The importance of engineering education research began to surface in the United States in the mid-1980s when the National Science Board issued its report Undergraduate Science, Mathematics, and Engineering Education …, in which it stated: 'The recommendations of this report make renewed demands on the academic community – especially that its best scholarship [emphasis added] be applied to the manifold activities needed to strengthen undergraduate science, engineering, and mathematics education in the United States' … These and other efforts paved the way for the assembly of a small community of scholars in engineering education by the beginning of this century.' (p. 9, cited in Beddoes, 2014).

For instance, in 2003, a group of researchers, from Purdue University in the state of Indiana, United States, proposed a new framework to attract engineering faculties and to have them engaged in the field of EER. The group proposed a formal academic program, called the School of Engineering Education Degree (SEED), within the School of Engineering, at Purdue University. SEED offers bachelor, master, and doctorate degrees in engineering education (Katehi et. al., 2014).

Beddoes (2014) linked the emergence of the EER field to rigor and methodology discourses, rather than descriptive engineering education publications. As well, it is linked to institutional structures, national interests, and the activities of professional societies; for example, the first Cambridge Handbook of EER was published in 2014. Beddoes (2014) illustrated many examples of articles favoring the discourse of the methodology diversity; she quoted Koro-Ljungberg et. al. (2008) who stated, 'While quantitative research requires the use of statistical methods which can provide an aura of trustworthiness, qualitative research can appear at first glance as if it simply involves interviewing a few people and then writing up a summary … In fact, qualitative research can be just as difficult to conceptualize, and be as methodologically and theoretically challenging, if not more challenging, than quantitative research. It is important for qualitative researchers to strive for high standards of rigor … Continuous and systematic exposure to the methodological tools available to study complex problems and socio-cultural phenomena … would assist researchers interested in qualitative research questions and methods to conduct rigorous studies.' (p. 172–73, cited in Beddoes, 2014)

2.2.2 Engineering Education as Part of STEM Research

Chomphuphra et. al. (2019) investigated only 56 research articles in STEM that have been published, between 2007 and 2017, in the SCOPUS database, in addition to the other two journals. They stated that published articles on STEM research have been rapidly increasing over 10 years. Ten worldwide countries were involved in publishing these chosen articles: the United States published 46 out of this set of 56 articles, while Australia, Canada, and the UK published two articles each, in addition to six more countries, each published one article. The main popular published topics were innovation for STEM learning, professional development, and gender gap and career in STEM, respectively. More comprehensively, Takeuchi et. al. (2020) followed the trend of peer-reviewed publications on STEM education, which has been growing exponentially, between 2007 and 2017, with a total of 2,171 articles globally. They reported that in 2017, the number of publications in STEM education increased by a factor of 20 compared to the number published in 2007.

Lack of enough qualified engineers, ready to face the challenges of the century, has been the focus of a vast amount of research; and many researchers have attributed this issue to the shortage of high school graduates with STEM concentration, low enrolment, and poor retention of STEM students at both high school and at tertiary education levels. Internationally, many organizations have put efforts into investigating and diagnosing the shortage of STEM graduates; of them are UNESCO, the National Research Council (NRC), and the Royal Academy of Engineering (RAE). They regularly produce reports on this matter.

As well, researchers have attempted to address STEM-related issues and how to resolve them. Many of them have devoted their efforts to investigating pre-college academic performance, providing good high school graduates with strong STEM knowledge necessary for their success at tertiary level education; few examples are: (i) Appiah-Castel et. al. (2020) analyzed the trend of female enrollment, over sixteen years between 2003 and 2018, in STEM disciplines at the Kwame Nkrumah University of

Science and Technology (KNUST), Ghana in West Africa. They concluded that the progress of KNUST’s directives to increase the enrolment of female students in STEM tertiary education has been very slow. (ii) Shahali et. Al. (2017) presented an overview of STEM education in Malaysia, which included the Malaysian government's commitment to a STEM-driven economy. STEM curricula, from pre-school to pre-college, have been one of the main focuses of all stakeholders. (iii) Hulme et. al. (2014) produced a report titled, ‘Tackling transition in STEM disciplines project’. It is about issues facing students approaching STEM higher education in England and Wales. The report identified five comprehensive themes: ‘1. The strategic importance of student transition into higher education. 2. The STEM student journey. 3. Student preparedness for transition from pre-tertiary education to higher education. 4. Awareness, communication, and transition from pre-tertiary to higher education curricula. 5. Change and collaborative initiatives to ease transition’.

Alam (2022), Tandrayen-Ragoobur et. al. (2022), Reilly et. al. (2017), Jamil et. al. (2019), and García-Holgado et. al. (2018), among other researchers, have studied gender disparity in the engineering education field: (i) Alam (2022) analyzed academic research over the past three decades, and he concluded with six reasons for the female underrepresentation in STEM professions; he wrote, ‘(a) preconceptions and biases based on gender, (b) field-specific ability beliefs, (c) lifestyle values or work-family balance preferences, (d) professional inclinations or desires, (e) comparative cerebral capabilities, and (f) cognitive aptitude.’ (ii) Tandrayen-Ragoobur et. al. (2022) investigated the effect of personal, environmental, and behavioral factors on gender disparity in STEM education in Mauritius, Africa. They stated that controlling these three factors would allow other reasons to play an important role in the student’s STEM degree choice, namely self-efficacy, and the student’s academic performance in related subjects at the secondary school level. They demonstrated that women are more likely to choose STEM degrees than their male counterparts whenever they get family, school, and teacher support. (iii) Reilly et. al. (2017) provided an overview of the research literature on the topic of spatial ability, which is responsible for quantitative reasoning, including science and mathematics. Although researchers proved that there is a gender difference in spatial ability; however, introducing brief spatial learning into early education resulted in a significant improvement in spatial ability. (iv) Jamil et. al. (2019) combined gender essentialist ideology with self-expressive value systems to compare gender disparity in engineering education in the USA to the same issue in Jordan and Malaysia. They rescoped the problem of increasing women enrolment in engineering education programs in the USA, and identified factors that led to gender parity in Jordanian and Malaysian engineering programs. The authors were planning to develop a systematic framework for discussing women in engineering across various cultures. (v) García-Holgado et. al. (2018) believes that nowadays societies should approach and end the foundation of gender disparity in education by minimizing stereotyping and dominant culture.

Others have researched the ethnicity and socio-economic background of high school students who have been less fortunate to attend quality STEM schools due to their financial problems and/or due to a lack of awareness about the importance of STEM education. Many studies have studied the effect of demographic data on STEM career aspirations in the USA (e.g., Saw et. al., 2018; Niu, 2017; Betancur et. al., 2018; Cribbs, et. al., 2021). Both Saw et. al. (2018) and Niu (2017) have investigated similar sources of data about the influence of gender, race, ethnicity, and socioeconomic status (SES) on choosing a STEM career. The former team of researchers investigated the nationally representative High School Longitudinal Study of 2009, while Niu has mainly examined the Education Longitudinal Study of 2002 by the National Center for Education Statistics. (i) Saw et. al. (2018) studied the influence of gender, race, ethnicity, and SES, independently and collectively, on the disparities in STEM careers. Their findings demonstrated the negative effect of the low SES and nonwhite background on choosing STEM professions; they state, '… indicated that female, Black, Hispanic, and low SES students were less likely to show, maintain, and develop an interest in STEM careers during high school years. Compared with White boys from higher SES backgrounds, girls from all racial/ethnic and SES groups, as well as Black and Hispanic boys from lower SES groups, consistently had lower rates of interest, persistence, and developing an interest in STEM fields.'. (ii) The same conclusion, related to the SES, was drawn by Niu (2017). She concluded that ‘family SES is a source of inequality in STEM enrollment’. She added, ‘Higher SES students, including those traditionally underrepresented in STEM fields, benefit from pushing effect to pursue STEM studies, while lower SES students are disadvantaged in making well-informed decisions of STEM enrollment.’ (iii) Also, Betancur et. al. (2018), independently, researched the effect of socioeconomic status on science achievement. (iv) Most of the above-reviewed research has attributed the lack of success in STEM education to limited access to STEM subjects, due to minority underrepresentation and low SES; inappropriate pre-college STEM curricula; and/or inefficient T&L methods. At the same time, all suggested solutions were designed to include: Introducing early STEM curricula (K-12), facilitating early access, for all, to STEM subjects, and adopting efficient T&L methods. In other words, all attributes and suggested solutions are centered around students and their socio-cultural and socio-economic contexts. Nevertheless, connecting these issues to the broader T&L environment may reveal additional perspectives and a better understanding of these issues (see knowledge gap, section 1.1.2).

2.2.3 Engineering Education as Standalone Research

This section is concerned with existing EER, as a standalone discursive field, using discourse analysis; in addition to some frameworks and models that have been developed while resolving certain issues within the EER field.

2.2.3.1 Engineering Education Research- Using Discourse Analysis

Although Foucault has developed Discourse Analysis (DA) in the field of social sciences, criminology, nursing and health, many researchers have widely employed DA in academic research as well as in other practical fields. Examples are: Development studies (Gasper, 2022); economics (Aghajani et. al., 2020; Fairclough, 2023); education

(Warriner et. al., 2017; Fairclough, 2023); medical field (Yazdannik et. al., 2017); STEM education (Schwortz et. al., 2022; Takeuchi et. al., 2020; Langman et. al. 2017); and, in the engineering education field.

As far as engineering education is concerned, the following paragraphs discuss the utilization of DA in the field of engineering education research as a standalone field.

The process of identifying and framing a problem, which is called 'Problematization' is essential for seeking any solution (Beddoes, 2021). Using discourse analysis, Beddoes (2021) investigated how underrepresentation is problematized. She examined journal articles and conference proceedings, on engineering education, for the period between 1995 and 2008. The focus of her study was on women and gender issues; however, she pointed out that the same analysis might help to shed light on the broader diversity issues. The reviewed dataset revealed three discourses: economic competitiveness, benefits to the field, and social justice and equality; accordingly, Beddoes identified four categories of problematization; she names them as follows, '… they are: economic competitiveness, professional service and representativeness, women's attributes, and social justice.' (Beddoes, 2021).

Syed et. al. (2022) used a mixed research method to perform document analysis, based on Fairclough's critical discourse analysis (CDA), towards achieving their research goals, namely: '1) Identify the gaps in Malaysian engineering education toward preparing 21st Century educators. 2) Study the transition of engineering educators in their attempt to implement innovative education. 3) Develop a framework for transforming engineering education through the infusion of innovative teaching and learning to support the development of 21st Century Engineers.' It is notable, that this work represents a partial result of a comprehensive EER, a work in progress, in the Malaysian context.

Jia-Ling et. al. (2014) applied discourse analysis to evaluate the effectiveness of the 'Four-Practice Instructional Model in flipping classrooms' in facilitating engineering learning through dialogic discussions and maximizing the teaching and learning potentials through better instructional approaches. They conclude that flipped classrooms have a positive impact on students learning beliefs and learning habits; they wrote 'We recognize that both students and instructors are offered a unique opportunity to reach the important educational goal of maximizing learning potentials while recognizing gaps between the level of students' learning and the potential of their learning. "Flipping lectures" sets a context to meet this goal through the joint effort supported by the Four-Practice instructional approach.

Douglas et. al. (2014) interviewed eight senior students, studying Materials Science and Engineering, at a large Southeastern University, after they had solved four engineering problems. The objective of the study was to determine how students describe their existing and emerging identities as engineers. Analyzed data identified six discourses, namely pedagogical, economic, individualistic, peer collaboration, math, and research. Accordingly, these senior students perceived themselves as students rather than as emerging engineers, and, while solving engineering problems, they could not make connections between their academic experiences and engineering practices. This disconnect led to the questioning of the education of future engineers. To help students perceive themselves as emerging engineers, the study asked the following, 'What are the implications for how students ultimately practice engineering? What pedagogical practices promote the self-identification of students as engineers?

Abd Rahman et. al. (2020) investigated educators' transition from traditional teaching to active learning; they employed the CDA methodology to develop and conduct a 2-hours Focus Group Discussion (FGD) with a group of lecturers at one of the universities in Malaysia. FGD was about the aspect of social practices surrounding the implementation of active learning. The discussion revealed a positive attitude toward active learning practices. However, the study identified that any educators' resistance was due to the imposter syndrome among resistance educators. They stated, 'The imposter syndrome, therefore, emerges from the ill relationship between intention and action. Thus, the practice of active learning is habitus rather than reflexive.

Berge et. al. (2018) utilized CDA to investigate documents, in the form of text, pictures, and photos, obtained from the websites of nine different Swedish mechanical engineering programs. They identified three societal discourses concerning 'technological progression', 'sustainability', and 'neoliberal ideals'; accordingly, engineering identities have been labeled: traditional, contemporary, responsible, and self-made engineer, which means the bachelor's in engineering may be designed for students who wish to develop products, present vocational options, and/or learn to understand and improve technology.

It is worth mentioning that the discourse analysis methodology has been used mainly, within the EER field, to investigate fragmented topics/issues such as: Curricular design, educators' readiness to support engineering students, innovative T&L methods, 21st-century engineering attributes, technological progress, underrepresentation issue, sustainability, etc. (see knowledge gap, section 1.1.2).

2.2.3.2 Engineering Education Research- Additional Frameworks and Models

In addition to OBE, CA, and HPL frameworks (sections 2.5.1 to 2.5.3), which have been utilized to elevate engineering education programs in many countries, worldwide, this section presents many frameworks available for improving individual elements of engineering education.

2.2.3.2.1 Curriculum Design: Engineering Design Curricular

Bloom's taxonomy of educational objectives (1956) and Kolb's learning cycle (1984) are highly appreciated in engineering education, especially for teaching design. Moreover, integrating design into the engineering curriculum is necessary for graduating effective engineers. Atman et al. (2014) state, 'For engineers, designing integrates engineering knowledge, skill, and vision in the pursuit of innovations to solve problems and enable modern life’. Therefore, faculties have to inject, into engineering programs, design curricular and pedagogical experiences to enhance the learning outcome. However, design requires a higher level of Bloom’s taxonomy namely synthesis, analysis, and evaluation. The dilemma is the mismatch between teaching and assessing, which results in unsatisfactory learning outcomes (Lord, 2014); he quoted Stice, ‘However, too often in engineering education, instructors teach at the lower levels of Bloom’s taxonomy but assess at the higher Levels, or do not consider all aspects of the Kolb learning cycle.’ (Stice, 1976, cited in Lord, 2014). See Figure 2.6.

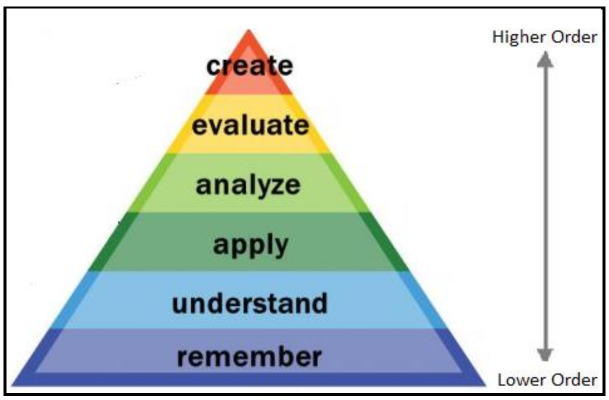

Figure 2.6: Lower and Higher Levels of Bloom’s Taxonomy

To address this issue, incorporating open-ended problems and identifying different learning styles of students are found to be very effective (Felder and Brent, 2017; Passarelli and Kolb, 2023).

According to many researchers, the engineering design approach is the integration of the learning objectives (learning outcomes), assessment of the outcomes, and teaching (Pellegrino, 2020; Lord, 2014; Streveler et al., 2014). Streveler et al. (2014) encouraged engineering educators to align content, pedagogy, and assessment of outcomes for curricula, framing this as an ‘engineering design approach.’

Lord (2014) argued that the ‘engineering design approach’ should be utilized for the engineering curriculum throughout the engineering program, ‘… this approach should be used for all years of the engineering curriculum and not reserved for the “special” design courses for first year and senior students.’

2.2.3.2.2 Conceptual Change and Misconceptions in Engineering Education

The issue of engineering graduates not understanding simple foundational engineering concepts was addressed by Streveler et al. (2014) using their research on ‘Conceptual Change and Misconceptions in Engineering Education’. They stated that one’s conceptual understanding of a topic is the collection of his/her concepts, beliefs, and mental models. Furthermore, they defined a few terminologies as follows: ‘Concepts are pieces or clusters of knowledge, for example, “force,” “mass,” “causation,” and “acceleration.” Beliefs are propositional relationships between concepts, for example, “a force on a mass causes acceleration.” Mental models are groups of meaningfully related beliefs and concepts that allow people to explain phenomena and make predictions; for example, an expert dynamics instructor would use her mental model of Newtonian physics to predict an object’s motion.’ (Streveler et al., 2014).

Additional definitions are: ‘Conceptual change is the process of altering one’s conceptual understanding.’ and ‘Misconception is any aspect of an individual’s conceptual understanding that resists conceptual change and contributes to an incorrect, naïve, or unproductive conceptual understanding.’ Theories of conceptual change (CC) assume that a learner’s conceptual understanding may dictate greatly his or her learning. Streveler et al. (2014) stated, ‘… what an individual learns is at least partially controlled by what they already know.’ However, these theories disagree on the structure and the effect of the existing knowledge.

Streveler et al., (2014) named 3 opposing theories to describe conceptual understanding: '1) Hierarchical categorization of knowledge, describe conceptual understanding as categories and subcategories. 2) Weak grouping of experiences and perceptions, describe conceptual understanding as component pieces. 3) Form of social behavior.' As well, they divided their conceptual change research into three parts according to the research questions of each part: (1) Curriculum-focused research: Research questions are, 'What can the engineering educators do to address students' misconceptions?' or, 'How do students respond to conceptual change interventions?' (Streveler et al., 2014). This research focuses on improving pedagogy. They ranked the following pedagogies- from most effective to least effective, '(i) team discussions with hands-on activities and concept sketching; (ii) team discussions with contextualized concept mini-lectures and activities; (iii) team discussions, contextualized concept lectures and activities, plus pre-/post- topic assessments and daily reflections; (iv) lecture with some discussions; and (v) lecture only with no team discussions or activities.' (2) Measurement-focused research: Research questions are, 'How reliable is X measure of conceptual change?' or, 'What exactly does instrument Y measure?' (Streveler et al., 2014). This focuses on concept inventories to measure pedagogical practices for conceptual change. (3) Theory-focused research: Open-ended research questions are, 'How do students relate concepts A and B in contexts X and Y?'

2.2.3.2.3 Problem-Based and Project-Based Learning in Engineering Education

It is well known that one-way dissemination of knowledge using lectures is not very effective. Furthermore, Kolmos and Graaf (2014) mentioned that many learner-centered models were introduced after WWII; they state, 'In higher education concepts such as "self-directed-learning," "case-based learning," "inquiry-based learning," "experiential learning," "service learning," "project-based service learning," "active learning," "CDIO (Conceive, Design, Implement, and Operate)", "project-based learning," and "problem-based learning" were introduced in the decades after the Second World War.'

The last two learning models: problem-based learning and project-based learning, both known as (PBL) were introduced between 1965 and 1975, by what is known as new reform universities. According to Kolmos and Graaf (2014), three ideas led to the foundation of the new universities, '(i) a need for new knowledge and skills in the labor market, (ii) the study programs were too fragmented and without relation to the outside world, and (iii) there was a need for more democracy and student influence.'

The medical faculty of McMaster University in Canada and Maastricht University in the Netherlands are the first, among others, to initiate the PBL models. Also, two universities in Denmark, Aalborg, and Roskilde University, have combined both problem-based learning and project-based learning models into problem-based project-organized learning (PBL). Table 2.11 shows the six characteristics of the learning process by Barrows (1996), and the five characteristics of both the learning process and the implications for the social and the content dimension of learning by Illeris (1976).

Table 2.11: Original Learning Principles- PBL Universities (Kolmos and Graaf, 2014)

McMaster & Maastricht Universities- PBL (Barrows, 1996)	**Aalborg and Roskilde Universities PBL & PBL (Illeris, 1976)**
• Problems form the focus and stimulus for learning. • Problems are the vehicle for the development of problem-solving skills. • New information is acquired through self-directed learning. • Student-centered • Small student groups • Teachers are facilitators/guides	• Problem orientation • Interdisciplinary • Exemplary learning • Participant-directed • Teams or group work

In the problem-based learning model a team of students starts with a well-defined problem; while in the project-based learning model, a team works on solving an ill-defined problem, and presenting a project report; Prince and Felder (2020) state the difference between these two learning models as, 'Problem-based learning (PBL) begins when students are confronted with an open-ended, ill-structured, authentic (real-world) problem and work in teams to identify learning needs and develop a viable solution, with instructors acting as facilitators rather than primary sources of information'. Prince and Felder (2020) view the problem-based as a process-oriented approach, while the project-based as a product-oriented approach; Table 2.12 shows the difference between process-oriented and product-oriented approaches. As well Figure 2.7 depicts the differences and commonalities between the PBL and PjBL, according to Brundiers and Wiek, (2014). They propose a framework, see Figure 2.8 based on PBL and PjBL to allow students to gain sustainability competencies, participatory research education, and experiential learning.

The employability of graduating engineers requires engineering knowledge, competencies, and professional skills. Therefore, accreditation agencies (ABET for example) included professional skills in the engineering curriculum. Moreover, universities have been collaborating with industries and society to address real-life problems and community needs (Kolmos, 2014; Kolmos and Graaff, 2014).

Over the last fifty years, worldwide universities, including engineering programs, have developed diverse, in terms of size and scope, PBL models, and practice. Implementing PBL models has boosted the retention rate of engineering students, in addition to addressing the market needs for competent engineers (Kolmos, 2014).

Table 2.12: Differences Between Problem- & Project-Based Learning- (Kolmos, 2014)

Problem-based learning	**Project-based learning**
• Process	• Product and outcome
• Focus on the problem	• Focus on the problem solving
• Students work out learning needs	• Lectures
• Facilitation	• Supervision
• Can be from the beginning	• Often at the end of the degree
• Learning cross-disciplines is a necessity	• Can bring together taught subjects

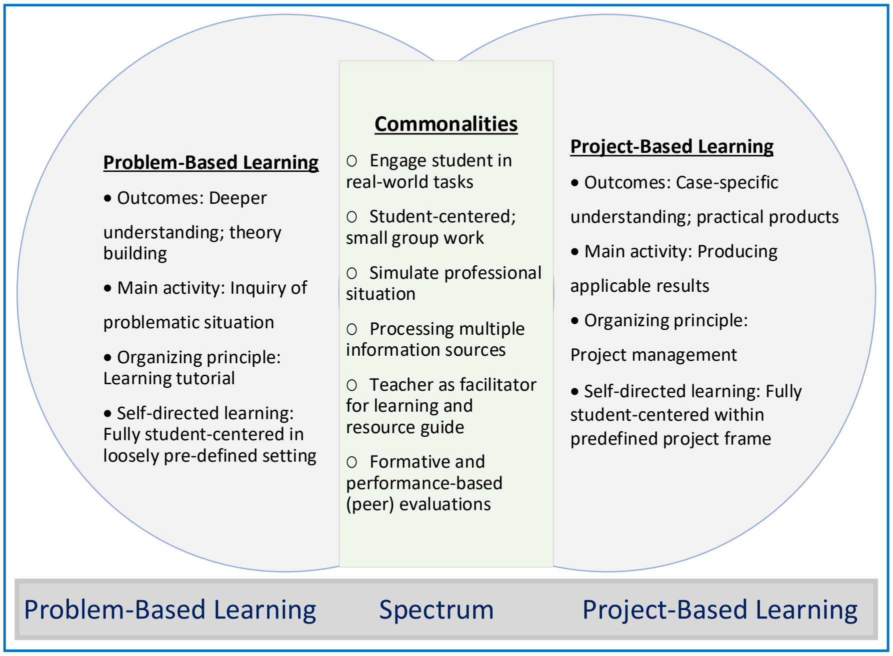

Figure 2.7: Commonalities and Differences between PBL/PjBL (Adopted from Brundiers and Wiek, 2014)

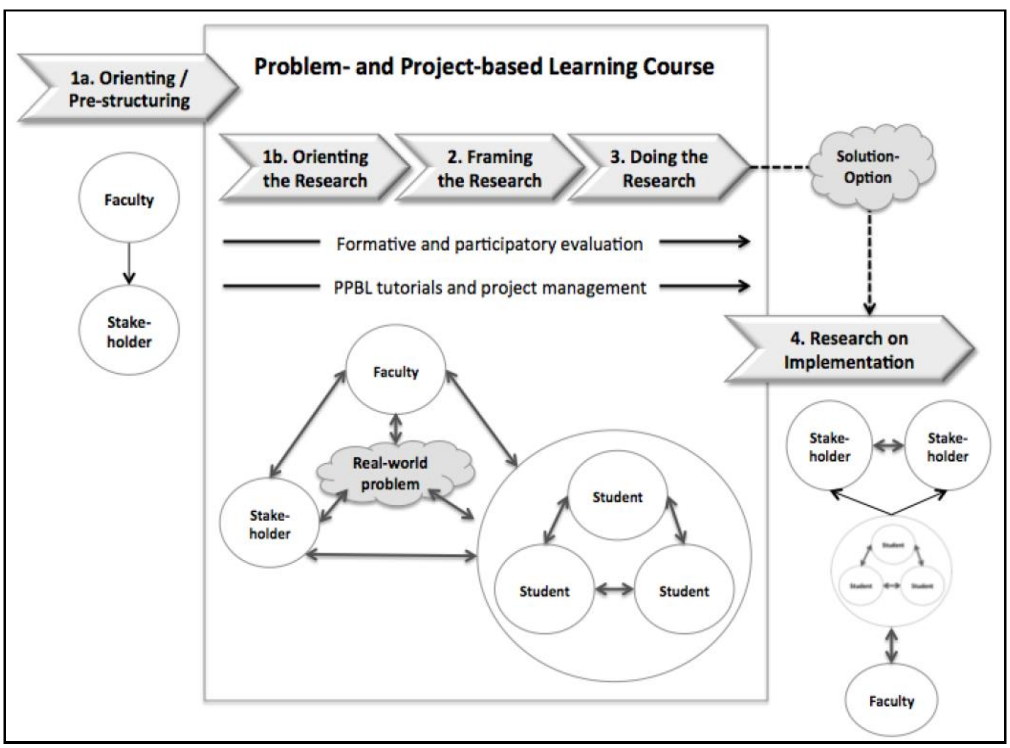

Figure 2.8. Process Model of PPBL courses—Steps, Processes, Actors Involved, and Outcomes (Brundiers and Wiek, 2014).

2.2.3.2.4 Cooperative Problem-based Learning (CPBL)

To prepare engineering graduates from UTM, ready for 21st-century challenges, Yusof et al. (2015) propose a CPBL framework, which combines cooperative learning (CL) and problem-based learning (PBL). They noted that PBL is more applicable in small class sizes of up to 10 students, which is not the case in the engineering program at UTM. Figure 2.9 shows PBL as implemented by the engineering program at UTM, which consists of three phases: i) problem restatement and identification phase; ii) peer teaching, synthesis of information, and solution formulation phase; and iii) generalization, closure, and reflection phase (Yusof et al., 2014).

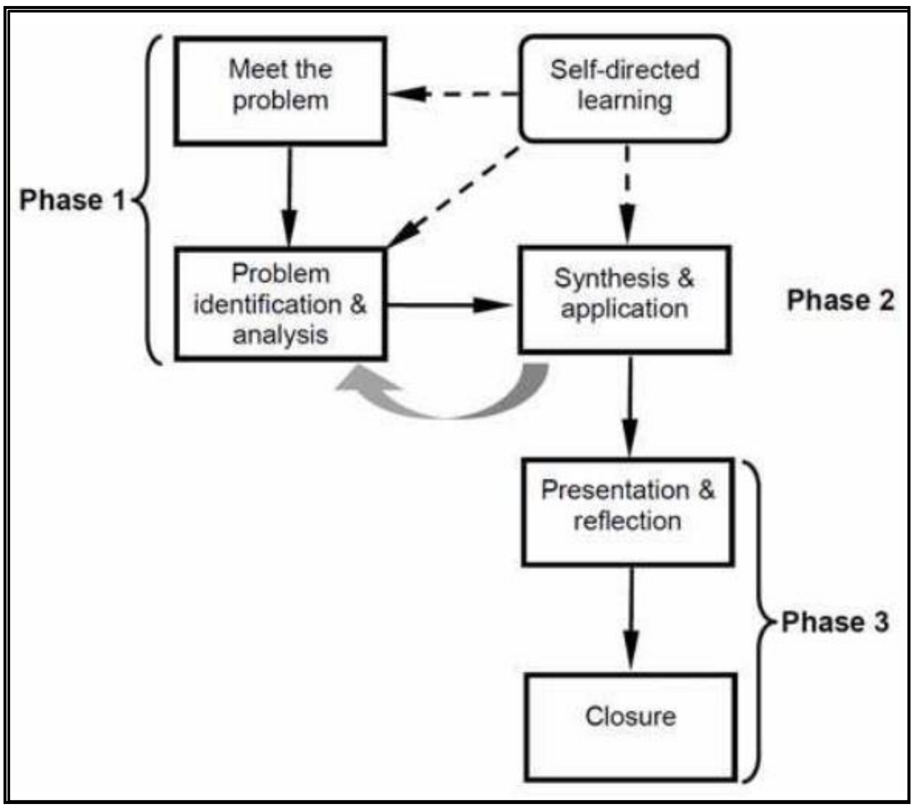

Figure 2.9: The UTM PBL Framework (Yusof et al., 2014)

Yusof et al. (2014) claim that CPBL is more suitable for large class sizes, between 40 and 60 students, working in small groups of 3 to 5 students. They quoted M. J. Price (2004), ‘Cooperative Learning (CL) is proven, through various studies, to promote cooperation among students resulting in improved learning quality and skills, such as academic achievement, interpersonal skills, and self-esteem'. As illustrated by Figure 2.10, CPBL includes the same 3 phases of PBL with emphasis on the five CL principles, to ensure achieving good teamwork: positive interdependence, individual accountability, face-to-face interaction, appropriate interpersonal skills, and regular group function assessment.

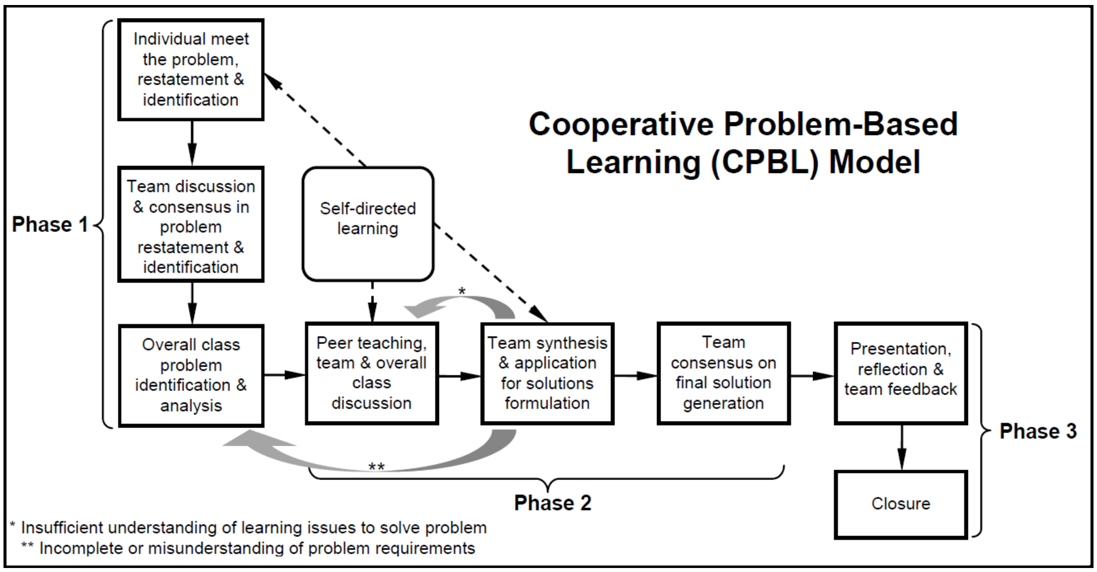

Figure 2.10: The Cooperative Problem-Based Learning Cycle (Yusof et al., 2014)

2.2.3.2.5 Project-Based Learning (PjBL) in Developing non-Technical Skills

Noordin et al. (2018) proposed a framework based on PjBL for developing non-technical skills required by the industry. Figure 2.11 depicts the framework, which consists of 3 elements: coaching and supervision, continuous assessment, and real-world experience. For the first element, coaching and supervision, two types of facilitators are required to guide students through their projects: lecturers who are responsible of ensuring that objectives and learning outcomes are achieved; and engineers who provide students with real-world engineering feedback. The second element, continuous assessment, is required to ensure the progress and functionality of the project and technical and non-technical skills. The third element, real-world experience, consists of three parts: real-world project, industrial involvement, and multidisciplinary team.

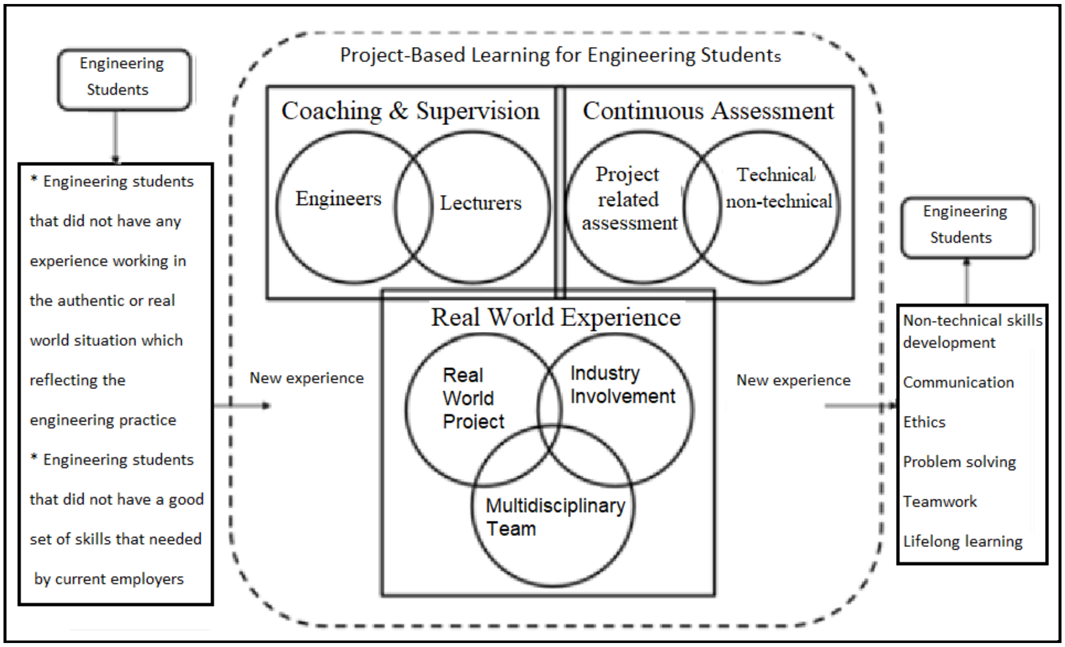

Figure 2.11: PjBL Framework to Develop Non-Technical Skills for Engineering Students (Noordin et al., 2018)

2.2.3.2.6 Lean Engineering Education Framework

For decades, many big companies, such as Toyota Motor Company, GE, GM, etc., have been following the Lean Production model to stay competitive, in the global market, and to maximize their profitability. The term 'Lean Production' was based on what is known as TPS (Toyota Production System). The essence of TPS is to identify and eliminate all non-value-added activities, called wastes, from a process, and create value for the final customer who would not want to pay for these wastes. To promote TPS, Toyota Motor Company adopted the Toyota Education Model, or learning by doing. The successful story of Lean Production in the industry has led many researchers to consider the concept of 'Lean Thinking' in academia to achieve quality and customer satisfaction, see Figure 2.12 (Jasti et al., 2020; Pusca and Northwood, 2016; Flumerfelt et al., 2014). Although the academic environment is completely different than the industry, still lean tools, such as: value stream mapping, root cause analysis, and kaizen, may be used to identify problems and find solutions for curriculum development (Pusca and Northwood, 2016). Table 2.13 compares lean thinking principles from the Lean Production point of view versus the LEE point of view.

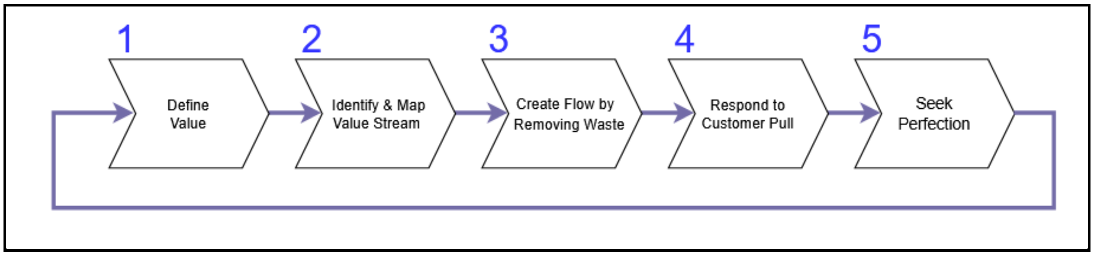

Figure 2.12: Lean Thinking Principles

Table 2.13: Lean Principles from Lean Production/ LEE Point of View

Lean Thinking Principles	Lean Production	Lean Engineering Education
Value	Defined by the customer, and the customer is willing to pay for	value (education) client (students)
Value Stream	Identify/map processes consist of all value-/non-value- added actions required to create value. increases understanding of value-adding and nonvalue-adding activities	Engineering students want an education that perfectly serves the employer and society's needs, with faculty collaboration and engagement that care for them.
Continuous flow	smooth and leveled workload without waste pushing back	workload pushing back the students, faculty, and society.
Pull System	Convert from a push to a pull system that is driven by customer demand	--
Pursuit perfection	Search continuous improvement	--

Flumerfelt et al. (2014) defined Lean Engineering Education (LEE) as, 'A systematic, student-centered and value-enhanced approach to educational service delivery that enables students to holistically meet, lead and shape industrial, individual and societal needs by integrating comprehension, appreciation, and application of tools and concepts of engineering fundamentals and professional practice through principles based on respect for people and the environment and continuous improvement.' Based on this definition, they propose (the LEE) framework to address the challenges facing 21st-century engineers, such as technological development, climate change, global market, etc., see section 2.1.2, and to resolve the discrepancies between engineering programs outcomes and the required skills by the engineering professional practice (Flumerfelt et at., 2014). As illustrated by Figure 2.13, the LEE framework combines technical content with competency development, namely: Ethics, System Thinking, and Sustainability.

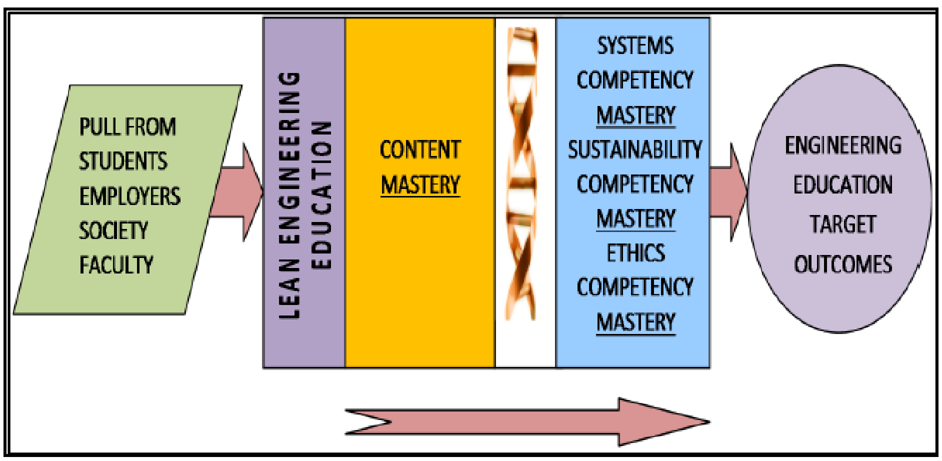

Figure 2.13: LEE Framework (Flumerfelt et al. 2014)

2.2.3.2.7 Framework for Assessing Teaching Effectiveness

Teaching and learning, in tertiary education, are complex and hard. This is because of many factors that influence how people learn, and because of a faculty's multiple roles in instruction, course and content design, material construction, mentoring and advising, etc. One of these factors, which adds to the complexity of teaching and learning in tertiary education, is the lack of appropriate faculty preparation. There are 3 levels of professional teaching knowledge: The first level is the content knowledge, which is acquired during graduate study; the second level is the general pedagogical knowledge, which represents the general teaching tools; and the third level is the content pedagogical knowledge. Tertiary education should have in place proper professional development programs to ensure that the latter two levels of professional knowledge are met, and good teaching preparation occurs (Simonson et al. 2021).

Newly hired educators are supposed to be, at least, at the first level of professional teaching knowledge (pre-service); the latter two levels should be developed using (in-service) professional development programs. Academic institutions usually have procedures and policies to evaluate the effectiveness of their academic programs as well as their faculties for tenure and promotion. Simonson et al. (2021) claimed that most of the in-place procedures to evaluate teaching are inadequate and fall short of achieving the intended goal of improving teaching. They propose a Framework for Assessing Teaching Effectiveness (FATE) by following these 3 steps: 'i) identify the activities to be evaluated; ii) define observable achievements, products, and/or performances; and iii) identify sources of information'. Figure 2.14 shows the interaction among the 4 elements of the FATE in a rubric (categories) for effective teaching evaluation (Simonson, 2021).

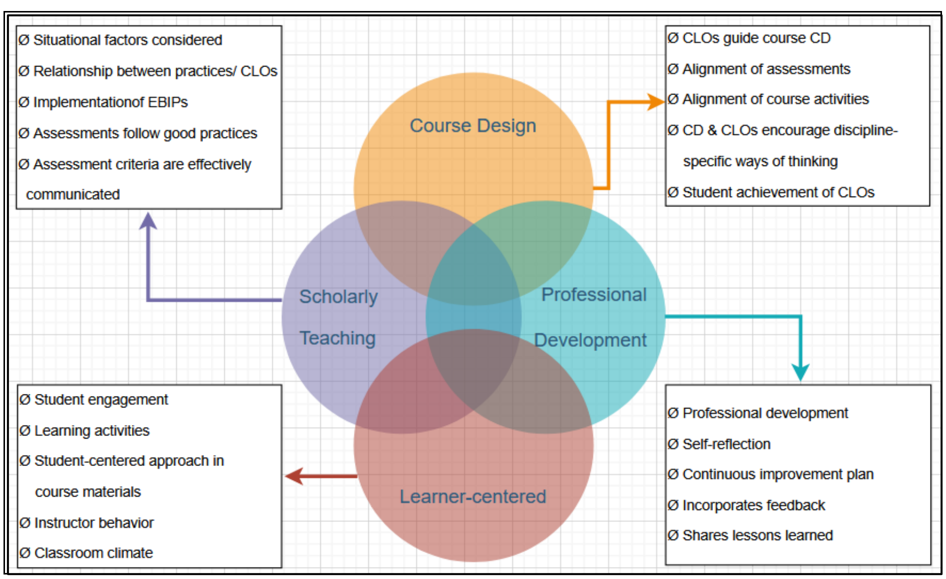

Figure 2.14: Framework for Assessing Teaching Effectiveness (FATE) (Adopted from Simonson, 2021)

To complete teaching evaluation, educators have to identify and follow a process to compile their own teaching portfolios, which are necessary for tenure and promotion application, using multiple sources of information. In addition, FATE requires an objective, reliable, and valid evaluation form (Simonson, 2021).

2.2.3.2.8 Engineering Ecosystem Conceptual Framework for Research and Training in SSA Countries

Klassen and Wallace (2019) proposed an engineering ecosystem framework, that depicts the interaction between 4 engineering components: a) National policy agencies, which are in charge of funding, laws, and regulations, include: (i) higher education, technical education, and research policy; (ii) science, technology, and innovation policy; and (iii) industrial policy. b) Higher education institutions, which grant degrees in engineering, consist of universities and technical vocational education and training (TVET). c) Industry, which includes all sectors engaged with engineering activities, including local and global industries. d) In addition, there are 3 more organizations: quality assurance agencies, civil society organizations, and donors.

The framework, Figure 2.15, has 3 main features: first, depicts the interaction between all agencies with a stake in engineering; second, the arrows represent influence, funding, and flow of information among all stakeholders; and the third feature shows the importance of quality assurance and training in the African higher education. They claim that this framework would help to frame research questions and to promote initiatives for change.

