INDUSTRIAL MATHEMATICS CURRICULUM DEVELOPMENT FOR ETHIOPIAN SCIENCE AND TECHNOLOGY UNIVERSITIES

By

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DECLARATION

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I further declare that I submitted the thesis to originality checking software and that it falls within the accepted requirements for originality.

I further declare that I have not previously submitted this work, or part of it, for examination at Unisa for another qualification or at any other higher education institution.

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DEDICATION

This Ph.D. dissertation is dedicated to the fact that "a good teacher, like a candle, consumes itself to light the way for others."

Abstract

This study aimed to examine the development and implementation of the new industrial mathematics curriculum for Ethiopian Science and Technology universities. Ethiopia is in the process of transforming to industry led economy and to facilitate this transformation, the government needs competent graduates in science and technology field. The goal was to gain insight into the process of developing and implementing the industrial mathematics curriculum by studying the needs of stakeholders. The study employed the APOS theoretical framework for curriculum development process of mathematics education.

The study was conducted at two universities of Science and Technology using a sequential explanatory mixed methods design in which the qualitative analysis followed from quantitative analysis. Primary data were collected from purposely selected mathematics, applied science, engineering teachers and industry personnel who have better links with the two Science and Technology universities, using questionnaires and focus group discussion methods. Additionally, secondary data was obtained through document analysis. The collected data were analysed using descriptive statistics and an inductive content analysis approach.

The findings of the study revealed that the development of the industrial mathematics curriculum was driven by industry demands, specifically, the need for skilled graduates who could contribute to productivity and improvement of services. However, the implementation of the curriculum faced several challenges. These included a weak connection between universities and industry, lack of information on graduates' job market performance, scarcity of resources impacting teaching and learning, pedagogical practices not aligned with industry needs, inadequate knowledge in adopting appropriate technology and ineffective assessment mechanisms. Based on the study findings, several recommendations were made to facilitate the successful implementation of the industrial curriculum.

These recommendations include better stakeholder participation in the curriculum development process, creating awareness and understanding among science and technology teaching staff about curriculum development and continuous training for *teachers to improve their teaching and assessment skills. In summary, this study explored the development of an industrial mathematics curriculum in Ethiopian Science and Technology universities. It identified the needs of stakeholders and highlighted the challenges faced during curriculum development and implementation. The recommendations aim to address these challenges and ensure a successful implementation of the industrial curriculum.*

Key Words: *industrial mathematics, science and Technology University, and APOS theory, curriculum development ,curriculum implementation and mathematics education.*

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ABBREVIATIONS

AASTU	Addis Ababa Science and Technology University
APOS	Action, Process, Object, and Schemas
ASTU	Adama Science and Technology University
CBE	Competency-based education
ECMI	European Consortium for Mathematics in Industry
ECTS	European Credit Transfer and Accumulation System
ESF	European Science Foundation
ESTU	Ethiopia Science and Technology University
FDRE	Federal Democratic Republic of Ethiopia
FOS	Field of Science and Technology
HEI	Higher Education Institutions
ICT	Information Communication Technology
ITEA	International Technology Education Association,
MFI	Mathematics for industry
MIBI	Mathematics inspired by industry
MII	Mathematics in industry
MOE	Ministry of Education

MOSHE	Ministry of Science and Higher Education
MOST	Ministry of Science and Technology
MDE	Massachusetts Department of Education
NGO	Nongovernmental Organization
NSTIP	National Science and Technology Policy
OECD	Organization for Economic Co-operation and Development
NRENs	National Research and Education Networks
RERC	Research Ethics Review Committees
R&D	Research and experimental development
STEM	Science, Technology Engineering and Mathematics
SIAM	Society of Applied and Industrial Mathematics
S & T	Science and Technology

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CHAPTER ONE: INTRODUCTION AND RESEARCH APPROACH

1.1. Intoduction and Background of the research

This study assesses the contributions of mathematics to the industrial development of Ethiopia and suggests a guideline for the development of industrial mathematics curriculum for graduate and undergraduate programmes in Ethiopian universities of science and technology. Currently, Ethiopia is in the process of transforming from an agricultural-based economy to an industry-based economy. To facilitate this transformation, the Ethiopian government has established two universities, named Addis Ababa Science and Technology University (AASTU) and Adama Science and Technology University (ASTU), both under the Ministry of Science and Technology. Since their establishment, both universities have been working to meet the needs of the country's transformation. The two universities are the target areas of this study.

The current study tries to understand how mathematical concepts are being applied in industry and the capacity of industry experts and workers to apply mathematical concepts in their work. Furthermore, the study assesses the suitability of the current mathematics curriculum of the two targeted universities to develop the industrial mathematics curriculum in the Ethiopian context.

According to a quote by Peter Löscher, the ex-chairman of the board of Siemens, Inc., mentioned in a study by Neunzert & Wolters (2015), mathematics is considered as the language of science and technology. This implies that mathematics plays a fundamental role in driving advancements and innovations in high-tech. Löscher argues that mathematics is a crucial discipline for industrialized nations, as it provides the foundation for effective technological progress.