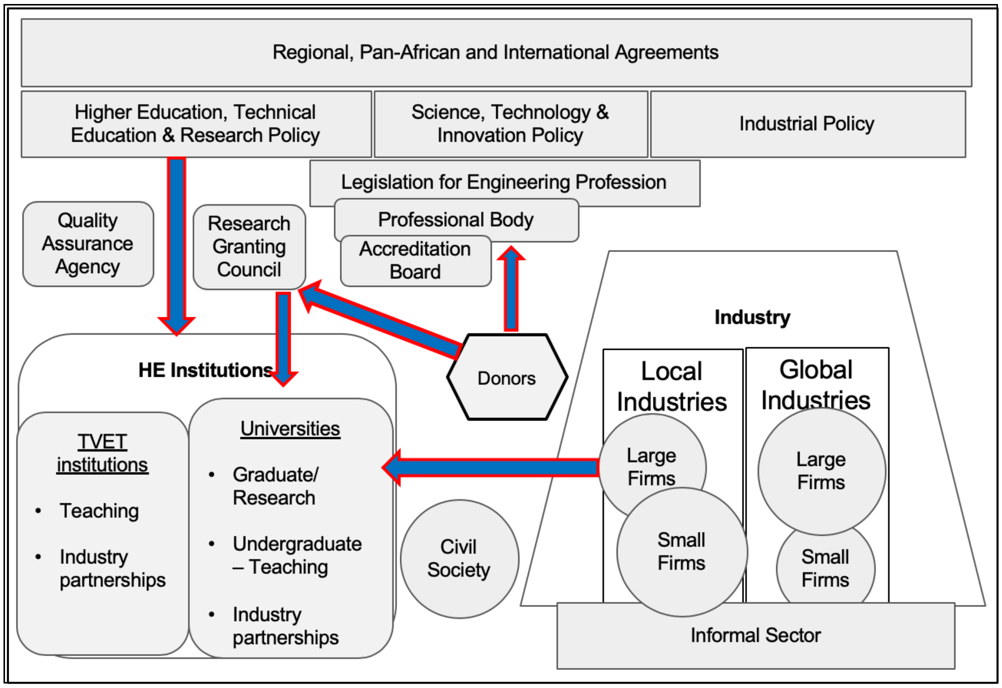

Figure 2.15: Engineering Ecosystem Conceptual Framework for Research and Training in SSA Countries (Klassen and Wallace, 2019)

2.3 Learning Theories

Scholars, through history, have studied and developed an enormous amount of learning theories. In his article, '15 Learning Theories in Education', Paul Stevens-Fulbrook summarized a list of 15 learning theories, '1. Piaget's Theory of Cognitive Development. 2. Vygotsky's Theory of Learning. 3. Bloom's Domains of Learning. 4. Gagné's Conditions of Learning. 5. Bruner's Spiral Curriculum (1960). 6. Maslow's Hierarchy of Needs. 7. Howard Gardner's Multiple Intelligences. 8. Erikson's 8 Stages of Psychological Development. 9. Kolb's Experiential Theory. 10. The Peter Principle. 11. Laird's Sensory Theory. 12. Skinner's Behaviourist Theory. 13. Rogers' Humanist Theory. 14. Canter's Theory of Assertive Discipline. 15. Dreikur's Classroom Management Theory' (Stevens-Fulbrook, 2020).

Stevens-Fulbrook (2020) stated, 'learning theories are a set of principles that explain how best a student can acquire, retain, and recall new information'. According to Hassan (2014), educators must consider the philosophical foundation of teaching and learning theories while providing (or constructing) a proper learning environment.

Engineering education aims to graduate engineers with sets of technical and soft skills required by industries. To achieve this goal both students (learners) and faculties (educators) have certain roles in the teaching and learning process. Educators' role is to design and deliver classes to get the best of the learners or to graduate competent engineers with knowledge and the right set of skills. Since the nineties of the last century engineering educators have started utilizing, in their teaching activities, research findings in the area of engineering education. However, engineering educators don't receive pedagogy training and/or formal preparation for their instructional duties during their graduate study. Although they are experts in their fields, engineering educators are not instructional designers with learning fundamentals knowledge (Syahmaidi et al., 2019; Smirnova and Vatolkina, 2018).

Many researchers attempt to integrate designing learning environments with various learning theories. These attempts may help engineering faculty not only to understand learning theories but also utilize them as a tool for designing classroom activities. Johri and Olds (2014) identified a few scholars and their ideas that influenced both the theoretical development and design of learning environments: Vygotsky's cultural-historical theory; Piaget's genetic epistemology; Dewey's transactional account; James's pragmatism and realism; Polanyi's tacit knowledge; and Garfinkel's ethnomethodology. Accordingly, the researcher has been reviewing various learning theories with the goal of identifying suitable ones for underpinning this study.

2.3.1 Classification of learning theories

Researchers, within the engineering education area, have classified learning theories differently, based on their most dominant traits. For instance: Stevens-Fulbrook (2020) categorized all learning theories into three schemas of learning theories: Behaviorism, Cognitivism, and Constructivism.

Newstetter and Svinicki (2014) compared and analyzed three theories behaviorist; cognitive, which includes a few sub-theories; and situative frameworks as they relate to the field of engineering education. It is worth noting that Newstetter et al. (2014) consider the constructivism framework as a sub-theory of the cognitive framework.

This study adopted the classification of educational learning theories, as outlined by Western Governors University (WGU), into five major ones and an additional three minor learning theories, see Figure 2.16 (www.wgu.edu). It is worth noting that this classification considers constructivism as one of the main learning theories rather than a subset of cognitivism learning theory as perceived by Newstetter et al. (2014). Also, this classification introduced connectivisim theory, which is described as a learning theory for the digital age.

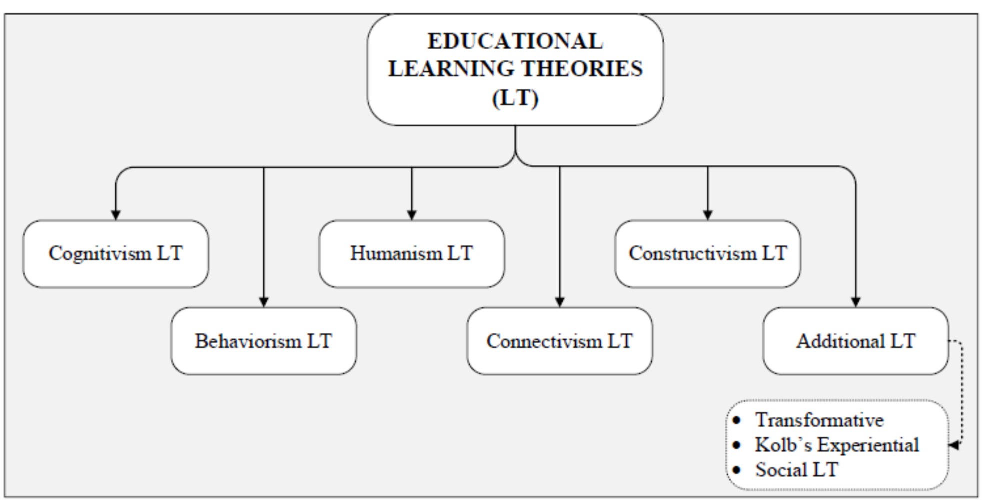

Figure 2.16: Classification of Educational Learning Theories (www.wgu.edu)

The remainder of this section will address the nature of knowing and learning as well as the instructional design according to cognitivism, behaviorism, humanism, constructivism, connectivism, and experiential learning theories:

2.3.1.1 The Cognitive Learning Theory

Cognitive theory started in the fifties of the last century and was developed by Jean Piaget. Piaget's theory led the way for additional brilliant ones: 'Cognitive Load Theory' by John Sweller, and 'Metacognition' by John Flavell. Contrary to behaviorism, cognitivism is based on the idea that the learner processes received information rather than just responses to stimuli as in the case of behaviorism (Barrouillet, 2015). Newstetter et al. (2014) describe the nature of knowing and learning as, 'knowing consists of having mental models that have been created and stored in the learner's long-term memory as a function of interacting with the environment.' and 'learning is the process of creating those models.' He identified the following five elements of the cognitive paradigm: (i) A focus on emphasizing the key features of the concepts to be learned. (ii) Taking advantage of prior knowledge and experience of the learner. (iii) Aiming for deep processing of information (learning with understanding) rather than passive dependence on surface features. (iv) Involve the learner actively in selecting, organizing, and integrating new information. (v) Developing metacognitive knowledge that allows students to control their learning (Newstetter et al., 2014).

The cognitive framework includes the following two sub-theories that try to explain different parts of learning: (i) Information-Processing Theory where the instructor (in control) presents the learning facts while the learner listens to the designed lectures without getting involved in deep processing of the information (Newstetter and Svinicki, 2014). (ii) Social-Cognitive Theory (SCT) "Observational Learning", which was developed by Albert Bandura in 1989 along with the Social Learning Theory (SLT). SCT, which is based on the SLT, is a more detailed theory, and it is connected to cognitive learning theory. According to Bandura (2023), learning comes from observing others' behavior, and it involves a mental model. SCL theory connects an individual's emotion with his/her cognitive skills within the social context. Bandura sets a three-way relationship of 'reciprocal determinism' among personal, environmental, and behavioral factors to emerge and assess the learning outcomes of the learner, see Figure 2.17. According to Mayer (2020b), environmental factors, with implications on the learning outcome, include parents, teachers, and faculty; personal factors include personality traits, which are shaped by environmental and genetic factors; and behavioral factors, which include positive and negative behavioral engagement of the students inside the classroom, for instance: attendance, participation, submitting assignments, and efforts in group work.

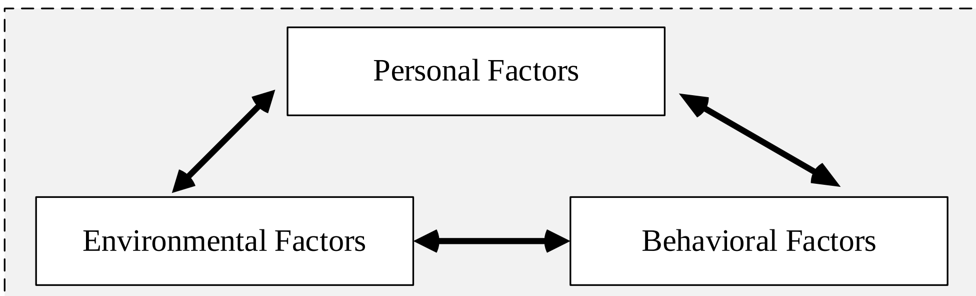

Figure 2.17: Bandura Reciprocal Determinism (Bandura, 2023)

2.3.1.2 The Behaviorism Learning Theory

This framework was first proposed by Watson in 1913, and it was developed by other researchers, during the period from 1932 to 1971, Guthrie, 1935; Skinner, 1938, 1950, 1971; and Tolman, 1932. According to Skinner, behaviorism learning theory has been the basis for observable and measurable psychology (Cranmore, 2022). Behaviorism theory deals with learning through a behavior change (classical conditioning, as demonstrated by Pavlov's dog experiment) and the principles of reinforcement, or operant conditioning. Behavioral procedure is concerned only with the observable behavior in the observable environment without the intervention of internal mental processes. According to Newstetter et al. (2014), in the behaviorist framework:

knowing consists of Stimulus-Response pairing; learning is their connection through exposure, repetition, and consequences; and instruction is a sequence of exposure, response, consequence and repeat, to ensure the behavior is changed, or learned. They summarized the following design principles as learning fundamentals based on the behaviorist framework: (i) Instructional objectives, where the instructor needs to set the objective of the instruction, standardize the instructions, and make a proper assessment tool to measure the outcome. (ii) Task analysis, learning a new behavior through a sequence of chronological steps. (iii) Shaping in small steps, learning is an incremental change to the current learners' level of performance. (iv) Observable stimulus-response association, learners are exposed to the stimulus-response with positive reinforcement, and the instructor has to repeat the stimulus until the majority of learners get the write response. (v) Mastery and self-pacing, students learn at their own pace independent of the progress of the whole class. (vi) Reinforcement, learners are rewarded based on their progress. Modern learning theories consider that behaviorism is an outdated theoretical orientation (Newstetter et al. (2014).

2.3.1.3 The Humanism Learning Theory

Abraham Maslow (1908-1970) was considered the father of humanism psychology, which emerged from both behaviorism and psychoanalysis. Whereas the former theory, as above discussed, sees that people's behaviors are solely controlled by their environment, psychoanalysis argues that people's behaviors are completely influenced by their unconscious desires rather than their ability to grow and make choices, freely. Toward humanistic theory, Maslow (in 1943), first, developed motivation theory, which identifies six types of needs, ordered into his hierarchy of needs, as shown in Figure 2.18: physiological needs, safety needs, belongingness needs, love needs, self-esteem needs, and self-actualization needs. From the bottom up, when one's basic need is met, he/she seeks to fulfill the next need, and so on until the hierarchy reaches its climax, self-actualization. Fulfilling all basic needs is necessary for someone to achieve self-actualization. It means that someone becomes the best version of himself, based on his potential; self-actualization is not guaranteed, though (Hare, 2019; McLeod, 2018).

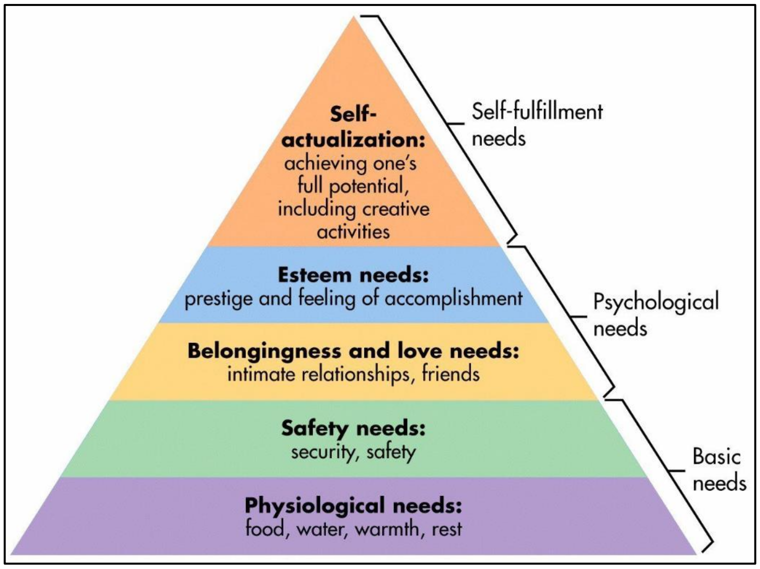

Figure 2.18: Maslow Hierarchy of Needs (McLeod, 2018)

To achieve self-actualization, humanistic learning theory is based on four principles: (i) Humanism is a student-centered learning theory where students are actively taking control of their learning; while teachers' role is to engage students and encourage them to align their learning goals with topics that are passionate about. (ii) As well, teachers should help students to perform self-evaluation, which leads to meaningful learning. (iii) Humanism suggests that cognitive and affective learning are coupled together; therefore, a student's feelings, along with his intellect, are collectively important in the humanistic learning process. (iv) Finally, humanistic learning requires that students feel safe physically, mentally, and emotionally; the teachers' role is to create an environment that would allow students to meet their basic needs and position themselves to learn and grow toward self-actualization (McLeod, 2018).

The researcher believes that Maslow was brilliant: More than 80 years ago, he included cognitive, affective, and social factors in the learning process, where the learner actively sets and monitors his/her learning goals. While the educator acts as a facilitator capable of engaging and encouraging learners toward self-actualization, an advanced SCL theory. Similarly, Lashari (2015) developed her "Affective- Cognitive T&L Framework" to promote the learner's behavioral engagement.

2.3.1.4 The Connectivism Learning Theory

During the last 50 years, waves of innovation have been accelerating exponentially due to accelerating growth in technology. Innovations and technologies have laid the groundwork for technology utilization in people's daily lives, which has been under constant change due to what is known as the digital age or information age. For instance, computer technology allowed not only the existence of vast amounts of information but also people's ability to access information at their fingertips.

Connectivism, described as a Learning Theory for the Digital Age, is a theory dealing with learning in the digital age. Connectivism learning theory means that learning occurs due to shared ideas, opinions, and points of view over created networks. Connectivism was first introduced by Siemens, G. and Downes, S between 2004 and 2005. They wrote two articles: Connectivism: A Learning Theory for the Digital Age (Siemens et al., 2020), and An Introduction to Connective Knowledge (Downes, 2019).

Siemens argues that behaviorism, cognitivism, and constructivism, which are the most prominent learning theories, were developed before the current wave of innovation and technology advancement (Siemens et al., 2020). In addition, all these learning theories suggest that knowledge is an attainable object through a learning process. That is experience, thinking and reasoning, and construction, according to behaviorism, cognitivism, and constructivism, respectively. All traditional theories suggest that learning occurs inside a person, with no regard to learning that is stored and manipulated by technology, as Siemens suggests. Moreover, traditional theories fail to describe how learning happens within organizations (Siemens et al., 2020).

Traditional learning theories have been under continuous revision to adapt to technological advancement; nevertheless, Siemens has realized the need for an alternative learning theory to incorporate the significant technological advancement rather than keep performing ineffective revision, as he believes, of traditional theories.

Downes (2019) expanded the connectivism theory. In addition to two well-known major types of knowledge, qualitative and quantitative knowledge, he introduced a third one, which is called distributed/connective knowledge; it requires an interaction between correlated events. Downes (2019) defines connectivism as, 'At its heart, connectivism is the thesis that knowledge is distributed across a network of connections, and therefore that learning consists of the ability to construct and traverse those networks.' Hence, one's ability to recognize connections, synthesize patterns, and draw information, out of his/her own primary knowledge, is a valuable skill. This skill may help one to take necessary actions, in the digital age, without personal learning. Therefore, connectivism states that learning is actionable knowledge rather than an object, and learning can occur within an organization or a database, as well can reside inside learners (Siemens et al., 2020).

Siemens et al. (2020) states, 'Connectivism is the integration of principles explored by chaos, network and complexity, and self-organization theories.' He formulates the following principles of connectivism: i) Learning and knowledge rests in a diversity of opinions. ii) Learning is a process of connecting specialized nodes or information sources. iii) Learning may reside in non-human appliances. iv) The capacity to know more is more critical than what is currently known. v) Nurturing and maintaining connections is needed to facilitate continual learning. vi) Ability to see connections between fields, ideas, and concepts is a core skill. vii) Currency (accurate, up-to-date knowledge) is the intent of all connectivists' learning activities. viii) Decision-making is a learning process. Choosing what to learn and the meaning of incoming information is seen through the lens of a shifting reality. While there is a right answer now, it may be wrong tomorrow due to alterations in the information climate affecting the decision (Siemens et al., 2020).

The researcher believes that the connectivism learning theory paved the way for the current scholars' efforts to investigate and introduce artificial intelligence (AI) in the learning process (Singh et al., 2022; Fitria, 2021; Jain et al., 2020).

2.3.1.5 The Constructivism Theory

Constructivism is a widespread theory that deals with humans constructing their knowledge through experience and learning through active processes (Newstetter, 2014). With the learner in control, he/she creates and stores mental models (Hirst 2022; Dewey 2018; Walshe, 2020). These learned models (constructions) vary among learners based on their prior experiences and interpretations of at-hand situations. There are three types of constructivism: (i) Cognitive constructivism, which is based on Piaget's theory of 1953. It relates learning to the learner's stage of cognitive development. Piaget developed this theory based on his work on children's cognitive development. (ii) Social constructivism, based on Vygotsky's social learning theory of 1962. This theory emphasizes the collaborative nature of learning, which means, in addition to their stage of cognitive, learners develop knowledge from people interactions, among themselves, their culture, and society. (iii) Radical constructivism, developed by Glasersfeld in 1974, based on his interpretation of Piaget's constructivism; still, radical constructivism differs from both cognitive and social constructivism. It is based on the idea that nothing is true about either learners or their constructions. There is no truth in the world, but individual perceptions about it (Tan and Ng, 2021). The researcher illustrates the types of this theory in Figure 2.19.

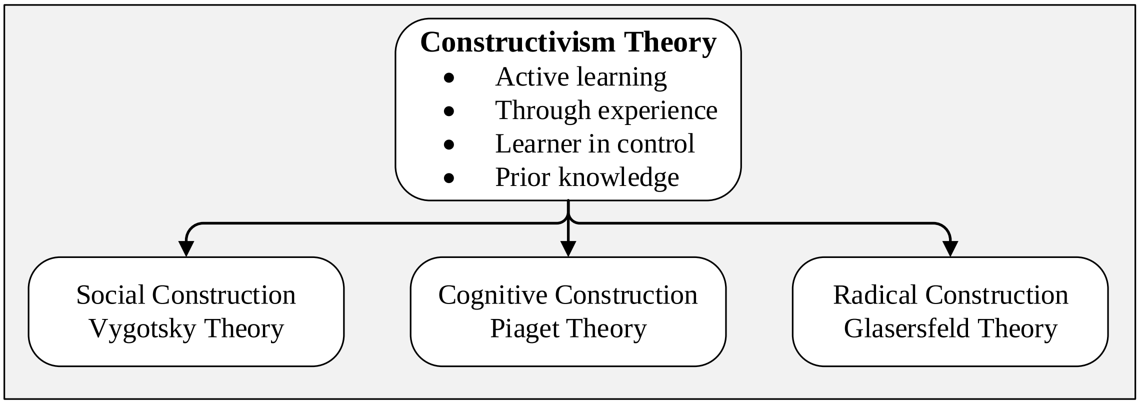

Figure 2.19: Types of Constructivism Theory

Although there are fundamental differences between these types of constructivism theory, still all of them are based on active learners (on control) constructing and storing new knowledge based on their prior knowledge, while educators act as facilitators (Brundiers and Wiek, 2014).

Creswell (2017, p5) reported the following constructivism assumptions, '1) Meanings are constructed by human beings as they engage with the world they are interpreting. Qualitative researchers tend to use open-ended questions so that the participants can share their views. 2) Humans engage with their world and make sense of it based on their historical and social perspectives—we are all born into a world of meaning bestowed upon us by our culture. Thus, qualitative researchers seek to understand the context or setting of the participants by visiting this context and gathering information personally. They also interpret what they find, an interpretation shaped by the researcher's own experiences and background. 3) The basic generation of meaning is always social, arising in and out of interaction with a human community. The process of qualitative research is largely inductive, with the inquirer generating meaning from the data collected in the field.'

Constructivism proponents give the following remarks about the ontology, epistemology, and methodology questions: Ontology Question- Realities are apprehendable in the form of multiple, intangible mental constructions, socially and experientially based, local and specific in nature (although elements are often shared among many individuals and even across cultures), and dependent for their form and content on the individual persons or groups holding the constructions. Epistemology Question- As far as the constructivism paradigm is concerned, there is no solid distinction between ontology and epistemology. Also, epistemology assumes a strong link between the investigator and the participants. The investigator and the participant in the investigation are assumed to be interactively linked so that the findings are literally created as the investigation proceeds. Methodology Question- Methodology is hermeneutical and dialectical. The variable and personal nature of social constructions suggests that individual constructions can be elicited and refined through interaction among investigators and participants. These varying constructions are interpreted using conventional hermeneutical techniques and are compared and contrasted through a dialectical interchange. The final aim is to distill a consensus construction that is more informed and sophisticated than any of the predecessor constructions, including the etic construction of the investigator (Ugwu et al., 2021; Lincoln and Guba, 2018; Gupta, 2022; Lincoln et al., 2018)

According to Gupta (2022), there are eight main principles of constructivism: (i) Knowledge is actively constructed. (ii) Learning is an individual and social process. (iii) Learning is an organizational process; new knowledge is assimilated with old knowledge to construct new meanings and understandings. (iv) Learning is based on personal experiences; different people understand the ‘truth' differently. (v) The concept of reality is based on individual interpretation. (vi) Learning is socially situated and enhanced through meaningful context; situated learning focuses on creating meaning from the real activities of daily life. (vii) Language plays an essential role in learning; the sharing of knowledge happens through communication. (viii) Motivation is key to learning; individuals must want to actively engage and reflect on their prior knowledge in learning.

Many researchers have reported a few problems associated with the constructivist theory, such as: Constructivism doubts the existence of the real-world, prevents teachers from calling wrong students and focuses on the process of learning rather than who influences the learning. Another criticism of constructivist theory is the lack of structure, which may affect students who struggle with an unstructured learning approach; whereas dominant children control the classroom and others are left behind (Allen et al., 2022; Gupta, 2022).

However, constructivism theory has been a theory of choice in qualitative engineering education research (EER), because EER belongs to the research in the social world; it requires qualitative models to understand and describe it comprehensively.

2.3.1.6 Kolb’s Experiential Learning Theory (KEL)

Kolb developed this theory based on the work of John Dewey, Kurt Lewin, and Jean Piaget: Kolb used Dewey’s cyclic arrangement of observation and knowledge as a framework for his learning theory. Dewey considered experiential learning as transforming theoretical ideas into practical work. The theoretical foundation of KEL was based on Lewin’s four learning stages, ‘Concrete experience, observation and reflection, abstract formation, and generation and testing the implication’. Piaget's theory on the four development stages (sensory-motor; pre-operational, concrete operational and formal operational; concept of formation; and schema development) was a novel contribution to KEL (Morris, 2020).

Accordingly, Passarelli and Kolb (2023) stated that knowledge is a result of grasping and transforming experience. He defines learning as, ‘the process whereby knowledge is created through the transformation of experience’; the name itself, Experiential Learning Theory, reveals that this model emphasizes experience. As depicted by Figure 2.20, his model consists of: (i) A vertical dimension, which represents knowledge transformation from concrete experience (feeling) to abstract conceptualization (thinking). (ii) A horizontal dimension, which represents knowledge acquisition from reflective observation (watching) to active experimentation (doing).

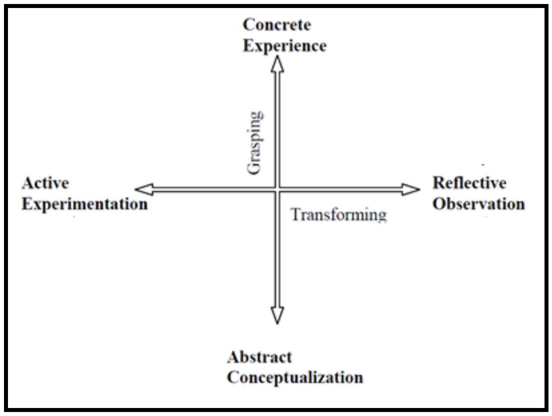

Figure 2.20: Kolb's Learning Model (Passarelli and Kolb, 2023)

Kolb's learning cycle showed how students learn better while conducting their academic and practical activities. The learning cycle includes the following four modes, see Figure 2.21: (i) Diverging learning style, where students combine both concrete experience and reflective observation learning strategies. (ii) Assimilating learning style, in this case, learners combine reflective observation and abstract conceptualization learning strategies. (iii) Converging learning style, this category of learners combines abstract conceptualization and active experimentation learning strategies. (iv) Accommodating learning style, where learners adopt both active experimentation and concrete experience learning strategies.

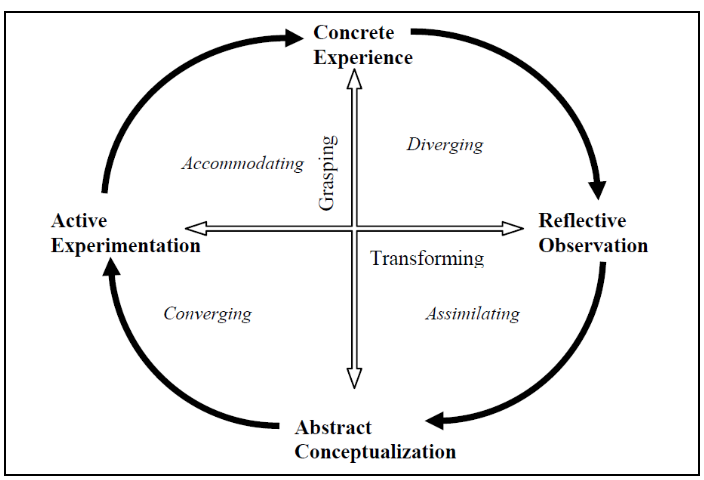

Figure 2.21: Kolb's Learning Cycle (Passarelli and Kolb, 2023)

2.4 Theoretical Perspectives- Post-structuralism Theory

The researcher chose post-structuralism theory (PST) for this study because of its ability to analyze engineering education, as a social practice, which is influenced by many other social, economic, and political factors. This part provides an overview of (PST), a brief of Foucault's contribution, and PST's key concepts, relevant to this study, as viewed by Foucault. The discussion introduces the theory and its origin and explains its concepts, namely discourse, truth, and power.

2.4.1 An Overview of Post-structuralism Theory

PST started in France during the late 60s through the 70s of the last Century. Some scholars consider post-structuralism a continuation of structuralism (among them are: Harcourt, 2007; Levi-Strauss, 1969; May, 2014; and Drew, 2003-b), while others believe it was a movement against structuralism (some are: Crick, 2016; William, 2014; Gaventa, 2021; Fairclough, 2023; and Rabinow, 2022). There are many branches of PST, and it is hard to define it, if not impossible; nevertheless, Crick (2016) defined PST as, 'Post-structuralism represents a set of attitudes and a style of critique that developed in critical response to the growth and identification of the logic of structural relations that underlie social institutions—whether they exist in terms of politics, economics, education, medicine, literature, or the sciences.' Crick elaborated on how one should think about PST as a methodology, rather than a philosophy, at the disposal of researchers to understand, interpret, and change any established system. He wrote, 'Post-structuralism should therefore not be thought of as a distinct philosophy that exists separately as its own "structure"—a proposition that would undermine its most fundamental attitudes. Rather, post-structuralism should be thought of as developing or arising only in response to pre-existing structures and, as a set of attitudes, helping us better understand, interpret, and alter our social environment by calling established meanings into question, revealing the points of ambiguity and indeterminacy inherent in any system, rejecting the rationalistic piety that all systems are internally coherent and circle an unchanging center, showing how discourses are carriers of power capable of turning us into subjects, and placing upon us the burden of ethical responsibility that accompanies the acceptance of freedom.' (Crick, 2016)

Crick (2016) highlighted the thoughts of three poststructuralists, Derrida, Barthes, and Foucault, as follows: 'First, following Derrida, post-structuralist thought invites a critical deconstruction of any discourse that presents itself as completely coherent, centered, and rational.'; ' Second, following Barthes, post-structuralism refuses to locate any single point of origin of any text that can ground its meaning—particularly by pointing to some ground of the author.'; and ' Lastly, following Foucault, post-structuralism invites an inquiry into how discourses, texts, and acts of communication are always implicated in relations of power that act upon possible actions.' He added, ‘Following the first two propositions, post-structuralism does not analyze these relations of power as completely structured and determinate, however. Power relations are always within a dynamic relationship with acts of resistance, thereby constantly leaving space for freedom and possibility.’ Crick (2016).

May (2014) states that PST has become dominant within French philosophy as a result of the decline of existentialism and structuralism. At the same time, May (2014) classified post-structuralism into two types: The first type concerns anti-representationalism, which emphasizes the diversity and the practices of one’s experience. The second type is deconstruction, which emphasizes otherness and exclusion in the language (no universal meaning). The former type consists of the work of Michel Foucault, Gilles Deleuze, and Jean-François Lyotard, and the latter type is illustrated by the work of Jacques Derrida and Emmanuel Levinas (May, 2014). While Drew (2023-b) states, ‘Post-structuralism is not ‘post’ in the sense of having killed Structuralism off, it is ‘post’ only in the sense of coming after and of seeking to extend Structuralism in its rightful direction.’

According to Williams (2014), PST is a movement that began in the 1960s, in France, and it has controversial influence, in addition to philosophy, over many other subjects, such as literature, politics, art, cultural criticisms, history, and sociology. Williams (2014) critically handled PST through selected works of five poststructuralists: Derrida, Deleuze, Lyotard, Foucault, and Kristeva. Williams (2014) considers them as the most important figures in the area of PST; in addition, each took a stand on key injustices and conflicts; he stated, 'Derrida has written powerfully against apartheid. Lyotard militated for the Algerian struggles for independence and revolution, as well as the May 1968 student uprisings in his own university. Foucault and Deleuze campaigned for better conditions in prisons. Kristeva is an important figure in contemporary feminism.' Williams (2014, p18). Below, the researcher very briefly outlines Williams' views about those five poststructuralists; however, his detailed views are beyond the scope of this study.

Jacques Derrida's Of Grammatology- PST as deconstruction: Of Grammatology was first published in 1967, where deconstructed structuralism claims of absolute truth. Of Grammatology defines PST and relates it to the other post-structuralism texts; one of them is Lyotard's Discourse, figure, which claimed itself as deconstruction, with some reservations. Williams discussed and reflected on: Many critical remarks of Grammatology; Keywords of deconstruction (origin, presence, trace, difference, and play); Deconstruction and metaphysics; and Deconstruction and science (Williams, 2014 p25; Derrida, 2016).

Gilles Deleuze's Difference and Repetition- PST as a philosophy of difference: Deleuze's concepts emerged from the transformation of the following seven structuralism criteria: The symbolic; locality or position; the differential and singular; differentiating and differentiation; the serial; empty place; and the move from the subject to practice. His post-structuralism focuses on practice and strategic transformation. In his work 'Difference and Repetition', Deleuze explains 'how things work, rather than what they are' (William, 2014; Mollison, 2023). William wrote, ' They are a matter of practical and strategic transformation, with political and ethical goals. The question "What is this?" is always the wrong starting question from this point of view. We are always thrown into an ongoing series of tense transformations and stresses. The right question is how to transform and work with them: how to thrive with them as intensely as a situation allows, but with no certainties to fall back on.' (William, 2014 p55).

Jean-François Lyotard's Discours, figure- PST as a philosophy of the event: Lyotard emphasizes aesthetics and art; he seeks deconstruction of structuralism by introducing aesthetic events because he believes that language or discourse cannot capture events. William (2014) believes that Lyotard's Discourse, figure is between Derrida's deconstruction and Deleuze's difference and repetition. William wrote, 'Lyotard's Discours, figure is between Derrida's deconstruction and Deleuze's difference and repetition. It takes the practice of working within texts to open them up from the former. It takes the creative and metaphysical side of the latter. Together, they underpin one of the most underrated and rich texts of poststructuralism.' (William, 2014 p80)

Michel Foucault's The Archaeology of Knowledge- PST, history, genealogy: William (2014) discusses Foucault as a philosopher/historian, rather than one of the two since his works extended throughout philosophy and history. Foucault's significant addition is how history is written. He published 'The Archaeology of Knowledge', in 1969, after he had published 'Madness and Civilization', 'The Birth of the Clinic', and 'The Order of Things'. These were published in 1961, 1963, and 1966, respectively. His later works include: 'Discipline and Punish' in 1975, and the three volumes of 'The History of Sexuality' in 1976, 1984, and 1984, in addition to a collection of other related works 'Power/Knowledge (1980)' William (2014 p105); refer to section 2.4.2 for more detail about Foucault's works.

Julia Kristeva's Revolution in Poetic Language- PST, psychoanalysis, linguistics: Julia Kristeva is a Bulgarian-French philosopher, born in 1941. The English translation of the above-mentioned Kristeva's work is, "the revolution of poetic language" (RPL). This work is more about the 'revolutionary power of art' and not just a 'dramatic change in art'. William (2014) states that RPL depends on Freudian psychoanalysis and provides a comprehensive study of linguistics, which allowed her to focus mainly on the theoretical basis of processes, such as ‘negation’ and ‘negation of negation’ in language. William wrote the following on Kristeva’s RPL, ‘Her argument takes two routes. First, using psychoanalysis, she studies processes that lie outside language, but that are presupposed by it and that it depends upon. Secondly, she shows that this dependence leaves language open to internal revolutionary transformations.’ (William, 2014 p134).

2.4.2 A Brief of Foucault’s Contribution and Concepts: Discourse/ Discourse Analysis, Truth, and Power

Michel Foucault (1926-1984) is a French philosopher. His works have dealt with various subjects in many areas, such as philosophy, history, science, medicine, and state apparatus, including correction, justice, administrative, political, and social institutions. Through his earlier works, Madness and Civilization (1961); The Birth of the Clinic (1963); The Order of Things (1966); and The Archaeology of Knowledge (1972), Foucault employed the concept of Archaeology method for discourse analysis of texts, whether interviews or documents, independent of individuals who produced the text, to reveal the relationship between power and knowledge at work. Archaeology is a form of analysis process that investigates discursive changes over time, without understanding the reasons behind these changes (Foucault, 2020; cited in Rabinow, 2022).

Then Foucault shifted his attention to employing a genealogy approach, which means exploring how and why things are changing over time, rather than just investigating the causes of discursive changes. The concept of genealogy was initiated in the Order of Discourse (1970) and continued throughout Discipline and Punish (1975), and The History of Sexuality, Volume I (1976). (Foucault, 2023, Cited in Rabinow, 2022).

At a later stage, Foucault introduced and continued developing the concept of biopower in The History of Sexuality- Volume I (1976), Society Must Be Defended 1975–76 (2021), Security, Territory, Population 1977–78 (2007), and the Birth of Biopolitics 1978–79 (2023). Accordingly, biopower is a power with a positive effect on people's lives, Foucault wrote that power, 'exerts a positive influence on life, that endeavors to administer, optimize, and multiply it, subjecting it to precise controls and comprehensive regulations' (Foucault 2021, p.137). He meant that biopower, coupled with governmentality, controls individuals' lives, at different levels, through experts in charge of various institutions like hospitals, workplaces, prisons, and educational institutions (Foucault 2021, p.137; Shen et al., 2022; Rabinow, 2022 p105).

Foucault is considered by many as one of the prominent post-structuralists. For instance, he was considered a post-structuralist with significant social and political views (William, 2014); in addition, William labeled him as a philosopher/historian, rather than one of the two, since his works extended throughout philosophy and history. Nevertheless, Rabinow (2022) states, 'Foucault did not characterize himself as a political theorist or philosopher and wrote no text intended to sum up his political thought.' Others labeled him as a structuralist. However, Foucault discarded all given labels due to any of his positions. Foucault is not a Freudian, Marxist, Socialist, Structuralist or Literary Theorist but a post-structuralist thinker. However, he draws on ideas and assumptions from them.

In this study, the researcher considers Foucault 'The Post-structuralist', and below is a brief about his post-structuralism views on certain concepts: Discourse, Discourse Analysis, Truth, and Power.

2.4.2.1 Discourse and Discourse Analysis

Discourse is understood as a way of perceiving, framing, and viewing the world (Drew 2023-a). Foucault was not the only poststructuralist to use the term 'Discourse', however, he promoted the term; as well, he came up with the 'Discourse Analysis' term. As above-mentioned, he shaped the 'Discourse Analysis' in two studies: Madness of Civilization and History of Sexuality, where he discussed how the West perceives insanity and sexuality, respectively, through language and over time (Drew 2023-a). In a broad sense, discourses are defined as systems of meaning that are related to the interactional and wider socio-cultural context and operate regardless of the speakers' intentions (Avdi and Georgaca, 2019).

According to Gaventa (2021), Discourse can be a site of both power and resistance, with the scope to ‘evade, subvert or contest strategies of power’. While Foucault sees discourse as a range of discursive elements; he wrote, ‘Discourses are not once and for all subservient to power or raised against it, any more than silences are. We must make allowances for the complex and unstable process whereby a discourse can be both an instrument and an effect of power, but also a hindrance, a stumbling block, a point of resistance, and a starting point for an opposing strategy. Discourse transmits and produces power; it reinforces it, but also undermines and exposes it, renders it fragile, and makes it possible to thwart it.’ (Foucault, 2021 p.100-101).

Foucault has explored the discourse change over time, which is known as discursive change. One of his anti-dominant discourse examples is the denial of the fact that ‘The Sun is the center of the Solar System’, which was against Christianity during the medieval time; back then Christianity used to construct the dominant course, due to Christianity’s power over others (Drew, 2023-b).

'Discourse Analysis' (DA), as emerged from social theory, has many meanings and interpretations; nevertheless, DA investigates the operation of power in the construction of meaning, at all levels of society. Avdi and Georgaca (2019) wrote, ‘Discourse analysis is a social constructionist approach. For social constructionism, reality and identity are systematically constructed and maintained through systems of meaning and through social practices.’

Avdi and Georgaca (2019) quoted, ‘Discourse analysis is a broad and diverse field, including a variety of approaches to the study of language, which derive from different scientific disciplines and utilize various analytical practices (Wetherell et al., 200l a & b, cited in Avdi and Georgaca, 2019).

According to Fairclough (2023), DA is both a method and methodology, combining an interpretive analysis of how society operates, and it is a qualitative approach rather than quantitative.

Foucault states that there is a relationship between discourse and power; Scholars utilize DA in many research areas, such as media, communication, culture, and education. DA allows researchers to show how people's perceptions are shaped and changed (discursive change), over time, through the power of text and language (Drew, 2023-a). He listed many examples of discourse analysis, 'study of television, film, newspaper, advertising, political speeches, and interviews.' He added, ‘A dominant discourse of gender often positions women as gentle and men as active heroes. A dominant discourse of race often positions whiteness as the norm and colored bodies as others’ (Drew 2023- a and b).

Many researchers, who were inspired by Foucault’s Discourse Analysis, have developed other forms of DA, known as FDA; among them are: Fairclough (2023), Avdi and Georgaca (2019). They claim that the FDA investigates systems of meanings within either a written or verbal document independent of the original intention of the author, rather than just examining the language as a means of constructing reality.

For instance, Fairclough has developed a framework 'Critical Discourse Analysis' (CDA) to analyze the relationship between discourse and power (Fairclough, 2023). The addition of the term ‘critical’ to the field of Discourse Analysis would allow CDA to not only analyze and understand a social practice, but also change it. This is because CDA combines both Foucault’s theory of power in the DA, and the ideology, which is represented by the term ‘critical’. However, the ideological influence varies according to the ideology itself, such as: ‘Class Struggle, by Karl Marx’, ‘Theories of Ideology, by Louis Althusser’, and ‘Social Theory, by Jürgen Habermas’, just to name a few. For instance, the latter theory calls for understanding and changing society rather than only understanding it (Rundell, 2020).

CDA is a type of discourse analytical research that primarily studies the way social power abuse, dominance, and inequality are enacted, reproduced, and resisted by text and talk in the social and political context. With such dissident research, critical discourse analysts take an explicit position and thus want to understand, expose, and ultimately resist social inequality (Fairclough, 2023).

2.4.2.2 The Truth

Unlike structuralism, post-structuralism sees that universal truth does not exist, and the truth at any point in time is dictated by the dominant discourse during that moment (Hampton et al., 2021). As well, Foucault’s views of the Truth, unlike essentialism, is the construction of discourse, which is under constant change, over time (Rabinow, 2022 p131). In other words, Truth takes the form of scientific discourse and the system that produces and sustains the Truth. Rabinow (2022 p132) states, "“Truth” is to be understood as a system of ordered procedures for the production, regulation, distribution, circulation, and operation of statements. “Truth” is linked in a circular relation with systems of power which produce and sustain it, and to effects of power which it induces, and which extend it.’ Rabinow (2022 p131) added, ‘The important thing here, I believe, is that truth isn't outside power, or lacking in power: contrary to a myth whose history and functions would repay further study, truth isn't the reward of free spirits, the child of protracted solitude, nor the privilege of those who have succeeded in liberating themselves.'

Foucault states, 'Truth is a thing of this world: it is produced only by virtue of multiple forms of constraint. And it induces regular effects of power. Each society has its regime of truth, its "general politics" of truth: that is, the types of discourse, which it accepts and makes function as true; the mechanisms and instances, which enable one to distinguish true and false statements, the means by which each is sanctioned; the techniques and procedures accorded value in the acquisition of truth; the status of those who are charged with saying what counts as true' (Foucault, cited in Rabinow, 2022 p131). Foucault added, 'These 'general politics' and 'regimes of truth' are the result of scientific discourse and institutions, and are reinforced (and redefined) constantly through the education system, the media, and the flux of political and economic ideologies. In this sense, the 'battle for truth' is not for some absolute truth that can be discovered and accepted but is a battle about 'the rules according to which the true and false are separated and specific effects of power are attached to the true'… a battle about 'the status of truth and the economic and political role it plays' (Foucault, cited in Rabinow, 2022).

2.4.2.3 The Power

Gaventa (2021) considers Foucault to be the most influential theorist of power of the 20th century. Gaventa listed a few 'Power Tools', as they were developed by the International Institute for Environment and Development, for the practical exercise of power; of these tools is 'Stakeholder Power Analysis', which is about the power, its origin, and who has it: The power of policies or institutions stems from the control of decisions with positive or negative effects. Stakeholder power can be understood as the extent to which stakeholders can persuade or coerce others into making decisions and following certain courses of action. Power may derive from the nature of a stakeholder's organization, or position with other stakeholders (for example, line ministries that control budgets and other departments). (Gaventa and Cornwall, 2015; Gaventa, 2021)

Foucault's views of power, as summarized by Gaventa: 'Power is diffuse rather than concentrated, embodied and enacted rather than possessed, discursive rather than purely coercive, and constitutes agents rather than being deployed by them' (Gaventa, 2021). Power is dispersed and exists independently of individuals and/or institutions. According to Foucault power is everywhere; he stated 'Power is everywhere: not because it embraces everything, but because it comes from everywhere. … Power is not an institution, nor a structure, nor a possession. It is the name we give to a complex strategic situation in a particular society.' (Foucault History of Sexuality p.93, cite in Gaventa, 2021). Rather than just negative and repressive, Foucault stated that power could be positive, as well: 'We must cease once and for all to describe the effects of power in negative terms: it 'excludes', it 'represses', it 'censors', it 'abstracts', it 'masks', it 'conceals'. In fact, power produces; it produces reality; it produces domains of objects and rituals of truth. The individual and the knowledge that may be gained of him belong to this production.' (Discipline and Punish p. 194, cite in Gaventa, 2021)

Moreover, power and knowledge are linked together (Gaventa and Cornwall, 2015), and even knowledge is power, as stated by Foucault. His theories dealt with the competing relationship between power and knowledge. As quoted by Rabinow (2022, p111), 'Power is also a major source of social discipline and conformity problems that arose was that of the political status of science and the ideological functions it could serve. It wasn't exactly the Lysenko business that dominated everything, but I believe that around that sordid affair- which had long remained buried and carefully hidden- a whole number of interesting questions were provoked. These can all be summed up in two words: power and knowledge.'

Dynamics of discourse, knowledge, and power have produced and legitimized competing representations of nature over time. As well, rather than it belongs to individuals' domain, knowledge is considered a form of social control, by the ones with power over the others without power, or according to Foucault, ‘the discourse of knowledge is driven by power’ or ‘knowledge is power’. Therefore, knowledge has its political domain, and it is controlled by whoever controls a country, institution, or discipline. Two examples may explain this concept: reservation of the biblical knowledge of the Church in the medieval era helped Christianity to control its followers; and the government used fear of the penalty attached to a crime to control the minds of people. (Drew, 2023-b).

2.5 Theoretical Perspectives and Frameworks (OBE, CA, and HPL Frameworks)

This section discusses three frameworks: Outcome Based Education (OBE), Constructive Alignment (CA), and How People Learn (HPL).

2.5.1 Outcome Based Education (OBE)

Many researchers consider William Spady to be the father of the OBE. Yet, he pleaded that the OBE system goes back more than 500 years; he stated that the world is filled with OBE examples. He listed the following examples: ‘Models Craft Guilds of the Middle Ages, Apprenticeship Training in the Skilled Trades, Personnel Training in Business, Professional Licensure, Military Training Programs, Scouting Merit Badges, Karate Instruction, Scuba Instruction, Flight Schools, Ski Schools, One-Room School houses, and "Alternative" High Schools Parenting.’ (Spady, 1994, p4). As well, he acknowledges that most of the OBE aspects were based on the work of prior scholars, such as Benjamin Bloom, James Block, and John Carroll (Spady, 1994, p4). Also, he acknowledged that others’ educational reforms that paved the way for his OBE: Tyler’s educational objectives movement (1949), Wheeler’s model of curriculum design, Bloom’s taxonomy for educational objectives (1956), Mager’s guidelines of expected performance (1962), the competency-based movement, the mastery learning movement, Glaser's criterion-referenced learning (1963).

According to Spady (1994), OBE means, 'clearly focusing and organizing everything in the education system around what is essential for all students to be able to do successfully at the end of their learning experiences.' This means starting with a clear picture of what is important for students to be able to do, then organizing the curriculum, instruction, and assessment to make sure that learning ultimately happens.' He added the OBE system needs, 'i) Develop a clear set of learning outcomes around which all of the system's components can be focused. ii) Establishing the conditions and opportunities within the system that enable and encourage all students to achieve those essential outcomes' (Spady, 1994, p1). He believed that the purpose of school is to prepare learners for their role in life after school years. This purpose is well serviced following what is known as transformational OBE rather than traditional OBE. Spady states, 'While more traditional forms of genuine OBE clearly showed merit by increasing the numbers of students who were learning more than ever before in higher-challenge programs, what they were learning was mainly preparing them for yet more education rather than preparing them for the complex life roles they ultimately would occupy as young adults' (Killen, 2016). As illustrated by Figure 2.22, Spady (1994, p8) constructed 'OBE Pyramid' of several elements for successful outcome-based models, namely one Paradigm (on the top of the pyramid), followed by two key Purposes, three key Premises, four operating principles, and five generic domains of Practice.

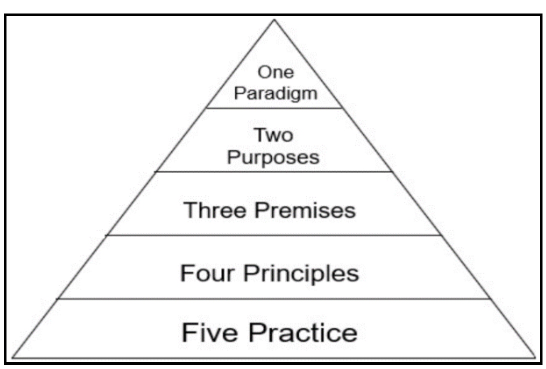

Figure 2.22: Spady's OBE Pyramid

As mentioned above, engineering educators and researchers are advocating OBE since it allows engineering students to graduate with the necessary skills and knowledge for the job market. However, others identified its limitation as OBE rooted in behaviorism theory. Biggs et al., (2020) identified two gaps in OBE: first, 'The gap between defining learning outcomes and supporting teaching and learning activities ...', and 'Another gap is between the roots of OBE in behaviorism, which could be considered an outdated theoretical orientation, by modern learning theory.' In Figure 2.23, the researcher summarizes the OBE: its roots, requirements, purposes, examples, and limitations.

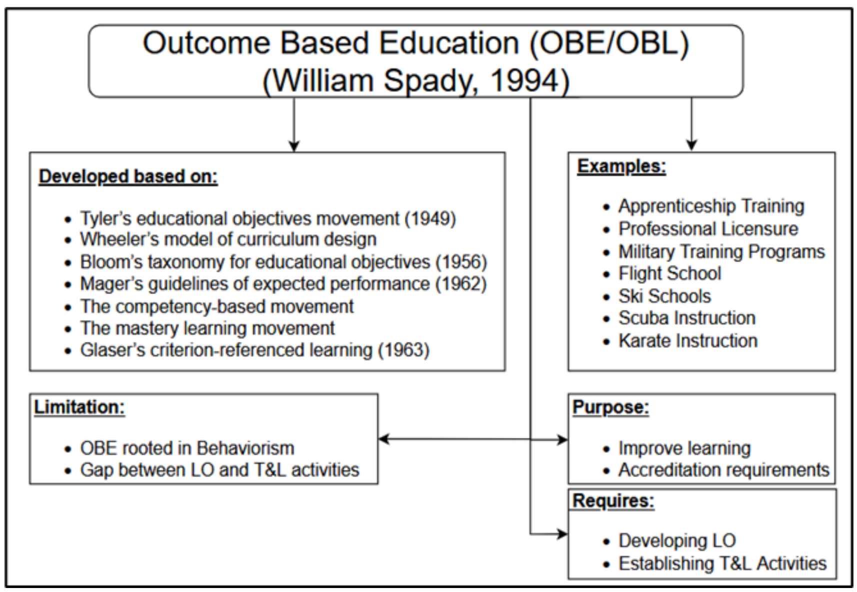

Figure 2.23: OBE Roots, Requirements, Purposes, Examples & Limitation

OBE has been adopted by many countries, worldwide, to resolve the mismatch between the quality of tertiary education and the required skills and knowledge by the job market. In other words, academic institutions have been using OBE to improve the quality of their graduates in terms of knowledge-based competencies and necessary soft skills. OBE is considered a student-centered learning philosophy measured by 'outcomes' (Felder and Brent, 2017).

Although OBE has drawn many critics, and there have been cases of failure, while implementing OBE, still there are a lot of engineering educators and researchers embracing OBE. Engineering programs have been utilizing the OBE framework either to improve learning (Biggs et al., 2020) or to meet accreditation requirements (Felder and Brent, 2017). OBE has become a key requirement for the accreditation of engineering programs worldwide. For instance: in the USA, ABET requires assessment and evaluation of students' learning outcomes (ABET, 2018); likewise, Engineering Australia set similar accreditation criteria; and the Engineering Accreditation Council (EAC) within the Board of Engineering Malaysia (BEM) has adopted OBE, since 2004. Figure 2.24 shows the implementation of the OBE framework as presented by Nakkeeran et al. (2018).

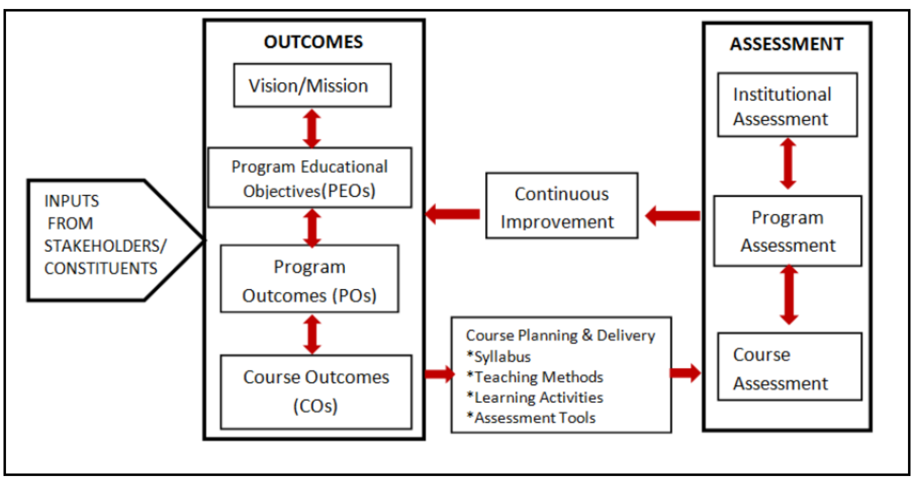

Figure 2.24: Implementation of OBE Framework (Nakkeeran et al., 2018)

2.5.2 Constructive Alignment (CA)

As above-mentioned, in section 2.5.1, OBE has two limitations: its root in behaviorism and the missing link between learning outcomes and teaching/learning activities. To overcome these two limitations, Biggs introduced the CA framework, which aligns both learning activities and assessment processes with predefined learning outcomes (Biggs et al., 2020). Like OBE, CA requires clear learning outcomes and assessment systems. In addition, CA plans teaching and learning activities that support deep learning and have students master desired learning outcomes by engaging actively in learning activities. Figure 2.25 shows the weak link between constructivism and OBE and the introduction of CA to overcome OBE limitations.

Ralph Tyler first introduced the CA idea in 1949 (Biggs 2014; Cruickshank, 2018). Then Tyler (1949) wrote his book, ‘Basic Principles of Curriculum and Instruction’ in which he included his fundamental four questions: What educational purposes should the school seek to attain? (ii) What educational experiences can be provided that are likely to attain these purposes? (iii) How can these educational experiences be effectively organized? (iv) How can we determine whether these purposes are being attained? In his book, Tyler (1949, p51) represented procedures on how to answer these questions, which represent the basis for what is known as Tyler’s Curriculum Model. Biggs et al. (2020) stated that Constructive Alignment (CA) has two elements: First, the ‘Constructive’ element, which refers to students ‘construct meaning’ by using relevant learning activities, while teachers act as learning facilitators. The other element is ‘Alignment’, which refers to the teacher’s role in designing learning environments suitable for achieving intended learning outcomes. These outcomes should reflect the level of understanding required by students.

Furthermore, Biggs (2020) specified the following orders for setting up an aligned system: (i) Defining the desired learning outcomes (DLOs). (ii) Choosing teaching/learning activities likely to lead to the DLOs. (iii) Assessing students’ actual learning outcomes to see how well they match what was intended. (iv) Arriving at the final grade.

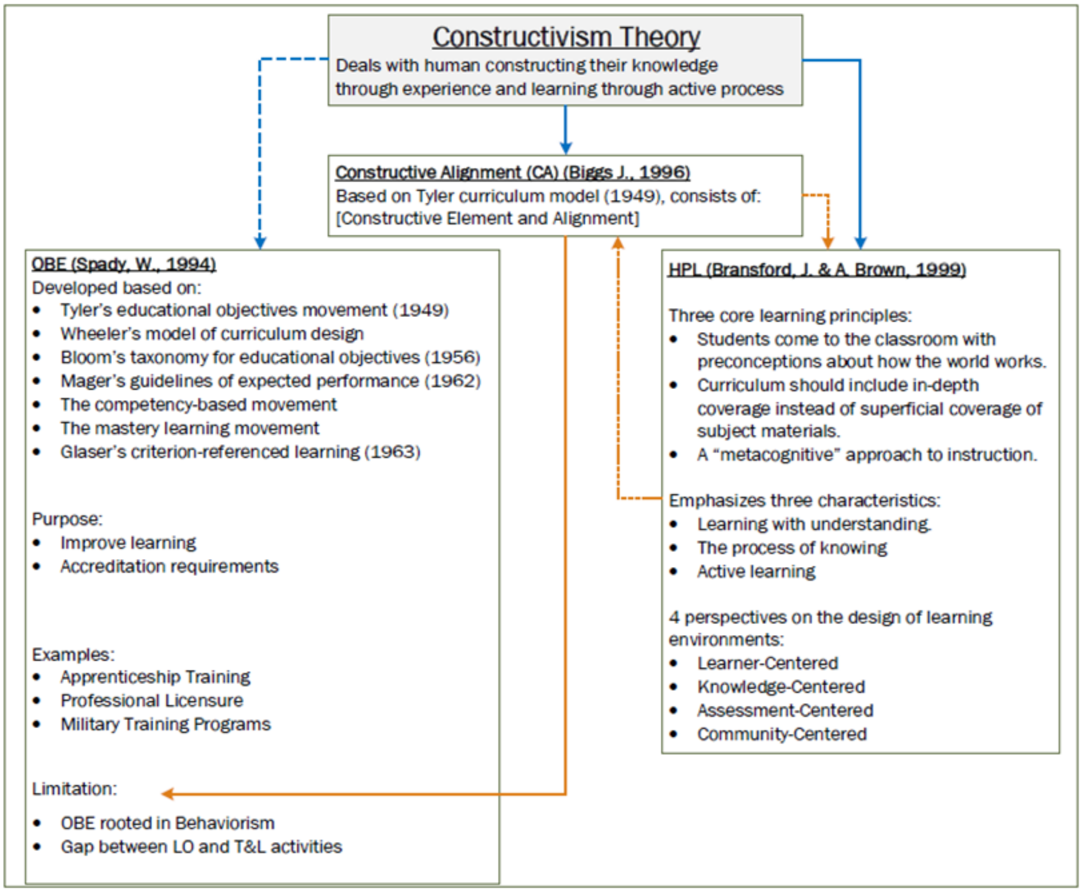

Figure 2.25: Relationship between Constructivism Theory and OBE, CA, and HPL

Biggs et al., (2020) claim that CA is a system that integrates all aspects of teaching and assessment for achieving high-level learning. He wrote, '… constructivism being used as a framework to guide decision-making at all stages in instructional design: in deriving curriculum objectives in terms of performances that represent a suitably high cognitive level, in deciding teaching/learning activities judged to elicit those performances, and to assess and summatively report student performance. The "performances of understanding" nominated in the objectives are thus used to systematically align the teaching methods and the assessment.' Figure 2.26 represents a model of an aligned curriculum for the assessment of teaching and learning activities.

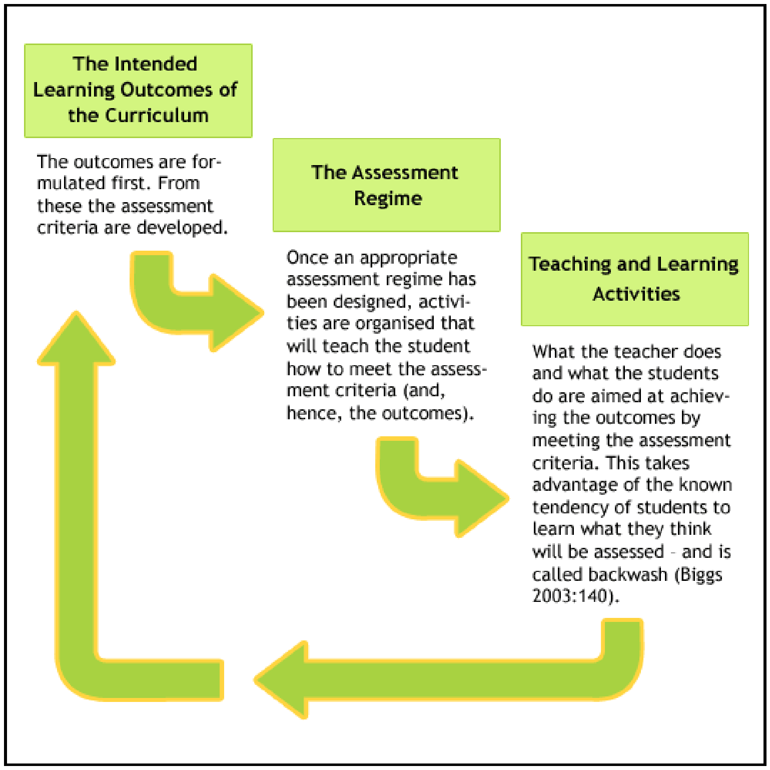

Figure 2.26: A Basic Model of an Aligned Curriculum (Biggs et al., 2020)

In agreement with Tyler (1949), Biggs et al.(2020) noted the significance of constructivism in improving tertiary education because constructivism sees learners actively construct meaning by using individual and social activities. He states, 'The learner brings an accumulation of assumptions, motives, intentions, and previous knowledge that envelopes every teaching/learning situation and determines the course and quality of the learning that may take place. The teacher may ignore or use this learner-structured framework, but the centrality of the learner is given.' (Biggs et al., 2020). It is similar to Shuell's statement; he stated, 'If students are to learn desired outcomes in a reasonably effective manner, then the teacher's fundamental task is to get students to engage in learning activities that are likely to result in their achieving those outcomes ...It is helpful to remember that what the student does is more important in determining what is learned than what the teacher does.' (Shuell, 1986; cited in Faz et al. 2022)

2.5.3 How People Learn (HPL) Framework

How People Learn (HPL) is a report, which was published in April 1999. The report was a product of 2-year research on the 'Science of Learning'. Two committees carried out the research: The Commission on Behavioral and Social Sciences and Education of the National Research Council (NRC- HPL, 2000).

2.5.3.1 Principles and Characteristics of HPL

Although the new science of learning appreciates knowing facts, it emphasizes learning with understanding. This requires a curriculum that encourages students' deep understanding and not only memory of disconnected facts. Deep understanding helps students to become knowledgeable in their domain and capable of transferring to new contexts. Learning with understanding leads to the second characteristic of the new science of learning, which emphasizes the process of knowing. While pursuing formal education, learners are equipped with pre-existing knowledge, which has a great effect on achieving their learning outcomes. This point of view is in line with other views that people build new knowledge and understanding on their current knowledge and beliefs; Piaget's 1978 cognitive learning theory and Vygotsky's 1978 social constructivism learning theory.

In addition, learning with understanding drives the third characteristic of the new science of learning, which stresses the importance of active learning. In active learning, people take control of their learning process, from recognition of their pre-existing knowledge, to setting the level of new understanding, and assessing their understanding. Active learning activities are considered as part of metacognition. Metacognition means people's ability to predict and monitor their progress on various tasks. HPL reports, 'Overall, the new science of learning is beginning to provide knowledge to improve significantly people's abilities to become active learners who seek to understand complex subject matter and are better prepared to transfer what they have learned to new problems and settings.' HPL added, 'The emerging science of learning underscores the importance of rethinking what is taught, how it is taught, and how learning is assessed. These ideas are developed throughout this volume.' Originally, the focus of HPL was on the formal educational environment: Primarily from kindergarten to grade 12 (K-12) and tertiary education, colleges to some extent. More researchers continued using the HPL framework for tertiary education focusing on science, engineering, and medicine. In addition, to lead learners to achieve their utmost potential, HPL addressed the design of curricular, instruction, assessment, and learning environments (NRC- HPL, 2000).

HPL framework highlighted the following three core learning principles: (i) Students come to the classroom with preconceptions about how the world works. (ii) To develop competence in an area of inquiry, students must: (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application. (iii) A "metacognitive" approach to instruction can help students learn to take control of their learning by defining learning goals and monitoring their progress in achieving them.

These learning principles have a significant effect on teaching and teacher preparation. According to HPL, 'Evidence from research indicates that when these three principles are incorporated into teaching, student achievement improves.' (NRC- HPL, 2000).

i. HPL states, 'Teachers must draw out and work with the preexisting understandings that their students bring with them.'

Teachers must be capable of exploring and working with students' preconceptions since preconceptions have a significant impact on learners' ability to acquire additional information, formal understanding of the subject matter, and new concepts. Effective teaching would recognize and work with learners' existing understanding; effective teaching would help learners to change their misconceptions and build on their accurate preconceptions, organize them, and integrate them into new concepts; and learning with understanding requires the use of formative assessment as a tool to monitor and refine learners' progress by themselves and/or their teachers (NRC-HPL, 2000).

ii. HPL states, 'Teachers must teach some subject matter in-depth, providing many examples in which the same concept is at work and providing a firm foundation of factual knowledge.'

The curriculum should include in-depth coverage instead of superficial coverage of subject materials. In-depth coverage would allow a deep understanding of subject concepts. Moreover, in-depth coverage of a domain may require a coordinated curriculum over the years of study instead of a disintegrating curriculum. For successful in-depth coverage of subject materials, in addition to their teaching and pedagogical expertise, teachers must be experts in the discipline area. As well, assessment must be aligned to test deep understanding rather than superficial facts memory (NRC- HPL, 2000).

iii. HPL states, 'The teaching of metacognitive skills should be integrated into the curriculum in a variety of subject areas.' (NRC- HPL, 2000).

Metacognitive instruction helps learners to set their learning goals and monitor their progress toward these goals. Students need metacognitive instruction to help them develop metacognitive skills and practices. Then students can use these skills to set their learning goals and monitor the progress toward these goals. Therefore, the curriculum of each discipline should include the teaching of metacognitive skills (NRC- HPL, 2000). Table 2.14 shows three principles and three characteristics of HPL.

Table 2.14: Three Principles and Three Characteristics of HPL

HPL (NRC- HPL, 2000)
<u>Three core learning principles:</u> • Students come to the classroom with preconceptions about how the world works. • The curriculum should include in-depth coverage instead of superficial coverage of subject materials. • A "metacognitive" approach to instruction. **<u>Emphasis three characteristics:</u>** • Learning with understanding • The process of knowing • Active learning

2.5.3.2 The Design of Learning Environments

Following the discussion of the core learning principles in light of educational goals for the 21st century, HPL discussed four perspectives on the design of learning environments, namely: Learner-centered, knowledge-centered, assessment-centered, and community-centered environments. As depicted by Figure 2.27, these perspectives are interrelated; Bransford et al stated that the above-mentioned characteristics of learning environments need to be conceptualized as a system of interconnected four components (NRC- HPL, 1999).

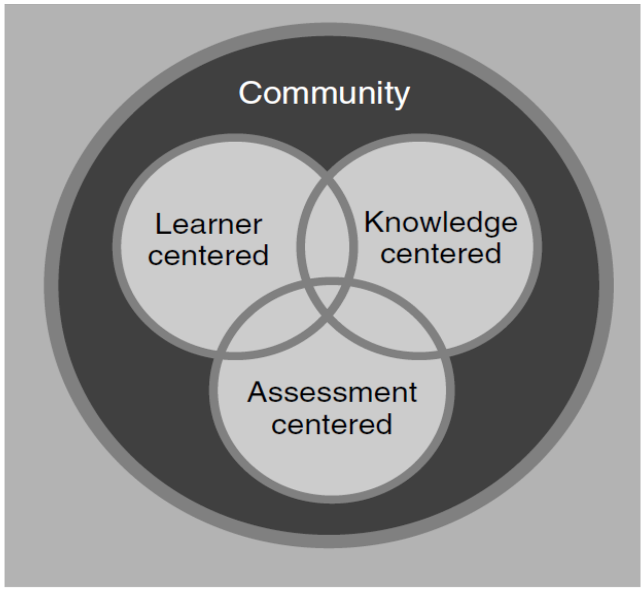

Figure 2.27: Perspectives on Learning Environments (NRC- HPL, 1999).

2.5.3.2.1 Learner-Centered Environments

In learner-centered environments, teachers need to understand and work with the learners' prior knowledge, skills, attitudes, and beliefs that they bring to their formal educational setting. As well, teachers should be culturally sensitive since culture and language barriers may affect students' performance. In learner-centered environments, teachers are required to monitor learner progress, maintain their engagement, and challenge them by providing manageable tasks (NRC- HPL, 2000). NRC- HPL, (1999) stated 'We use the term "learner-centered" to refer to environments that pay careful attention to the knowledge, skills, attitudes, and beliefs that learners bring to the educational setting.'

Learner-centered is about understanding the misconception of novice learners and their background, prior knowledge, and learning style. Theories of conceptual change (CC) assume that a learner's conceptual understanding may dictate greatly his or her learning. Streveler et al. (2014) stated, '… what an individual learns is at least partially controlled by what they already know.’ However, these theories disagree on the structure and the effect of the existing knowledge.

Kolmos and Graaf (2014) mentioned that many learner-centered models were introduced after WWII; they state, ‘In higher education concepts such as “self-directed learning,” “case-based learning,” “inquiry-based learning,” “experiential learning,” “service learning,” “project-based service learning,” “active learning,” “CDIO (Conceive, Design, Implement, and Operate)”, “project-based learning,” and “problem-based learning” were introduced in the decades after the Second World War.’

2.5.3.2.2 Knowledge-Centered Environments

Learner-centered and knowledge-centered environments seem to go hand in hand; otherwise, a learner-centered environment alone would not allow students to achieve their learning goals. NRC- HPL (1999) states, ‘The ability of experts to think and solve problems is not simply due to a generic set of “thinking skills” or strategies but, instead, requires well-organized bodies of knowledge that support planning and strategic thinking.’ Therefore, knowledge-centered environments focus on learning with understanding, which requires that knowledge-centered environments need to deliver in-depth knowledge and not only factual knowledge. In addition, knowledge-centered environments emphasize the importance of teaching students to become active learners; in other words, teach them metacognitive skills.

HPL discussed the difference between experts and novices as well as learning transfer to new contexts. Successful implementation of HPL framework principles should result in the transfer of learning from students’ previous academic experiences so that students become adaptive experts in their areas of study (NRC- HPL, 2000).

Therefore, the question is how to help people increase their expertise: McKeena (2014) introduced an 'adaptive expertise framework' for knowledge transfer and expertise development, in the context of engineering design and innovation. He states, 'The concept of adaptive expertise was introduced to extend our understanding of the meaning of expertise, as well as a way of thinking about how to prepare learners to respond flexibly to new learning situations.' There are two types of expertise: Routine experts, who are very efficient in problem-solving within their area of expertise; and, adaptive experts are innovative and capable of creating new ideas/knowledge based on their prior knowledge. Routine experts are outstanding in speed, accuracy, and automaticity of performance but lack flexibility and adaptability to new problems; and adaptive experts can be characterized by their flexibility, innovative, and creative competencies within the domain.

2.5.3.2.3 Assessment-Centered Environments

On top of learner-centered and knowledge-centered, a third perspective on learning environments is assessment-centered environments. Assessment must emphasize understanding and not memorizing facts and/or procedures, despite their importance (NRC- HPL, 2000). There are two types of evaluation: First type, summative assessments measure the students' outcome at the end of specific learning activities, for instance: tests given at the end of a unit of study, mid-terms given during the academic year, or finals given at the end of a semester or academic year. The other type is the formative assessments; examples include, but are not limited to classwork, tutorials, and teachers' comments on the students' progress during learning activities. Formative assessments are given with the purpose of helping both teachers and students monitor students' progress toward their learning objectives (NRC- HPL, 2000). NRC- HPL (1999) states, 'Formative assessments—ongoing assessments designed to make students' thinking visible to both teachers and students—are essential. They permit the teacher to grasp the students' preconceptions, understand where the students are in the "developmental corridor" from informal to formal thinking, and design instruction accordingly.'; other formative assessment features are that they must be frequent, learner-friendly, promote deep understanding, and support active learning (NRC- HPL, 2000).

There are many reasons for the assessment of student's knowledge and skills; at least, assessment results may be utilized (by educators, administrators, policymakers, students, parents, and researchers) to evaluate the state of teaching and learning and to act upon accordingly. Pellegrino et al. (2014) identify three assessment purposes, 'i) assessment to assist learning (formative assessment), ii) assessment of individual achievement (summative assessment), and iii) assessment to evaluate programs (administrators and policymakers assessment)'. These 3 types of assessment are also known as: assessment for learning (AfL), assessment of learning (AoL), and assessment as learning (AaL), respectively (Yang et al, 2022). Therefore, assessment tools, formal and/or informal, are developed aiming at the specific purpose of the assessment. For instance, the purpose of traditional testing is to meet accreditation requirements: Formative assessment, including mid-terms and in-/out- of class assignments is required to enhance students' performance in the final summative assessment (Lord and Chen, 2014). To assess the progress of engineering students "from novice to expert", ABET, originally adopted (a to k) criteria, which have been changed to (1 to 7) criteria, to evaluate engineering knowledge and problem-solving and professional engineering skills; see Table 2.15.

Table 2.15: Mapping- Original vs. Changed Student Outcomes Criterion (ABET, 2018)

ABET Student Outcomes (a) through (k)	**Combined ABET Student Outcomes (1) through (7)**
a) an ability to apply knowledge of mathematics, science, and engineering.	1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics (outcome a and e)
b) an ability to design and conduct experiments, as well as to analyze and interpret data.	2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors (outcome c)
c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.	3. an ability to communicate effectively with a range of audiences (outcome g)
d) an ability to function in multidisciplinary teams.	4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts (g) an ability to communicate effectively (outcome f, h and j)
e) an ability to identify, formulate, and solve engineering problems.	5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives (outcome d)
f) an understanding of professional and ethical responsibility.	6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions (outcome b)
g) an ability to communicate effectively.	7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies (outcome i)
h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.	--
i) a recognition of the need for, and an ability to engage in life-long learning.	--
j) a knowledge of contemporary issues.	--
k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice."	--

2.5.3.2.4 Community-Centered Environments

HPL considers two levels of communities, as shown in Figure 2.28: one level of classrooms and schools where students, teachers, and administration interact among themselves; the other level of community is between classrooms/school and the broader community, which includes homes, community centers, after-school programs, and businesses (NRC- HPL, 2000).

The different social norms imposed by different schools may affect learning greatly: learning tends to improve when classrooms and schools encourage the freedom of making mistakes and asking questions while learning. Opposite norms, that discourage asking questions to understand the materials or making mistakes while exploring new concepts have a negative impact on learning. In addition, classrooms and schools tend to enhance the learning process by encouraging students' participation to understand the subject matters, rather than memory of facts, and by developing a collaborating culture to have students learn from each other. Community-centered is based on Vygotsky's theory that learning is an integral part of cognitive development, and it is culture (Vygotsky, 1978).

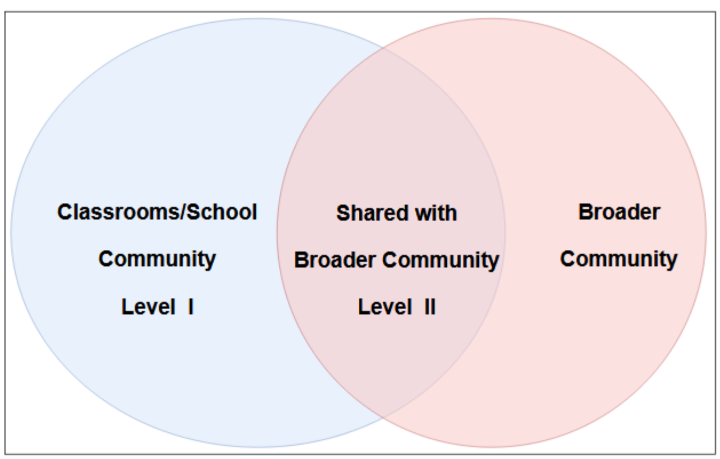

Figure 2.28: Two Levels of Community

A follow-up committee on learning research and practice (NCR-HPL, 1999) was formed by the National Academies of Science, Engineering, and Medicine to further link the findings of the original HPL research on the science of learning to the practice in the classrooms. The second committee's efforts resulted in a report titled, 'How People Learn: Birding Research and Practice', which was published in June 1999 (NCR-HPL, 1999). The committee led by M. Suzanne Donovan, John D. Bransford, and James W. Pellegrino noticed the weak link between learning research and classroom practice. One of the main reasons for this issue is that teachers, who represent the direct link between learning research and classroom practice, are not quite involved in research design. Moreover, teachers are concerned about the practicality of research findings, bearing in mind the actual size of the classroom and the limited time of the class session. The second HPL report states, "The concern of researchers for the validity and robustness of their work, as well as their focus on underlying constructs that explain learning, often differ from the focus of educators on the applicability of those constructs in real classroom settings with many students, restricted time, and a variety of demands." (NCR-HPL, 1999). However, one way to incorporate research findings in classroom practice requires both researchers and educators to collaborate in research design. The only other ways, to link research findings to practice, remain through educational materials, pre-service and in-service teacher education, public policy, and public opinion. The committee illustrates the path for research to influence classroom practice in Figure 2.29.

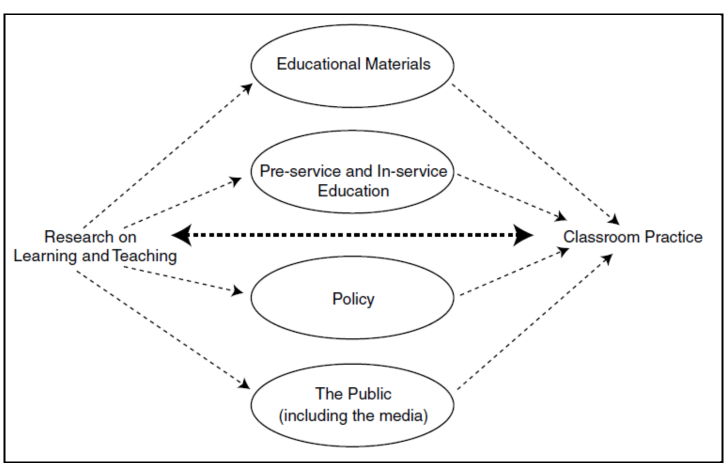

Figure 2.29: Paths Through Which Research Influences Practice (NCR-HPL, 1999)

The committee sees the three profound HPL learning principles have a great effect on education institutions; however, the question is how to incorporate the insights from HPL research into practice. To address this question, the committee held a conference and a workshop to bring together all stakeholders, teachers, administrators, researchers, curriculum specialists, and policymakers, for feedback on the HPL. The conference obtained feedback on the potential barriers of the HPL influencing classroom practice, while the workshop emphasized how research and development bridge research and practice. The committee concluded the following five goals to guide the design of the research agenda, 'i) Elaborate the messages in How People Learn at a level of detail that makes them usable to educators (including teacher educators) and policymakers. ii) Communicate the messages in How People Learn in a manner that is effective for each of the audiences that influences educational practice. iii) Use the principles of learning for understanding articulated in How People Learn as a lens through which to evaluate existing education practices (K-12 and teacher training programs) and policies. iv) Conduct research in teams that combine the expertise of researchers and the wisdom of practitioners. v) Extend the frontier of learning research through more intensive study of classroom practice.' (NCR-HPL, 1999).

The committee suggested research and development to improve the mediating means between the research and the practice: reviewing and testing educational materials, developing effective professional development tools for teachers, developing effective communication tools for policymakers, and developing of public awareness program on HPL (NCR-HPL, 1999).

Almost two decades later, The National Academies of Sciences, Engineering, and Medicine formed a committee to revise the original HPL I report according to emerging research across disciplines with influence on the science of learning. The 16-member committee, led by Cora Bagley Marrett, are experts in a variety of disciplines related to the science of learning and classroom practice: cognitive science, learning theory, cognitive neuroscience, educational psychology, developmental psychology, workforce development, and educational technology (HPL II, 2018).

HPL II stated the committee task as follows: ‘reviewing and synthesizing research that has emerged across the various disciplines that focus on the study of learning from birth through adulthood in both formal and informal settings. Consideration will be given to research and research approaches with the greatest potential to influence practice and policy. The report should specify directions for strategic investments in research and development to promote the knowledge, training, and technologies that are needed to support learning in today’s world’. The committee produced a third report (HPL II), which was built on the findings of the original HPL I report, intending to add new conclusions and recommendations based on emerging research related to the science and practice of learning, such as: The Complex Influence of Culture, Types and Processes of Learning, Knowledge and Reasoning, Motivation to Learn, Implications for Learning in School, Learning Technology, and Learning Across the Life Span (HPL II, 2018).

2.6 Taxonomy of Educational Objectives

There are three domains of learning that educators should know and utilize in teaching activities. These domains are: 1) Cognitive domain, which was developed, in 1956, by a group of college and university examiners (Bloom, Engelhart, Furst, Hill, and Krathwohl). This domain is related to mental processes. 2) The affective domain that was developed by Krathwohl in 1964. It involves feelings, emotions, and attitudes. 3) Psychomotor domain, which was developed by Harrow in 1970. This domain is based on utilizing motor skills. Each of these three domains has its taxonomy of educational objectives. Taxonomy, which means classification, was developed as a tool to facilitate communication. The following section briefs a few taxonomies based on these three domains (Bloom et al., 1956; Krathwohl et al., 1964; Krathwohl, 2002; Hoque, 2017).

2.6.1 Bloom's Taxonomy- Based on Cognitive Domain

The original taxonomy of educational objectives, known as Bloom's Taxonomy, was developed in 1956 by a group of college and university examiners (Bloom, Engelhart, Furst, Hill, and Krathwohl). Bloom's taxonomy consists of the following six categories in the cognitive domain: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation, respectively. Aside from the application, each of the other 5 categories has its subcategories, see Table 2.16 (Hoque, 2017; Bloom et al., 1956).

Table 2.16: Categories and Sub-Categories of Bloom's Taxonomy

Level	**Categories**	**Sub-Categories**
1	Knowledge	1. Knowledge of specifics 2. Knowledge of ways and means of dealing with specifics 3. Knowledge of universals and abstractions in a field
2	Comprehension	1. Translation 2. Interpretation 3. Extrapolation
3	Application	N/A
4	Analysis	1. Analysis of elements 2. Analysis of relationships 3. Analysis of organizational principles
5	Synthesis	1. Production of a unique communication 2. Production of a plan, or proposed set of operations 3. Derivation of a set of abstract relations
6	Evaluation	1. Evaluation in terms of internal evidence 2. Judgments in terms of external criteria

More than four decades later, a revised framework, known as Revised Taxonomy, was developed by Krathwohl, which was based on the original Bloom's taxonomy. As shown by Table 2.17, Krathwohl kept the same number of six categories; however, three categories were renamed; the order of the fifth and sixth categories was interchanged; and all categories were written using verb forms instead of noun forms. The six categories of the revised taxonomy are: 1) Remember 2) Understand 3) Apply 4) Analyze 5) Evaluate and 6) Create (Hoque, 2017; Krathwohl, 2002). The hierarchy of these six categories is split into two levels: Lower-level thinking, which includes remembering, understanding, and applying; and higher-level thinking which includes three stages of intellectual skills namely analyzing, evaluating, and creating. Table 2.17 shows the six categories, from lowest to highest level, and their respective cognition processes.

Table 2.17: Categories of Revised Bloom's Taxonomy

Level	**Categories**	**Specific Cognitive Processes**
1	Remember	i. Recognizing ii. Recalling
2	Understand	i. Interpreting ii. Exemplifying iii. Classifying iv. Summarizing v. Inferring vi. Comparing vii. Explaining
3	Apply	i. Executing ii. Implementing
4	Analyze	i. Differentiating ii. Organizing iii. Attributing
5	Evaluate	i. Checking ii. Critiquing
6	Create	i. Generating ii. Planning iii. Producing

2.6.2 Krathwohl's Taxonomy- Based on Affective Domain

Utilization of the affective dimension of learning in T&L activities would change the emotional aspects of the students such as empathy, care, enthusiasm, and motivation. Nevertheless, affective aspects of learning (such as feeling, emotion, and attitude) have never played an important role in engineering education compared to the cognitive aspects of learning. Some researchers attributed the lack of utilization of effective aspects of learning in engineering education to the lack of supporting the T&L model. Lashari (2015) states, "One of the factors that may contribute to this phenomenon is the lack of a teaching and learning model for supporting the utilization of the affective dimension in the teaching for cognitive learning."

Krathwohl (1964) identified five levels of learning in the affective domain, which are ordered as follows, from level 1 to level 5: Receiving, Responding, Valuing, Organization, and Characterization by Value. Below Table 2.18 shows the five categories and their foundational verbs (Krathwohl et al., 1964; Hoque, 2017).

Table 2.18: Categories of Krathwohl's Taxonomy

Level	Categories	Foundational Verbs
1	Receiving	Accept, Choose, Differentiate, Follow, List, Respond to, and Show interest
2	Responding	Acclaim, Answer, Commend, Comply, comply with, Follow, Spend leisure time in, Volunteer
3	Valuing	Associate with, assume responsibility, believe in, Debate, increase measured proficiency in, Participate, Relinquish, Subsidize, Support
4	Organization	Adhere to, Balance, Classify, Defend, Discuss, Examine, Formulate, identify with, Theorize
5	Characterization by Value	Avoid, change behavior, develop life philosophy, Influence, Manage, Rate high in the value, Require, Resist, Resolve, Revise

2.6.3 Harrow's and Simpson's Taxonomy- Based on Psychomotor Domain

In 1970 Anita Harrow introduced the first taxonomy based on the psychomotor domain. Many other taxonomies on the psychomotor domain were published, thereafter. Harrow's taxonomy was developed to assess the ability of children with physical limitations to perform a task/activity (Harrow, 1972). For comparison, Table 2.19 shows six levels of Harrow's taxonomy versus seven levels of Simpson's taxonomy (Harrow, 1972).

Table 2.19: Harrow's Taxonomy vs. Simpson's Taxonomy

Level	**Harrow's taxonomy**	**Simpson's taxonomy**
1	Reflex Movement	Perception
2	Basic Fundamental Movements	Set
3	Perceptual	Guided Response
4	Physical Activities	Mechanism
5	Skilled Movements	Complex
6	Non-Discursive Communication	Adaptation
7	--	Origination

2.7 Summary

This chapter includes a literature review related to the research topic. The review covered a wide range of subjects from Sudan's background and engineering and engineering education research, to learning theories and theoretical perspectives for underpinning the study. Sudan's background includes the country's profile and the situation of engineering education and related research within Sudan. Globally, the literature review covered the evolution of the engineering profession and associated technological growth and their impact on engineering education. The chapter also includes learning theories, their classification, and their impact on engineering education research. Part of the review covered theoretical perspectives and constructive models that were chosen to underpin this study. The chapter concluded with a taxonomy of educational objectives.

CHAPTER 3

METHODOLOGY

Based on the research problem, research objectives, and research questions discussed in sections 1.2, 1.3, and 1.4, respectively, Chapter 3 discusses the methodology that was used in this study; the discussion includes the research design, strategies of inquiry, research methods, and the instruments to execute the study. The discussion also consists of any justification associated with the research methodology. Figure 3.1 shows the methodology flowchart, from problem definition and research design approach to data analysis and interpretation.

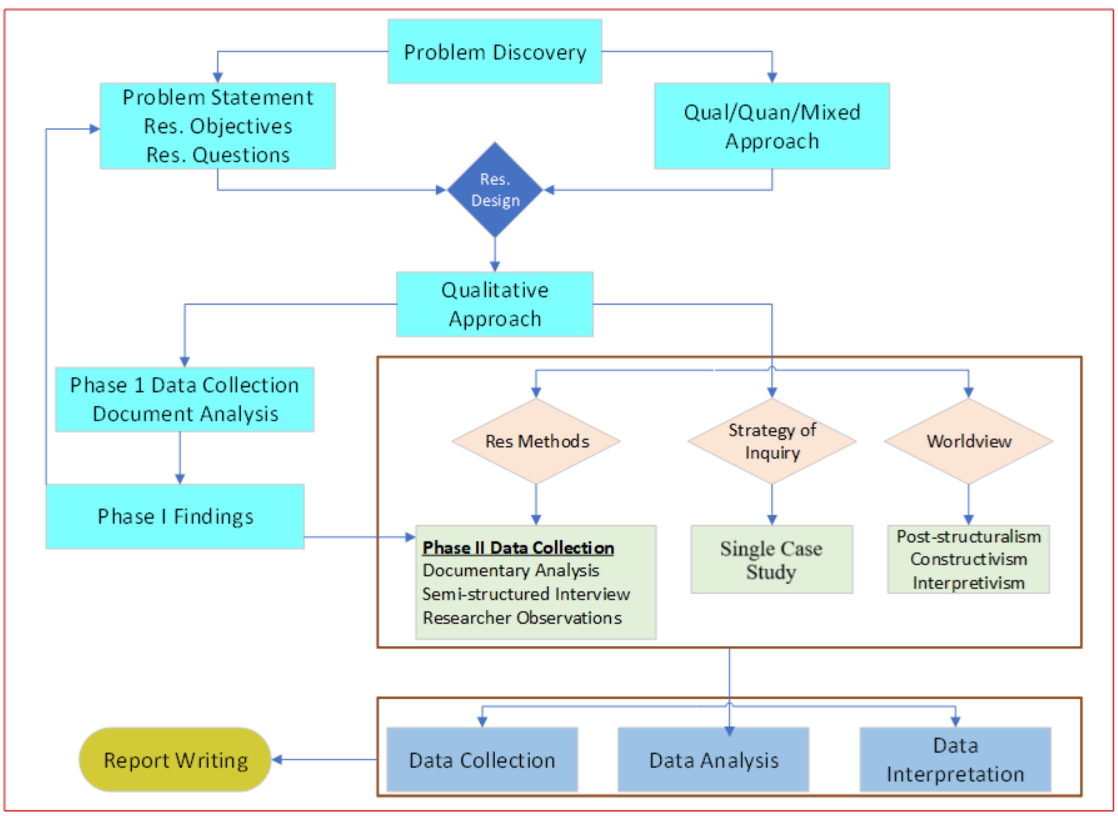

Figure 3.1: Methodology Flowchart- from Problem Definition to Final Report

3.1 Research Design and Methodology

Explicit philosophical and theoretical frameworks are key to achieving good qualitative research. There are three research strategies: qualitative, quantitative, and mixed. The latter approach represents features of the first two, qualitative and quantitative methods. The qualitative approach deals with words and open-ended questions while the quantitative one utilizes numbers to conclude the hypothesis test (Creswell, 2017).