In other words, without the application of mathematics, technological advancements would be futile and would lack effectiveness. Mathematics plays a crucial role in various industries, ultimately enhancing national economies. The Netherlands serves as a clear example in this regard. Based on standard input-output analyses, the Dutch economy illustrates that the so-called indirect and national income (Vliet, Oomes, Midden, & Nijhuis, 2014, p. 5). These data underline the significant contribution that mathematics makes to the overall growth of a country's economy.

There was a significant demand for the advancement of mathematical projects within the industrial sector of East Africa. The African Institute for Mathematical Sciences (AIMS) hosted the East African Modeling Week in Dar es Salaam in 2014, with Bahir Dar University (BDU) from Ethiopia being one of the project participants. The Sodankylä Geophysical Observatory (SGO) at the University of Oulu, a Finnish participant in the project, has maintained a long-lasting partnership with Bahir Dar University (BDU) in Ethiopia. Their joint efforts center on atmospheric science and radar data analysis. Nonetheless, their collaboration is limited to research activities. Presently, Ethiopian industries require a substantial number of graduates from science and technology universities to address the nation's challenges. Therefore, this partnership should evolve to include the development of a mathematics curriculum tailored for industrial applications (Matti , Matylda , & Godwin, 2016).

The current research focuses on industrial mathematics, which has significantly influenced the national economy of Ethiopia. The inability to adapt mathematical problem solving methods to industrial situations is one of the concerns in Ethiopian higher education, especially for math academics. There is a lack of comprehensive documentation that addresses the strategic and economic advantages of applying advanced mathematics solutions to industrial problems in Ethiopia within the two universities of science and technology, AASTU and ASTU.

One of the most challenging aspects for individuals who pursue mathematics research in Ethiopian higher institutions is the training provided to teachers, which does not encourage them to conduct mathematics research. Although the science and technology curriculum includes interdisciplinary subjects such as mathematics, computer science, and the natural sciences, they are not adequately addressed. For instance, in AASTU, the need for mathematics only extends to being a supporting course, with no establishment of an independent mathematics department.

Individuals involved in mathematics research in Ethiopian higher institutions face a particularly difficult challenge regarding the training provided to teachers. This training does not promote or encourage mathematics research. Although the science and technology curriculum includes various interdisciplinary subjects such as mathematics, computer science, and the natural sciences, they do not receive sufficient attention. This lack of attention is exemplified by the case of AASTU, where mathematics is treated as a supporting course rather than having its own independent department (AASTU, 2015).

The field of science and technology, as defined by the Frascati's Manual (FOS 2007) standard (OCED, 2007), consists of six primary subjects of study. These subjects include natural sciences, engineering and technology, medical and health sciences, agricultural sciences, social sciences, and humanities. These disciplines collectively form the core areas of focus within the science and technology field.

However, considering that over 80% of the Ethiopian population lives in rural areas relying on farming and livestock development, the need for agricultural science in Ethiopian science and technology universities is as significant as the demand for science, engineering, and technology. Furthermore, with most industries in Ethiopia increasingly dependent on high technologies, there is a high demand for trained manpower in the research and development sector. Therefore, the ESTU program should incorporate other fields of study listed in the FOS classification of science and technology disciplines.

Today, the growing demands in industrial mathematics have sparked academic interest among numerous mathematical groups worldwide, such as ECMI, which are committed to interacting with the industry as part of their research activities (Capass& Michelet, 2008). There is a high demand for advanced mathematics in various industries, but there is a greater need that is often overlooked and not fully appreciated. There are significant access barriers for companies to connect with academic mathematicians and gain access to their expertise. Academic mathematicians can play a crucial role in reducing these obstacles, which would be highly beneficial for both parties involved. By facilitating easier access to their expertise, academic mathematicians can create a mutually advantageous relationship with businesses. This observation was made by Stockie (2005) in his research. In this regard, mathematicians have the responsibility to conduct research on the problems of society and recommend new educational programmes to the educational systems of the country. The main focus of this study was to investigate how well the Industrial Mathematics curriculum is being implemented in Ethiopian higher education institutions. Additionally, the aim was to determine which curriculum of industrial mathematics would be the most effective in promoting Ethiopian industrial development. It is important to note that real-world industrial problems often encompass various disciplines, so finding solutions requires expertise that spans across different fields. As a result, industrial mathematicians must possess the ability and willingness to integrate knowledge from other areas and express it in a mathematical form. However, all industrial problems cannot be solved only by mathematicians; they need the knowledge of other experts, such as engineers and scholars of applied sciences. Thus, the collaboration of different stakeholder groups in the process of curriculum development and implementation is one of the core parts of the industrial mathematics programme. To promote research and development in Africa, collaboration should be established to have a similar curriculum in industrial mathematics that will facilitate the sharing of information and resources from one country to another. One example of collaboration in the field of industrial mathematics is the partnership between Higher Education Institutions (HEIs) in Tanzania and Rwanda with Higher Education Institutions (HEIs) in Finland. This collaboration involves training postgraduate students at the master's and Ph.D. levels, as well as providing retraining opportunities for academic staff. Training is carried out through eLearning, as demonstrated in a study by Masanja in 2010. Therefore, other African countries that have an industrial mathematics curriculum in their programmes should collaborate to develop a standard curriculum at the African level. Ethiopian Higher Education Proclamation Article 21 encourages joint curriculum development with industry: "Applied science universities may develop curriculum that can be jointly offered with industry and may offer dual degrees." (Proclamation Number 1152/2019).