Research design is a proposal to conduct research, and it has three components; these components are philosophy, methodology, and research methods (Creswell, 2017; Birks and Mills, 2014):

3.1.1 Philosophical Worldview

There are four different worldviews: postpositivism (associated with quantitative research), constructivism (linked with qualitative research), advocacy/participatory (deals with qualitative research in political areas), and pragmatism (associated with mixed methods research). These worldviews could be differentiated based on their ontology, epistemology, and methodology (Creswell, 2017).

Qualitative research allows deep insights and provides context and understanding of complex issues in the field of social science such as engineering education. Accordingly, the researcher had to select a research approach based on the research problem, the researcher's experiences, and the audience of the study. The researcher chose the qualitative research method because it is an appropriate approach for exploring complex issues in Sudanese engineering education (Pitterson et al., 2020; Glaser and Strauss, 2021; Corbin 2021). Also, the qualitative method allowed flexibility in data collection; accordingly, three data collection methods were used to gather data, including documentary analysis, semi-structured interviews, and observations. Seven purposeful participants were interviewed to collect various views to have rich data and meaningful findings (Patton, 2015). The study dealt with the lived experiences of expert participants and their views on Sudanese engineering education: Face-to-face semi-structured interviews were conducted; constant comparative and content analysis were used; and common themes emerged from gathered data (Creswell, 2016; Merriam, 2019; Patton, 2015). Thematic analysis of the participants' experiences with Sudanese engineering education allowed the researcher to find trends and patterns that might be impossible to discover whether by quantitative or mixed research methods (Miles et al., 2014; Bryman, 2021; Gibbs, 2015).

The qualitative model employs different philosophical assumptions, strategies of inquiry, and methods of data collection, analysis, and interpretation. This study combined these elements into the following qualitative approach scenario: Constructivist/PST combined with interpretivism as a qualitative research approach; case study; and open-ended interview, researcher's observation, and document analysis.

3.1.1.1 Constructivist Worldview

As explained in section 2.2.1.5, there are three main types of constructivism: cognitive, social, and radical constructivism. Nevertheless, there are three main elements of constructivism: 1) Ontology, which refers to the nature of reality; based on constructivism, multiple realities exist rather than a single reality. 2) Epistemology, which refers to the subjectivity of knowledge, assumes a strong and interactive link between the investigator and the participants while creating meanings. 3) Methodology, which refers to the process of research, includes methods of data collection, analysis, and interpretation (Lincoln and Guba, 2018; Gupta, 2022).

Refer to section 2.2.1.5 for additional details on constructivism.

3.1.1.2 Post-structuralism

Section 2.4 detailed Foucault’s PST, including his concepts of discourse, discourse analysis, power, and truth. PST allowed the researcher to depict the complex power structure among engineering education stakeholders, academic institutions, educational policies, and operational activities.

3.1.1.3 Interpretivism

Interpretivism refers to epistemologies or theories about gaining knowledge of the world; it is based on how humans understand and interpret their actions (Ryan, 2018). This definition is in line with many scholars who suggest that research in social science is concerned with Verstehen, which is different from research in natural science, which deals with Erklären. Verstehen and Erklären are German words for understanding and explaining, respectively (Pozzo, 2020). Therefore, social inquiries need methods that are different from natural ones. The latter requires an explicative approach, while the former, social inquiries, require an interpretive approach to understand them (Creswell, 2016; Denzin and Lincoln, 2022). As well, Creswell (2016), among other scholars, claims that interpretivists prefer qualitative methodology because there is a strong connection between the interpretivist paradigm and qualitative methodology.

The interpretive paradigm's main features are: (i) Interpretivist researchers understand and discover social reality through people’s perceptions and experiences. Therefore, reality is socially constructed, and multiple realities do exist due to varying human experiences. (ii) The interpretive paradigm is underpinned by the interpretation of gathered data, which comes from participants’ understandings and experiences. (iii) The subjectivity of the interpretive paradigm depends on the relationship between the researcher and the participant. (iv) Interpretivism can accept multiple viewpoints of different individuals from different groups (multiple perspectives and truths), which may lead to a comprehensive understanding. (Denzin and Lincoln, 2022; Ryan, 2018).

3.1.2 Strategy of Inquiry

Strategies of inquiry direct the research design either qualitatively, quantitatively, or a mix of both. There are many qualitative strategies of inquiry; these are narrative analysis, phenomenological method, grounded theory, ethnographic procedures, case study, discourse analysis, and action research (Creswell, 2016). To answer the research questions, section 1.4, this study employed the qualitative case study, section 3.1.2.1.

3.1.2.1 Case Study

The qualitative case study is defined as a thorough description and analysis of an integrated situation within a bounded system (Stake, 1995; Merriam, 1998, cited in Merriam, 2019). The case study is about a detailed description of a phenomenon within a unit of analysis (Merriam, 2019). Cases are bounded by time and activity, and researchers collect detailed information using a variety of data collection procedures over a sustained period (Merriam, 2019).

Yazan (2015) compared, side-by-side, three case study works that were produced by three prominent scholars; these works are: Case Study Research- Design and Methods, by Robert K. Yin (2002); Qualitative Research and Case Study Applications in Education, by Sharan B. Merriam (1998); and The Art of Case Study Research, by Robert E. Stake (1995). Yazan's comparative review pointed out differences, similarities, and complementarities among these three case-study works. For instance, Yin's epistemological view is toward positivism quantitative case study. Unlike Yin, both Stake and Merriam's epistemological views suggest a constructivism qualitative case study.

As shown in Figure 3.2, Yin classified the case study, based on its size, into four types: Single holistic, single embedded (multiple analysis units), multiple holistic, and multiple embedded design. There is an additional case study classification, based on the intent, whether single instrumental, collective/multiple, or intrinsic case study (Creswell, 2016).

Case study is one of the frequently employed methodologies in qualitative education research, although it lacks a well-structured protocol; however, case study allows the researcher to analyze a phenomenon within a certain context (Yazan, 2015).

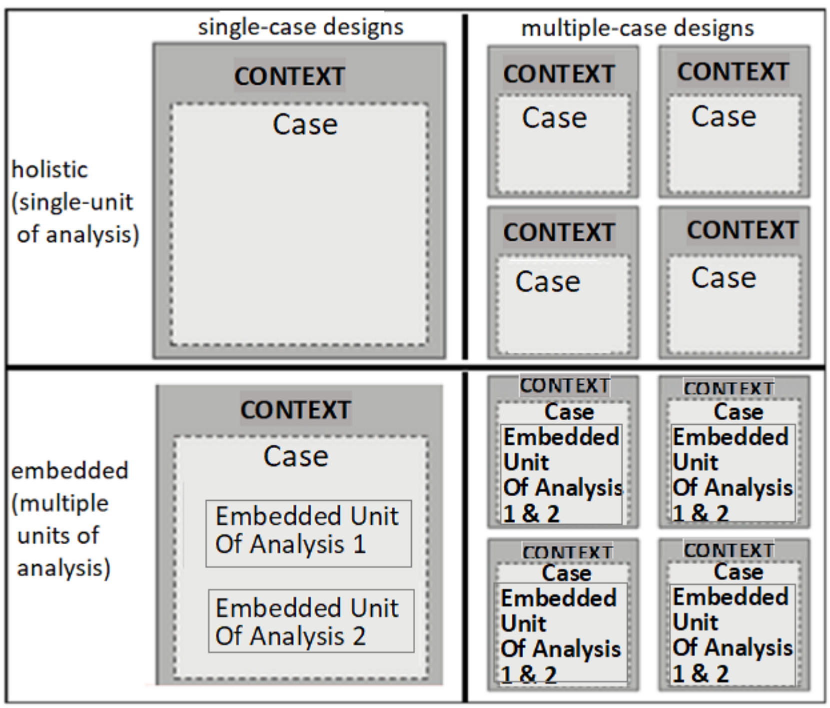

Figure 3.2: Types of Case Studies (Adopted from Yin 2003, p. 40)

Based on the defining characteristics of the case study, this research followed the following procedural steps, as proposed by Merriam (2015): Determine whether the case study is suitable for the research topic; identify the research case, single or multiple cases and single or multiple analysis units, with clear boundaries; decide on the data resources and data collection methods; identify the type of analysis (analysis of few themes or analysis of multiple cases); and identify interpretation of the findings, instrumental case or intrinsic case (Creswell, 2016 p100; Yazan, 2015).

This case study is about the undergraduate engineering education program at UofK, Sudan. UofK is a public university, and it is fully financed by the government of Sudan. It is the oldest, second largest, and most prestigious academic institution in the country; its students, graduates, and academic staff believe that they are the best in higher education in the country. This belief comes from the fact that UofK accepts the top high school graduates. Also, its administration and academic staff have significant social and academic influences. (https://www.uofk.edu/en/). Most Sudanese universities and higher education regulatory agencies use UofK as a benchmark for higher education in the country. In addition, this case study interests the researcher himself because it has not been researched properly, see the problem statement, section 1.2; and the researcher, who comes from Sudan, is convenient for conducting the case study, from gathering and analyzing the data to interpreting the findings (Yin, 2009). The researcher selected the single-embedded case study (one holistic case and multiple analysis units). This design allowed in-depth investigation of the situation of the engineering education field within the context of Sudan, see section 2.1.4.

On the other hand, the case study allowed the researcher to utilize multiple instruments of data collection (Merriam, 2015; Creswell, 2016) to answer research questions (section 1.4) and to achieve a deep understanding of engineering education in Sudan. Finally, case study has been widely utilized with discourse analysis in the field of engineering education (section 2.3.3.1). Single-embedded cases, which require multiple analysis units, vary according to the research objectives and research questions, as discussed in sections 1.3 and 1.4, respectively.

As part of the case study design, this research followed Merriam's, detailed and flexible, process of qualitative case study. Her approach, which is a combination of Stake and Yin approaches, includes performing a literature review, developing a theoretical framework, discovering a research problem, formulating research questions, and selecting the sample (Yazan, 2015).

Since the qualitative case study requires multiple instruments of data collection, this study employed three data collection instruments, namely semi-structured interviews, researcher's observations, and documentary analysis, see section 3.1.3. It is worth noting that the quality of gathered data, using these three methods, depends heavily on two elements: First, the researcher's ability to conduct effective interviews, record careful observations, and perform quality documentary analysis (sensitivity and skepticism); and second, well-developed protocols and procedures to gather data (Stake, 1995; cited in Yazan, 2015).

Merriam's constructivism epistemological point of view led her to define data analysis as a process of making meaning out of gathered data, which involves consolidating, reducing, and interpreting the perspectives and experiences of the participants (Merriam, 2015). Therefore, this case study followed thematic data analysis, which is in line with Merriam's model of data analysis for a few reasons: (i) She pointed out steps for data analysis, "consolidating, reducing, and interpreting", which implies constructivism in the analytic process. (ii) Merriam's model complemented both data analysis models of Yin and Stake. (iii) Like Stake, Merriam suggests that the data analysis step could be performed concurrently with the data collection step, which allows using the constant comparative method. (iv) The researcher believes that simultaneous data collection and analysis provided him with the freedom to stop data collection upon 'data saturation', rather than stop the analysis based on insufficient gathered data (Yazan, 2015). More about 'data saturation' is included in section 3.1.3.

Constructivists' views of concepts of validity and reliability are completely different from positivists' views due to their opposing epistemology, knowing that positivists use these concepts in quantitative social science. Constructivism epistemology is based on their assumption regarding reality, which has been discussed by many constructivists, see section 3.8. Among them are Stake and Merriam; the former stated that accuracy requires discipline and protocols rather than just mere intuition and good intention to 'get it right' (Stake, 1995: cited in Yazan, 2015); and the latter claimed that qualitative research assumes the reality is holistic, multidimensional, and under continuous change rather than a single, fixed, objective phenomenon awaiting to be discovered (Merriam, 1998, p. 202, cited in Yazan, 2015). This research follows Merriam's view of data validation, which is in line with Stake's view. Their views include triangulation, see section 3.4, and the researcher's position, section 3.5.

3.1.3 Research Method

The research method represents the third element in a qualitative research approach, which involves data collection, data analysis, and data interpretation that researchers propose for their studies.

3.1.3.1 The Data Gathering for This Study

This study used a two-phase data collection while employing a tri-level triangulation, section 3.4, to view and understand the research topic comprehensively. To generate the required data for the study, three data collection instruments, document analysis, interview, and researcher observation, were identified. Table 3.1 shows the sources of the data with their respective data collection instruments.

Table 3.1: Three Data Collection Methods

Sources of the Data	Data Collection instruments			Note
	Documentary Analysis	Interview	Observation	
MoHESR[1]	✓	--	--	Phase 1
MOE[1]	✓	--	--	
SUST[1]	✓	--	--	
USAS[1]	✓	--	--	
UofK[1]	✓	--	--	
UNESCO, WB, RAE[2]	✓	--	--	
MoHESR	✓	✓	✓	Phase 2
SEC	✓	✓	✓	
UofK	✓	✓	✓	

[1] Websites and sites visits.

[2] UNESCO, World Bank & RAE websites

As illustrated by Figure 3.3, data collection consisted of two sequential phases: Phase 1 was the first stage of document analysis, which resulted in the base for the following data collection phase. Phase 2 consisted of three data collection instruments: (i) the second stage of the document analysis, (ii) a semi-structured interview, and (iii) researcher's observations; all of them were performed concurrently; three data collection methods provided an additional level of method triangulation (Creswell and Plano Clark, 2017). Accordingly, data for this study was gathered using three distinctive stages, as shown in Figure 3.4: Documentary analysis, preliminary study, and the main study.

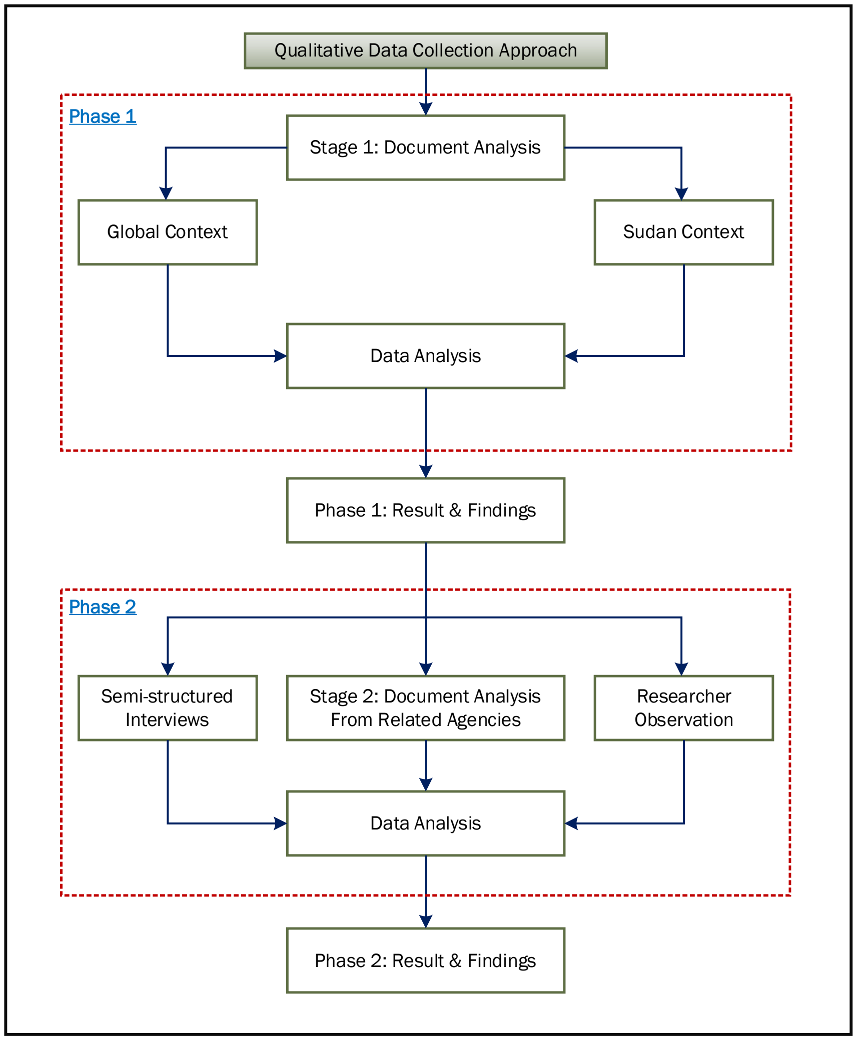

Figure 3.3: Two Phases of Qualitative Data Collection Approach

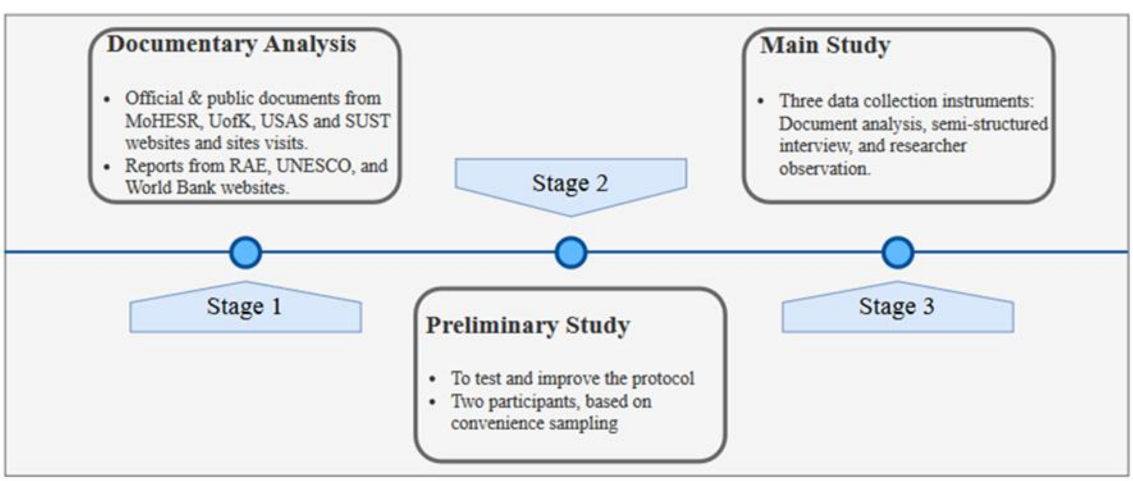

Figure 3.4: Three Distinctive Stages of Data Collection

3.1.3.1.1 The Documentary Analysis

The first stage is the documentary analysis, which represents a source of secondary data, and provides an additional level of triangulation. Documentary analysis was completed through two phases of data collection. The first phase was only documentary analysis, which laid the groundwork for the preliminary study (Section 3.1.3.1.2) and the main study (Section 3.1.3.1.3). Documents were obtained from academic institutions, governmental organizations, and international organizations, through site visits and related websites. Documents included reports, curriculum, and official committee findings. Of course, these documents were originally produced using different methods and intended for various and completely different purposes. Still, these documents provided insights into the practices in the area of engineering education.

Documents for phase I included: Official and public records from various sources, namely MoHESR, SEC, UofK, USAS, and SUST websites and site visits; Additional reports were collected from RAE, UNESCO, and World Bank websites. The second phase of documentary analysis was continued throughout the main study, along with the other two data collection methods: Semi-structured interview and researcher's observations. Documents were collected from UofK.

Documentary analysis and the researcher's observations were very helpful in filling the gap of information required in the analysis of interviews; however, on a few occasions, the documentary data was used as standalone information.

3.1.3.1.2 Preliminary Study

A preliminary study was crucial before the commencement of the actual semi-structured interviews. The preliminary study allowed the researcher to test the clarity and appropriateness of the semi-structured interview protocol namely the number, types, order, and flow of the questions; the language, and the time of the interviews; and his skills to conduct the semi-structured interviews, without following a certain order of questioning interviewees. Also, the researcher evaluated any potential biases due to inadequate questioning, the researcher's subjectivity, participants' perspectives, and many challenges during the interviews.

Based on convenience sampling, the researcher chose two participants, Int1 and Int2, as shown in Table 3.2 for the preliminary study. They were contacted and F2F semi-structured interviews were completed in July 2022. The semi-structured interviews were handwritten. One lasted almost two hours, while the second was completed in about one hour. The data was revised, and additional clarification was obtained through phone calls (Int1 and Int2).

Table 3.2: Two Participants in the Preliminary Study

Participant	**Gender**	**Affiliation**	**Experience**
Int1	Male	UofK	Academia 25+ yrs
Int2	Female	MoHESR	Administration & Academia 10+ yrs

Accordingly, an improved, bilingual (English/Arabic) version of the semi-structured interview protocol was produced (Section 3.2.2); the researcher tested and practiced his interviewing skills; and he decided to conduct the interviews, based on the participant's preference, either in the Arabic or English language. Also, the researcher established procedural steps to record his observations, notes, memos, and challenges that emerged during the interviews.

3.1.3.1.3 Main Study

As shown in Table 3.3, phase II, which was the main data collection for this study, used 3 different instruments: a semi-structured interview, the main source of primary data, the second phase of the documentary analysis, and the researcher's observations. Data was collected between July 2022 and March 2023, mainly from the University of Khartoum (UofK); additional data related to UofK was collected from the Ministry of Higher Education and Scientific Research (MoHESR), and the Sudan Engineering Council (SEC). The formal research activities, during the main study, have been split into fieldwork and follow-up clarification through the Zoom Conference Platform. Fieldwork included site visits (UofK, MoHESR, SEC), semi-structured interviews, document collection, and recording of observations. The purpose of the follow-up step was for the completion of data and clarification of any misinformation. The researcher has interviewed 7 participants from the list of potential participants using a semi-structured interview protocol.

i) Document Analysis

This study used a document analysis instrument, as a source of secondary data, which provided an additional level of triangulation. Documents included all types of written communication like books, reports, catalogs, journal articles, magazines, websites, meeting minutes, written policies, procedures, etc. (Peel, 2020). Document analysis was performed in two stages:

The first stage obtained official and public documents from MoHESR, SEC, UofK, USAS, and SUST websites and site visits, in addition to reports from RAE, UNESCO, and World Bank websites. Examples of reviewed databases are the Social Science Citation Index, Google Scholar, etc. The researcher reviewed and split the document content into two parts: The first part was concerned with the evolution of learning science, learning theories, the engineering profession, and engineering education, globally; while the other part was about higher education, including engineering education, and engineering profession within the context of Sudan, namely vision and mission statements, educational objectives, learning modules, learning outcomes, and programs structures and outcomes. By the end of this stage, the researcher was able to identify missing parts of the required data and to plan phase two of data collection.

The second stage was reserved to fill the knowledge gap of undergraduate engineering programs in the country and their educational objectives and learning outcomes. This stage of document analysis was conducted through direct contact with related agencies. During this phase, the researcher obtained documents of interest as hard and/or soft copies while visiting those academic institutions.

ii) Semi-structured Interviews

Face-to-face (F2F) interviews are a very important qualitative data collection instrument because the perspectives of interviewees are expected to shed meaningful insights about the research topic. Moreover, interviews would allow the researcher to confirm the validity and credibility of collected data using other methods (Peel, 2020). Although there are many types of interviews, the most used in qualitative research are only three, structured, unstructured, and semi-structured interviews (Bryman, 2021). The researcher, himself, conducted F2F semi-structured interviews to collect specific and similar information from all participants, one participant at a time. The researcher aimed to understand the perspectives of engineering education stakeholders, in Sudan, and make their perspectives explicit. See Section 3.2 for the preparation and conduction of the semi-structured interview.

iii) Researcher's Observation

This study used observation as a third instrument of qualitative data collection. The researcher's observation is one of the qualitative data collection methods, and it is to record unquantifiable information during the fieldwork of the main study; observations could be used to confirm research findings (Creswell, 2016). During the main data collection phase, the researcher recorded his thoughts and observations (memo writing) about the site visits, the accuracy, and consistency of participants' answers to given questions, participants' willingness to provide information, and the completeness of collected data. Also, the researcher has recorded his observations related to the engineering facilities at UofK, including lecture halls, chemical and computer labs, and workshops. Also, the researcher recorded challenges that he had faced during the interviews. There are many types of observations depending on the researcher's role as a participant, an observer, or a combined role of the former two; each type has its pros and cons. The researcher prepared an observation protocol for recording descriptive and/or reflective observations. He recorded his observations using audiotaping and/or handwritten forms (Creswell, 2017). Qualitative observations are on-site recorded notes or research diaries, unstructured or semi-structured, regarding the behavior and activities of participants. Field notes and research diaries are very important during field visits, and they may allow the researcher to capture unplanned and/or unnoticeable information. A list of recorded observations is discussed in Chapter 4.

Table 3.3: Phase Two Data Collection Instruments

Research Objectives To investigate:	**Research Questions**	**Data Sources* and Collection Methods**
1. the current situation of the engineering curricular.	1. What is the current situation of engineering curricula in Sudan?	• Semi-structured interviews • Document No.: 1, 4, 6, 8, 11, 13, 17, 21, 22, 25, 26 and 27 (from Table 4.1) • Observation No. 5a (from Table 4.4)
2. the situation of engineering educators in terms of qualification and professional development.	2. What is the situation of engineering educators in Sudan with regard to their teaching effectiveness, qualification, and professional development?	• Semi-structured interviews • Document No.: 1, 4, 5, 6, 8, 11, 17, 22 and 27 (from Table 4.1) • Observation No. 5b (from Table 4.4)
3. adopted teaching and learning philosophy by engineering programs.	3. What are the current teaching and learning approaches adopted by the Sudanese engineering education programs?	• Semi-structured interviews • Document No.: 1, 4, 8, 11, 25, 26, and 27 (from Table 4.1) • Observation No. 5c (from Table 4.4)
4. To construct a transformational framework for the Sudanese engineering education programs.	4. What is the importance of developing a framework to transform the Sudanese engineering education programs?	• Semi-structured interviews • Document No.: 5, 8, 10, 17, 22, 23 and 27 (from Table 4.1) • Observation No. 5a and 6 (from Table 4.4)

* Phase II data sources: UofK and MoHESR & SEC as related to UofK

3.2 Conducting the Semi-structured Interview

The researcher had to prepare for the semi-structured interview, and he had to practice how to conduct the interview. The following section very briefly discusses the preparation and conduction of the semi-structured interview.

3.2.1 Prepare for the interview

The researcher prepared the semi-structured interview guide, called the protocol, by breaking down research objectives and research questions into sub-questions and follow-up questions. Following the preliminary study, the protocol has been improved and finalized. The researcher finalized the research information sheet that includes the title of the research; research objectives; data collection procedures, activities, confidentiality, and data usage; and the researcher's contact info. Potential participants were contacted by email and phone calls to schedule a time and venue for 45-60-minute interviews. The researcher took care of other logistics required for the interviews: The means for recording the interview, a fully charged Samsung Galaxy S8-Plus smartphone, with a backup recorder; stationaries for taking notes; printout of the interview protocol, research information sheet, and the consent form; and any additional information about the participant and the interview venue.

3.2.2 The Interview Protocol

The researcher developed a semi-structured interview protocol to help him gather insights on the research topic, by asking necessary and sufficient questions during the interview and asking all participants the same questions. To allow participants to provide similar information freely, in their own words, these questions should be open-ended, informal, without specific order, and no leading questions. Moreover, the protocol's role was to guide the researcher to conduct flexible interviews in a normal human conversation fashion while allowing the participant to do most of the talk.

To obtain appropriate responses from participants, the researcher utilized a combination of six types of interview questions: Experience/behavior questions, opinion/values questions, feelings/emotions questions, knowledge questions, sensory questions, and background/demographic questions (Patton, 2015).

The protocol is bilingual (Arabic/English), and it contains four parts: The first part contains general questions to allow the participant to start talking and provide his info/background. The second part is to pursue in-depth answers to the research questions and sub-questions. These are detailed and probed questions. The third part includes clarification and follow-up questions about the research topic or its theoretical considerations. The fourth part is to conclude the interview by collecting the participant’s final remarks and suggestions. See Appendix A.

3.2.3 Participants Profile

Usually, the qualitative approach needs a smaller sample size than the quantitative one. This study considered the concept of saturation, as Glaser and Strauss (2021) recommended, to determine the appropriate number of participants for semi-structured interviews. Saturation means that the researcher actively involved in F2F interviews, should decide adding more participants to the study would not add meaningful information to the research topic. The initial plan was to interview around 10 participants; this number is based on Creswell's (2016) suggestion of between 5 and 30 participants for qualitative data collection. The number of participants might be increased or decreased, at the researcher’s discretion, based on the wealth of gathered data until information saturation. To ensure information saturation, the participants’ selection process considered diversity in terms of their views regarding the research topic and their expertise in the Sudanese higher education sector, including engineering educators, curriculum designers, administrators, and policymakers. In other words, the researcher selects a large enough number of participants who should provide relevant and accurate information about the research topic.

A mix of a few purposeful sampling strategies was the guide for selecting purposeful participants, because of two reasons: First, the researcher's connections with Sudanese academicians and Sudanese culture allowed him to access easily knowledgeable and experienced participants. However, there was the risk of losing the richness of information (Patton, 2015). To mitigate such a risk, the researcher's responsibility and the mutual respect between participants and the researcher are essential. A list of seven purposeful participants was selected through a mixture of three sampling strategies, namely typical case sampling, criterion sampling, and intensity sampling. Participants demonstrated diversified expertise in higher and engineering education in the country and the engineering profession (typical case sampling); they represented academicians, education and engineering education administrators, policymakers, engineering professionals, and industry practitioners (criterion sampling); Also, participants provided in-depth information about their experiences in engineering education in Sudan (intensity sampling). (Patton, 2015). As Table 3.4 shows, their experiences ranged between 5 and 30 years.

Table 3.4: Participants in Semi-structured Interview (Main Study)

Participant	**Gender**	**Affiliation**	**Experience**
Int3	Male	MoHESR	Administration & Academia 10+ yrs
Int4	Female	UofK	Academia 5+ yrs
Int5	Male	Industry	Industry & Academia 30+ yrs
Int6	Male	Industry	Industry 30+ yrs
Int7	Female	UofK/MoHESR	Administration & Academia 30+ yrs
Int8	Female	MoHESR	Administration & Academia 10+ yrs
Int9	Male	SEC & USAS	Academia 25+ yrs

3.2.4 Conducting the interview

Participants were contacted by email, phone calls, and/or direct personal contact. Participants were formally informed about the purpose of the study. Upon their acceptance to participate in the study, interviews were scheduled. Before the interviews participants' consents were obtained. During the interview, the researcher introduced himself and explained the purpose of the interview. Then, he presented the research information sheet and informed the participant that the interview needed to be audio recorded, using a smartphone. A total of 7 participants were interviewed using the interview guide (bilingual Arabic/English semi-structured interview protocol) one participant at a time. To ensure that participants' thoughts and opinions were precisely captured, the researcher decided that interviews be conducted in Arabic unless participants chose otherwise; this was because Arabic is the country's official language, and it is the mother tongue of most Sudanese. To collect similar information, the researcher asked each participant the same questions, not necessarily in the same order, though. The questioning began with simple, direct, and even informal questions followed by more complex open-ended questions; then moved to more detailed and probing questions. The interview continued with clarification and follow-up questions; it concluded with collecting the participant's final remarks and suggestions.

3.3 Data Collection Instruments for Each Research Question

To answer the four research questions (section 1.4), the study used three different data collection instruments, document analysis, semi-structured interview, and researcher observation, which were discussed in detail in the previous section. Here, the researcher identified procedural steps to collect data for each research question independently. However, similar steps were applied to all research questions.

3.3.1 First Research Question: What is the current situation of engineering curricula in Sudan?

Three different data instruments were considered to answer this question: (i) Document Analysis Instrument- the researcher obtained and reviewed documents related to the first research question, which included: Vision and mission statements, educational objectives, learning modules, learning outcomes, program structures and outcomes, and syllabus course sheets. (ii) Semi-structured Interviews- as far as the first research question is concerned, interviewees filled in the knowledge gap after the document analysis stage. Therefore, the semi-structured interview protocol gathered information about: The current curriculum, the total number of credit hours, the categories of the courses, courses with and without lab components, courses with design components, the process of curriculum design and curriculum revision. (iii) Observation and Research Diary- for recording descriptive, reflective, and/or census observations, the researcher recorded his observations using audiotaping and/or handwritten forms. It is worth noting that observations covered all four research questions simultaneously.

3.3.2 Second Research Question: What is the situation of engineering educators in Sudan with regard to their teaching effectiveness, qualification, and professional development?

Three data instruments were considered to answer this question: (i) Document Analysis Instrument- related documents to the second research question included the situation of academic staff, hiring structure, the process of assessing teaching effectiveness, and faculty promotion. (ii) Semi-structured Interviews- for the second research question, the semi-structured interview protocol included the following set of topics: Describe the situation of academic staff in terms of number and ranking, pre-service qualification, professional development program (in-service training), and instructor-to-student ratio; evaluate engineering educators' ability to understand and work with the preexisting knowledge, skills, attitudes, and beliefs of engineering students; evaluate engineering educators' capabilities to monitor students' progress, maintain their engagement, and challenge them; and describe the process of assessing teaching effectiveness, faculty promotion, compensation, and hiring structure. (iii) Observation and Research Diary- as mentioned in section 3.2.1(iii) observation recording was simultaneous for all four research questions.

3.3.3 Third Research Question: What are the current teaching and learning approaches adopted by the Sudanese engineering education programs?

Three data instruments were considered to answer this question: (i) Document Analysis Instrument- related documents to the third research question included assessment strategy documents, course assessment protocol, records of summative and formative assessment, and design of teaching and learning activities. (ii) Semi-structured Interviews- for the third research question, the semi-structured interview protocol included the following topics: Explain the assessment criteria and the role of summative assessment for evaluation of teaching effectiveness, and formative assessment for improvement of teaching; describe the teaching and learning activities necessary to meet the assessment criteria and lead to the desired learning outcome; list the necessary skills required and covered by the curriculum, and show that the curriculum encourages active learning, deep understanding, and teaching skills; describe the situation of engineering facilities (labs, workshops, libraries). (iii) Observation and Research Diary- as mentioned in section 3.2.1(iii) observation recording was simultaneous for all four research questions.

3.3.4 Fourth Research Question: What is the importance of developing a framework to transform the Sudanese engineering education programs?

Three data instruments were considered to answer this question: (i) Document Analysis Instrument- related documents to the fourth research question included the situation of the whole engineering education including infrastructure and capacity; also, policies, regulations, and contracts organizing relationships among stakeholders. (ii) Semi-structured Interviews- for the fourth research question, the semi-structured interview protocol should include, but not be limited to, the following set of topics: Identification of stakeholders; determining the power structure among stakeholders; the need for a transformational framework; and challenges facing the construction of a transformational framework. (iii) Observation and Research Diary- as mentioned in section 3.2.1(iii) observation recording was simultaneous for all four research questions. Table 3.5 summarizes data collected for each research question.

3.4 Triangulation

Triangulation has been used in land surveying, where one needs two landmarks to pinpoint his/her location at the intersection of these two points (Patton, 2015). There are many levels and types of triangulations. The researcher used a triangulation strategy to guard the gathered data against any possibility of systematic bias, to improve the quality of the gathered data, and to improve the validity of the findings (Patton, 2015 Merriam, 2015).

As explained in Section 3.1.3.1, the study used three methods to gather data (methods triangulation): Documentary analysis, semi-structured interviews, and researcher’s observations. Also, the study integrated post-structuralism, constructivism theory, OBE, HPL, and constructive alignment model and used them as fundamental theoretical perspectives (theory/perspective triangulation). The third type of triangulation “purposeful participants triangulation” was achieved through interviewing purposeful participants: typical case sampling, criterion sampling, and intensity sampling.

Table 3.5: Summary of Data Collection for each Research Question

Res. Ques	**Data Collection Instrument**			**Obs**
	Document Analysis	**Semi-structured Interview**		
		Sub-questions	**Follow-up Questions Topics**	
No.1	Vision & mission statements, educational objectives, learning modules, learning outcomes, program structures & outcomes, syllabus course sheets.	• Can you describe the current engineering curriculum at UofK?	• Total number of credit hours? Course categories? Lab & design component?	observation recording was mixed for all three research questions.
		• Can you describe the process of curriculum design?	• Curriculum revision cycles & the recent one?	
No. 2	The situation of academic staff, hiring structure, assessing teaching effectiveness, and faculty promotion.	• How to evaluate engineering educators' ability to understand & work with preexisting knowledge, skills, and attitudes of students?	• Situation of academic staff: Number, ranking, Qualification, SSR, etc.	
		• How to evaluate Eng. educators' capabilities to monitor students' progress, maintain their engagement, and challenge them?	• In-service training? • Teaching effectiveness? • Is it linked to faculty promotion, compensation, hiring structure, etc.?	
No. 3	Assessment strategy documents, course assessment protocol, records of summative and formative assessment, and design of teaching and learning activities.	Does the engineering curriculum teach skills?	• Description of engineering facilities? • Required skills? Covered by the curriculum? • Does the curriculum support deep understanding? And encourage active learning?	
No. 4	Documents, regulations & contracts organize relationships among stakeholders. Pros & cons of the Top-down approach, and its appropriateness for EE.	• What is the need for a transformational framework? • Who are the stakeholders of the EE? • What is the power structure among stakeholders?	Discuss the need for: • Engineering education reform. • Challenges facing reform. • What is the possibility of developing a transforming framework?	

3.5 The Researcher's Role

The researcher considers himself a seasoned professional engineer, a multidisciplinary researcher, and an experienced chemical engineering educator. The researcher, who was born and raised in Sudan, has studied, worked, and traveled extensively in Europe, the USA, Africa, the Middle East, and Asia. After he had earned his first chemical engineering degree from Romania, the researcher returned to his homeland, Sudan, and worked as an engineer in the energy sector. Then, obtained a master's degree in chemical engineering from the USA, where he has been working as a Research and Development Engineer in multiciliary areas, namely biotechnology, microfluidic technology, and nanotechnology. Since 2015 the researcher has moved to the United Arab Emirates (UAE), and he has been working as a chemical engineering lecturer at the Higher Colleges of Technology, UAE. While working as an engineering lecturer, the researcher showed interest in the engineering education research area. It is worth noting that, while pursuing his career, the researcher has been learning and gaining knowledge about various cultures. In short, the researcher brings a wealth of experience, skills, and knowledge to the research into the engineering education field.

3.6 Analysis and Interpretation of Gathered Data

As discussed earlier, this study used a three-level triangulation; qualitative case study; and generated data through three data collection instruments, document analysis, semi-structured interview, and researcher's observations. The qualitative case study allowed concurrent data collection, data analysis, and data interpretation. Below the Gantt chart, Figure 3.5, shows these overlapping tasks.

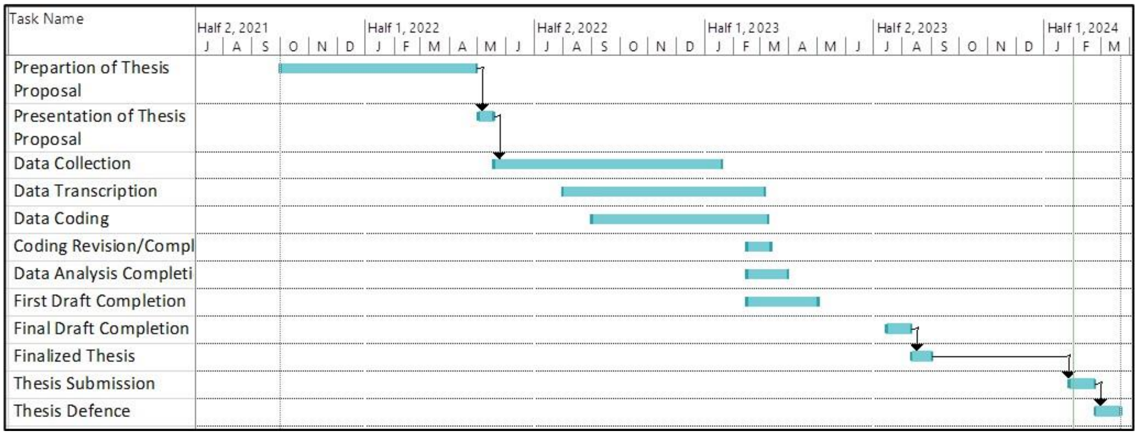

Figure 3.5: Timeline of the Study- from the Proposal to the Thesis Presentation

3.6.1 Analysis of Collected Documents

Document analysis, which includes all types of written communication, section 3.1.3(i), would serve as an additional level of triangulation and must undergo a systematic document revision. Therefore, to develop realistic meanings, the researcher analyzed both obvious and deep written content, also called manifest and latent analysis, respectively (Bengtsson, 2016).

3.6.2 Analysis of Semi-structured Interview and Observation

As discussed in section 3.1.2.1, this research followed Bryman's thematic analysis, which is similar to Merriam's qualitative case study data analysis model. Data analysis followed the following six-step data analysis and interpretation process, illustrated in Figure 3.6: (i) The Data preparation step was concerned with transcribing semi-structured interviews, field notes, and observations. (ii) The initial reading of transcribed data was to capture and record the researcher's reflections and thoughts on the overall meaning of the gathered data. (iii) Coding process, which was the process of organizing transcribed data according to its common themes and categories. The study used inductive coding, rather than deductive coding, to emerge codes during data analysis; the researcher performed manual coding. (iv) The study used a coding process (open coding, axial coding, and selective coding) to generate descriptions and categories that represented the findings of the qualitative studies. (v) The researcher developed interconnected themes and categories into a Framework. (vi) The final step of the data analysis process was the interpretation of the findings. (Bryman, 2021; Merriam, 2015; Creswell, 2016).

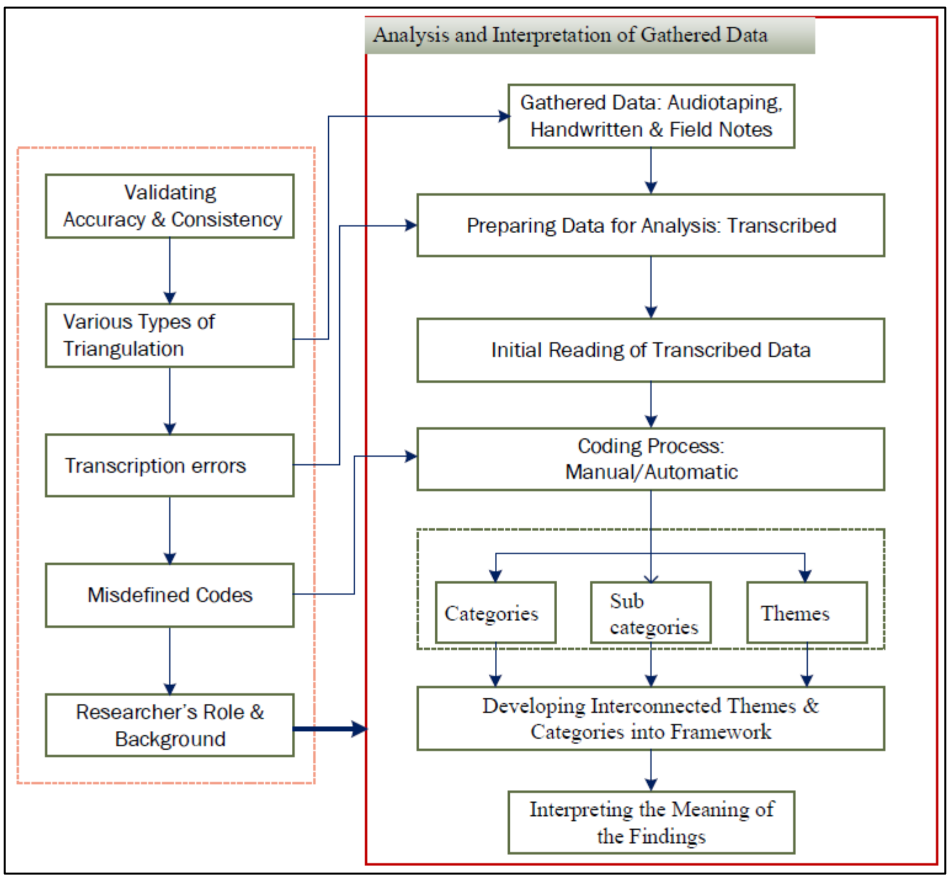

Figure 3.6: The Processes of Validating & Qualitative Data Analysis

3.7 Analytic Generalization Using Discourse Analysis

Since this research chose the qualitative “single” case study, the researcher realized its shortcomings: Lack of scientific rigor and not allowing statistical generalization of the results from the data to the wider population, which was impossible from a single case. Therefore, the researcher constructed validity through triangulation, internal validity through pattern matching, external validity through analytic generalization, and reliability through case study protocols and databases (Yazan, 2015). In addition to the single case study analysis, the researcher performed analytic generalization, rather than statistical generalization, using discourse analysis of PST, to achieve external validity (Jorgensen and Phillips, 2020).

Discourse analysis of engineering stakeholders highlighted how power operates and represents the interconnection operation of a complex network of power. This network of power, among all stakeholders (Governmental Agencies, Academic Institutions, Engineering Educators, Engineering Students, T&L Environment, National Agencies, and International Agencies) has its impact on each one of them, individually and collectively, as shown in Table 3.6. In other words, each stakeholder manifests and exercises power (rights and privilege) over the rest of the stakeholders within the discursive engineering education field; while the same stakeholder bears certain responsibilities and accountabilities since it is subject to the others’ power.

Table 3.6: List of Stakeholders Exercising Power/Responsibilities among Themselves

<table>
<tr><th>Stakeholders</th><th>Rights & Privileges</th><th>Duties & Responsibilities</th></tr>
<tr><td>Governmental Agencies</td><td rowspan="7">Power as manifested/exercised by each stakeholder.
Others expected to comply with.</td><td rowspan="7">Responsibilities of each stakeholder towards other stakeholders</td></tr>
<tr><td>Academic Institutions</td></tr>
<tr><td>Engineering Educators</td></tr>
<tr><td>Engineering Students</td></tr>
<tr><td>T&L Environment</td></tr>
<tr><td>National Agencies (including industry)</td></tr>
<tr><td>International Agencies</td></tr>
</table>

3.8 Validity and Reliability

The concepts of validity and reliability differ based on whether the approach is qualitative or quantitative research. Both Merriam and Stake knew it was unrealistic to consider the concept of validity and reliability in a qualitative case study, the same as applied to quantitative research (Merriam, 2015). Qualitative validity means the accuracy of the findings throughout the research steps by following certain procedures, while qualitative reliability indicates the consistency of the researcher’s approach (Creswell, 2017; Merriam, 2015). Moreover, Creswell (2017) suggests that a researcher should indicate his/her procedures for the validity and reliability of qualitative research.

To ensure qualitative reliability, the researcher checked transcription mistakes and mis-defined codes. As far as the validity of the findings is concerned, the study followed the following procedure, which is illustrated in Figure 3.6: (i) As discussed in section 3.4, the study uses three levels of triangulation (methods triangulation, triangulation of sources, theory/perspective triangulation, and purposeful participants triangulation) to provide a rich and thick description, which adds to the validity of the findings. (ii) The researcher looked for, presented, and discussed contradictory evidence to the general perspectives of the research topic. (iii) Moreover, the researcher utilized his experience as an engineering educator and a multidisciplinary researcher to fully understand participants’ perspectives, improving the findings' validity. (iv) Epistemology, or subjectivity of knowledge, is one of the constructivism elements; therefore, the researcher addressed the bias he may bring to the study.

Systematic monitoring of the researcher’s subjectivity and its impact on the research was key to ensuring a positive impact on the study. The researcher used reflexivity, which means critical reflection, to monitor his subjectivity and to ensure his trustworthiness. The researcher's experience and knowledge helped him to reflect critically on his role during the research process, from research design, data collection, data analysis, and interpretation of the findings. Therefore, writing notes and memos was essential throughout the research process. At the same time, qualitative interpretative research requires a strong link between the researcher and the participants while creating meanings (Lincoln et al., 2018), which means certain researcher biases might influence the study. Nevertheless, the researcher believes that his bias, values, beliefs, and background had a positive addition to this study rather than a negative impact.

3.9 Ethical Issues

The research quality could be improved by two premises: (i) connecting the motivations and intentions of the research topic to the cultural agenda and assumptions; and (ii) seeking justice for the participants, co-investigators, and readers of the research findings (Sochacka et al., 2018). This study considered two types of ethics: One type is the formal procedural ethics, which was considered during the research design stage. Therefore, a formal ethical review of the intended research topic was prepared before the start of the data collection in July 2022. In addition, the ethical review should follow any required ethical procedures. The other type is in-practice ethics, which was considered during the research process, including the Sudanese social, cultural, and political contexts (Sochacka et al., 2018). The researcher considered the ethical issues of this study beyond regulations and procedures and used research findings (outcomes) to promote social justice and cultural norms (Mertens, 2020).

Before the commencement of data collection, each participant was notified of the purpose of the research verbally and by providing the research information sheet (Appendix B); his/her consent was obtained according to the consent form. The researcher confirmed to all interviewees that participation in this study was voluntary, and each participant was free not to answer any question and/or to withdraw completely from the study at any time without any consequences.

During the interviews, the researcher asked participants for permission to take written notes and/or to voice-record the interviews. Also, participants were notified that their audio/transcribed interviews would be stored and/or utilized anonymously, and each participant had the opportunity to review a copy of their transcribed interview. All interviews were conducted utilizing a bilingual protocol (English/Arabic), and subsequent translation from English to Arabic, or vice versa, was done by the researcher; however, he was clarifying the interviews' content with the respective participant.

This research was conducted after the collapse of the authoritarian regime, in April 2019. This has been a significant political change in the country, toward a more democratic state, where academic institutions started to enjoy research and academic freedom due to political liberty. Therefore, the research topic was considered very interesting and desperately needed by the participants. Moreover, the uniqueness of the Sudanese culture in general, and the unfamiliarity with research formalities culture in particular, prepared the researcher to use a flexible approach to data collection techniques. Also, his awareness and sensitivity to the participants' social and political stands helped the researcher to build mutually respectful relationships with all participants

Sochacka et al. (2018) claim that the research quality is connected to its ethics; accordingly, the researcher considered the ethical issues of his work to improve its quality. He explored the intersections between his intentions and the cultural agendas and assumptions related to the research topic while seeking to do justice to the participants, co-investigators, and the audiences of the research (Sochacka et al., 2018). Therefore, a formal ethical review of the intended research topic was prepared before the start of the data collection phase, which started in May 2022 (Mertens, 2020).

3.10 Framework- Transformation Engineering Education

As discussed in section 1.2, The ultimate goal of this study was to establish a framework capable of transforming the Sudanese undergraduate engineering programs that are capable of graduating enough qualified engineers for the sake of the country's sustainable development. However, first and foremost, the study started with the evaluation of the holistic engineering education system in Sudan, based on a sound theoretical framework. First, the study developed the IFW, Figure 1.1, by integrating PST, constructivism theory, OBE, HPL, and constructive alignment (CA). The IFW served as a fundamental theoretical perspective underpinning the study. Constructivism theory, HPL, OBE, and CA were used to determine the gap between elements of the current engineering programs and the principles of the integrated framework, including issues and challenges facing engineering education in Sudan. While PST, including Foucault's concepts of discourse, discourse analysis, power, and the truth, allowed the researcher to depict the complex power structure within the broader engineering education field, which includes engineering education stakeholders, academic institutions, educational policies, and operational activities. These are expected to represent the components of the proposed framework.

3.11 Summary

This study chose the qualitative research approach, which was outlined in the Chapter. The Chapter started with a methodology flowchart, from problem definition and research design approach to data analysis and interpretation. The chapter continued the discussion of the research design, including the philosophical worldview, which combined PST, constructivism, and interpretivism; case study as a strategy of inquiry; and research methods that include various methods and sources of data collection, thematic analysis of the data, along with constant comparative method, and interpretation of the findings. In addition, the discussion included purposeful participants' selection using three sampling strategies. The chapter concluded with the researcher's role, a discussion of the validity and reliability of the study, and ethical remarks.

CHAPTER 4

FINDINGS OF THE STUDY

The Chapter consists of three parts: The first part (section 4.1) is about the collected data for this study; the second part (section 4.2) contains the analysis of gathered data; and the third part (section 4.3) details the findings of the study.

4.1 Collected Data for This Study

This study used the qualitative case study (Section 3.1.2.1), which requires: Multiple instruments of data collection; the researcher's ability to conduct effective interviews, record careful observations, and perform quality documentary analysis; and well-developed protocols and procedures to gather data (Merriam, 2015). Accordingly, data for this study was gathered using documentary analysis, semi-structured interviews, and researcher observations. Data was collected between July 2022 and March 2023, mainly from the University of Khartoum (UofK); additional data related to UofK was collected from the Ministry of Higher Education and Scientific Research (MoHESR), and the Sudan Engineering Council (SEC). MoHESR and SEC are the Sudanese regulatory bodies for engineering education and the engineering profession.

4.1.1 The Documentary Analysis

Documentary analysis, which represents a source of secondary data, and provides an additional level of triangulation, was completed through two phases of data collection. The first phase was only documentary analysis, which laid the groundwork for the preliminary study (Section 3.1.3.1.2) and the main study (Section 3.1.3.1.3). As shown in Table 4.1, documents were obtained from academic institutions, governmental organizations, and international organizations, through site visits and related websites. Documents for phase I included: Official and public records from various sources, namely MoHESR, SEC, UofK, websites, and site visits; additional reports were collected from RAE, UNESCO, and World Bank websites. The second phase of documentary analysis continued throughout the main study, along with the other two data collection methods: Semi-structured interview and researcher's observations. Documents were collected from UofK. Of course, these documents were originally produced using different methods and intended for various and completely different purposes. Still, these documents provided insights into the practices in the area of engineering education. Documentary analysis was very helpful in filling the gap of information required in the analysis of interviews; however, on a few occasions, documentary data was used as standalone information.

4.1.2 Semi-structured interview

A total of 7 participants, Table 3.4, were interviewed using the interview guide (bilingual Arabic/English semi-structured interview protocol), one participant at a time, to collect similar information. Before the interviews, participants' consent was obtained. All 7 participants provided in-depth information about their own experiences in the area of engineering education in Sudan. All seven interviews took place between July 2022 and March 2023. Each lasted between 50 to 90 minutes, except Int6, which lasted for 115 minutes. All face-to-face interviews were audio recorded using the researcher's smartphone 'Galaxy S8+'; while zoom meeting interviews (follow-up interviews) were recorded using the Zoom recording feature. For example, the Int9 interview transcript is included in Appendix D. Semi-structured interviews have gone through a coding process (Section 4.2.1.3).

Table 4.1: List of Obtained Documents & Their Sources.

Phase	No.	Document	Source
Phase I	1	Strategic Plan of Higher Education & Scientific Research 2021-2025.	MoHESR
	2	Report about Non-governmental Higher Education Institutes, 2020.	MoHESR
	3	Performance Evaluation Report during the period 2019-2020.	MoHESR
	4	Exemplary Engineering College Document, 2011.	MoHESR
	5	Reform of Higher Education and Scientific Research in Sudan-Policies, June 2020.	MoHESR
	6	Reports on Evaluation of Engineering Programs.	MoHESR
	7	Studies Reports on Independent Track of Technical Education.	MoHESR
	8	Reports on Report on the Urgent Needs of Engineering Colleges at Public Universities.	MoHESR
	9	Admission Guide into Higher Education Institutions, Sudan (Daleel Algobool, 2022-23)	mohe.gov.sd
	10	Ministry of Higher Education and Scientific Research Census Data, 1984-2018	mohe.gov.sd
	11	Sudanese Engineering Council Documents (Laws, Bylaws, Policies, etc.)	SEC
	12	UNESCO 6th African Engineering Week and 4th African Engineering Conference Proceedings, 2019.	UNESCO
	13	Framework for the Implementation of Education for Sustainable Development (ESD), 2019.	UNESCO
	14	Sudan Education Policy Review, Paving the road to 2030, 2018.	UNESCO
	15	Benchmarking Institutions of Applied Sciences, Engineering and Technology (ASET) in Sub-Saharan Africa, 2016.	UNESCO
	16	UNESCO Report in Sudan in 2016–17.	UNESCO
	17	Engineering: Issues Challenges and Opportunities for Development, 2010.	UNESCO
	18	Improving Higher Education Performance in Kenya: Policy Report, 2021.	UNESCO
	19	Sudan United Nations Development Assistance Framework (UNDAF), 2018-2021.	UNESCO
	20	The Human Capital Project, 2018.	WB
	21	Sub-Saharan African Science, Technology, Engineering & Mathematics Research, 2016.	WB
	22	The Status of the Education Sector in Sudan, African Human Development Series, 2012.	WB
	23	Sudan's Infrastructure: A Continental Perspective, 2011.	WB
	24	Assessing Engineering Education, Sub-Saharan Africa- African Technical Series, 1993.	WB
Phase II	25	Aldaleel (2012)- The catalog of the engineering college.	UofK
	26	Engineering programs structures and syllabuses of the courses	
	27	Accreditation Criteria of Engineering Programs in Sudan (SEC).	

4.1.3 Researcher's Observations

The researcher's observations are one of the qualitative data collection methods, for recording unquantifiable information during the fieldwork of the main study.

Observations could be used to confirm research findings (Creswell, 2016). During the main data collection phase, the researcher recorded his thoughts and observations (memo writing) about the site visits, the accuracy and consistency of participants' answers to given questions, participants' willingness to provide information, and the completeness of collected data. Also, the researcher has recorded his observations related to the engineering facilities at UofK, including lecture halls, chemical and computer labs, and workshops. Also, the researcher recorded challenges that he had faced during the interviews. See section 4.1.2 about the challenges and the researcher's effort to overcome them. Table 4.2 shows details of the main observations and required actions.

Table 4.2: Main Observations- Details and Required Actions

Main Observations	
No.	**Details & Required Actions**
1	• Details: Two Participants were unwilling to provide enough information. • Action: Cancelled Participants
2	• Details: One participant gave inconsistent answers to many questions. • Action: Cancelled the interview
3	• Details: Two incomplete interviews because participants had to leave for unplanned events. • Action: Complete the interview using Zoom Conference meeting
4	• Details: One participant had been engaged in other duties during the interview. • Action: Rescheduled the interview and changed the venue.
5 a-d	• All participants: a) agreed on the outdated curriculum with a lot of theoretical components and irrelevant engineering materials. b) confirmed the need for a hiring structure including competitive working conditions for academic & non-academic staff. c) asked for advanced T&L methods. d) called for a desperate need of improvement of the engineering system in the country.
6	• Details: Observations about lecture halls, chemical and computer labs, and workshops. • Action: Confirmed participants' perspectives about the limited engineering capacity to admit more engineering students.
7	• Details: Some of the challenges are the language barrier, completeness of the interview, and interview distraction. • Action: Conducted interviews in Arabic; completed interviews through Zoom meeting; and rescheduled/cancelled interviews due to distractions.

4.1.4 Sources of Information

As discussed in section 3.1.3, data was collected using two phases: Phase I was only a documentary analysis. During this phase, documents related to Sudan were collected from the University of Khartoum (UofK), the Sudan University of Science and Technology (SUST), the University of Science and Applied Studies (USAS), the Sudanese Engineering Council (SEC), and the Ministry of Higher Education and Scientific Research (MoHESR). While the main source of phase II data collection was the University of Khartoum (UofK); however, additional information related to the engineering program at UofK was obtained from SEC and MoHESR.

4.1.5 Challenges and Solutions

While gathering information through semi-structured interviews, the researcher encountered many challenges. This section discusses these challenges and the researcher's effort to overcome them.

4.1.5.1 Engagement with Experienced Participants

A good quality interview requires experienced participants in the area of engineering education who are willing to share their own experiences in their fields. As well, participants' availability to engage in the interview is very crucial for the study. It can be very challenging to prepare and approach a list of experienced participants. For instance: Finding enough participants may not be an easy task; Santoso and colleagues reported that only 4 participants, out of 45 potential ones, agreed to participate in the interview (Minalla, 2022). Also, in some cases, participants are unwilling to fully share their own experiences due to various reasons; of them are: the language barrier (Kakilla, 2021), limited understanding of the topic (Denzin, 2017; Nguyen, 2015), and/or distinct cultural values (Nguyen, 2015)

Solution: Being a Sudanese who has connections with many Sudanese academicians and professionals, in addition to the Sudanese culture that allows ease of connections and networking, enabled the researcher to assemble a list of purposeful participants, and easily approach them and access their institutions. Table 3.4 shows the list of participants who have already been involved in the interviews.

It is worth noting that, throughout his career as a professional engineer, and as an engineering educator, the researcher has established his professional network, which includes Sudanese scholars inside the country and diaspora.

According to Lincoln et al. (2018), qualitative interpretative research requires a strong link between the researcher and the participants while creating meanings, which means certain researcher biases may influence the study. Nevertheless, the researcher believes that his bias, values, beliefs, and background have a positive addition to this study rather than a negative impact.

4.1.5.2 Semi-structured Interview Protocol

A well-developed semi-structured interview protocol is crucial for generating quality data in terms of objectivity and trustworthiness, which means plausible results. Like structured interviews, the semi-structured interview allows the researcher to write fixed questions without following a certain number or order of questions; as well, the researcher has the flexibility to ask follow-up questions, when the need arises, to clarify, elaborate, and/or confirm participants' answers. However, it is not easy to develop a good set of questions for conducting a proper interview (DeJonckheere, 2019; Kallio, 2016). George (2022) states, 'Semi-structured interviews can be difficult to conduct correctly due to their delicate balance of prior planning and spontaneous asides. Every participant is different in their willingness to share. It can be difficult to be both encouraging and unbiased.'

Solution: Starting with research objectives and research questions, the researcher developed a bilingual (English/Arabic) semi-structured interview protocol draft; see next section about the language barrier. This draft has been tested, revised, and finalized during the preliminary study. Then, the predetermined semi-structured interview protocol was used to collect the data for the main study.

After completion of the first few semi-structured interviews, the researcher was able to determine that their quality was unsatisfactory, in terms of the amount of gathered information, missing information about certain topics, and unreliable information. Unsatisfactory data might be caused by biased and leading questions. Therefore, another semi-structured interview protocol revision had been completed, and a well-developed, bilingual semi-structured interview protocol was produced. Then, the main data collection was resumed.

4.1.5.3 Language Barrier

Although English is the official teaching language in most Sudanese universities, the researcher decided to prepare a bilingual (Arabic/ English) semi-structured interview protocol because Arabic is the country's official language, and it is the mother tongue of most Sudanese. As well, to ensure that participants' thoughts and opinions were precisely captured, the researcher decided that interviews be performed in Arabic unless participants choose otherwise; then, the following step was a translation of transcribed interviews to English. The challenge was to accurately translate back and forth between Arabic and English languages.

Solution: At the beginning, the semi-structured interview protocol was prepared in English, then translated into the Arabic language through a two-step translation process: The first step was translation using Google Translator. Although Google Translate has done a reasonable job producing the Arabic version of the protocol, still a second step was performed to revise and correct any mistranslation. A proper bilingual protocol was obtained.

On top of that, a rigorous understanding and translation of Arabic interviews are crucial to capture, without distortion, all gathered information. Google Translator, followed by a rigorous editing step resulted in a neat translation of transcribed interviews. This was a very time-consuming task, but it was critical, though. The researcher's knowledge of both Arabic and English languages guaranteed the translation accuracy.

4.1.5.4 Transcription of Arabic Interviews

As above-mentioned, the researcher decided to conduct all interviews in Arabic, which resulted in the burden of transcribing Arabic audio to text. This has become one of the main challenges because of one or more of the following reasons: Zoom Conference Platform does not support transcription of audio in the Arabic language; free transcription software cannot support lengthy audio interviews; Commercial transcription software is too expensive, at a rate between $90-$180 per one-hour audio. The researcher was very reluctant to utilize expensive commercial Arabic transcription software, with no guarantee that these types of software would complete the transcription accurately; bear in mind, interviewees, most of the time, were talking using the Sudanese dialect rather than the standard Arabic language.

Solution: Manual intelligent verbatim transcription was the option, knowing that it is a very time-consuming task; however, the researcher took the opportunity to complete simultaneously multiple tasks, namely: transcription, translation, and coding; in addition, verbatim transcription allowed the researcher, who knows both Arabic and English languages, to identify and address any inconsistency within the interview or questions that come up as he listens to the recorded interviews.

4.1.5.5 Interview Cancellation

Some scheduled interviews have been cancelled due to one or more of the following reasons: i) unplanned work-related commitments of participants; ii) unexpected social events that happened to them; and/or iii) a wave of political unrest during the period of data collection. In addition, some Face-to-Face interviews were cut very short for the same reasons.

Solution: Interview cancellation forced the researcher either to reschedule missing interviews (Int3 and Int7), or in a few cases to omit the interview completely and replace it with another participant. Incomplete Face-to-Face interviews were continued using the Zoom Conference Platform (Int5, Int6, and Int9). At the same time, the researcher capitalized on a few opportunities and conducted informal meetings/discussions. These meetings, in some instances, turned out to be very fruitful, where participants willingly provided meaningful insights about the research topic. One example was the meeting with the chair of the chemical engineering program (Int4), which has become a complete interview.

4.1.5.6 Avoiding Interview Distraction

Avoiding distraction, during the interview, is key for gathering high-quality Information. Distraction may occur due to various reasons, for instance: lack of interviewing experience, inaccurate preparation for the interview, interview surroundings, etc.

Focusing on a research topic during the interview has represented another challenge since conducting a successful semi-structured interview requires that the interviewer remains an active listener and non-judgmental and can let the participant guide the interview, while keeping him focused on the research topics (Mannan and Afni, 2020).

Solution: However, to overcome these challenges: the researcher prepared well for the interview (participants and logistics), and used a well-developed, bilingual semi-structured interview protocol; during the interview, he avoided leading questions and closed-ended questions, and he became a good listener rather than a participant in the discussion.

4.1.5.7 Completeness of the Interview

Incomplete interviews and/or loss of data represent a real challenge. Potential data loss might be caused by: a language barrier, a limited understanding of the research topic, the uncooperative participant who fails to share his own experience, and an incomplete interview (Kakilla, 2021).

Solution: Performing data analysis immediately, after the data was collected, helped the researcher improve and correct any errors. For instance, the researcher found out that the first few interviews were poorly conducted due to the semi-structured interview protocol. Accordingly, the interview protocol was reviewed and improved. Then, the researcher continued interviewing; a total of 7 participants were interviewed. To ensure the integrity and completion of the interview, the researcher allowed himself some time, at the end of each interview, to review it, write his remarks, record the gap, and evaluate the quality of the information. Although the quality of the interviews was much better than the first few, the researcher noticed reasonable gaps within the collected data. He had been filling in the information gaps and followed up clarification through the Zoom Conference Platform with Int5, Int6, and Int7. Zoom meetings have been working very well; the best complete semi-structured interview (Int9) was conducted through the Zoom Conference Platform.

In conclusion, the researcher has encountered many challenges while performing engineering education research in the context of Sudan. These challenges included but were not limited to preparing a list of experienced participants, developing a semi-structured interview protocol, language barrier, interview environment and logistics, interviewer's experience and training, and transcription of Arabic interviews to text.

4.2 Analysis of Gathered Data

Data analysis was greatly influenced by the chosen strategy of inquiry (Creswell, 2017). The researcher adopted the qualitative case study as the strategy of inquiry, which is discussed in section 3.1.2.1. In addition, being a qualitative case study researcher requires 'Knowing what leads to significant understanding, recognizing good sources of data, and consciously and unconsciously testing out the veracity of their eyes and robustness of their interpretations. It requires sensitivity and skepticism' (Stake, 1995; cited in Yazan, 2015). Like Stake, Merriam suggests that data collection and data analysis steps could be performed simultaneously, which allows using constant comparative methods (Merriam, 2015). The researcher believed that simultaneous data collection and analysis provided him with the freedom to stop data collection upon 'data saturation', rather than stop the analysis based on insufficient gathered data.

The researcher started analyzing the data as it was collected; Creswell (2017, p171). This study utilized Bryman's (2021, p578-581) thematic analysis approach for data analysis. Although some believe that the steps of thematic analysis are not well-defined, his approach consists of six steps: Become familiar with the data, generate initial codes, search for themes, review themes, define themes, and write up. Accordingly, the matrix-based method was adopted to organize and analyze the seven interviews. Table 4.3 shows the interview analysis matrix: the first column illustrates the broad categories: (i) as predefined codes that revolve around research questions; however, these codes were identified and confirmed by transcribed interviews, and (ii) an additional 5 data-driven codes were obtained and finalized from the interviews. The second column shows sub-categories that emerged from the interviews. Participants were depicted in the third column. While the fifth column regrouped similar codes (fourth column) under themes, which uphold the findings for the research questions.

Table 4.3: Data (Interview) Analysis Matrix

Categories		**Participants**	**Codes**	**Themes**
Broad	**Sub-Category**			
Predefined and data-driven coding	From transcribed interviews	Semi-structured interview Participants	Produced from multi-level coding	Regrouped similar codes

Displaying information in an organized and systematic format helped the researcher to visualize and analyze the data. It is worth noting that thematic analysis is similar to Merriam’s model of qualitative case study data analysis, which is a well-vetted process, as described below.

4.2.1 Six-Step Data Analysis

As above-mentioned, this research followed thematic analysis, which is similar to Merriam’s model of qualitative case study data analysis. In line with Bryman (2021) and Merriam (2015), Creswell (2016) proposes the following six-step process of data analysis: i) Data Preparation, ii) Initial Reading, iii) Coding Process, iv) Generating Categories and Descriptions, v) Developing a Theoretical Model, and vi) Interpretation of the Findings.

4.2.1.1 Data Preparation

The first step in the preparation of the interviews for analysis was transcription from verbal to written MS Word documents. A total of 7 interviews were transcribed manually, see section 4.1.5 about the challenges and solutions. Then written texts were edited, and necessary corrections were made. This is a crucial step to prevent misinterpretation of the findings due to unnoticed/uncorrected errors. Electronic files were used to store verbal and written data; however, the researcher preferred to work with hard copies. It is worth noting that at a later stage during the data preparation step, the researcher discovered that 'Microsoft 365' has a feature of transcription of Arabic audio into Arabic text, as well as translation of the Arabic text into English. Although generated written text by Microsoft 365, whether in Arabic or English, needed a lot of correction and editing, still Microsoft 365 was very useful and a time saver. I used it to redo the transcription of Int5, Int6, and Int9. As an example, Appendix D illustrates the edited version of Int9 transcription.

4.2.1.2 Initial Reading Step

After each interview, the researcher reviewed the collected data, both audio recording and transcribed data. During this initial reading step, the researcher wrote his memos and observations about the depth and quality of the data. These notes and observations have become handy while performing the coding process.

4.2.1.3 Coding Process

The third step was the coding process, which is key in qualitative data analysis. Creswell (2017) stated that the coding process has three systematic steps: (i) Open coding- to generate categories of information. (ii) Axial coding- to select and position categories within a theoretical model. (iii) Selective coding- to link categories and explicate a story from interconnected categories. According to Bryman (2021, p568), coding involves reviewing transcripts and field notes and labeling (naming) significant study findings. Accordingly, collected data has gone through multiple levels of coding, and constant coding comparison (Creswell, 2017; Bryman, 2021).

The researcher started with the interview protocol, which was developed in accordance with the research objectives and research questions. Accordingly, 4 pre-defined categories, known as concept-drive coding, were identified, each category for each research question: curriculum, engineering educators, T&L methods, and framework. Then the researcher shifted to 'data-driven coding', which was performed through multiple levels of coding: Initial coding, known as broad coding (Bazeley, 2023), was completed. During this level of coding, the researcher analyzed, line by line, all 7 transcribed interviews, each one at a time. Upon completion of the initial coding, he was able to confirm the predefined 4 broad categories; also, an additional 5 data-driven categories were obtained from the transcribed interviews, see Table 4.4.

The researcher continued initial coding; a total of 85 codes were obtained from the 7 semi-structured interviews (Appendix D). Then, the researcher performed the second level of coding, where he revised and finalized the 9 categories, which represent the findings of this study. Also, based on common themes, the 85 codes were reduced and regrouped into 39 sub-categories. In the end, similar sub-categories were regrouped under appropriate categories.

Table 4.4: Pre-defined and Data-driven Broad Categories

Category	**Pre-defined coding**	**Data-driven coding**
1. Curriculum	Res. objective 1 Res. Question 1	--
2. Engineering educators	Res. objective 2 Res. Question 2	--
3. Teaching & Learning (T&L)	Res. objective 3 Res. Question 3	--
4. Engineering graduates	--	Semi-structured Interview
5. Admission of engineering students	--	Semi-structured Interview
6. Relationship with the industry	--	Semi-structured Interview
7. Collaborations	--	Semi-structured Interview
8. Accreditation	--	Semi-structured Interview
9. Framework	Res. objective 4 Res. Question 4	--

4.2.1.4 Generating Categories and Sub-categories

The researcher continued the coding process (third and fourth levels) to generate categories and themes for analysis and identify how they are linked together (Creswell, 2017). Table 4.5 summarizes the findings of the interviews. It includes established sub-categories (column 2) and emerging themes (column 3) from interview analysis related to all investigated categories (column 1), each one separately, in this study. Emerged themes were analyzed in section 4.3.

Table 4.5: Summary of the Interview Findings

Categories	Sub-categories	Themes
1. Curriculum	1) Outdated curriculum a. Last revision 2012 b. On average revision every 10 years 2) Students' workload a. The duration of the program- 10 semesters/ 5 years b. 171-183 credit hours/ 65 courses 3) Theoretical curriculum a. Only two project-base courses (PBL/PjBL) b. Only three design courses c. No industrial training (see Category No. 6) 4) Irrelevant engineering materials 5) Untrue claim of OBE/CBE	Res. Obj1 Res. Q1
2. Engineering educators	6) Most of the educators are not capable of graduating qualified engineers a. Some engineering educators are without proper PhD degrees. b. Proper PhD holders, from Western universities, have been trained to perform research rather than teaching. c. They miss the practical elements of the Sudanese industries. d. They stop performing research due to poor research capabilities in Sudanese universities. e. Most of them haven't worked or even seen a factory in Sudan. f. knowledge is related to the countries from where they obtained their degrees. 7) No annual professional development programs 8) No professional development requirements a. Exception: 2 weeks of pedagogy training 9) No KPI for educators 10) No accountability 11) UofK affiliation is a prestige rather than for the financial merit	Res. Obj2 Res. Q2
3. Teaching & Learning (T&L)	<u>T&L Philosophy</u> 12) Traditional T&L is the norm 13) No evidence of SCL (see section 4.3.3 for details) 14) Duration of Study a. EC has been following the annual system. b. Changed to semester system. c. Only superficial change, without change in the curriculum, teaching materials, and/or traditional teaching method. <u>Academic Staff</u> 15) Teaching Ranking a. UofK- PhDs hold teaching ranking. b. MSc and PhD hold TA positions. c. other universities- MSc & PhD hold teaching ranking. 16) Poor financial compensation 17) Engaged in other academic and non-academic activities 18) No fund for research or training, 19) They are keen to help students. <u>Infrastructure</u> 20) Limited Buildings, Libraries, etc. (Not enough) 21) Laboratories a. Good for demonstration only, not for research b. Many instruments/ equipment are not functional.	Res. Obj3 Res. Q3

Table 4.5 (continued): Summary of the Interview Findings

Categories	**Sub-categories**	**Themes**
4. Engineering graduates	22) All it takes to graduate is to memorize the materials and take the test. a. Graduates are very good at theoretical knowledge. b. Graduates are very weak in practical skills. 23) The university used to link students with industry. a. Before: Students are familiar with the practical elements in their fields. b. Currently, training is achieved at a personal level and after graduation. 24) The training: Talent, competencies, and skills. a. Training should be impeded in the engineering curriculum; or even the pre-college curriculum	--
5. Admission of engineering students	25) Only top high school graduates a. Admission to different engineering programs is based on high School GPA b. Changing the major is almost impossible. 26) Technology awareness is not the norm	--
6. Relationship with the industry	27) Industry- Incompetent engineering graduates a. Industry wants ready engineering graduates. b. Prefer to recruit engineers from outside the country. 28) Industry- Universities don't put the effort to collaborate with industry 29) Industry- Educators are not interested in a proper relationship between academia and industry 30) Industry- Collaboration is done at a personal level rather than undertaking strategies 31) Universities- Believe that the industry is not keen on academia and/or research. 32) Universities- Industries in Sudan are not technically advanced, and they are not interested in research, but in only profitable activities. Note: One of SEC requirements is that each engineering graduate must complete 600 hours of on-the-job training.	--
7. Collaborations	33) Lack of collaboration with local, regional, and international institutions 34) UNESCO is the exception	--
8. Accreditation	35) Local accreditation by the MoHESR 36) No regional and/or international accreditation	--
9. Framework	37) Need for engineering education reform 38) Challenges facing engineering education reform 39) The possibility of developing a transforming curriculum framework	Res. Obj4 Res. Q4

4.2.1.5 Developing a Theoretical Model

This step was concerned with the researcher's plans to convey the study findings using figures and/or tables. The ultimate goal was to develop categories into theoretical models. The researcher developed a framework, which is discussed in Chapter 5.

4.2.1.6 Interpretation of the Findings

Interpretation of the findings was the last step in the data analysis process. Interpretation included the researcher's interpretation, comparison of the findings with the literature, and realization of whether the findings confirm or dispute the past information. In addition, interpretation led to further actions for future reform and change in the Sudanese engineering education system (Creswell, 2016).

4.3 Findings of the Study

This section discusses the study findings, which were divided into 3 groups: First, the engineering education environment; then, components necessary for graduating qualified engineers; and collaboration with professional and academic institutions.

4.3.1 Engineering Education Environment

This section discusses the Engineering Education Environment (EE Env), which consists of 3 elements: The curriculum, engineering educators, and T&L methods, as shown in Figure 4.1.

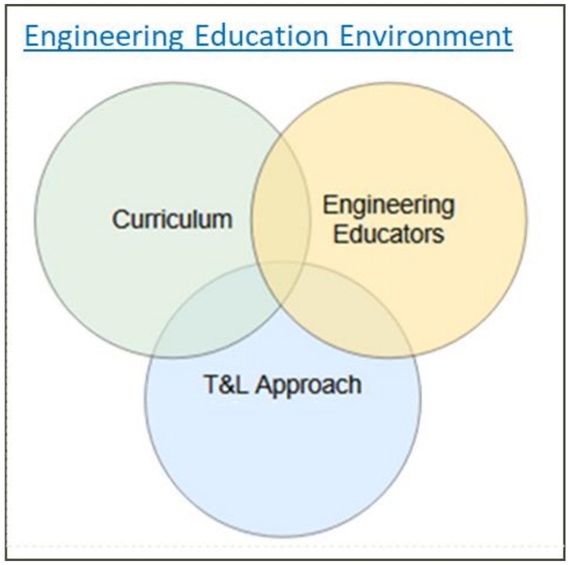

Figure 4.1: Elements of Engineering Education Environment

As explained earlier, principles of Spady's OBE, Biggs' constructive alignment, and HPL were used to evaluate elements of the engineering education environment (EE Env). The findings of the study confirmed that there is a gap between these principles and the elements of EE Env. For instance: The curriculum is not an OBE, and the course learning outcomes (CLOs) are not aligned with assessment tasks (AT) and teaching and learning activities (TLA), as required by both OBE and CA frameworks. Unlike HPL, the curriculum is not a knowledge center, and it does not include integrating the teaching of metacognitive skills (how the knowledge is actually being used); it focuses only on superficial coverage of memorizing facts rather than in-depth coverage of the subject matter.

The findings confirmed that engineering educators are not trained to incorporate the principles and characteristics of HPL, to impact the learning process, such as: working with the student's preexisting knowledge, beliefs, and background; teaching metacognitive skills to help students actively set their learning goals and monitor their progress toward achieving them. Also, as required by Biggs' (2020) CA: Educators are not trained to act as learning facilitators to help students construct knowledge using relevant learning activities. Also, educators do not properly assume their role in designing learning environments suitable for achieving intended learning outcomes.

Moreover, findings confirmed that traditional T&L methods are the norm in the engineering education field, although emerging learning theories and constructive frameworks such as OBE, CA, and HPL require the implementation of advanced T&L methods, student-centered rather than teacher-centered approaches.

4.3.1.1 The Curriculum

The duration of the chemical engineering program, at UofK, is 5 academic years, divided into a total of 10 semesters. In these 10 semesters, a chemical engineering student has to complete 171 credit hours, distributed over 65 courses, to earn his/her bachelor's degree. Table 4.6 shows the credit-hours distribution over three different categories of courses: 32 engineering core courses (89 credit-hours), 22 math and natural science courses (60 credit-hours), and 11 general studies courses, (22 credit-hours). It is worth noting that only 53 credit hours, which represent about 31% out of 171 total credit hours, have practical components such as laboratory work, projects, or design courses. As shown by Table 4.7, this number of credit hours is comparable to all other engineering programs at UofK, between 171 and 183 (Aldaleel, Table 4.1). Aldaleel represents the latest curriculum revision, which occurred in 2012.

Table 4.6: Credit-hours of the Chemical Engineering Program*

Year	Semester	Credit Hours	Total Courses	Humanities Courses[1]	EGS Courses[2]	CHE Courses[3]
I	1	19	7	2	5	--
	2	19	7	2	5	--
II	3	19	8	1	6	1
	4	18	8	2	4	2
III	5	17	6	--	1	5
	6	18	6	--	1	5
IV	7	15	6	1	--	5
	8	17	7	2	--	5
V	9	15	5	--	--	5
	10	14	5	1		4
5	10	171	65	11	22	32

* Adopted from (Aldaleel, Table 4.1)
1) 11 humanities courses make 22 credit hours with no lab components
2) 22 EGS courses make 60 credit hours
3) 32 CHE courses make 89 credit hours

Table 4.7: Total number of Credit Hours for each Engineering Program*

Engineering Program	Total Credit-hours
Agriculture & Biology Engineering	180
Chemical Engineering	171
Civil Engineering	181
Electrical Engineering	181
Mechanical Engineering	180
Surveying	179
Mining Engineering	171
Petroleum & Petrochemical	183

*Adopted from (Aldaleel, Table 4.1)

Moreover, the researcher realized that all schools of engineering in Sudan have a similar duration of engineering program in terms of the number of academic years and the total number of credit hours; for instance, the total number of credit hours for engineering programs at SUST and USAS ranges between 180 and 190 (SUST website and Int9). The researcher believes that the required credit hours to earn an engineering bachelor's degree are too many. Noting that ABET accreditation does not require a certain number of credit hours to earn a bachelor's degree in engineering. Nonetheless, ABET curriculum requirements include: (i) a minimum of 30 semester credit hours of college-level mathematics and basic sciences; (ii) a minimum of 45 semester credit hours of engineering topics appropriate to the program; (iii) general education courses to complement the technical part of the curriculum; and (iv) engineering design knowledge and experience (ABET, 2019).

Overloading engineering students with too many courses may not necessarily be a good recipe for graduating knowledgeable and skillful engineers. For comparison, two ABET-accredited chemical engineering programs in the United States of America (USA) limit their programs to only 120 credit hours, namely San Jose State University, California (SJSU) and the University of California Berkeley (UCB). SJSU offers a bachelor’s in chemical engineering upon completion of 120 credit hours (SJSU website); while UCB bachelor's requires a minimum of 120 and a maximum of 129 credit hours (UCB website). While a bachelor’s degree in chemical engineering at the University of Technology Malaysia (UTM) and Higher Colleges of Technology (HCT), in the United Arab Emirates, requires completion of 139 (UTM website) and 138 (HCT website) credit hours, respectively. Table 4.8 shows required credit hours by chemical engineering programs at UTM, HCT, SJSU, and UCB. Also, HCT has approved a new, 120-credit-hour chemical engineering program, as of Spring 2024.

Table 4.8: Bachelor of Chemical Engineering- Required Credit-Hours*

Categories of Courses	**Program Credit Hours**				
	UofK	**UTM**	**HCT**	**SJSU**	**UCB**
Engineering Core	89	99	80	56	87
Math & Natural Sciences	60	17	15	31	
Electives	--	--	10	9	20
General Studies	22	23	33	24	22
Total Credits	171	139	138	120	129

* Adopted from UTM, HCT, SJSU, and UCB websites

Aldaleel (Table 4.1) states that the engineering curriculum revision was developed according to ABET OBE guidelines and the program learning objectives (PLO). Upon graduation, a UofK engineering graduate should demonstrate the following PLO:

i. An ability to apply knowledge, techniques, skills, and modern tools of mathematics, science, and engineering.
ii. An ability to design experiments, conduct tests and measurements, and analyze and interpret the results.
iii. An ability to design systems, components, and processes to meet specified needs for broadly defined engineering problems, bearing in mind economic, environmental, social, political, ethical, health and safety, and sustainability aspects.
iv. An ability to apply written, oral, and graphical communication skills, teamwork skills, and lifelong learning skills.
v. An ability to perform effectively within diverse technical teams, as a member and/or as a leader.
vi. An ability to transform an engineering design (system, process, product, services, etc.) into a business plan.

(Aldaleel, Table 4.1)

Int7 confirmed the fact that the latest revision occurred in 2012, and it was based on ABET OBE guidelines. After he had handed the researcher the Catalog of the Engineering College, known as Aldaleel (Table 4.1); Int7 said:

‘This document represents the latest version of the engineering curriculum, which was updated in 2012. Before that, the curriculum has been revised three times since 1982.’

This means the curriculum has been revised on average every 10 years. The researcher asked Int7 about the curriculum development process at UofK and who has input. He stated:

'The academic senate formed a curriculum committee to revise and update the existing curriculum. Although the committee is free to solicit any additional expertise and/or others' feedback, the industry feedback is very insignificant. This is because of the weak relationship between industry and the university. In addition, the committee has to make sure that the curriculum meets SEC requirements.'

After the researcher had asked Int7 about SEC curriculum requirements, he handed him a document containing these requirements.

Separately, Int4 confirmed the above statement that was given by Int7. She said:

'Curriculum revision usually is done by a committee of academicians and rarely feedback from industry'.

When asked the same question, initially, Int9 explained thoroughly the process of curriculum development as laid out by the SEC. He reports:

'The curriculum development process is the same, for us or in almost all higher education institutions in the engineering education sector. Of course, the start is the old curriculum, after each graduation cycle, which is every five years, because all engineering studies in Sudan is 5 years for a bachelor of honors. Every five years the curriculum is supposed to be revised. The process is long; so, it starts with the previous curriculum being reviewed. It is evaluated according to the latest developments in science and technology, and the latest development in the labor market. These are two of the very crucial elements in the form of change and modification in any possible curriculum. The starting point of the process is to determine the strengths and weaknesses of the old curriculum. Of course, this whole issue is done by a committee; I don't know if the details here are useful or not, but anyway, I will mention it. A committee consists of the director of the designated educational institution and the concerned department or the dean of the concerned college, as a technical

secretariat; and the committee includes academicians from inside and outside the respective institution. Well, the committee that has the basic work methodology does something compared to the model curriculum. The Ministry of Higher Education and Scientific Research has a model curriculum for all specializations. After the old curriculum is compared with the model curriculum. After that, they moved to the stage of formulating new terminologies. The new terminologies in question and in the mind of the committee use all stakeholders' feedback in the educational process, professors, students, graduates, and representatives of the labor market in the particular specialty. After that, it is compared to the requirements of specialized professional councils; for example, we have in engineering the Sudanese Engineering Council (SEC) requirements. The Sudanese Engineering Council has certain criteria, to evaluate and approve each curriculum. For further development, it is also compared to the criteria required for international engineering education (ABET). I mean each one of them has requirements; what the curriculum is supposed to contain, in terms of basic sciences, engineering sciences, design subjects, and in terms of complementary sciences. Well, after formulating the proposed curriculum, it is presented to a selection of two or three senior scholars in the relevant specialization in Sudan for approval. Then the revised curriculum shall be presented to the authorities of the National Council for Higher Education and Scientific Research, which has a committee called the Committee for the Organization of Higher Education and Scientific Research Institutions. This committee has different departments for all sciences: The Engineering Science Committee, Medical Sciences Committee, Agricultural Sciences Committee, Computer Science Committee, and Environmental Science Committee. The final approval comes from this Committee. I mean, this is the process of updating the existing curriculum or developing a new one. This is a summary of the curriculum development process, and I am ready if there is a need for additional information.'

As the above statement shows, SEC has put in place a well-designed curriculum development process; however, Int9 believes that engineering programs do not follow the process, which is evident by the outdated curriculum. He continued:

> *'The first need is that curriculum is supposed to be tied to the development requirements of the particular country. I mean, engineering curricula in America and Germany shouldn't be the same curriculum as in Sudan. Accordingly, it is supposed to be linked, in one way or another, with development priorities, development requirements, and degrees of development. The university student is supposed to learn learning skills because the university is supposed to provide students with keys to learning. After all, the subject that you are learning today may not be relevant tomorrow. None of these needs is met by the Sudanese engineering curriculum.'*

In addition, OBE and PLO phrases are present in the outline of most chemical engineering course syllabi (Syllabus, 2020), and MoHESR documents (Exemplary Engineering College Document).

Int8 said:

> *'MoHESR website (http://mohe.gov.sd/), includes many documents, which demonstrate that universities have to include outcome-based/ competency-based elements in their curriculum. However, these requirements are not implemented properly.'*

The researcher confirmed the above statement with a similar one given by Int8, and by reviewing documents either given by Int8 as soft copies or posted on mohe.gov.sd (see Table 4.1 for a list of documents).

In line with Int8, Int3 said:

> *'MoHESR has certain guidelines that require universities to develop OBE/CBE curricula. Usually, universities write learning outcomes in their curriculum; however, these outcomes might not relate to the course content.'*

When the researcher asked the reason behind the improper implementation of MoHESR's guidelines. Int3 and Int8 gave almost the same answer; Int8 said:

> *'The reason is that MoHESR has no leverage to impose its authority over prominent public universities in Sudan, such as UofK. This is for two reasons: First, MOHESR's inadequate capacity wouldn't allow it to assume its role efficiently; and public universities are protected by constitutional policies and authorities. Moreover, administration bodies of higher education institutions believe that their institutions are independent and should be governed according to their laws and regulations.'*

Therefore, the engineering curriculum at UofK is content-focused rather than OBE. This observation is proved by the following facts: The high number of credit hours, at least 171 for a bachelor's degree in chemical engineering; traditional T&L philosophy (section 4.3.3); and the theoretical curriculum with very low practical content.

The outdated chemical engineering curriculum lacks enough courses with practical components, problem-based learning (PBL) and/or project-based learning (PjBL). As Table 4.8 shows, the chemical engineering curriculum, which was revised in 2012, is mostly theoretical with only 21% of the courses having practical components. The researcher noticed that none of the 171 credit hours covers any kind of training/internship within a related industry. It is worth noting that, the industrial training/internship component is one of the SEC requirements, in addition to the specified credit hours in Table 4.8, to recognize and accredit any engineering program in the country; otherwise, the SEC won't grant a license to any engineering graduate without fulfilling the industrial training/internship requirement, see section 4.3.6.

Int4 stated:

'The curriculum has only two project-based courses, CHE 41105 and CHE42105, during semesters seven and eight, respectively. As well, only three design courses include: a third-year design course (CHE31105) and two senior design projects, during the fifth year, (CHE51001) and (CHE51001).'

Int4 has her reservations about the way these PBL courses and the senior design projects have been taught; she comments as follows:

'These courses have been taught without any industry feedback, industry attachment, or joint academic-industry real-life projects.'

While Int5 openly elaborated on this issue; he said:

'The current engineering curriculum is loaded with irrelevant engineering materials, which were introduced, by the previous dictatorship regime, as part of the curriculum for only political reasons. As well, the current curriculum is mostly theoretical, without enough practical components, and no vocational and/or industrial training. In contrast, during our college time, mid the 1980s, the engineering curriculum included: vocational training at Khartoum Polytechnic Institute (KPI), attachment with related industries, and field trips to abroad industries, namely in Egypt. Currently, all it takes to graduate is to memorize the materials and to take a test on the materials.'

OBE-based curriculum may be required or suggested by MoHESR and/or the curriculum development committee itself (Int3, Int7, Int8, and Int9). At the same time, the revised curriculum in 2012 indicates that OBE is implemented. However, the implementation is unlike the actual OBE as known and described globally.

Outcome-Based Education (OBE) was developed by W. Spady in 1994. He believed that the purpose of school is to prepare learners for their role in life after school years, which could be achieved following what is known as transformational OBE (Spady, 1994). According to Spady (1994), OBE means, 'clearly focusing and organizing everything in the education system around what is essential for all students to be able to do successfully at the end of their learning experiences.' This means starting with a clear picture of what is important for students to be able to do, and then organizing the curriculum, instruction, and assessment to make sure that learning ultimately happens.

Accordingly, ABET outlined a certain procedure to develop the OBE curriculum. This procedure is followed by almost all programs that apply the OBE system. However, in the case of the engineering curriculum at UofK, OBE has been included after the course content is fully developed, which is supposed to be the other way around; as stated by Spady's OBE: the proper way of developing an OBE-based curriculum may start with defining learning outcomes (LO). Moreover, industry feedback on setting learning objectives is very important. This procedure is not typical during the development of the engineering curriculum at UofK.

Although MoHESR and SEC have in place a well-documented curriculum development process, curriculum development is usually owned by the universities. Each university forms a curriculum committee, mainly academicians, in charge independently of identifying curriculum objectives and outcomes (PLO & CLO); as well, the industry has no impact on curriculum development, such as identifying required competencies and skills. The insignificant role of industry in developing engineering education curricula is due to the weak relationship between the industry and the university; see section 4.3.6 (Int3, Int4, Int5, Int6, Int7, Int8, and Int9). Although there is nothing wrong with academicians developing engineering curricula, there are a few concerns: (i) The lack of prescribed competencies whether by the Sudanese industry or by professional entities in the country. (ii) There are no local or international accreditation standards to follow. Although Int7 mentioned that 'the 2012 curriculum revision is done based on ABET OBE and LO' but was not followed. The Int7 statement is confirmed by Aldaleel (Table 4.1). (iii) There is a discrepancy between MoHESR/SEC established policies/ requirements and the actual practice of curriculum development.

The curriculum category covers the first research objective, and Table 4.9 summarizes this category along with its sub-categories, and evidence as emerges from collected data.

Table 4.9: Curriculum Category, Sub-categories and Evidence

Cat.	Sub-categories	Evidence (emerged from the data)
1. Curriculum	1) Outdated curriculum	a. Last revision 2012 b. On average every 10 years c. Required every 5 years
	2) Students' workload	a. 10 semesters in 5 years. b. 171-183 credit hours/ 65 courses c. ABET Benchmark (UCB & SJSU): 120 credit hours
	3) Theoretical curriculum	a. Only two project-base courses (PBL/PjBL) b. Only three design courses c. No industrial training
	4) Irrelevant engineering materials	a. 33 out of 65 courses are not disciplined-related courses
	5) Untrue claim of OBE	a. Define Desired Learning Outcomes (DLO) b. T&L activates to lead to DLOs c. Assessing student outcomes d. Reaching the final grade

4.3.1.2 Engineering Educators

Findings confirmed that engineering education has been influenced by the scarcity of well-qualified academic staff, in terms of pre-service qualification and in-service training, and by low Staff-to-Student Ratio (SSR). Gasim (2014) stated, 'more than two-thirds of all academic staff, from teaching assistant and lecturer to professorial ranks, did not hold PhD degrees in their field'. On top of that, the SSR was estimated to be 1:34, which was far below the 1:15 required ratio by the local regulatory agencies to recognize and accredit any engineering program. These numbers show that most engineering programs do not satisfy the requirement of SSR to be recognized or granted accreditation (Osman, 2014).

As far as the qualification of academic staff, Int6 said:

> '*At UofK teaching ranking is held by only PhD holders, while master's degree and first-class bachelor's degree graduates hold TA positions. However, in most other universities, teaching ranking is occupied by both master's degree and PhD holders. The reason is that these universities cannot afford the relatively high cost of hiring only PhDs in teaching positions.'*

Contrary to Int6, both Int4 and Int9 confirmed the fact that even UofK started hiring master's degree holders as lecturers. Int4 said:

> *'The permanent academic staff of the chemical engineering program includes 10 PhD holders: 3 professors, 5 associate professors, and 2 assistant professors; in addition to 3 lecturers with master's degrees.'*

According to Int4, the chemical engineering program at UofK has an SSR of around 1:25, which is based on about 330 chemical engineering students.

Almost, all engineering programs in the country suffer from low SSR; this issue was explained by Int9 as follows:

> *'I was working in one of the MoHESR committees to evaluate and follow up on the evaluation of Sudanese higher education institutions. The committee has uncovered the entire situation of these engineering programs. Give you some examples: I told you that a faculty member is supposed to be one for every 15 students. We found that SSR varies; in some cases, this ratio is 1:60, 1:50, 1:40,*

and 1:30, although it is stipulated that one faculty to 15 students. The situation in public universities is even worse; this is because the Council mandate over the public engineering programs is very weak; and this is because public universities are supported by sovereign bodies. I found that, in the average Sudanese educational institution, the proportion of the faculty to students is one to 53.'

Int9 continued, with the following example:

'Let me give you another example: the MoHESR issued the admission guideline for the 2023 academic year, which plans to admit about 35 thousand engineering students. However, the actual number so far is about 20 thousand first-year engineering students. This number makes the total number of engineering students in Sudan about 140 thousand. While the teaching staff is not more than 2500 faculties, or one faculty for 56 engineering students (1:56). Therefore, the academic staff criteria are the weakest ones. Universities fill this gap by hiring part-time teaching positions. The situation of the teaching staff is due to three factors: First, poor compensation of the university teachers; even in our neighboring countries such as Chad, Uganda, and Ethiopia, the compensation of the university teacher is better than in Sudan, although their macroeconomic indicators are less than the Sudanese ones. Therefore, most good graduates prefer to work in industry rather than in academia. The second reason is the immigration to the Gulf countries, where the academic allocations are far better than in Sudan. The third reason is the lack of professional development.'

The issue of the low SSR in public universities is well documented in a report "The Urgent Needs of Engineering Colleges at Public Universities" generated by the Committee of the Engineering and Technical Studies, which is part of MoHESR.

Although UofK requires only PhD holders for teaching ranking, there is no upskilling program to expand the academic staff's capabilities (no in-service training programs). Int4 stated:

'UofK has no annual professional development programs for engineering educators, and they are not required to complete any professional development hours on an annual basis. The exception is that, during his/her career, each of the engineering educators must complete only two weeks of pedagogy training within the faculty of education.'

Int6 agreed with Int4 on the lack of professional development programs for academic staff, and his reasoning is the lack of funds. He said:

'UofK has no funds for research or training, and faculties are not required to complete any professional development during their teaching career. Nevertheless, some faculties seek, at the individual level, some kind of research activities and/or professional development opportunities.'

Int6 added:

'Because of the prolonged international embargo against the country, for political reasons, many engineering faculties have completed their graduate study inside the country. I believe inadequate research infrastructure in the area of engineering is one of the main issues related to the qualification of engineering educators in the country. Nonetheless, some of the PhD holders, who obtained their degrees from Sudanese universities, had to put more effort into overcoming difficult study circumstances and getting better in their field.'

When he asked about the capability of engineering faculties to graduate competent engineers, Int5's answer was:

'Most engineering faculties are not capable of graduating qualified engineers to work for the industry, because of the following reasons: (i) PhD holders, from Western universities, have been trained to perform research rather than teaching. On top of that, they missed the practical elements of the Sudanese industries. Most of them haven't worked or even seen any Sudanese factory; their

knowledge is related to the countries from where they obtained their degrees. (ii) Although they are good researchers, engineering faculties have stopped performing research due to poor research capabilities in Sudanese universities. (iii) There is no accountability at UofK, and no key performance indicator (KPI) for faculties.'

The researcher asked Int5 about his knowledge of- and experience with- engineering educators; he replied:

'My knowledge of engineering educators, in the country, and their performance has been gained from direct experience with a number of them during conferences and joint projects.'

As far as accountability and KPIs are concerned. Int4 agreed with Int5, she said:

'I am not aware of any annual performance review for the engineering faculties.' Knowing that Int4 has been affiliated with UofK for over two decades.

One of the concerns related to engineering educators is the fact that they are more comfortable with their traditional way of teaching because their education and training were mostly traditional; not only that but they do not receive any training in the area of SCL. Int4 and Int6 confirmed that there are no professional development programs for engineering educators at UofK. Related participants' perspectives are included in section 4.3.3.

Another concern is the poor financial compensation of engineering educators. Out of necessity, they get engaged in other academic and non-academic activities to generate extra income for their financial obligations. This means that engineering educators do not have enough time and/or incentives to fulfill their other academic obligations, get trained, and change their teaching method from traditional T&L to SCL

(Int4, Int5, Int6, Int9). The participants' (Int4, Int5, Int6, Int7, Int8, and Int9) views on the matter of the educators' financial compensation are alike; as an example, Int5 said:

> *'Most engineering faculties are only available, in the premises of the university, to deliver their theoretical lectures; and they are not available to perform their other academic duties, to help engineering students to accomplish their educational goals.'*

Int5 added:

> *'Faculty's poor financial compensation, forces them to get engaged in part-time academic activities in many other universities, for additional income, without regard to the negative impact to their main obligation towards their students.'*

Aside from what has been discussed in this section, there is an impression related to "fake academic degrees", which has been a notorious idea in the country for so long. People from all walks of life, professionals, lawyers, journalists, politicians, and academicians, just to name a few, have been talking and writing about this notorious idea for so long. All participants in this study agreed on the existence of this problem in the country; however, they disagreed on its severity (Int4, Int5, Int6, Int7, and Int9). Two of them (Int5 and Int9) have argued that the problem has been aggravated. The researcher asked each of them separately whether anyone might be able to quantify or come up with objective evidence about the issue of fake academic degrees. Ironically, both of them gave the same answer, which was a known story about an influential politician, who is known for his military career in the Sudanese army, who obtained a master's degree from one of the top public universities in the country. And his wife earned her master's and PhD, although some believe that she had not even attended a high school before her second marriage to this influential figure.

To illustrate this issue, the researcher quotes Int9 who painted a gloomy picture of the situation.

'Fake degrees represent one of the intertwined corruption rings within the country during the previous regime, which ruled the country with an iron fist for more than 30 years. Some luxurious and large universities have issued fake degrees (bachelor, master, and doctorate degrees) for influential figures in politics, business, and public services. I mean, I am also not talking about politics but speaking facts. For example, WB, the wife of an influential figure in the previous totalitarian regime, has a doctorate in strategic planning at one of the Sudanese public universities, although it is doubtful that she has a Sudanese high school certificate.

In addition, there are some who counterfeit university seals to issue counterfeiting certificates. Because of this issue, there are offices representing employers from Gulf countries such as Saudi Arabia and UAE, for verification of the authenticity of academic degrees and legal documents presented by Sudanese applicants. The fact that companies have been established to verify the validity of university degrees that have been granted by Sudanese higher education institutions is a great indication of the magnitude of the phenomenon. I do not like to speak in numbers since I do not have a proven study on the matter, but I can tell you from the reality of the indicators the magnification of the problem.

On top of that, there is what I call knowledge falsification: there are offices in the market established to help master and doctoral students with research, questionnaires, field surveys, statistics, and any need for a doctorate thesis. The worst thing is that their advertisements are on the national television of the Republic of Sudan.

Another way of knowledge falsification is that postgraduate studies programs have started relaxing admission requirements for graduate studies and have become more lenient in awarding the degrees, for the sake of commercial gains. All universities have opened bachelor's, master's, and doctoral degrees for whomever they want, regardless of their academic readiness. Graduate studies have become a source of income for public and private universities. Students, *who cannot continue higher studies outside Sudan, resorted to postgraduate studies inside Sudan.'*

The engineering educator's category covers the second research objective, and Table 4.10 summarizes this category along with its sub-categories, and evidence as emerged from collected data.

Table 4.10: Engineering Educators Category, Sub-categories, and Evidence

Cat.	Sub-categories	Evidence
2. Engineering Educators	6) Most of the educators are not capable of graduating qualified engineers.	a. Some of them without proper PhD degrees b. Proper PhD holders, from Western universities, have been trained to perform research rather than teaching. c. They miss the practical elements of the Sudanese industries. d. They stop performing research due to poor research capabilities in Sudanese universities. e. Most of them haven't worked or even seen a factory in Sudan. f. knowledge is related to the countries from where they obtained their degrees. g. No annual professional development programs and no professional development requirements. h. No KPI for educators and no accountability

4.3.1.3 Teaching and Learning Approach

It is well known that one-way dissemination of knowledge using lectures is not very effective. The ineffective traditional teaching and learning method, as discussed in section 1.1.2, is one of the main issues of Sudanese engineering education (Osman, 2014). Prince and Felder (2017) described this traditional teaching method as deductive instruction, which implies that: the lecturer explains, to his/her students, general principles and applications of a certain topic; and allows students to practice these principles by solving a set of homework problems, and finally assesses students' abilities to resolve similar problems. This ineffective teaching method does not consider the various learning styles of engineering students (Felder, 2020; Prince and Felder, 2017; Tulsi et al., 2016).

The SCL approach is very important to graduate competent engineers, where teachers are required to monitor learner progress, maintain their engagement, and challenge them by providing manageable tasks (NRC- HPL, 1999; NRC- HPL, 2000). According to Kolmos and Graaf (2014), there are many learner-centered models of Problem-Based and Project-Based Learning (PBL) in Engineering Education (Suradika et al., 2023; Holmes et al., 2016; Brundiers and Wiek, 2014). Yusof et al. (2015) introduced another example of the SCL model namely, Cooperative Problem-based Learning (CPBL), to prepare engineering graduates from UTM, ready for 21st-century challenges; see section 2.3.3.2.4.

All participants confirmed the fact that all engineering courses, either at UofK or other universities in the country, are delivered using the traditional style as above-described by Prince and Felder (2017). Particularly at UofK, findings confirmed that the traditional T&L method is the norm, which is evident by the following: (i) Engineering educators are used to the traditional T&L approach, and they have not been trained in SCL methods. The absence of proper training for engineering educators, whether in the area of advanced T&L approaches or any other area, is mainly due to a lack of resources; as well as educators are not required to complete any professional development. On top of that they do not have enough time and/or incentives for in-service training; see section 4.3.2 (Int4, Int5, Int6, and Int9). (ii) SSR is a concern; according to Int4, this ratio varies between 1:24 and 1:39, while Int9 believes that the SSR is even close to 1:53. This low ratio is a real obstacle for faculties to learn and implement an advanced T&L approach, like SCL; see section 4.3.2. (iii) As proved earlier, poor financial compensation is one of the main reasons for the shortage of devoted engineering educators who are ready to help their students become active learners, learn with understanding, and learn skills; see section 4.3.2. (iv) The outdated curriculum focuses more on the theoretical part with insignificant learner-centered models such as PBL, see section 4.3.1. (v) Inadequate facilities/infrastructure to support students' active learning, deep understanding, and metacognitive skills. Int4 said:

> *'The current infrastructure (building, libraries, workshops, and equipped laboratories), at UofK, is not enough to accommodate more than a batch of 50 chemical engineering students each academic year, or a total of 250 chemical engineering students. Moreover, laboratories are good only for demonstration, but not for research, knowing that many lab equipment and instruments are not functional.'*

Changing the traditional T&L method to the SCL method, along with changing the curriculum, is necessary to improve the quality of engineering graduates. Many participants believe that changing the traditional T&L method needs time and effort, in addition to realistic funding. Time and effort are required to train and change the mindsets of both engineering educators, at the operation levels, and the top management, and policymakers.

It is worth mentioning that UofK, which was established in 1902, is the first university, and is the most prestigious one in the country. Hence, changing its traditional style of teaching may require significant efforts and time to convince stakeholders of the benefits of SCL.

Int6 suggests:

> *'There is an opportunity for changing traditional T&L approaches to more advanced T&L methods. I believe a serious discussion is needed at faculty and administrative levels. Also, Sudanese scholars in the diaspora should have a role in any development efforts.'*

Moreover, there is no evidence that student-centered learning (SCL) has been practiced at UofK. The structure of the UofK academia is an important factor in the traditional T&L approach rather than SCL. The academic structure is mostly grounded on the academicians who have insignificant industrial experience, see section 4.3.2.

It is worth mentioning that the chemical engineering program includes two PBL courses, CHE41105 and CHE42105, during semesters seven and eight, respectively. Although PBL and PjBL courses are considered SCL approaches; however, the way these two courses have been delivered does not reflect SCL. Int4 has her reservations about the way these PBL courses and the senior design projects have been taught; she comments as follows: *'These courses have been taught without any industry feedback, industry attachment, or joint academic-industry real-life projects.'*

At the same time, Int5 questions the authenticity of delivered senior design projects; he said:

> *'The university is about memorizing the materials and assessing memorization. Most of the graduation projects have been copied from the internet, because of inadequate educators' supervision while mentoring graduation projects.'*

Int9 claims that more than 90% of academic institutions utilize traditional T&L methods; the following is his perspective regarding the traditional T&L approach:

> *'… The second issue, which is the most serious, is the nature of education itself. Ok, what is the nature of education in Sudan? Is it to indoctrinate the learner or to stimulate the learner to learn? That's a very big question! I think that in 90 percent of the institutions of higher education in Sudan, education is just indoctrination that feeds students with information and instructions, and not teaches them skills to learn. However, modern education, not just in universities, but even in schools, teaches the student basic learning skills, methods of scientific thinking, and skills to learn. The learner is a creator of knowledge who makes it clear that he is a participant in what material is presented to them.'*

The traditional T&L category covers the third research objective, and Table 4.11 summarizes this category along with its sub-categories, and evidence as emerged from collected data.

Table 4.11: . T&L Category, Sub-categories, and Evidence

Cat.	Sub-categories	Evidence (Emerged from Data)
3. T&L Philosophy	12) Traditional T&L	a. No evidence of SCL
	14) Duration of Study	a. EC has been following the annual system b. Changed to semester system c. Only superficial change, without change in the curriculum, teaching materials, and/or traditional teaching method
	Academic Staff 15) Teaching Ranking	a. UofK- PhDs hold teaching ranking b. MSc holds TA positions. c. Other universities- MSc & PhD hold teaching ranking
	16) Poor financial compensation 17) Engaged in other academic and non-academic activities 18) No fund for research or training, 19) They are eager to help students.	a. Share of the education sector is about 1.3% of GDP. b. Poor educators' working conditions. c. Lack of PD in SCL.
	20) Limited Buildings, Libraries, etc.	a. Observation # 6, about the limited engineering infrastructure.
	21) Laboratories	a. Good for demonstration only, not for research b. Much equipment/instruments are not functional.

4.3.2 Graduating Qualified Engineers

This section discusses the necessary components for graduating qualified engineers including programs for graduating engineers and preparation of high school graduates. See below Figure 4.2.

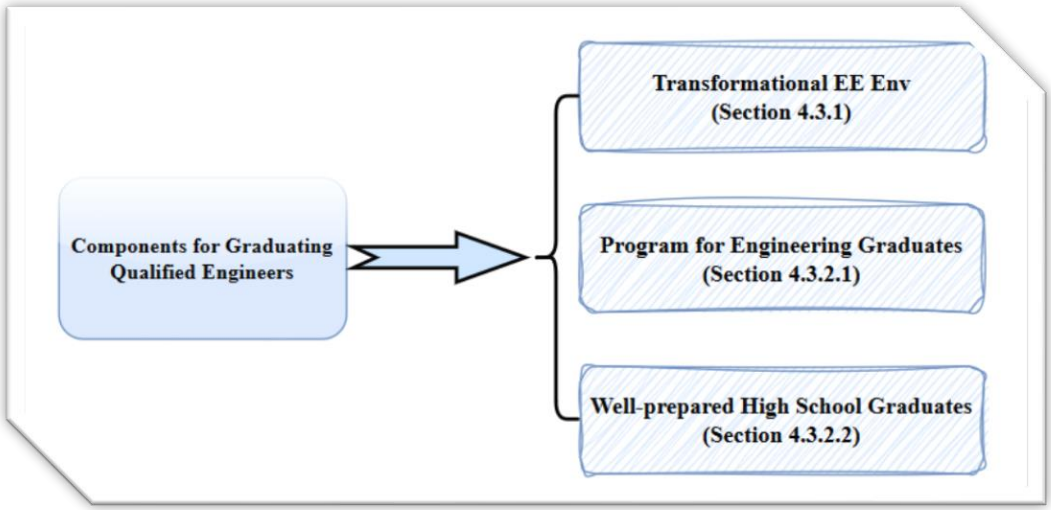

Figure 4.2: Components for Graduating Qualified Engineers

4.3.2.1 Engineering Graduates

Brundiers and Wiek, (2014) propose a framework, shown in Figure 2.12 based on PBL and PjBL, to allow students to gain sustainability competencies, participatory research education, and experiential learning. As well, many scholars have discussed and identified important competencies for engineers in the 21st century or global engineers.

Therefore, graduating competent engineers requires: i) curriculum that includes prescribed competencies, and approaches for teaching and assessing competencies. ii) enough qualified engineering educators. iii) Advanced T&L models. iv) adequate engineering infrastructure. v) Qualified high school graduates for engineering discipline.

Findings confirmed the fact that the engineering education system, in Sudan, is incapable of graduating enough competent engineers, which is a key pillar for the country's development. As well, gathered data proved that incompetent engineering graduates are due to the following reasons: The outdated curriculum without prescribed competencies and do not teach metacognitive skills (section 4.3.1.1); the insufficient number of qualified engineering educators (section 4.3.1.2); traditional T&L methods (section 4.3.1.3); under-preparedness of high school graduates (section 4.3.2.2) and inadequate infrastructure (Int4, Int5, Int6, Int7, and Int9).

As far as prescribed competencies, many participants agreed on the following as necessary for 21st-century engineers: Knowledge of theoretical and practical engineering fundamentals; the ability to effective verbal and written communication skills; in-depth command of technical competence in a specific engineering discipline; ability to design and evaluate operational performance; ability to work effectively in a technical team as a member or a leader; understanding of the social, cultural, global and environmental responsibilities and ethics of a professional engineer and the need for sustainable development; in addition to other skills such as: problem-solving skill, entrepreneurial skill, lifelong learning skill.

Int4 stated that the chemical engineering program graduates around 50 chemical engineers every year. Both Int4 and Int6 believe that the program graduates very knowledgeable chemical engineers with good communication skills. Int4 said:

> *'Every year, on average, the program graduates around 50 knowledgeable engineering graduates, with good communication skills.'*

Int5 believes that UofK graduates engineering students with theoretical knowledge, and limited skills; his explanation is below:

> *'Most engineering graduates, from UofK, have very good theoretical knowledge; however, their practical skills are very weak, and they are not aware whether they have the talent, or not, to proceed in their career. Knowing that if they are talented, engineering graduates would gain quicker practical experience. Lack of practical skills is because the university is about memorizing the materials and taking tests on memorized materials.'*

Int5 compared the current engineering graduates from UofK to the earlier graduates, from the 1980s:

> *'As engineering graduates, from the mid-80s of the last century, we believed that we used to be familiar with the practical elements in our fields. In some instances, we were even more competent than engineering graduates from abroad. This is because the university used to link the students with industry. Currently, training is achieved at a personal level and after graduation rather than during the duration of the study.'*

Int5 claims that his company designed a training program for freshly graduated engineers who lack industrial experience. He reported that around 80% of them have succeeded in the program. He described their training program as follows:

> *'In our industry, the training of engineering graduates is designed to discover and to know their capabilities, including talent, competencies, and skills. This type of training should be impeded in the engineering curriculum, and even before the college curriculum rather than after graduation.'*

Int6 agreed with Int5 regarding the quality of the current engineering graduates compared to their counterparts from decades ago. One of his reasons is the industrial training during college time. As an example, he told his own experience:

> *'... my senior graduation project was about the gasification of agricultural wastes for renewable energy. Upon graduation, I landed an engineering position with the Ministry of Energy; and a few years later, I was sent to France to pursue my PhD on the same topic.'*

The engineering graduate's category is related to the research objective number 1, 2, and 3. Table 4.12 summarizes this category along with its sub-categories, and evidence as emerged from collected data.

Table 4.12: . Engineering Graduates Category, Sub-categories, and Evidence

Cat.	Sub-categories	Evidence (Emerged from Data)
4. Engineering Graduates	22) All it takes to graduate is to memorize the materials and take the test	a. Graduates are very good in theoretical knowledge b. Graduates are very weak in practical skills
	23) The university used to link the student with the industry.	a. Before: Students are familiar with the practical elements in their fields. b. Currently, training is achieved at a personal level, and after graduation
	24) The training: Talent, competencies, and skills.	a. Training should be impeded in the engineering curriculum; or even the pre-college curriculum
	26) Technology awareness is not the norm	a. Unavailability of internet connection.

4.3.2.2 Admission of Engineering Students

Tertiary education in Sudan requires obtaining a high school certificate, with at least, a passing grade in all required subjects. These subjects depend on the discipline of the study that high school graduates apply for. For instance, majoring in engineering requires a high school graduate to obtain a certificate with, at least, a passing grade in the following subjects: Math, Physics, Chemistry, English, Arabic, and Islamic Studies. On top of that, an applicant to any engineering program should achieve a high school certificate with a minimum grade of 65% (Daleel Algobool, 2022-23; Int9). Int8 said:

> *'Each academic year and based on the results of the national high school certificate, jointly with the MOE, MoHESR decides on the admission requirements for higher education, including engineering education, which requires at least 65% for the current academic year.'*

The researcher asked Int8 about the significance of the 65%; she said:

'For engineering programs, the requirement was even higher than the 65%; however, the 65% would allow universities to increase their intake for financial reasons, knowing that they charge low-grade students with high school fees.'

Findings proved the inability of engineering education to accommodate the increasing number of high school graduates who desire to study engineering. This is because of many reasons such as: Usually, top-tier high school graduates get the opportunity to get accepted into one of the good public engineering programs in Sudan, such as UofK, SUST, Aljazeera University, and Alneelain University. In particular, to secure admission as an engineering student at UofK, a high school graduate has to earn a high school certificate with a high grade of 90% or higher, according to MoHESR guidelines for admission to Sudanese universities (2022-23). Even students who achieved top high school certificates cannot choose the type of engineering program, instead, they would be enrolled according to their high school certificate. This is because of the limited capacity of the engineering college. For instance, the total number of chemical engineering students, at UofK, is about 330 students (Int4). Another example is about a high school graduate with 94%, during the 2021-22 academic year. She told the researcher that 94% was not enough to be enrolled in electrical engineering, and she settled for mechanical engineering. Also, it is almost impossible to change one's major at UofK. Int5 told two stories from his own experience:

'AA has been accepted as a medical school student at UofK, which means that he has been one of the best high school graduates since medical school at UofK accepts only the top high school graduates. After he had completed three years in medical school, he decided to study engineering. He fulfilled his dream after he had pursued his only option, which was to quit medical school, again enroll in high school, and obtain a new high school certificate that allowed him to join an engineering college.

Another example was a science major student at UofK. She wanted to study linguistics instead of science. To achieve her dream, she had to quit her science major at UofK and moved to Egypt to study linguistics.'

On the other hand, since high school graduates represent the input for engineering programs, the quality of engineering graduates is directly proportional to the quality of high school graduates. Three of the participants (Int5, Int6, and Int9) linked the low quality of the output, engineering graduates, among other reasons, to the under-preparedness of the high school graduates, the input.

Int5 said:

'Pre-college engineering curriculum, along with advanced T&L methods, may well prepare high school graduates to proceed in their engineering college programs.'

While Int9 stated:

' I was for long periods, engaged with teaching more than administrative work at the university. I was interviewing students nominated for admission. Those students with 75% or higher high school certificates. These interviews proved to me that high school graduates are very weak academically in studying engineering. As well, I taught many courses, at the University of Khartoum and the University of Sudan. I noticed that the student's preparation is very weak and not comparable to the preparation of students until the late eighties.'

Contrary to Int5 and Int9, Int6 believes that high school graduates are more technically savvy and have good English communication skills. He said:

'I believe current admitted college students are technically more advanced than the past generation and their English communication skills are very good.'

When the researcher asked him about the reason behind his impression, Int6 gave the following example:

> *'My own three kids have attended a public high school; two of them, who have graduated from UofK, have been working in the USA: one is a physician, and the other is an engineer.'*

Engineering Admission category is related to the research objective number 1, 2, and 3. Table 4.13 summarizes this category along with its sub-categories, and evidence as emerged from collected data.

Table 4.13: . Engineering Admission Category, Sub-categories, and Evidence

Cat.	Sub-categories	Evidence (Emerged from Data)
5. Engineering Admission	25) Only top high school graduates	a. Admission in different engineering programs is based on high school GPA b. Changing the major is almost impossible
	26) Technology awareness is not the norm	a. Unavailability of internet connection.

4.3.3 Collaboration with Professional and Academic Institutions

This section discusses Sudanese higher education institutions, including engineering education, collaboration with local, regional, and international professional and academic institutions, including industry and accreditation bodies, as shown in Figure 4.3. Higher education institutions may benefit in areas such as: research collaboration, student exchange and professional development programs, joint conferences, and workshops.

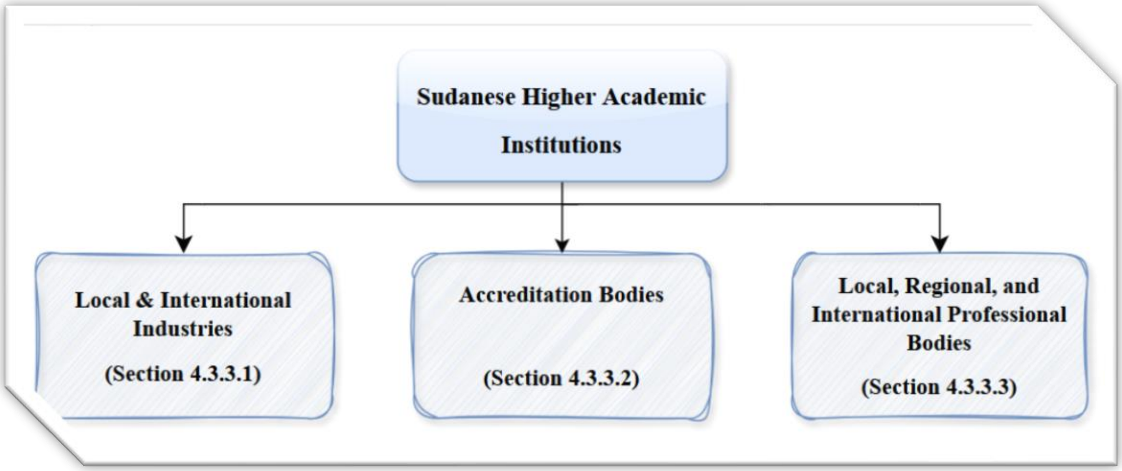

Figure 4.3: Collaboration with Professional and Academic Institutions

4.3.3.1 Relationship with the Industry

The reasons for a good relationship between the industry and academia are twofold: On one side, the industry relies on academia to supply them with competent engineers. On the other side, the industry represents the field where engineering students get trained to fulfill one of the graduation requirements set by the SEC; as the SEC would not grant an engineering license to any engineering graduate, unless he/she proves completion of a certain industrial training: Six weeks (150 hours), after the first year; six weeks (150 hours), after the second year; eight weeks (200 hours), after the third year; and four weeks (100 hours), after the fourth year (SEC document, Int9). At the same time, the industry may offer a lot to the academia, from feedback on prescribed competencies, and training and research opportunities, to providing different T&L models.

Unfortunately, findings showed that the relationship between industry, as an area where engineers practice professional engineering, and engineering education, where engineering students should become competent engineering graduates, is very weak. The weak relationship is due to differences in focus and interest within these two areas.

Int5 said:

‘Industries would prefer to recruit engineers from outside the country because they believe that engineering graduates, from Sudanese universities, are not competent and are not trained. The industries want ready engineering graduates who can have an immediate impact on the respective industry.’

Int5 believes that universities do not put the effort to collaborate with industry. He told the following about his own experience with a few universities:

"We provided a proposal, about the relationship between our industry and academia, to UofK, SUST, and the National University. As well, we expressed our interest in training engineering students. We have received no positive feedback and no interest from any of these universities.’

Int5 added:

‘I believe engineering faculties are not enthusiastic or interested in a proper relationship between the academia and the industry. They believe that industries in Sudan are not technically advanced, and they do not have a keen research interest, but only in profitable activities.’

Int5 believes there is a limited collaboration, between industry and academia, that needs to be expanded; he said:

‘Still, there is some kind of collaboration between the academia and the industry; however, this collaboration is done at personal levels rather than strategic plans for the universities.’

The following is another example of collaboration between the industry and academia; as stated on its website, the Materials and Nanotechnology Research Centre (MNRC) at UofK has established a collaboration with the Materials Research Center-

Giad Industrial Group (https://mnrc.uofk.edu). However, there are no details about the areas and/or the level of collaboration.

As has been discussed earlier, Sudanese engineering programs used to have a strong relationship with industry. This fact is evident in the statements given by many participants (Int5, Int6, Int7, and Int9).

4.3.3.2 Accreditation

Higher education institutions in Sudan, including engineering education, must be registered within-, accredited, and recognized by MoHESR. All engineering degrees, whether obtained from within the country or from engineering colleges abroad, must be recognized and attested by MoHESR. Thereafter, engineers should register with the Sudanese Engineering Council (SEC) to practice officially. MoHESR has a comprehensive process that must be followed by any higher education institution, under construction, to get recognized and accredited. In addition to accreditation, MoHESR's role is to provide consultancy and guidelines, to all academic institutions, related to curriculum. For example, on its website, MoHESR developed a document that contains the components of the 'Exemplary College of Engineering', which includes: Exemplary infrastructure, the qualification and number of academic and non-academic staff, the number of students, and the curriculum.

After the accreditation is granted, MoHESR's role is to conduct revision cycles, every now and then, to ensure that engineering programs follow the accreditation requirements. However, in the case of well-established public universities, such as UofK, neither MoHESR nor UofK follows these review cycles seriously. This is because MoHESR cannot oversee UofK programs; at the same time, UofK sees itself above MoHESR. Int3 said:

‘Annually we send a survey to all higher education institutions in the country to capture the information for the annual consensus of higher education for the whole country; some universities do not even provide the required information. These institutions are established by their laws and founding orders. These institutions have their scientific, administrative, and financial independence and are supervised by their own boards and administrative bodies.’

When the researcher asked Int9 about the relationship between MoHESR and SEC, he gave the following answer:

'The relationship is very, very overlapping between the SEC and MoHESR. Both of them share the mandate of overseeing engineering programs in the country. However, MoHESR leaves this part of its responsibilities to the SEC, which has the ultimate jurisdiction over the engineering programs in the country. First, SEC is a member of the National Council for Higher Education and Scientific Research (NCHESR), which is part of MoHESR. This is the overlap between the Engineering Council, as a Professional Board, and between the engineering faculty in any academic institution. The strange thing is that this matter is not stated in the Constitution or any other legal form. But in the end, the de facto, that the Engineering Council is the first and most basic curator of engineering education than the Ministry of Higher Education and Scientific Research and the various committees.’

Although the Engineering Council has in place very clear requirements, and the Council inspects all engineering programs continuously, still the actual situation in all engineering institutions in Sudan, in private and public universities, is far from consistent with the norms, as set by the Council. Accordingly, Int9 claims that the SEC evaluation process is very flawed evaluation; he explained how the evaluation process is flawed:

‘The council evaluation of engineering programs is very flawed and is based on the evaluation of six criteria together: The curriculum, the admission

requirements, the means of evaluating the performance of students and following up on graduates, the administration and teaching staff, the infrastructure, and research and graduate studies; none of them is a decisive factor on the overall evaluation. For instance, each program gets certain points for each criterion; and if the total of the points is 50% or more, the council would conclude that the program passed the evaluation, with a respective percentage, providing completion of a list of observations.

For instance, one of the SEC accreditation requirements is SSR of 1:15. However, as I mentioned earlier, this ratio is 1:53. In this case the council asks the institution to improve this requirement to start at 1:30, then 1:20, and the ultimate goal to reach 1:15. Well, institutions behave differently: some of them work genuinely to complete this requirement; others circumvent either by registering faculties for a certain period and then they abandon or by faking teaching contracts.'

According to Int8, there is a mutual relationship between MoHESR and SEC, she mentioned:

'The relationship between MoHESR and SEC overlaps when it comes to overseeing engineering education; both agencies coordinate their efforts through the NCHESR, which is affiliated with MoHESR. However, most of the time, MoHESR lets the SEC oversee the whole process of engineering education.'

Accreditation by international accreditation agencies, such as ABET, or even by regional agencies, within East Africa, is very important. This international accreditation would allow valuable recognition of engineering programs, and hence students transfer to similar programs, and graduate employability abroad. Yet, no Sudanese engineering program has been accredited by any international or regional accreditation agency, such as ABET; and no engineering program has even applied for international accreditation.

Int7 said:

'The international accreditation is very difficult to get, and the process itself is very laborious and costly. On top of that, UofK cannot get involved in hard-to-achieve accreditation.'

4.3.3.3 Collaboration with Professional and Academic Institutions

This section is about the collaboration between UofK and other professional and academic institutions, at local, regional, and/or international levels.

4.3.3.3.1 Local Professional Bodies

In addition to the MoHESR and SEC, there are two more professional agencies related to the engineering profession in the country: the Association of Sudanese Industries (ASI) and the Sudanese Engineering Association (SEA). None of these two agencies has any link with engineering education in the country, as confirmed by a few participants (Int4, Int5, Int6, Int7, and Int9). The relationship between the UofK and MoHESR/SEC is governed by the fact that both MoHESR and SEC are in charge of overseeing all higher education and engineering education, respectively, although UofK, like all other academic institutions, is governed by its regulation. Int7 said:

'The academic institutions in the country, including UofK, are formed and governed, independently, by their laws and orders. These institutions have their administrative bodies that oversee their respective scientific, administrative, and financial operations.'

However, to operate legally in the country, all higher education institutions must abide by MoHESR regulations. As mentioned earlier, MoHESR has entrusted SEC with overseeing accreditation, curriculum development process, and audit of engineering programs (Int9). At the same time, UofK has been following SEC curriculum requirements for engineering programs (Aldaleel; Int7), see section 4.3.1.1.

About the relationship between SEC and engineering programs in the country, Int9 said:

> *'Ok, the accreditation process governs the relationship between the SEC and the designated engineering program. SEC is the accreditation body. Students graduating from a particular engineering department are not allowed to practice the profession unless licensed by the SEC, known as the engineering number. The relationship with the SEC begins with the admission requirements; currently, the first requirement for admission to engineering majors by order of SEC is 65% in scientific major (mathematics or biology) but mathematics is preferable. After that SEC has six basic criteria to evaluate the particular engineering program: The curriculum, the admission requirements, the means of evaluating the performance of students and following up on graduates, the administration and teaching staff, the infrastructure, and research and graduate studies. Unless the Engineering Council is convinced that the academic institution has achieved all six, the institution is not granted accreditation, and its graduates are not granted engineering licenses. The engineering council forms a committee to audit the engineering educational institutions almost annually or every two years; and accordingly, the committee decides whether to extend or to freeze the recognition of the engineering institution/program.'*

4.3.3.3.2 Regional Professional Bodies

Although East African countries, including Sudan, have established many forms of political, social, and economic collaboration, there is no evidence that any professional and/or academic institution, from Sudan, is part of sub-regional/regional collaboration, within East Africa, in the area of engineering education or professional engineering. For instance, the Inter-University Council of East Africa (IUCEA) has members from Uganda, Tanzania, South Sudan, Rwanda, Kenya, and Burundi, and none from Sudan (https://www.iucea.org/). Another professional body, known as the 'Mutual Recognition Agreement (MRA) for Professional Engineering Services in East Africa' was formed in 2012 by the Engineers Board of Kenya, the Engineers Registration Board of Tanzania, and the Engineers Registration Board of Uganda. MRA states, *'The MRA enables professional Engineers within the East African Community (EAC) countries to move freely across the common borders without any impediments. This is expected to facilitate economic integration and increase greater consumer choice of engineering services within the region'* (https://www.ebk.go.ke).

4.3.3.3.3 International Professional Bodies

The researcher has not found any evidence of any kind of collaboration between UofK and any international professional bodies such as ABET, RAE, and Washington Accord (WA). As well there is no evidence of collaboration with international academic institutions.

UNESCO Khartoum has been established to address sharing vision programs for Sudan, Since 2006 (https://www.unesco.org/en/fieldoffice/khartoum/about). Still, Sudan and its academic institutions have not been actively participating in UNESCO events and conferences, or providing sufficient statistics for UNESCO reports, such as: the UNESCO Institute of Statistics Africa Regional Report, January 2021 on Sustainable Development Goals (SDG); UNESCO, (2019)- 6TH Africa Engineering Week and 4TH Africa Engineering Conference, Conference Proceedings, ISBN: 978-9982-70-915-6; UNESCO (2020)- Report Engineering: Issues, Challenges and Opportunities for Development, ISBN 978-92-3-104156-3.

Nevertheless, since 2011, there have been a couple of bright events that may prove a limited level of collaboration between UofK, and international agencies, such as the International Network on Appropriate Technology (INAT), UNESCO, and IEEE: (i) Recently, UofK has become part of INAT. UofK and SUST have hosted the 10th International Conference on Appropriate Technology, between 22 and 25 November 2022 (https://www.appropriatetech.net/). (ii) In November 2018, UNESCO established the UNESCO Chair in Materials and Nanotechnology at the University of Khartoum. Accordingly, the Materials and Nanotechnology Research Centre (MNRC) at UofK was established. The UNESCO program covers training, research, and exchange of academics and offers a platform for information sharing in all fields within the competence of UNESCO. (iii) As early as June of 2011, UofK formed the IEEE Sudan chapter (www.ieeesudan.org). Int7 said:

> *'IEEE Sudan chapter's most recent activity was the International Conference on Computer, control, electrical, and electronic engineering, held by IEEE on December 16, 2022 (https://www.facebook.com/iccceee20).'*

The industrial relationship category is related to the first research objective, and Table 4.14 summarizes this category along with its sub-categories, and evidence as emerged from collected data.

Table 4.14: Industrial Relationship Category, Sub-categories, and Evidence

Cat.	Sub-categories	Evidence (Emerged from Data)
6. Relationship with the industry	Industry- 27) Incompetent engineering graduates 28) Industry- Universities don't put the effort to collaborate with industry 29) Educators are not interested in a proper relationship between academia and the industry 30) Collaboration is done at a personal level rather than undertaking strategies Universities- 31) Believe the industry is not keen on academia and research. 32) Industries in Sudan are not technically advanced. They are not interested in research but only in profitable activities.	a. Industry wants ready engineering graduates b. Prefer to recruit engineers from outside the country. c. No industrial-academic committees. d. No Programs for senior design projects that are related to real-life projects. e. Lack of industrial feedback, research and training opportunities, and learning through industry. f. Lack of internship and training programs.

4.3.3.3.4 Framework

To develop a transforming engineering curriculum framework, the researcher asked participants about the need for engineering education reform, and if so, what are the constraints restricting any required reform. All of the participants agreed that engineering education programs, in the country, are in desperate need of reform, to allow them to graduate competent engineers. As well, participants discussed some of the constraints that might restrict efforts to reform the engineering programs (Int3, Int4, Int5, Int6, Int7, Int8, and Int9). Below the researcher includes perspectives of Int5, Int6, and Int9 on the issue of reforming engineering programs in the country:

(i) When he was asked whether there is a need for engineering education reform, at UofK, and any associated challenges, Int5's reply was:

'I agree that UofK and other universities need to improve their engineering programs. Improvement may include the preparedness of high school graduates, curriculum, T&L approaches, and education alignment with the market needs. As well, I may summarize the challenges fronting the improvement of engineering programs as follows: (i) The overall system of higher education, as imposed by the government, including: strategies and vision, the role of education, university requirements, higher education requirements and policies, and accreditation. (ii) Incompetent staff who are unaware of the role of the university and its capabilities. (iii) Overstaffing of public universities (iv) Funding.'

(ii) While Int6's response, to the same question, was:

'I believe there is a much-needed reform of engineering education in Sudan, *including UofK. The reform should include: training and professional development of academic staff, curriculum, relationship with the industry, infrastructure, and collaboration with regional and international academic*

institutions. I think the starting point is a serious discussion at the top administrative level and at the faculty level.'

(iii) Regarding the challenges that might obstruct the reform of the engineering programs, Int6 listed them as:

'Political stability, funds, transparencies, and openness to global engineering advancement.'

(iv) Int9 provided the following perspective about the necessity of the engineering program reforms:

'Definitely engineering education programs in Sudan need rehabilitation, because of the following challenges and/or weaknesses: Weak infrastructure of engineering programs, a weakness in human resources, quality and quantity of teaching staff, budgets allocated for the development of education in general and engineering education in particular, poor engineering curricula. Treating these challenges begins with recognition of the deteriorating reality of engineering education, and the will to change this reality; then allocating a realistic budget for teaching reform, including engineering education, in terms of infrastructure rehabilitating, qualifying and training cadres and human resources, providing modern teaching aids, and developing relevant curricular; as well reforming of the related governmental institution in terms of management, mentalities, policies and regulations, etc. I believe there is hope, and change will happen. Providing the political reform, which started after the December 2019 revolution, would continue. Completion of the democratic change provides the opportunity for qualified Sudanese who can bring change; they are present inside and outside Sudan. Note, I don't want to sound political, and I want to keep the scientific aspect of this interview; however, political factors are very important for any education reform.'

The framework category covers the fourth research objective number, and Table 4.15 summarizes this category along with its sub-categories, and evidence as emerged from collected data.

Table 4.15: Framework Category, Sub-categories, and Evidence

Cat.	Sub-categories	Evidence (Emerged from Data)
9. Framework	37) Need for engineering education reform.	a. All participants agreed on the need for reform.
	38) Challenges facing engineering education reform.	a. Political stability, funding, transparency, and openness to global engineering advancement.
	39) The possibility of developing a transforming curriculum framework.	a. This is the main contribution of the study.

4.4 Summary

Chapter 4 analyzed gathered data about transforming engineering education in Sudan. The chapter includes collected data, using three data collection methods, documentary analysis, semi-structured interviews, and researcher's observations. Also, there is a section about the challenges encountered during the data collection phase and how the researcher addressed them. The final part of this chapter provided a systematic data analysis and interpretation according to research questions and objectives. Analyzed data resulted in 9 categories, which represent the study findings: Curriculum, engineering educators, T&L method, engineering graduates, admission of engineering students, relationship with the industry, collaboration with local, regional, and international institutions, accreditation, and framework. The findings are illustrated and summarized using tables and figures according to research questions and objectives.

CHAPTER 5

DISCUSSION OF THE FINDINGS

The previous chapter covers the analysis of obtained information from 7 participants who are scholars with various expertise in engineering and higher education sectors. This chapter discusses the study's findings, of the Sudanese engineering education system, and the reason behind the inability of its elements to graduate qualified engineers. It is worth noting that the essence of an advanced engineering program is to graduate qualified engineers capable of facing the revolving 21st-century challenges: globalization, the digital age, climate change, illegal immigration, poverty, water shortage, world hunger, etc. Achieving this goal of the engineering program requires certain elements, as shown in Figure 5.1: (i) Transformational engineering education environment (EE Env) consists of the OBE curriculum, qualified educators, advanced T&L methods, and adequate infrastructure; (ii) a strong relationship between engineering programs and the industry; (iii) collaboration with professional and academic institutions; and (iv) well-prepared high secondary school graduates (Global Issues. https://www.un.org/en/global-issues/).

The discussion of the findings followed the formulated research questions; as illustrated in section 1.4, they are: 1) What is the current situation of engineering curricula in Sudan? 2) What is the situation of engineering educators in Sudan with regard to their teaching effectiveness, qualification, and professional development? 3) What is the current teaching and learning approach adopted by the Sudanese engineering education programs? 4) Why is there a need for a new framework to transform the Sudanese engineering education programs?

The first three questions are linked to the first three categories, namely: Curriculum, engineering educators, and T&L approach, respectively. They are discussed in section 5.1 as components of the Engineering Education Environment (EE Env). Categories 4 and 5 are about engineering admission and engineering graduates, and they are discussed in section 5.2. Categories 6, 7, and 8 are concerned with the relationship between the engineering programs and the professional and academic institutions, and they are discussed in section 5.3. Category 9, which is linked to the fourth research question, represents the novelty contribution of the study; and it is a pivotal framework for transforming engineering education programs in Sudan. This framework incorporates all study findings, and it is illustrated and discussed in Section 5.4.

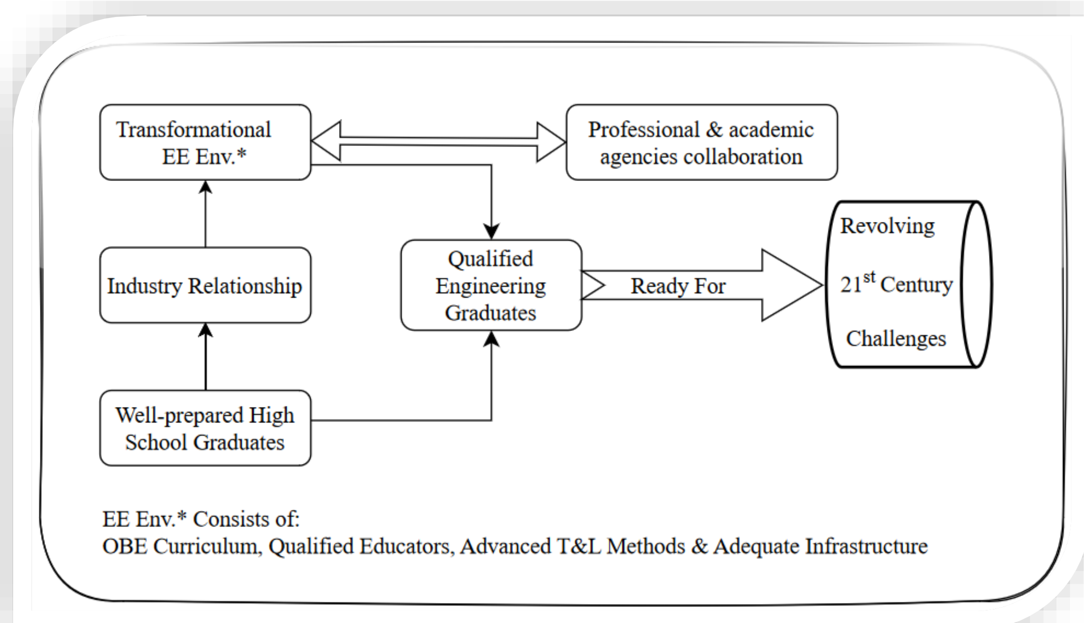

Figure 5.1: Graduating Qualified Engineers Ready for the 21st-Century Challenges

5.1. Engineering Education Environment (EE Env)

This section discussed the first three categories, curriculum, engineering educators, and T&L approach, as emerged from the first three research questions, and confirmed and finalized from the gathered information.

As far as the curriculum is concerned, received information, from documentary analysis and semi-structured interviews, confirmed that the engineering curriculum is content-focused rather than OBE. This fact has been concluded from the amount of theoretical material required to earn an engineering bachelor's degree. For instance, to earn a bachelor's degree in engineering, a UofK student has to complete between 171 and 183 credit hours; a chemical engineering program requires 171 credit hours distributed over 10 semesters in five academic years (Aldaleel, Table 4.1). Also, the course learning outcomes (CLOs) are not aligned with assessment tasks (AT) and teaching and learning activities (TLA), as required by both OBE and constructive alignment (CA) frameworks. In addition, unlike HPL, the curriculum is not knowledge-centered, and it does not include teaching metacognitive skills; it focuses only on superficial coverage of memorizing facts rather than in-depth coverage of the subject matter; see section 4.3.1.1.

Moreover, most of the materials are covered theoretically; only 31% of the courses have practical components such as laboratory work, design, or projects. On the other hand, the curriculum itself is very outdated; the latest revision occurred in 2012, and the revision cycle, at best, takes place every 10 years. Nevertheless, MoHESR and SEC require that all engineering curricula must be outcome-based curriculum and must be revised every 5 years (www.mohe.gov.sd; Int3, Int7, Int8, and Int9). As well, UofK documents untruly claims that the engineering curriculum is OBE, and it has been developed in accordance with the ABET guidelines (Aldaleel, Table 4.1). Engineering programs at UofK are similar to the other engineering programs in Sudan; for example, engineering programs, at SUST and USAS, require between 180 and 190 credit hours, over a 5-year duration of study (SUST website; Int9).

The researcher agrees with all participants' calls for engineering curriculum reform to improve students' outcomes (section 4.3.1.1). He believes that overloading engineering students with too many theoretical materials may not necessarily graduate competent engineers. Therefore, this outdated curriculum represents an area for improvement regarding students' workload, study duration, and the balance between practical and theoretical materials.

For comparison, many worldwide engineering programs offer the bachelor of engineering upon completion of only 120 credit hours in 3 to 4 years. Examples include San Jose State University, California (SJSU); University of California Berkeley (UCB); Higher Colleges of Technology (HCT), UAE; University of Johannesburg (UJ), South Africa; The University of Sydney (USYD), Australia; etc. A bachelor's degree in engineering at the University of Technology Malaysia (UTM) requires the completion of 139, in 4 years. (SJSU, UCB, HCT, UJ, USYD, and UTM websites).

When it comes to engineering educators (section 4.3.1.2), many of the participants in the semi-structured interviews agreed that engineering educators are incapable of graduating competent engineers. Findings listed many reasons for the inability of engineering educators, such as: Pre-service qualification, in-service training, accountability, low SSR, poor working conditions, etc. They do not receive training in the area of SCL; staff to student ratio is between 1:24 and 1:39, which is less than the recommended ratio of 1:15; engineering educators are not incentivized to get trained and to change their teaching method from traditional T&L to SCL; there are no prescribed competences from the industry; and inadequate facilities/infrastructure is another obstacle to the students active learning and deep understanding.

The dilemma of engineering educators in Sudan may be summarized as follows: (i) Most well-educated engineering faculties with PhDs, even from prominent foreign universities, have not adapted their advanced knowledge and research skills to suit the situation of the engineering profession and education in Sudan. (ii) Findings confirmed that PhD holders from local universities may be divided into two groups. One group with questionable academic qualifications, either due to inadequate engineering research capabilities or due to the relaxing admission requirements and leniency in awarding PhD degrees. The other group had to put more effort into overcoming all challenges and obtaining PhD degrees with reasonable knowledge and competencies. (iii) On the other hand, the Sudanese engineering faculties have been affected, and for so long, by poor working conditions, including low financial compensation, lack of in-service training, and inadequate engineering education infrastructure. All of the above led most of the qualified engineering faculties to leave the country for better opportunities; the rest of them, who are still in the country, usually engage in academic or non-academic activities to meet their financial needs. Therefore, the researcher, among others, including many participants, believes that resolving the working conditions issue is the starting point for tackling other engineering education issues in the country. (Int4, Int5, Int6, Int7, and Int9).

The findings confirmed that engineering educators: are not trained to work with students' preexisting knowledge, beliefs, and backgrounds; are incapable of teaching metacognitive skills to help students actively set their learning goals and monitor their progress toward achieving them; and are not trained to incorporate the principles and characteristics of HPL, to impact the learning process, such as working with the student's preexisting knowledge, beliefs, and background; teaching metacognitive skills to help students actively set their learning goals and monitor their progress toward achieving them. Moreover, as required by Biggs et al. (2020) CA, educators are not trained to act as learning facilitators to help students construct knowledge using relevant learning activities; and educators do not properly assume their role in designing learning environments suitable for achieving intended learning outcomes.

Also, received information from participants confirmed that traditional T&L is the norm at UofK, although the engineering curriculum contains some PBL courses; the PBL approach is considered a form of SCL. However, the percentage of the PBL courses represents only 7.6% out of the total 171 credit hours. Moreover, the practice of teaching these PBL courses is questionable, according to some participants (Int4, Int5, Int6, and Int9). The practice of the traditional T&L approach is mainly because engineering educators are more experienced and comfortable with the traditional T&L approach, and they lack training in the area of advanced T&L methods.

The traditional T&L approach, TCL rather than SCL that has been utilized by most engineering educators, adds to the gloomy state of Sudanese engineering education. Changing the traditional T&L method to the SCL method, along with changing the curriculum, is necessary to improve the quality of engineering graduates. All participants believe that changing the traditional T&L method needs time, effort, and realistic funding. Time and effort are required to train and to change the mindsets of both engineering educators, at the operation levels, the top management, and policymakers (section 4.3.1.3).

Findings confirmed that traditional T&L methods are the norm in the engineering education field, although emerging learning theories and constructive frameworks such as OBE, CA, and HPL require the implementation of advanced T&L methods, student-centered rather than teacher-centered approaches. It is worth mentioning that UofK, which was established in 1902, was the first university, and it is the most prestigious one in the country. Hence, changing their traditional style of teaching may require significant efforts and time to convince stakeholders of the benefits of SCL. However, the researcher believes that improving engineering education at UofK level may encourage other universities to follow.

The researcher realized that the situation of Sudanese engineering education is more or less similar to the situation in most of the SSA countries due to outdated engineering curricula, incapable engineering educators, traditional T&L approaches, and inadequate engineering education infrastructures (Ebekozien and Aigbavboa, 2023; Sebola 2023; Sigahi et. al., 2023; Aguboshim et. al., 2021; Igbokwe, 2019; Oloyede et. al., 2017). To put this in context, many worldwide engineering education programs have advanced their programs, in terms of effectiveness and accreditation, by implementing: a 4-year OBE curriculum that teaches competencies and metacognitive skills, professional development of academic and non-academic staff, and advanced T&L methods. Some examples are listed in section 5.1 (SJSU, UCB, HCT, UJ, USYD, and UTM websites).

5.2. Engineering Enrolment and Engineering Graduates

UofK, which is one of the best universities in the country, currently graduates not only a low number of engineers, but also their quality, as confirmed by gathered data, is far below the quality of engineering graduates from abroad. Participants revealed that UofK engineering graduates have reasonable theoretical knowledge, but limited skills, due to many reasons, as discussed in section 4.3.3. This fact led many engineering companies in the country to recruit foreign engineers, at the same time, local engineering graduates are engaged in unrelated engineering professions.

The desire to study engineering among high school graduates is very compelling, which is a nice problem to have, as perceived by the researcher. However, gathered data confirmed the inability of the Sudanese engineering education system to accommodate the increasing number of high school graduates who dare to study engineering. The participants acknowledged that it is a very profound problem due to the limited infrastructure of the engineering education system; this problem is the reason behind the competitive admission criteria into engineering programs, at UofK. On the other hand, as confirmed by the findings, the quality of high school graduates needs improvement. This could be achieved, as participants suggested, by improving the pre-college engineering curriculum. Of course, to increase the intake of the engineering programs, the situation of these programs must improve, in terms of capacity and infrastructure.

As discussed earlier in section 4.3.2, both the quality of admitted students into an engineering discipline and the engineering education environment hurt the quality and quantity of engineering graduates. Therefore, graduating competent engineers requires: i) curriculum that includes prescribed competencies, and approaches for teaching and assessing competencies. ii) enough qualified engineering educators. iii) Advanced T&L models. iv) adequate engineering infrastructure. v) Qualified high school graduates for engineering discipline.

As well, engineering programs have to ensure students' progress throughout the duration of study from freshman, sophomore, and junior to senior year (Grayson et al., 2013). Accordingly, the researcher believes that the engineering curriculum should include developmental courses that promote the success of engineering students through their course of study: (i) Foundation math and science courses, which help underprepared high school graduates transition from high school setup to college atmosphere. (ii) Design and engineering science courses at the start of the engineering program lead to an effective transition from basic sciences to engineering sciences. (iii) Design courses, such as Design Thinking, Sophomore Design Project (SoDP), and Senior Capstone Design Project (CDP), help engineering students gain engineering design experience and knowledge acquisition (Lord and Chen, 2014). (iv) Teaching of metacognitive skills, which is necessary to enable students to analyze systems and integrate knowledge. (v) Project Based Learning (PjBL) is one of the learner-centered models (Kolmos and Graaff, 2014). PjBL's approach allows engineering students to gain sustainability competencies and experiential learning (Brundiers and Wiek, 2014).

For the sake of comparison, engineering graduates in Sudan represent about 10.7% of the total tertiary graduates, which is better than the percentage of 6% of the total tertiary graduates in SSA countries. However, engineering graduates' percentages in Jordan, Algeria, and Malaysia are 16.4%, 22%, and 30.1%, respectively. These high percentages of engineering graduates are due to the advanced engineering education systems in these countries (World Bank, 2018).

5.3. The Relationship with Professional Bodies

This group of categories includes the relationship between engineering education, from one side, and the other side: the Sudanese industry; local, regional, and international academic and professional institutions; and accreditation bodies.

The academia and industry relationship, in the context of Sudan, is very weak due to many reasons, as shown in section 4.3.3. Nevertheless, both need each other, and they must work together to develop a mutual relationship between themselves. A mutual relationship would benefit the engineering education system in Sudan, in terms of industrial feedback, research and training opportunities, and learning through industry. Likewise, academia would be ready to meet the industry's demand for qualified engineering graduates and innovative ideas in the engineering profession. Not to mention that one of the SEC graduation requirements is on-the-job training within a relevant industry; this represents another area of collaboration that is beneficial for both parties.

In addition to the Sudanese industries, academia has to improve its relationship with engineering regulatory bodies, MoHESR and SEC, beyond their role as policy and regulation agencies. On top of that academia has to establish various levels of relationship with all parties who have a stake in engineering education such as: Relevant governmental and non-governmental agencies, community, civil societies, alumni, parents, Sudanese academicians in the diaspora, etc.

Historically, universities in Sudan used to have strong relationships with foreign engineering agencies. These relationships have been beneficial to engineering programs at these universities. For example, engineering programs were used to receive research opportunities and training for their students and educators. In addition, many foreign universities have been providing scholarships for Sudanese students to earn their master's and doctorate degrees and postdoc opportunities. For more than 30 years, between 1989 and 2020, the relationship between Sudanese academic and professional institutions and their foreign counterparts has been deteriorating, until stopped completely because of the political situation in Sudan.

Recently, the political situation has been improving, which led to the country's return to the international community and improving the country's foreign relationships. This improvement may allow Sudanese academic institutions to actively pursue relationships with regional and international academia and professional bodies.

As far as accreditation is concerned, MoHESR and SEC, along with academic institutions, have to work on revising the local accreditation process, to be more realistic, applicable, and with minimal loopholes. Stepping up local accreditation would pave the road for international accreditation possibilities.

Sudanese engineering education programs should establish relationships with regional professional and academic organizations such as: The Inter-University Council of East Africa (IUCEA) (https://www.iucea.org/). The Mutual Recognition Agreement (MRA) for Professional Engineering Services in East Africa (https://www.ebk.go.ke). Globally, Sudanese engineering programs should pursue relationships with engineering-related bodies such as ABET, Royal Academic Engineering (RAE), and Washington Accord (WA).

5.4. Discourse of Stakeholders at Work

This section discusses the interconnected power relationships among the above-discussed stakeholders where each stakeholder manifests/exercises its power (rights) while expecting others to comply, and the same stakeholder is subject to the other stakeholders' powers; in other words, identifying connections among stakeholders within the engineering education field, as a discursive field.

Gaventa listed several ‘Power Tools’, as they were developed by the International Institute for Environment and Development (IIED), for the practical exercise of power; of these tools is ‘Stakeholder Power Analysis’, which is about the power, its origin, and who has it: 'Power to influence policies or institutions stems from the control of decisions with positive or negative effects. Stakeholder power can be understood as the extent to which stakeholders can persuade or coerce others into making decisions and following certain courses of action. Power may be derived from the nature of stakeholders' organizations, or their positions with other stakeholders, for example, line ministries that control budgets and other departments (Gaventa, 2021).

Governmental agencies have the right to impose laws, regulations, targets, and strategies that ensure the graduation of a reasonable number of qualified engineers, according to global standards. At the same time, these agencies are responsible for providing realistic budgets to enable academic institutions to carry out their responsibilities and KPIs, such as graduating competent engineers. Other governmental agencies' responsibilities are finance, policies, legislation, accreditation, and recognition of engineering programs and engineering degrees.

At the same time, academic institutions, such as UofK, are subject to the power exercised by governmental agencies in charge of setting higher education policies and regulations, which means that UofK's responsibility (towards governmental agencies) is to comply with policies and regulations and to meet any governmental targets and standards, within the allocated budget. As well, UofK is responsible for preparing a good T&L environment that includes, but is not limited to, an enhanced engineering curriculum, SCL methods, and qualified engineering educators (section 5.1). While academic institutions have the right (power) to develop their strategies, policies, priorities, and budget allocation, in a manner that these institutions achieve their responsibilities and meet their accountability.

The level of rights and responsibilities cascades down to the day-to-day operations, where the engineering program translates UofK strategies and policies into practice from transformed engineering curriculum, and advanced T&L methods, to qualified engineering educators (section 5.1). The ultimate responsibility of the engineering program is to graduate enough competent engineers (the output), starting with well-prepared high school graduates, admitted to the engineering programs, according to admission criteria set by MoHESR and SEC (section 5.2).

To achieve this goal, engineering students have the right to a good T&L environment, financial support, and employment opportunities after graduation. Likewise, their responsibilities range from preparedness to study engineering, bearing the financial burden, to achieving good academic excellence.

When it comes to engineering educators, as well, they have the right to well-prepared high school graduates, a good T&L environment, and good working conditions. Yet, they are responsible for providing quality teaching, developing adequate curriculum, and designing appropriate assessments. Additional responsibilities may include accountability, upskilling educators' careers, and effective performance evaluation.

The power structure of the national and international agencies is governed by the areas and levels of collaboration between them, from one side, and the academic institutions, from the other side. The rights of these agencies, to be imposed upon academic institutions, may include strategies, policies, and legislations. On the other hand, these agencies have to carry out their responsibilities towards academic institutions, including funding, training, scholarships, employment opportunities, publications, conferences, accreditation, etc.

Table 5.1 identifies stakeholders relevant to this study; they represent an overview of the findings of this study, as discussed in Chapters 4 and 5. As well, the table also shows the intertwined power relationships, at work, among the stakeholders (rights versus responsibilities), within the engineering education discursive field, by the virtue of competing authority structures.

Table 5.1: Stakeholders and Power (Rights/Duties) Operating within Discursive Field.

Stakeholders	**Rights & Privileges**	**Duties & Responsibilities**
Governmental Agencies	Make laws, regulations, targets & standards. Demand quality & accountability.	Provide finance, policies, legislation, accreditation & recognition.
Academic Institutions	Develop strategies, policies, priorities, and budget allocation	Prepare a good T&L environment. Meet governmental targets & standards. Comply with laws & regulations.
Engineering Educators	Expect a good T&L environment and good working conditions.	Provide quality teaching, develop adequate curricula, and design appropriate assessments.
Engineering Students	Expect a good T&L environment, financial aid, and employment upon graduation.	Pre-college preparedness, school fees, and good academic performance during college.
T&L Environment	Transformed curriculum, qualified educators, advanced T&L approaches, and adequate infrastructure.	
National Agencies (including industry)	Develop strategies, policies, & legislations. Identify collaboration/ Market needs	Provide funding, training, employability,
International Agencies	Develop strategies & policies. Identify collaboration/ Market needs	Accreditation, conferences, workshops, training, publications, periodicals, funding, scholarships.

5.5. A Transformational Framework for the Development of Undergraduate Engineering Education Programs in Sudan

The novelty of this research is a transformational framework, which emerged from the study findings, the 9 categories discussed in sections 5.1, 5.2, and 5.3. These findings (called stakeholders) are governmental agencies, academic institutions, engineering educators, engineering students, the T&L environment, national agencies, and international agencies. They represent the components of the proposed framework, as shown in Table 5.2 and Figure 5.2. The framework underlines the overall process of transformation development of undergraduate engineering education programs in Sudan.

As depicted in Figure 1.1, section 1.76, the integrated framework (IFW) combines constructivism theory; OBE, CA, and HPL models; and PST, including Foucault's concepts of truth, discourse, discourse analysis, and power. The IFW represents the theoretical perspective that underpins this study. Accordingly, this section explains how HPL, OBE, and CA models; constructivism theory; and PST have helped develop the proposed framework.

To achieve the research objectives (section 1.3), by addressing the research questions (section 1.4), the researcher followed the conceptual framework, shown in Figure 1.2. Gathered data, using semi-structured interviews, documentary analysis, and the researcher's observations, was analyzed, to identify the mismatch between teaching and learning elements of the Sudanese engineering education programs, and the principles of the IFW, in other words, determining the gap between these elements and the OBE system, CA framework, and HPL principles.

In addition, Foucault's PST, including his concepts of truth, power, discourse, and discourse analysis, allowed the researcher to: Highlight the pre-existing power relationship among stakeholders, within the engineering education field; realize stakeholders' rights and responsibilities; and align the academic system with objectives as stated by the relevant governmental agencies. Stakeholder Power Analysis, which is one of the "Power Tools", can be understood as the extent to which stakeholders can persuade or coerce others into making decisions, and following certain courses of action (Gaventa, 2021). Therefore, discourse analysis of these stakeholders, section 5.4, describes the complex network of power, among them; and Table 5.1 lists all stakeholders and their intertwingled power relationships, within the engineering education discursive field. They represent the components of the proposed framework.

Generally speaking, the framework focuses on the interactions between a range of engineering-related institutions, from the education sector to professional engineering, intending to revamp the quality of engineering graduates (the output), which represents the result of the quality of high school graduates (the input) and the transformational engineering education program. Although there are many generic approaches for transforming engineering education programs, none can address the issues of the Sudanese engineering education programs. Nevertheless, the at-hand framework is available for the modernization of undergraduate engineering education in Sudan and anywhere with similar circumstances. Also, the framework may serve as a guide for advancing engineering programs at any academic institution, and as a measuring tool to evaluate the progress of any improvement.

The framework includes seven components: Higher Education Institutions, National Engineering Education Stakeholders, Sudanese Industry, Regional and International Agencies, High School Graduates (Input), Enough Number of Competent Engineering Graduates (Output), and Engineering Education Environment. Each component has its subcomponents; together, they represent all 9 categories that arise from the received information, as analyzed in Chapter 4 and discussed in sections 5.1 to 5.3. Below, the researcher introduces and explains the components and features of the framework, as depicted in Table 5.2, followed by a visual model of the framework, in Figure 5.2.

Table 5.2: Framework for Transformation of Undergraduate Eng. Ed. Program

Components of the Framework	**Sub-Components**	**Key Features**	**Notes**
Higher Education Institutions (HEI)	All HE institutions that provide EE. The heart of the FW Independent institutions	Interaction with all other elements of the FW	Offer bachelor/diploma The heart of the FW
National EE Stakeholders	MoHESR, MoE, MoF SEC, NRC, TVE Local donors Sudanese industries Related Civil Societies Alumni	Strategies Policies & Legislations Funding Collaboration Market needs	Dynamic features (under continuous revision) for: National strategy building; policies & legislations; necessary funding & sources; and areas & level of collaboration.
Sudanese Industry	Sudanese industry (local & foreign industries Sudan) Global industries	Define Competencies Training Market needs Research opportunities	Industry input in: National strategies EE environment
Regional & International Agencies	Accreditation Agencies Universities Research Institutions/centers Professional Engineering Agencies Donors UN organizations Sudanese Academicians in Diaspora	Accreditation opportunities Conferences & Workshops Training (Students & Faculties) Publications & Periodicals Research Funding Scholarships	Level and areas of collaborations
Input: HS Graduates	High Schools Graduates with interest in EE	Entry point: direct admission to the engineering program or requires foundation	How to evaluate and improve the quality and quantity of engineering enrolment
Output: Enough Competent Engineering Graduates	Graduating in 4 years Potential for 5th (honor yr.)	Graduating in 4 years Additional 5th year for academic performers	Separate workload for 4-year program, and 5-year program.
EE Environment	Curriculum, Engineering Educators, T&L Approach, infrastructure, etc.	OBE/CBE curriculum Curriculum revision every 5 years Advanced T&L methods Adequate infrastructure	Transform curriculum from content based (TCL) to OBE/CBE (SCL). Prescribed competencies. Improved infrastructures.

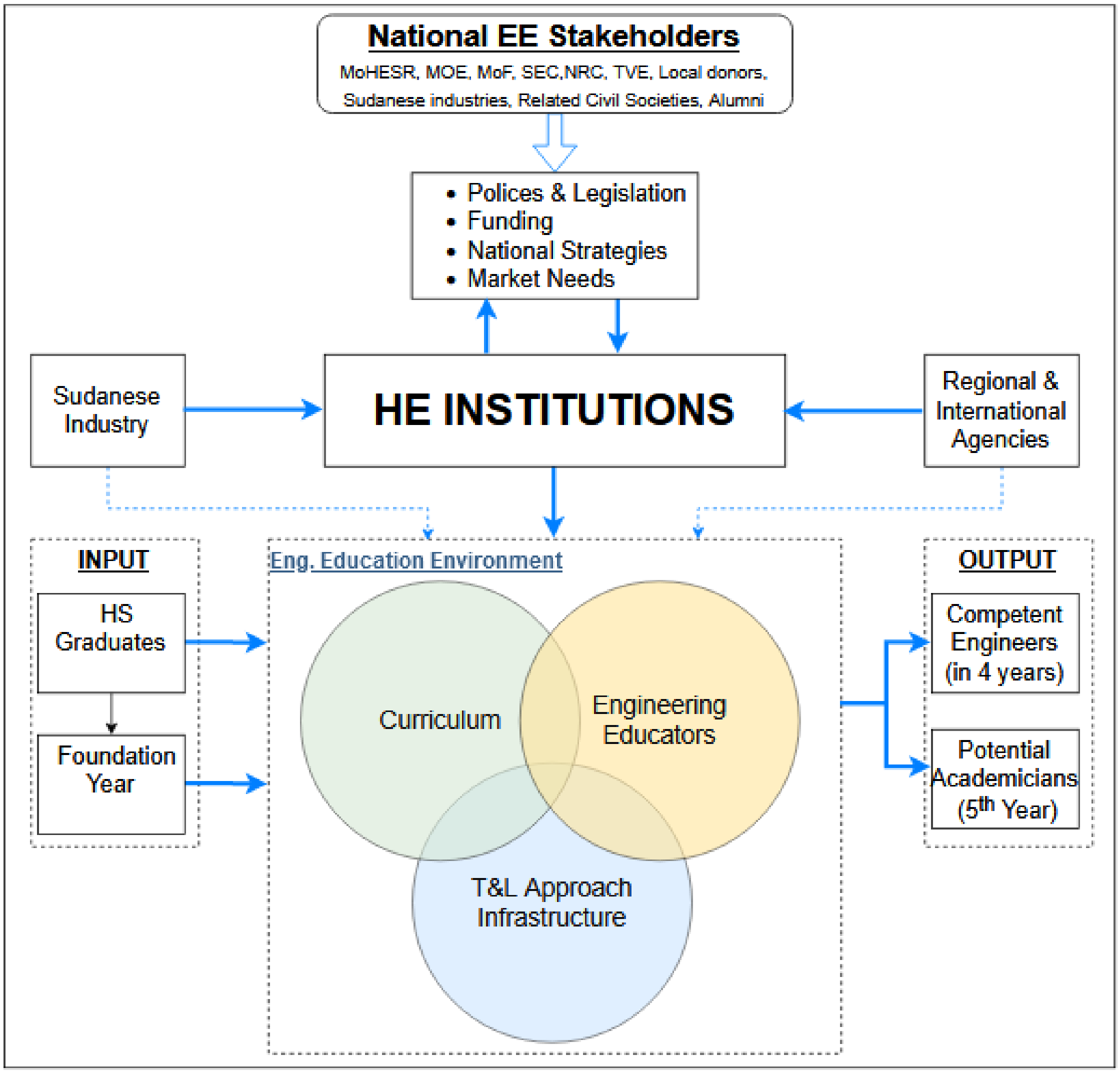

Figure 5.2: Framework of Transformation Engineering Education Program

5.5.1. Higher Education Institutions

Higher Education Institutions (HEI) include all universities and colleges that offer degrees in engineering, from diploma and bachelor's degrees to postgraduate studies. HEI represents the heart of this framework. HEI's main focus is to fill the gap between the industry's need for qualified and well-trained engineers and their ability to graduate enough of them. HEI are supposed to spearhead the interaction/collaboration with all other components of the framework, with only one strategic goal of producing a high enough number of future-ready engineers, which may require a major strategic change in engineering education. Within academia, strategic changes depend on leadership, decision-making procedures, communication, and evaluation (Stensaker et. al., 2014). Changes in education vary in many aspects. However, for the scope of this study, the researcher considers structural and cultural changes in engineering programs toward Transformational curricula, effective teaching and learning methods, capable administrative and academic staff, and structured and efficient training and evaluation programs. The question is how to empower Engineering Education as a top-down approach to achieve the desired changes.

The top-down approach means a strategy- in which the policy development and the decision-making process occur at the highest level, and then the implementation plan is cascaded down the hierarchy of the organization, to the rest of the team. This approach, which was originated by Ladislav Cerych and Paul Sabatier (1986), can be applied across various types of projects, companies, organizations, etc., and it can be adjusted to meet a specific entity's needs (Lingard and Lewis, 2016). The top-down approach has proved to be an important and effective tool in higher education, where decisions come from the HEI top management; its success relies mainly on the power of the top to execute tasks. However, success is limited without buy-in from administrators and academic staff, at lower management and operation levels, respectively. Many studies have claimed that a top-down approach is a preferable means of reducing the chaos resulting from educators who resist and confuse change processes. Also, the success of top-down management is predicated upon educators' readiness to execute (Lingard and Lewis, 2016; Wilson-Strydom, 2016; Kroon, 2015). Also, they have concluded the importance of the top-down approach in higher education, and it is a required strategy for systemic change.

The power of the top plays an important role in management, still, high-caliber leadership is essential in a top-down management approach. Gigliotti and Ruben (2017) suggested that the impact of leaders and leadership is critical to academic and administrative effectiveness. They should have teaching and research experience, curriculum design and problem-solving abilities, communication skills, and open-mindedness. Therefore, leadership capacity-building is required, through leadership development programs, to empower engineering education as a top-down approach.

5.5.2. National Engineering Education Stakeholders

National Engineering Education Stakeholders (EE Stakeholders) include, but are not limited to, the following entities: Ministry of Higher Education and Scientific Research (MoHESR), Ministry of General Education (MoE), Ministry of Finance (MoF), Sudanese Engineering Council (SEC), National Research Council (NRC), Technical Vocational Education (TVE), Sudanese Industry, Local Donors, Related Civil Societies, and Alumni. The interaction between these agencies and the HEI should lead to building a national education strategy, setting policies and legislations, assessing a realistic budget and securing funding, identifying market needs, and agreeing on levels and areas of collaboration among all engineering stakeholders, including higher education institutions and the industry. The interaction among stakeholders should be a dynamic feature under continuous revision, and they should agree on the level and areas of collaboration among them.

The starting point is a clear national mission and vision of education that includes establishing a first-rate engineering education system in Sudan. A radical improvement of engineering education, which is a pillar of the country's economic transformation, requires a strategic execution plan to achieve the ultimate goal of the first-rate engineering education system. That is, Sudan must have enough competent engineers, according to the global engineering standards. Therefore, national engineering education stakeholders should undergo a series of continuous training and workshops, aiming to promote and develop human capital; to create partnerships, based on mutual benefit, among all stakeholders; raise their awareness; and support them with knowledge, competencies, and professional skills, such as leadership, communication, time and project management, power and conflict resolution, etc.

5.5.3. Sudanese Industry

This component includes all industries operating inside the country, whether local or foreign industry. Both HEI and the industry have to develop a constructive collaboration between them to comprehend the needs of the Sudanese industries, from one side, and to realize the capability of the academia, from the other side. In other words, the industry should establish a strong link with HEI to have significant input in the following: Prescribing required competencies that make sense to the industry; identifying market needs (quantity and quality of various engineering disciplines); developing students' training programs; funding and mentoring capstone graduation projects; and generating research opportunities. While academia should design courses (such as design thinking, sophomore design projects, internships, and senior capstone projects) through them, students can solve real-life industrial problems.

5.5.4. Regional and International Agencies

Regional and international agencies may include but are not limited to the following agencies: Accreditation Agencies, such as ABET and Washington Accord (WA); Universities; Research Centres; Professional Engineering Agencies, such as Royal Academy of Engineering (RAE); Donors; and UN Organization, such as UNESCO.

HEI has to seek collaboration with those agencies, at multiple levels and in various areas, such as training of students and engineering educators; accreditation opportunities; conferences and workshops; periodicals and publications; research funds; and scholarships.

5.5.5. High School Graduates (Input)

High school graduates (HS Graduates) represent the main customers of the engineering programs; therefore, these programs should have a say on the admission criteria to engineering disciplines, in conjugation with all related stakeholders. On the other hand, findings confirmed that general education, in Sudan, has been facing profound issues that bleed into the quality of higher education, including engineering education. Hence, the real question is how to improve the intake of engineering programs, qualitatively and quantitatively.

For the intake improvement, EE stakeholders' collaborative efforts should focus on the following: First, the pre-college engineering curriculum, which includes STEM programs that target the performance of primary and elementary schools in mathematics and science, and pre-college engineering courses to elevate the level of the high secondary school students in engineering disciplines. In addition, the entry point of engineering programs should permit either direct admission to a 4-year engineering bachelor program or build in a foundation year, for whoever needs additional preparation before getting into the 4-year program.

5.5.6. Enough Number of Competent Engineering Graduates (Output)

The quality of engineering graduates (the output) represents the resultant of the quality of high school graduates (the input) and the transformational engineering education program. Therefore, starting with quality input (HS Graduates) would significantly impact the output of competent engineers. Moreover, increasing engineering students' workload may not necessarily help in the quality of graduating engineers, between 171 and 183 credit hours in 5 academic years; to the contrary, the practice proved that a workload of around 120 credit hours in only 4 years is enough to graduate qualified engineers. At the same time, a flexible engineering program may allow academic performers, who show interest in graduate studies, to be given a chance for an additional 5th year, to prepare for an advanced degree, master/doctorate program, in engineering.

5.5.7. Engineering Education Environment

Engineering Education Environment (EE Env) consists of: (i) a Transformed curriculum that: should adopt OBE instead of a content-based curriculum; must encourage students' deep understanding rather than only memorizing facts; and should include the teaching of metacognitive skills and prescribed competencies. Also, the curriculum should be under continuous revision, every 5 years. (ii) Qualified engineering educators, who are capable and willing to work with pre-existing learners' knowledge, assume a facilitator role to engage and challenge their students to actively set and monitor their learning goals (metacognitive approach), and to achieve a deep understanding of subject matter. This feature requires adequate working conditions, compensation and reward programs, professional development, academic freedom, effective performance evaluation, and accountability. (iii) Student-centered-learning (SCL) approach, where educators act as facilitators, and students do the learning. There are many models of SCL; of them are: Problem-Based learning (PBL), Project-Based Learning (PjBL), Cooperative Problem-based Learning (CPBL), Experiential Learning (EL), etc. (iv) Adequate infrastructure is one of the key features for transformation of undergraduate engineering education, which requires a realistic budget and appropriate funding.

It is agreed upon that a PhD degree in an engineering discipline is a necessary step to join academia; nonetheless, the degree itself is not a guarantor for one to become a competent engineering educator since this is not the goal of the engineering PhD programs. These programs do not teach college teachers to teach. They receive training as researchers and join colleges without proper training to teach. Therefore, Sudanese engineering education programs must break, rather than settle for, the status quo of existing teaching and learning practices to transform their faculties into capable academic staff ready for graduating competent engineers. Hiring and retaining competent engineering educators starts with a good hiring structure, that seeks to recruit qualified educators, pre-service qualification, design overarching professional development (PD) programs, and in-service training. With the goal of better qualifying and retaining academic staff, PD may include training, workshops, and certificates to cover, but not limited, to the following: (i) Curriculum design that focuses on OBE curriculum, including problem-based learning (PBL) and project-based learning (PjBL), by joint academic-industry real-life projects; developmental courses to promote the success of engineering students through their course of study from freshman, and sophomore, and junior to senior year; and teaching and assessing prescribed competencies, competency-based learning (CBL). (ii) Assessment strategies and processes in engineering, including educators' role in each of the following interrelated types of assessment: summative assessment (assessments of learning), formative assessment (assessments for learning), and self-assessment (assessments as learning. (iii) Topics in STEM teaching and learning practices, engineering pedagogy (tech-based pedagogy, collaborative approach, etc.), and advanced teaching and learning philosophies (SCL). (iv) Topics in emerged learning theories and in engineering education research.

On top of that, the Sudanese engineering education system should devise a mechanism to enforce, encourage, and/or motivate the implementation of the required PD programs, not just for engineering educators, but also for leadership at the top of HEI and administrators at lower management levels, and National Engineering Education Stakeholders. (i) The hiring structure, which includes competitive compensation, teaching track promotion, and both monetary and non-monetary rewards, should be tied to an effective annual performance review. (ii) Make a PD mandatory with measurable requirements (e.g. a minimum of 40 hours annual PD, in the area of curriculum development, SCL, OBE, CBL, learning theories, etc.; and a minimum number of certificates, publications, and/or workshops per year). (iii) Develop an engineering education unit, within the engineering program, and equip the unit with experts who can guide, assist, advise, and provide training, workshops, etc. in the above-mentioned areas.

SEC, along with MoHESR, has to organize workshops to train stakeholders on SEC's requirements and to solicit formal transparent feedback, from experts and stakeholders, on the implementation process of these requirements.

5.6. Summary

This chapter discusses the study findings following the formulated four research questions. The discussion included a brief comparison with engineering education systems in similar contexts in other countries. Also, the chapter illustrates the proposed framework, in Table 5.2 and Figure 5.2. Also, the discussion emphasizes the importance of continuous interaction and feedback between the various components of the framework for improving the engineering education system in Sudan and other regions facing similar challenges.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

This chapter concludes the research on "A Transformational Framework For The Development Of Undergraduate Engineering Education Programs In Sudan". Here, the researcher highlights the study findings, its contribution and implication, and its limitations. At the end, the chapter includes recommendations, for stakeholders, to improve the current problems in Sudan, limitations of the Study, and recommendations for future research work.

6.1. Conclusion

This section includes three sub-sections: Findings, contribution, and implication of the study.

6.1.1. Findings of the study

In Chapter 1, section 1.1.2, the researcher established the knowledge gap in engineering education research globally and in Sudan. As well, the study formulated four research questions, in section 1.4: i) What is the current situation of engineering curricula in Sudan? ii) What is the situation of engineering educators in Sudan regarding their teaching effectiveness, qualification, and professional development? iii) What are the current teaching and learning approaches adopted by the Sudanese engineering education programs? iv) What is the importance of developing a framework to transform the Sudanese engineering education programs?

To answer these research questions, in addition to the documentary analysis and researcher's observations, the study explored the expertise and perspectives of 7 purposeful participants, Table 4.3, on the research topic. The study findings entail nine categories namely: Curriculum, engineering educators, teaching & learning (T&L) methods, engineering graduates, admission of engineering students, relationship with the industry, collaborations, accreditation, and framework. These findings were analyzed and discussed in Chapters 4 and 5, respectively; they represent the components of the proposed framework in Section 5.5.

The teaching and Learning Environment consists of the first three categories curriculum, engineering educators, and T&L methods. Findings confirmed that: (i) The engineering curriculum at UofK is outdated; the last revision was in 2012; and it is content-focused rather than OBE. The content is filled with a lot of theoretical materials, and some of the materials add no value to an engineering graduate. To earn an engineering bachelor’s degree from UofK, a student has to complete between 171 and 183 credit hours, distributed over 10 semesters in 5 academic years. (ii) The traditional T&L approach is the norm at UofK, TCL rather than SCL; this is because engineering educators are more comfortable with their traditional way of teaching, and they do not receive any training in the area of SCL. (iii) Engineering education has been affected, to a great extent, by the scarcity of well-qualified academic staff and by the low staff-to-student ratio, SSR between 1:25 and 1:39. While the engineering education system is unable to graduate competent engineers, and to accommodate the increasing number of high school graduates who are interested in pursuing engineering careers.

The study determined the urgent need for a comprehensive reform of Sudanese engineering education. Also, the study flagged the following as necessary factors for the successful reforming process of engineering education: (i) As received data suggest, the motivation of academicians and administrators is key to ensuring their efficient input toward engineering education reform. Hence, authorities in the area of engineering education have to establish appropriate conditions for enabling and engaging academic and non-academic staff in advancing engineering education. The working conditions, including financial compensation and non-financial rewards, are one of the essential factors to keep staff motivated and engaged. (ii) Moreover, the study confirmed that professional development, through workshops and seminars, is necessary for all parties involved in the reforming process of engineering programs. Therefore, professional development, in the area of pedagogy, T&L approaches, curriculum development, etc., would speed up the process of improving the engineering programs, increase the capacity of academic and non-academic staff, prepare and motivate them to adopt the 21st century trends in curriculum design and SCL methods. Equally important is staff training in accountability and effective performance review against predetermined objectives. (iv) The study reported that reform requires better interaction and collaboration, among stakeholders, at all levels to ensure transparent communication, regarding the reality of the situation of the Sudanese engineering education, and to establish formal and informal channels for feedback. (v) As proved by the findings, collaboration among stakeholders in various areas at multiple levels is strategically important in the efforts to improve engineering education. This is because reform requires transparent communication, regarding the reality of the situation of the Sudanese engineering education, as well as formal and informal channels for feedback. At the same time, the study suggested and confirmed that collaboration is beneficial for all parties. For instance: Collaboration with industry, community, and civil society provides students with opportunities for practical engineering training; students with hands-on and non-traditional teaching activities (workshops, seminars, lectures, etc.); researchers with real-life research projects; and curriculum designers with prescribed competencies, as required by the market. Collaboration with professional and academic institutions provides students and educators with training, periodicals, and teaching and research opportunities. Collaboration with policymakers and governmental authorities would create a mutual understanding of engineering education issues and how to resolve them.

6.1.2. Contribution and Implication of the Study

The study has two main contributions, and each of them has its own implications. The first contribution is the proposed framework, as discussed in section 5.5. The researcher believes that the framework, Figure 5.2, sheds light on the element of engineering education in Sudan. In addition, the framework should guide the stakeholders to formulate a process for engineering education reform in the country.

This framework is a tool at the disposal of governmental agencies that are in charge of engineering education, MoHESR and SEC, in conjunction with major engineering programs for a comprehensive reform of engineering education in the country. As well, individual academic institutions may find the framework instrumental for either reforming a holistic engineering program or for incremental improvement of engineering education components, such as curriculum, engineering educators, and T&L approaches. Moreover, academic institutions may utilize the framework as a tool for measuring their success while reforming their engineering programs.

Furthermore, the study developed a simple and flexible IFW (section 1.7.6), which represents the second contribution. The IFW consists of two parts with dual functions, the constructivism part and the PST part. Both parts could be utilized, in tandem, for a holistic evaluation of any SSA engineering education system, which operates in unique and complex social, economic, and political conditions. The role of the constructivism part is to investigate and understand the T&L environment, while the PST part is concerned with the deconstruction of the pre-existing structure of the broader engineering education field, which includes engineering education stakeholders, academic institutions, educational policies, and operational activities. Nevertheless, these two parts could be utilized separately, in parallel, or sequentially, to achieve similar research objectives.

The two contributions may stimulate others to research in the area of engineering education in Sudan and similar countries. As well, the study may be considered as a base and guidelines for related future work, see section 6.4.

6.2. Recommendations for Improving Engineering Education in Sudan

As established above, Sudanese engineering education is in desperate need of reform. The required reform should be comprehensive and at a national level. This needs a top-down effort, led by the governmental agencies that are in charge of engineering education (MoHESR and SEC), in collaboration with the major engineering programs, engineering educators and administrators, and professional engineering bodies.

The reform should deal with the well-defined issues, as discussed in sections 2.1.4.5, that have crippled the engineering education in the country, to resolve them and advance the engineering education programs, in other words establishing programs that can graduate a high number of qualified Sudanese engineers. Therefore, the main recommendation revolves around graduating a high enough number of qualified engineers, which is based on the following sub-recommendations:

i. Increasing the intake of engineering education programs by allowing high school graduates to enroll in the engineering discipline of their choice. Nevertheless, high school graduates should be well-prepared to study engineering by introducing a pre-college engineering curriculum and establishing a foundation year within engineering programs.

ii. Improving the quality of engineering graduates by implementing a 4-year OBE curriculum that supports a deep understanding of the subject matter and teaches metacognitive skills and prescribed competencies.

iii. Establishing a hiring structure of academic staff that focuses on recruiting and retaining qualified educators and linking their promotion and pay hierarchy to professional development and effective teaching, including more advanced student-centered learning (SCL).

iv. Increasing the capacity of engineering programs by improving the engineering education infrastructure and introducing a hybrid model that combines both online/offline e-learning, and the traditional face-to-face course delivery mode. The hybrid model may secure more opportunities for students to pursue engineering programs; hence, increasing the percentage of engineering enrolment, which was only 9.1% out of the total tertiary enrolment in 2018.

v. Collaboration between engineering programs and: local, regional, and international engineering education experts, including educators from the Sudanese diaspora, in the areas of curriculum design, professional development, etc.; local and international industries that can provide students with training, internships, and project funds; and international academic institutions for scholarships, and training of students and educators.

vi. Adopting a mandatory professional development culture, for engineering educators, leadership at the top of HEI, and administrators at lower management levels in the areas of curriculum development, SCL, OBE, CBL, learning theories, etc.

vii. Establishing engineering education units, within the engineering programs, and equipping the units with experts who can guide, assist, advise, and provide training, and workshops related to engineering education.

viii. Resolving the human capacity issues: The academic administration should audit the existing job hierarchy for any malpractice related to hiring administrative and academic staff and restructure and eliminate any redundancy within the non-academic staff.

The following steps may be taken to ensure the implantation of the above-mentioned recommendations:

i. First and foremost, this study should be a starting point for revolutionizing the Sudanese engineering education system; and the researcher has to present it to all stakeholders, namely: Ministries of general and higher education, academic administration at institutional levels, policymakers, engineers and engineering educators, whether from within Sudan or from Sudanese diaspora.

ii. MoHESR and SEC should start with forming governmental committees and subcommittees with a clear governmental mandate to proceed with the reform. The committees should: Establish the purpose of the reform, along with its vision and mission; develop a preliminary short- and long-term action plan that includes specific, measurable, and attainable goals; gather and file electronically engineering education-related documents (such as research papers, reports, policies, and legislations), and make them available for researchers, educators, and administrators; review up-to-date efforts related to the reform of engineering education in the county and identify areas of success and failure; summarize reasons behind previous successes/failures while reforming the engineering education; set up workshops for training engineering educators and administrators; organize a conference on engineering education reforms to solicit participants' expertise and their feedback, establish formal and informal channels for feedback, finalize the action plan and break it down into smaller and specific action plans, develop a timetable and associated budget for implementing the reform action plans, and develop criteria and technical bodies for monitoring and evaluating the progress of the reform.

The extremely poor funding remains the truism of engineering education, which represents one of the main barriers to implementing these recommendations. Therefore, stakeholders and the in-charge governmental agencies, such as MoHESR and SEC, should start by developing realistic budgets and pursuing the government of Sudan to secure decent expenditure on the education sector in general, and tertiary education, including engineering education, in particular. Also, Sudanese academic institutions should target their global counterparts and local and international donors for funding academic projects within Sudan. Another possibility is that the Sudanese engineering program should explore investing in profitable schemes for financial gain.

6.3. Limitations of the Study

This study is to investigate engineering education in Sudan. Accordingly, gathered data is supposed to achieve the research objectives. However, the researcher split data collection into two phases: phase I is a documentary analysis of the holistic higher education in Sudan, including engineering education. The scope of phase II is limited to the engineering program at UofK, which is the most prestigious university in the country. The researcher believes that this limitation would not adversely influence the study since its findings could be generalized to overall engineering programs in Sudan. Another limitation of this study is the incomplete validation of the transformational framework, which represents an area for future work.

6.4. Recommendations for Future Research Work

i. Future work is necessary to evaluate the proposed framework and scrutinize its applicability and effectiveness in reforming a holistic engineering education in the country and/or improving individual engineering programs.

ii. At the same time, the researcher believes that this study may serve as guidelines for others' related future research; for instance, researchers may expand their work for evaluation of the overall engineering education in the context of Sudan and/or broadening the context to include other SSA countries.

iii. Other potential research areas may cover (1) The role of the Sudanese socio-economic situation and its culture in the adaptation of the global elements of engineering education to meet the local needs of engineering education and the engineering profession. (2) The role of Sudanese scholars in the localization of technology and global engineering elements for the country's economic development.

6.5. Summary

The chapter concludes the study on “A Transformational Framework for the Development of Undergraduate Engineering Education Programs in Sudan”. In addition to the written conclusion, the chapter includes the study's contribution and its implications. Also, the chapter includes practical and relevant recommendations for improving engineering education in Sudan. Based on the limitations of the study, the chapter recommends necessary topics for future research work.

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Appendix A – Interview Guide (Protocol)

This appendix shows the interview guide, hereafter called the protocol, used to perform the semi-structured interview of an engineering education research, about the engineering education in Sudan.

<u>First Part</u>:

Participant's Background Information

A: Answered before the interview. (if possible)

1. Personal Information,
   a. Personal information
   b. Full Name:
   c. Contact info: (phone and e-mail):
2. Education (highest degree/discipline):
3. Professional experience
   a. Years in industry:
   b. Years in academia:
   c. Research area:
4. Relationship/ Role within the engineering education in Sudan
   a. Name of academic institution/organization:
   b. Position/Role:
   c. Years in this position/role:

B: Answered during the interview.

5. Confirmation of participant's background information

<u>Second Part</u>:

In depth answers to the research questions, sub-questions, and follow up questions.

<u>Objective One:</u>

Whether the current engineering **<u>curricular</u>** include appropriate set of skills and knowledge for the 21st century.

ما إذا كان المنهج الهندسي الحالي يتضمن مجموعة مناسبة من المهارات والمعرفة للقرن الحادي والعشرين

Research Questions:

1. Does the current engineering curriculum support knowledge-based competences and soft skills?
   هل يدعم منهج الهندسة الحالي الكفاءات القائمة على المعرفة والمهارات الشخصية؟

   1.1. Can you describe the current curriculum of chem. Eng. Program at UofK ?
   هل يمكنك وصف المنهج الحالي لبرنامج الهندسة الكيميائية؟

      1.1.1. What is the total number of credit hours?
      ما هو إجمالي عدد الساعات المعتمدة؟

      1.1.2. What are the categories of the courses?
      ما هي اقسام الكورسات، المواد؟

      1.1.3. What are the courses w/ and w/out lab component?
      ما هي المواد التي تحتوي، او لا تحتوي، على جانب عملي (مختبرات) ؟

      1.1.4. What are the courses that concern engineering design?
      ما هي المواد التي تعنى بالتصميم الهندسي؟

      1.1.5. What are the courses that include project component (PBL &PjBL)?
      ؟ ما هي المواد التي تحتوي، او لا تحتوي، على المشاريع

   1.2. Does Engineering Curriculum teach skills?
   هل منهج الهندسة يعلم المهارات؟

      1.2.1. What are the technical and non-technical skills covered by the curriculum?
      ما هي المهارات الفنية وغير الفنية التي يشملها المنهج؟

1.2.2. What are the necessary and required skills in the 21st century engineer?

ما هي المهارات الضرورية والمطلوبة في مهندس القرن الحادي والعشرين؟

1.2.3. Does the curriculum allow students to acquire and apply theoretical and practical knowledge of engineering fundamentals?

هل يسمح المنهج للطلاب باكتساب وتطبيق المعرفة النظرية والعملية والبحثية لأساسيات الهندسة؟

1.2.4. Does the curriculum support students to design and conduct experiments, as well as to analyze and interpret data?

هل يدعم المنهج الطلاب في تصميم التجارب وإجرائها ، وكذلك لتحليل البيانات وتفسيرها؟

1.2.5. Does the curriculum support in-depth technical competence in a specific engineering discipline?

هل يدعم المنهج الكفاءة التقنية المتعمقة في تخصص هندسي معين؟

1.2.5.1. Does the curriculum support deep understanding?

هل المنهج يدعم الفهم العميق؟

1.2.5.2. Does the curriculum encourage active learning?

هل المنهج يشجع التعلم النشط؟

1.3. Can you describe the process of curriculum design/development?

هل يمكنك وصف عملية تصميم المناهج؟

1.3.1. Do you have any knowledge and/or interest with curriculum design?

هل لديك أي معرفة و / أو اهتمام بتصميم المناهج الدراسية؟

1.3.2. How often curriculum revision occurs? When was the last one?

كم مرة تحدث مراجعة المنهج؟ متى كانت آخر مرة؟

1.3.3. Explain curriculum design procedure.

اشرح إجراءات تصميم المناهج

1.3.4. Who are involved in curriculum design/development (stakeholders)?

من هم المشاركون في تصميم / تطوير المناهج (أصحاب المصلحة)؟

1.4. Engineering Curriculum

منهج بكالوريوس الهندسة

1.4.1. What are the learning objectives of the engineering curriculum?

ما هي أهداف التعلم لمنهج الهندسة؟

1.4.2. How are they established?

كيف يتم تأسيسها؟

1.4.3. Explain any feedback from academia, industry, professional institutions, and/or accreditation agencies.

اشرح أي تعليقات من الأوساط الأكاديمية ، والصناعة ، والمؤسسات المهنية ، و / أو وكالات

1.4.4. What do you think about the existing engineering curriculum in UofK? Is it Current or outdated?

ما رأيك في منهج الهندسة الحالي؟ هل هو حالي أم قديم؟

1.4.5. Describe issues related to curriculum development/ design?

وصف القضايا المتعلقة بتطوير / تصميم المناهج؟

1.4.6. What is the effect of economic, political, environmental, and cultural factors on curriculum design/development?

ما هو تأثير العوامل الاقتصادية والسياسية والبيئية والثقافية على تصميم / تطوير المناهج؟

1.4.7. OBE and CBE: Should curriculum teach competencies (CBE)

هل يجب أن يعلم المنهج الدراسي الكفاءات

Objective Two:

The adopted **Teaching and Learning philosophy**, strategy, and method, by the undergraduate engineering programs.

فلسفة واستراتيجية وطريقة التدريس والتعلم المعتمدة من قبل برامج الهندسة الجامعية

Research Questions:

2. Do the current teaching and learning approaches support the 21st Century Learning?

هل أساليب التدريس والتعلم الحالية تدعم التعلم في القرن الحادي والعشرين؟

2.1.1. Can you describe the engineering facilities (labs, workshops, libraries, etc.?

هل يمكنك وصف المرافق الهندسية (المعامل ، ورش العمل ، والمكتبات ، وما إلى ذلك؟

2.1.2. How do you assess teaching effectiveness?

كيف تقيم فعالية التدريس؟

2.1.3. Any modern technologies are used in engineering education at UofK? Examples: online learning, social networking, interactive whiteboards, podcasting, class blogs and wikis, mobile devices, 3D printing, virtual reality, gamification, and cloud technology.

2.1.4. Which is preferred at your engineering program: traditional T&L or student-centered learning (SCL), and why?

Objective Three:

Qualification and in-service training of **engineering educators**.

تأهيل المعلمين الهندسيين وتدريبهم أثناء الخدمة

Research Questions:

3. Do the current engineering lecturers are future-ready educators?
هل المحاضرين الهندسيين الحاليين هم معلمين جاهزين للمستقبل؟

3.1. Can you describe the situation of academic staffs? In terms of number and ranking, pre-service training, instructor-to-student ratio, etc.

هل يمكنك وصف حالة أعضاء هيئة التدريس؟ من حيث العدد والترتيب ، التدريب قبل الخدمة ، نسبة المدرس إلى الطلاب ، إلخ..

3.2. How do you evaluate engineering educators' ability to understand and work with preexisting knowledge, skills, attitudes, and beliefs of engineering students?

كيف تقيم قدرة معلمي الهندسة على فهم المعرفة والمهارات والمواقف والمعتقدات الموجودة مسبقًا لدى طلاب الهندسة والعمل معهم؟

3.3. How do you evaluate engineering educators' capabilities to monitor students' progress, maintain their engagement, and challenge them?

كيف تقيم قدرات المعلمين الهندسيين على مراقبة تقدم الطلاب والحفاظ على مشاركتهم وتحديهم؟

3.4. Describe the relationship between the engineering educators and their students from one side and the community from the other side.

صف العلاقة بين معلمي الهندسة وطلابهم من جهة والمجتمع من الجانب الآخر

3.5. Can you describe the performance evaluation process of engineering educators? Is it link to faculty promotion, compensation, hiring structure, etc.?

هل يمكنك وصف عملية تقييم أداء المعلمين الهندسيين؟ هل هو مرتبط بترقية أعضاء هيئة التدريس ، والمكافآت ، وهيكل التوظيف ، وما إلى ذلك؟

3.6. Can you describe professional development program (in-service training)?

هل يمكنك وصف برنامج التطوير المهني (التدريب أثناء الخدمة)؟

Objective Four:

4. The possibility of developing transforming engineering curriculum framework.

إمكانية تطوير إطار تحويلي للمناهج الهندسية

4.1. All 3 research questions.

4.2. Do you think there is a need for engineering education reform?

هل تعتقد أن هناك حاجة لإصلاح التعليم الهندسي؟

4.3. What are the challenges for engineering education reform?
ما هي تحديات إصلاح التعليم الهندسي؟

Theme 1: Engineering Education

A. Engineering **admission**
   1) What are the admission requirements?
   2) What are the social economic backgrounds of admitted students to engineering programs?

B. (**Relationship with the industry** and potential employers)
   1) Describe the relationship between the industry and engineering program, in terms of: internship, research projects, curriculum development input, etc.
   2) What type of feedback (if any) do engineering programs collect from the industry and potential employers?

3) How is the feedback collected from the industry and potential employers?
4) How is the feedback incorporated into curriculum development/design?

C. Engineering **<u>Graduates Competencies</u>** (Knowledge and Skills) (Theme 5)
    1) How competent are your engineering graduates?
    2) How an engineering student acquires competencies, demonstrates competencies, or assessed for competencies)?

المحور الأول: التعليم الهندسي

أ. القبول الهندسي

ما هي شروط القبول؟ (1

ما هي الخلفيات الاجتماعية والاقتصادية للطلاب المقبولين في برامج الهندسة؟ (2

(العلاقة مع الصناعة وأصحاب العمل المحتملين)

وصف العلاقة بين برنامج الصناعة والهندسة ، من حيث: التدريب ، ومشاريع البحث ، ومدخلات تطوير (1
المناهج ، وما إلى ذلك.

ما نوع التعليقات (إن وجدت) التي تجمعها البرامج الهندسية من الصناعة ومن أصحاب العمل المحتملين؟ (2

كيف يتم جمع الملاحظات من الصناعة وأصحاب العمل المحتملين؟ (3

كيف يتم دمج الملاحظات في تطوير / تصميم المناهج؟ (4

كفاءات خريجي الهندسة (المعرفة والمهارات) (المحور الخامس).

ما مدى كفاءة خريجي الهندسة لديك؟ (1

كيف يكتسب طالب الهندسة الكفاءات أو يُظهر الكفاءات أو يتم تقييمه للكفاءات)؟ (2

<u>Theme 2: Accreditation of Engineering Programs</u>

A. Describe accreditation system available for engineering programs, at national, regional, and international levels.

B. National Accreditation
    1) Name national accreditation agencies.
    2) What is accreditation significance?
    3) What is (are) accreditation procedure (s)?

C. Regional and International Accreditation
    1) Name regional and international accreditation agencies.

2) Does any of engineering programs accredited by any regional and/ or international agencies? Why (if yes or no)?
3) What is the importance of regional/ international accreditation?

المحور الثاني: اعتماد البرامج الهندسية

أ. وصف نظام الاعتماد المتاح للبرامج الهندسية ، على المستويات الوطنية والإقليمية والدولية.

الاعتماد الوطني

1) تسمية وكالات الاعتماد الوطنية.

2) ما هي أهمية الاعتماد؟

3) ما هي (هي) إجراءات الاعتماد؟

ج- الاعتماد الإقليمي والدولي

1) تسمية وكالات الاعتماد الإقليمية والدولية.

2) هل تم اعتماد أي من البرامج الهندسية من قبل أي وكالة إقليمية و / أو دولية؟ لماذا (إذا كانت الإجابة بنعم أو لا)؟

3) ما هي أهمية الاعتماد الإقليمي / الدولي؟

<u>Theme 3&4: Academic and Professional Institutions</u>

1) Describe any type of collaboration between engineering programs at UofK and other academic and professional institutions, at local, regional, and international level.
2) Name academic and professional institutions.
    i. National
        1. SEC- Sudanese Engineering Council
        2. SEA- Sudanese Engineering Association (Trade Union)
        3. MoHESR- Ministry of Higher Education and Scientific Research
    ii. Regional
        1. MRA for EAC- Mutual Recognition Agreement for Engineer in East Africa

2. IUCEA- Inter University Council for East Africa

iii. International

1. ABET- American Board of Engineering and Technology
2. WA- Washington Accord
3. RAE- Royal Academy for Engineering
4. UNESCO-

المحور الثالث والرابع: المؤسسات الأكاديمية والمهنية

والمؤسسات الأكاديمية والمهنية الأخرى ، على UofK وصف أي نوع من التعاون بين البرامج الهندسية في (1
.المستوى المحلي والإقليمي والدولي

تسمية المؤسسات الأكاديمية والمهنية (2

أنا. وطني

المجلس الهندسي السوداني -1. SEC

اتحاد المهندسين السودانيين (نقابة) - 2. SEA

وزارة التعليم العالي والبحث العلمي- وزارة التعليم العالي والبحث العلمي .3

ثانيا. إقليمي

اتفاقية الاعتراف المتبادل للمهندس في شرق إفريقيا -1. MRA for EAC

المجلس المشترك بين الجامعات لشرق إفريقيا - 2. IUCEA

ثالثا. دولي

المجلس الأمريكي للهندسة والتكنولوجيا -1. ABET

اتفاق واشنطن -2. WA

الأكاديمية الملكية للهندسة -3. RAE

-اليونسكو .4

I. **List of attributes used for this study**

1. Ability to acquire and apply **knowledge of engineering fundamentals**.
القدرة على اكتساب وتطبيق المعرفة بأساسيات الهندسة.
2. Having competency **in theoretical and research engineering**.
امتلاك الكفاءة في الهندسة النظرية والبحثية
3. Having **competency in application and practically oriented engineering**.
أن يتمتع بالكفاءة في الهندسة التطبيقية والعملية الموجهة
4. Ability to **communicate effectively**, not only with engineers but also with the community at large.
القدرة على التواصل بشكل فعال ، ليس فقط مع المهندسين ولكن أيضًا مع المجتمع ككل
5. Having **in-depth technical competence** in a specific engineering discipline.
امتلاك كفاءة تقنية متعمقة في تخصص هندسي معين
6. Ability to undertake **problem identification, formulation and solution**
القدرة على تحديد المشكلة وصياغتها وحلها
7. Ability to utilize a systems approach to **design and evaluate operational performance**.
القدرة على استخدام نهج النظم لتصميم وتقييم الأداء التشغيلي
8. Ability to function effectively **as an individual and in a group with the capacity to be a leader or manager as well as an effective team member**.
القدرة على العمل بفعالية كفرد وفي مجموعة مع القدرة على أن تكون قائدًا أو مديرًا بالإضافة إلى عضو فعال في الفريق
9. Having the understanding of **the social, cultural, global and environmental responsibilities and ethics of a professional engineer and the need for sustainable development**.
فهم المسؤوليات الاجتماعية والثقافية والعالمية والبيئية وأخلاقيات المهندس المحترف والحاجة إلى التنمية المستدامة
10. Recognizing the need to undertake **lifelong learning**, and possessing/acquiring the capacity to do so.
الاعتراف بالحاجة إلى إجراء التعلم مدى الحياة ، وامتلاك / اكتساب القدرة على القيام بذلك
11. Ability to **design and conduct experiments**, as well as to analyze and interpret data.
القدرة على تصميم وإجراء التجارب وتحليل البيانات وتفسيرها
12. Having **the knowledge of contemporary issues**.
الإلمام بالقضايا المعاصرة
13. Having the basic **entrepreneurial skills**
امتلاك المهارات الأساسية في تنظيم المشاريع

Appendix B – Research Information Sheet (RIS)

Research Title:

FRAMEWORK FOR TRANSFORMATION DEVELOPMENT OF SUDAN UNDERGRADUATE ENGINEERING EDUCATION PROGRAM

Research Objectives:

The main objective of this study is to evaluate elements of engineering education in Sudan, in light of educational goals for the 21st century, including: the current engineering curricula, the assessment tools, and the engineering educators.

Data Collection Procedures:

Sources of the Data	Data Collection instruments			Note
	Documentary Analysis	Interview	Observation	
MoHESR[1]	✓	--	--	Phase 1
MOE[1]	✓	--	--	
SUST[1]	✓	--	--	
UofK[1]	✓	--	--	
UNESCO, WB, RAE[2]	✓	--	--	
MoHESR	✓	✓	✓	Phase 2
SUST	✓	✓	✓	
UofK	✓	✓	✓	

[1] Websites and sites visits.

[2] UNESCO, World Bank & RAE websites

The Researcher:

My name is Abdelrahim Minalla who work as a chemical engineering lecturer at Higher Colleges of Technology (HCT), United Arab Emirates (UAE). I am gathering data for my PhD dissertation, about the situation of engineering education in Sudan.

Purposeful Participants/ Voluntary participation:

A small sample of experienced participants has been chosen to provide in-depth information about their own experiences in the area of engineering education in Sudan. Based on your background, you are invited to participate in this interview. However, participation is voluntary, and you have the right to decline participation in the interview, answering any question, and/or withdrawing from the interview at any time without any reasoning.

Benefits/Risks to Participants:
This research is about evaluation of engineering education in UofK, which is a public university, and it is the most prestigious one in Sudan. The main benefit of the research is to identify strengths and weaknesses of the engineering programs, and to come up with a set of recommendations to improve the engineering program.

Confidentiality:
Although the interview covers only public records and information, however the participant can refuse to answer any question he/she believes is not appropriate. Moreover, any provided information would not be utilized without a consent of the participants.

Data Recording and Findings Dissemination:
The researcher will utilize a smart phone to audio record the interview; the recording will be deleted from my phone after transcribing the data. Findings disseminated will include conferences, publications, and dissertation.

Contact info:
The researcher can be reached via: aminalla2000@yahoo.com, +971-501330284 (phone calls and WhatsApp).

Appendix C – Redacted Version of the Semi-structured Interview with Participant Number 9

Appendix C is an example of semi-structured interviews. It is a redacted version of the semi-structured interview with participant number 9 (Int9). The researcher removed all sensitive information from the original version, summarized and reorganized the transcribed text, and obtained the participant permission to include this redacted version as part of the Appendices.

Participant Number 9:

'My name is (XX). Born 1966 in Khartoum. All school stages, up to high school, were in Khartoum. Undergraduate and Master's studies at Mosco State University. Master of Civil Engineering specializing in concrete construction. I returned to Sudan and worked as an engineer and lecturer at (XX). Then I went to study in Germany in 2008, I was awarded a doctorate from the Technical University of Berlin in the specialty of construction in 2010. I returned to Sudan to continue my work as an engineer and academician. Now I am an associate professor and director of the University of (XX). I am interested in academic university writing and composition. I have almost 15 years of experience in higher education administration, and 20 years of experience in university teaching. You can ask me for any additional information.'

Asked Int9 about the ideal curriculum development process; he summarized it as follow:

'The curriculum development process for us or in almost all higher education institutions in the engineering education sector. Of course, the start is the old curriculum, after each graduation cycle, which is every five years, because all engineering studies in Sudan is 5 years for bachelor of honors. Every five years the curriculum is supposed to be revised. The process is long; so, it starts with the previous curriculum being reviewed. It is evaluated according to the latest developments in science and technology, and the latest development in the labor market. Two of the very crucial elements in the form of modification and change and modification in any possible curriculum. The starting point of the process is to determine the strengths and

the weaknesses of the old curriculum. Of course, this whole issue is done by a committee; I don't know if the details here are useful or not, but anyway I will mention it. A committee consists of the director of the designated educational institution and the concerned department or the dean of the concerned college, as a technical secretariat; and the committee includes academicians from inside and outside the respective institution. Well, the committee that has the basic work methodology does something compared to the model curriculum. The Ministry of Higher Education and Scientific Research has a model curriculum for all specialization. After the old curriculum is compared with the model curriculum. After that they moved to the stage of formulating new terminologies. The new terminologies in question and in the mind of the committee use all stakeholders feedback in the educational process, professors, students, graduates and representatives of the labor market in the particular specialty. After that, it is compared to the requirements of specialized professional councils; for example, we have in engineering the Sudanese Engineering Council (SEC) requirements. The Sudanese Engineering Council has certain criteria, to evaluate and approve each curriculum. For the purpose of further development and intonation, it is also compared to the criteria required on the international engineering education (ABET). I mean each one of them has requirements. In what the curriculum is supposed to contain, in terms of basic sciences, engineering sciences, design subjects, and in terms of complementary sciences. Well, after formulating the proposed curriculum, it is presented to a selection of two or three senior scholar in the relevant specialization in Sudan for approval. Then the revised curriculum shall be presented to the authorities of the National Council for Higher Education and Scientific Research, which has a committee called the Committee for the Organization of Higher Education and Scientific Research Institutions. This committee has different departments for all sciences: The Engineering Science Committee, Medical Sciences Committee, Agricultural Sciences Committee, Computer Science Committee, and Environmental Science Committee. The final approval comes from this Committee. I mean, this is the process of updating the existing curriculum or developing a new one. This is a brief of the curriculum development process, and I am ready if there is a need for additional information.'

When the researcher asked Int9 about the relationship between MoHESR and SEC, he gave the following answer:

'The relationship is very, very overlapping between the SEC and MoHESR. Both of them share the mandate of overseeing engineering programs in the country. However, MoHESR leaves this part of responsibilities to SEC, which has the ultimate jurisdiction over the engineering programs in the country. First, SEC is a member of the National Council for Higher Education and Scientific Research (NCHESR), which is part of MoHESR. This is the overlap between the Engineering Council, as a Professional Board, and between the engineering faculty in any academic institution. The strange thing is that this matter is not stated in the constitution or in any other legal forms. But in the end, the de facto, that the Engineering Council is the first and most basic curator of engineering education than the Ministry of Higher Education and Scientific Research and the various committees.'

About the relationship between SEC and engineering programs in the country, Int 9 said:

' Ok relationship, between the SEC and the designated engineering program is governed by the accreditation process. SEC is the accreditation body. Student graduating from a particular engineering department is not allowed to practice the profession unless they are licensed by the SEC, known as engineering number. The relationship with the SEC begins with the admission requirements; currently, the first requirement for the admission for engineering majors by the order of SEC is 65% in scientific major (mathematics or biology) but mathematic is preferable. After that SEC has six basic criteria to evaluate the particular engineering program: The curriculum, the admission requirements, the means of evaluating the performance of students and following up on graduates, the administration and teaching staff, the Infrastructure, and research and graduate studies. Unless the Engineering council is convinced that the academic institution has achieved all six, the institution is not granted accreditation and its graduates are not granted engineering licenses. The engineering council forms a committee to audit the engineering educational institutions almost annually or every two years; and accordingly, the committee decide whether to extend or to freeze the recognition of the engineering institution/program.'

Int9 added the following about the accreditation criteria:

'The Council will check the curriculum, which must agree with the specified components of the curriculum: The Engineering Council tell you that the components of the curriculum must be as follows: Basic Sciences, which means physics, chemistry, mathematics and the basics of computer, between 25 to 30%; basic engineering sciences, such as mechanics, materials resistance uniforms, engineering drawings, etc. between 25 and 35%; after that, the subjects of the specialization from 25 to 35%; and then the social sciences and humanities such as languages, religions, administration, engineering economics, and Sudanese studies, and it supposed to be from 10 to 15%.'

'Then, on-the-job training for training during the study period: Six weeks_150 hours, zero training, after the first year; six weeks_150 hours, after the second year; eight weeks_200 hours, after the third year; and four weeks_100 hours, after the fourth year.

'Another criterion is the administration and the faculties. The Engineering Council says SSR is supposed to be one for 15 (SSR = 1:15). According to faculty ranking SSR is as follow: The professorial rank: One full professor for every 100 students; one associate professor for every 65 students; one assistant professor for every 50 students; and one lecturer for every 25 students.'

'The Engineering Council has the full jurisdiction over the entire engineering institutions in Sudan. they follow up on these institutions even after they granted the recognition. By the way, the Engineering Council can inspect, and they do inspect these engineering institutions continuously.'

Does the Engineering Council have the capacity to follow up and inspect all engineering institutions in the country?

'Yes, the engineering council can inspect, and they do inspect engineering institutions continuously. By the way, the engineering institutions in Sudan are not so many. Here we talk about: 41 government universities; 24 private universities, which means that we have 65 universities; and 99 private colleges. Not all of these institutions

offer engineering studies, and the total engineering programs provided by these institutions are about 190 programs.'

'The Engineering Council has its branches in the major Sudanese cities; Whenever is needed, the council send delegations to inspect engineering programs in the areas with no council branch.'

<u>Who incur the cost of evaluation?</u>

'Although the Engineering Council, as an institution, is affiliated to the Council of Ministers, means that it is supposed to be financed by the public treasury and the Ministry of Finance, but the council does not carry the evaluation expenses, which are charged to the designated institution. These charges include: the mobilization logistics, food, and the inspectors' petty cash.'

<u>What is the actual situation of engineering programs?</u>

'Although the Engineering Council has in place very clear requirements, and the Council inspects all engineering program continuously, still the actual situation in all engineering institutions in Sudan, in private and public universities, is far from consistent with the norms, as set by the Council.'

'The council evaluation of engineering programs is very flawed, and is based on the evaluation of all six criteria together; none of these six criteria is a decisive factor on the overall evaluation. For instance, each program gets certain points for each criterion; and if the total of the points makes 50%, or more, the council would conclude that the program passed the evaluation, with a respective percentage, providing completion a list of observations.'

'I was working in one of the MoHESR committees to evaluate and follow up on the evaluation of Sudanese higher education institutions. The committee has uncovered the entire situation of these engineering programs. Give you some examples: I told you that a faculty member is supposed to be one for every 15 students. We found that SSR varies; in some cases, this ratio is: 1:60, 1:50, 1:40, and 1:30, although it is stipulated that one faculty to 15 students. The situation in public universities is even worse; this

because the Council mandate over the public engineering programs is very weak; and this is because public universities are supported by sovereign bodies.'

'I found that in the average Sudanese educational institutions that the proportion of the faculty to students is one to 53. In this case the council ask the institution to improve this requirement to start with 1:30, then 1:20, and the ultimate goal to reach 1:15. Well, the institutions behave differently: some of them work genuinely to complete this requirement; others circumvent either by registering faculties a certain period and then they abandon or by faking teaching contracts.'

Int9 continued:

'All in all, the outcomes of engineering education in Sudan are very weak. Definitely, all engineering programs in the country must be improved. Let me give you the following examples:

- *The MoHESR issued the admission guideline for the 2023 academic year, which plans for admitting about 35 thousand engineering students. However, the actual number so far is about 20 thousand first year engineering students. This number makes the total engineering students in Sudan about 140 thousand. While the teaching staff is not more than 2500 faculties, or 1 faculty for 56 engineering students. Therefore, the academic staff criteria is the weakest one. Universities fill this gap by hiring part time teaching positions. The situation of the teaching staff is due to three factors: First, poor compensation of the university teachers; even in our neighboring countries such as Chad, Uganda, and Ethiopia, the compensation of the university teacher is better than in Sudan, although their macroeconomic indicators are less than the Sudanese ones. Therefore, most good graduates prefer to work in industry rather than in academia. The second reason is the immigration to the Gulf countries, where the academician allocations are far better than in Sudan. the third reason is the lack of professional development.*
- *The number of professors is very low, with less qualification. Once upon a time there was an annual training for teaching members to send them abroad*

to earn their masters, PhDs and Post-doc. But currently there are no significant budgets allocated to the Department of Scientific Research and Training inside Sudan. Hence. We are not able to create specialists inside Sudan and train them to the higher grades, and we are not able to send them for foreign training in America and Europe, as it was in the past, because of the bad relationship, politically, with the international community. The final outcome is you have weak engineering graduates.

- *About the total number of Sudanese engineers: Here I am providing you with some statistics as I obtained from SEC about the total number of engineers in the country. SEC has three categories for engineers: Engineers with a bachelor's degree in engineering, technicians with three-year diploma, a two-year diploma, or a one-year diploma, in addition to the category of skilled workers who completed industrial high schools.*
- *The total number of engineers is classified, according to the SEC classification, as follow: 800 consultant engineers; 3000 specialist engineers; 50,000 graduate engineers; 40,000 technicians; and 2500 technicians. The total registered engineers within SEC, and assuming all of them are reside in Sudan, are 96300 engineers. Knowing that the total Sudan population is 40,096,300., then there are only 240 engineers per each 100,000 population. This is a very low number of engineers, even within the neighboring countries. For instance, per 100,000 population Egypt has 2800 engineers, Saudi Arabia has about 500 engineers, not including expat engineers, Germany has 2800 engineers. Only 240 engineers per 100,000 population is an indicator that you do not have human development and economic development.*
- *HS Graduates: I was for long periods of time, engaged with teaching more than administrative work at the university. I was interviewing students nominated for admission. Those students with 75% or higher high school certificate. These interviews proved to me that high school graduates are very weak academically for studying engineering. As well, I taught many courses, at the University of Khartoum and at the University of Sudan. I*

noticed that the student's preparation is very weak and not compared to the students until the late eighties.

- *Fake degrees represent one of the intertwined corruption rings within the country during the previous regime, that ruled the country with iron fist for more than 30 years.*
  - *Some luxurious and large universities, such as University of (XX), (XX), and (XX), have issued fake degrees (bachelor, master, and doctorate degrees) for influential figures in politics, business, and public services. I mean, I am also not talking about politics, but speaking facts. For example, WB, the wife of influential politician, has a doctorate in strategic planning at one of the Sudanese universities, although it is doubtful that she has a Sudanese high school certificate.*
  - *In addition, there are some who counterfeit university seals to issue counterfeiting certificates. Because of this issue, there are offices representing employers from Gulf countries such as Saudi Arabia and UAE, for the purpose of verification the authenticity of academic degrees and legal documents presented by Sudanese applicants. The fact that companies have been established for the purpose of verifying the validity of university degrees that have been granted by the Sudanese higher education institutions is a great indication of the magnitude of the phenomenon. I do not like to speak in numbers since I do not have a proven study on the matter, but I can tell you from the reality of the indicators the magnification of the problem.*
  - *On top of that there is what I call knowledge falsification: there are offices in the market established to help master and doctoral students with research, questionnaires, field survey, statistics, and any need for doctorate thesis. The worst thing is that their advertisements are on the national television of the Republic of Sudan.*
  - *Another way of knowledge falsification is that postgraduate studies programs have started relaxing admission requirements for graduate studies and have become more lenient in awarding the degrees, for the*

sake of commercial gains. All universities have opened bachelor's, master's and doctoral degrees for whomever they want, regardless of their academic readiness. Graduate studies have become a source of income for public and private universities. Students, who cannot continue higher studies outside Sudan, resorted to postgraduate studies inside Sudan.

When he was asked about the need for rehabilitation of the Sudanese engineering education, Int9 said:

'Definitely engineering education programs in Sudan need a rehabilitation, because of the following challenges and/or weaknesses: Weak infrastructure of engineering programs, a weakness in human resources, quality and quantity of teaching staff, budgets allocated for the development of education in general and engineering education in particular, poor engineering curricula. Treating these challenges begins with recognition of the deteriorating reality of engineering education, and the will to change this reality; then allocating a realistic budget for teaching reform, including engineering education, in terms of infrastructure rehabilitating, qualifying and training cadres and human resources, providing modern teaching aids, and developing relevant curricular; as well reforming of related governmental institution in terms of management, mentalities, policies and regulations, etc. I believe, there is hope, and change will happen. Providing the political reform, which started after the December 2019 revolution, would continue. Completion of the democratic change provides the opportunity for qualified Sudanese who are able to bring the change; they are present inside and outside Sudan. Noted, I don't want to sound political, and I want to keep the scientific aspect of this interview; however, political factor is very important for any education reform.'

We go back to the curricula:

'The first need is that curriculum supposed to be tied to the development requirements of the particular country. I mean, engineering curricular in America and Germany shouldn't be the same curriculum as in Sudan. Accordingly, it is supposed to

be linked, in one way or another, with development priorities, development requirements and degrees of development. The university student is supposed to learn learning skills because the university is supposed to provide students with keys to learn, because the subject that you are learning today may not be relevant tomorrow.'

Traditional Teaching & Learning Methods:

'The second issue, which is the most serious, is the nature of education itself. Ok, what is the nature of education in Sudan? is it to indoctrinate the learner or to stimulate to learn? That's a very big question! I think that in 90 percent of the institutions of higher education in Sudan, education is just indoctrination that feeds students with information and instructions, and not teaches them skills to learn. However, modern education, not just in universities, but even in schools, teaches the student basic learning skills, methods of scientific thinking, and skill to learn. Learner is a creator of knowledge who makes it clear that he is a participant in what material is presented to them.'

Duration of Engineering Program in Sudan:

'The duration of all engineering programs, in Sudan, is 5 years, 10 semesters, 190 credit-hours, except for architecture programs, which 180 credit hours. In my perspective for an engineering student, he can graduate in four years. And I saw it, some engineering colleges in England Like the University of Reading, for example, as I recall, engineering stayed in it for three years bachelors. If you break down the 190 credit hours, you may be able to get rid of many courses and reduce the number of the credit hours: Reduce the humanities courses: Islamic culture, Arabic language, Sudanese studies, Reduce science and math courses.'

'As well for families, 4-year program is better for their kids to graduate, join the force work, and help their families' financial burden. I can say less to the social sciences and humanities, less to the supporting sciences major.'

Appendix D – 85 Broad Coding from Transcribed Interviews

1. The curriculum

1) Outdated curriculum
2) Last revision 2012
3) On average revision every 10 years
4) Students' workload
5) The duration of the program- 10 semesters in 5 years
6) 171 credit hours/ 65 courses
7) Theoretical curriculum
8) Only two project-base courses (PBL/PjBL)
9) Only three design courses
10) No industrial training
11) Irrelevant engineering materials
12) Untrue claim of OBE/CBE

2. T&L Environment

T&L Philosophy

13) Traditional T&L is the norm
14) No evidence of SCL
15) Duration of Study
16) EC has been following the annual system
17) Changed to semester system
18) Only superficial change, without change in the curriculum, teaching materials, and/or traditional teaching method

Academic Staff

19) Teaching Ranking
20) UofK- PhDs hold teaching ranking
21) MSc and PhD hold TA positions.
22) Other universities- MSc and PhD hold teaching ranking
23) Poor financial compensations

24) Engaged in other academic and non-academic activities
25) teach as a part time in other universities
26) No fund for research or training,
27) They are keen to help students.

Infrastructure

28) Limited Building, Libraries, etc. (Not enough)
29) Laboratories
30) Good for demonstration only, not for research
31) Many equipment/instruments are not functional.

3. Engineering Educators

32) No annual PD programs, in place, for engineering educators, and
33) No PD requirements
34) Exception: 2 weeks of pedagogy training
35) Engineering educators are only available, in the premises of the university, to deliver their theoretical lectures
36) Most of educators are not capable to graduate qualified engineers
37) Some engineering educators are without proper PhD degrees
38) Proper PhD holders, from western universities, have been trained to perform research rather than teaching
39) They miss the practical elements of the Sudanese industries.
40) They stop performing research due to poor research capabilities in Sudanese universities.
41) Most of them haven't worked or even seen a factory in Sudan.
42) Knowledge is related to the countries from where they obtained their degrees.
43) Educators are not available for their students, research, or the relationship with industry.
44) No KPI for educators
45) No accountability
46) No teacher lose his/her job
47) UofK Faculties don't lose their jobs for any reason.

48) Poor financial compensations,

49) Engaged in other academic and non-academic activities to generate monetary support

50) Teach as a part time in other universities,

51) UofK as a prestige rather than for the financial

4. Framework

52) Need for engineering education reform

53) Challenges facing engineering education reform

54) The possibility for developing transforming curriculum framework

5. Admission of Engineering Students

55) Only top high school graduates

56) Admission in different engineering programs is based on high School GPA

57) Technology awareness is not the norm

58) Changing the major within UofK is almost impossible.

6. The link with the industry

59) Industry- Incompetent engineering graduates

60) Industry wants ready engineering graduates

61) prefer to recruit engineers from outside the country.

62) Industry- Universities don't put the effort to collaborate with industry

63) Industry- Educators are not interested in a proper relationship between the academia and the industry

64) Industry- Collaboration is done at a personal level rather than undertaking strategies

65) Universities- Believe that the industry are not keen about academia and/or research.

66) Universities- Industries in Sudan are not technically advanced, and they are not interested in researches, but in only profitable activities.

67) Industry distortions

7. Engineering Graduates

68) All it takes to graduate is to memorize the materials and take the test.
69) Graduates are very good in theoretical knowledge
70) Graduates are very weak in practical skills
71) The university used to link the student with industry.
72) Before: Student are familiar with the practical element in their fields.
73) Currently, training is achieved at a personal level and after graduation
74) The training: Talent, competences, and skills.
75) Training should be impeded in the engineering curriculum, or even pre-college curriculum
76) The university used to link the student with industry.
77) The training: Talent, competences, and skills. This type of training should be impeded in the engineering curriculum, within the duration of the college, and even prior to the college curriculum.
78) Are not aware whether they have the talent,
79) The university is about memorizing the materials
80) Match what they want with what they have.

8. Accreditation

81) Local accreditation by the MoHESR
82) No regional and/or international accreditation
83) No international accreditation

9. Collaboration

84) Lack of collaboration with local, regional, and international institutions
85) UNSCO is the exception

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