The researcher’s experience teaching mathematics in high schools, colleges and universities gave him deep insight into the problems of the mathematics curriculum in terms of teaching-learning and research in mathematics related to industrial problems and revealed the invisible part of mathematics. Most nonmathematicians' question to mathematics teachers was, "Where do we use mathematics in our job?" This was a question repeatedly asked. The development of an industrial park in Ethiopia around the top ten universities in the country had the purpose of linking universities with industries. The vision and mission of universities of science and technology and the related literature on industrial mathematics were the sources of the background for this study.

1.2. Problem Statement

Ethiopia is in the process of transforming from an agriculture-led economy to an industry-led economy. To support the overall transformation of Ethiopia, the government established two science and technology (S&T) universities: Adama Science and Technology University, which was separated from a comprehensive university, and Addis Ababa University of Science and Technology, which was upgraded from an Institute of Technology. The success of the national industrial plan and the objective of achieving a middle-income economy by 2025 are highely dependent on these two universities. Initially under the Ministry of Education, they were later transferred to the Ministry of Science and Technology, allowing them to implement various methods of personnel management and student admission (Salmi, Sursock, & Olefir., Improving the Performance of Ethiopian Universities in Science and Technology, 2017). According to Salmi, Sursock, and Olefir's research in (2017), the main priorities of these universities are focused on applied research and technology transfer.

However, Industrial Mathematics as a key element of technology has not yet been recognised in Ethiopian science and technology universities. Although universities have Science, Technology, Engineering and Mathematics (STEM) centres, STEM is sufficiently integrated into neither the curriculum nor classroom practise. Most of the university scholars (mathematics teachers) have less contribution in the area of research that focuses on problems related to industrial mathematics. The academic mathematician has limited knowledge of conducting mathematics research due to different factors, for instance, curriculum reform, different academic backgrounds (applied mathematics and mathematics for teaching purposes), and so on. Industrial mathematics is one field of study that should encourage mathematicians to conduct research in most developing countries, such as Ethiopia, though this is not the case at the moment. Therefore, Industrial Mathematics which was not recognised as a key element of technology in Ethiopian science and technology universities that were investigated in this study seek solutions.

1.3. Research Questions

Main Research Question

"What factors influence the development and implementations of industrial mathematics curriculatowards promoting mathematics in Ethiopia's industrial development agenda?

Sub-research questions

I. What are the limitations and strengths of the existing Mathematics Curriculum in promoting mathematics in industry?
II. What are the problems related to the application of the industrial mathematics curriculum?
III. How do a mathematician and industry expert work together to apply industrial mathematics in Ethiopian Industries and Ethiopian Science and Technology Universities?
IV. What benefits can be derived from deploying Industrial Mathematics to enrich careers in terms of professional development (research, teaching, training, and mentorship)?
V. What parts of an industrial mathematics curriculum are the promising models for Ethiopian industrial development?

1.4. The Purpose of the Study

The purpose of the study is firmly in line with the mission of the two Science and Technology Universities in Ethiopia. Thus, this study will provide input in the area of research and teaching to universities, consequently facilitating the achievement of the universities' vision and mission through the Industrial Mathematics Curriculum, and also create a conducive environment to conduct research through collaboration with industry, research, and academic institutions at the national level. It will also use the best teaching practises in educating the students.

The purpose of this study was to examine and understand issues and challenges related to the development and implementation of curricula in science and technology universities. This was done to establish a strategic framework for designing and implementing industrial mathematics curricula tailored to Ethiopian science and technology universities.

Specific Research Objectives

I. To identify the limitations and strengths of the existing Mathematics Curriculum in promoting mathematics in industry.
II. Identify problems pertaining to the application of the Industrial Mathematics Curriculum to Ethiopian science and technology universities.
III. To determine the mechanisms of work together between mathematicians and industry experts to apply industrial mathematics in Ethiopian industry and Ethiopian science and technology universities.
IV. Identify benefits that can be derived from deploying industrial mathematics in enriching careers in terms of professional development (research, teaching, training, and mentorship).
V. To suggest the appropriate model of an industrial mathematics curriculum for Ethiopian science and technology universities.

1.6. Scope of the Study

The scope of this study is limited in terms of time, location, participants, and study programs. In terms of time, it examines the development and practice of the Industrial Mathematics curriculum starting from 2015 until the time of the research. In terms of location, the study focuses on two specific universities of science and technology, namely Addis Ababa Science and Technology University and Adama Science and Technology University. These two universities were chosen from a total of 44 public universities in

Ethiopia. It should be noted that these two universities play a central role in the national industrial strategy and the goal of achieving a middle-income economy by 2025 (Salmi, Sursock, & Olefi, 2017).

Regarding the participants, this study specifically focuses on a selected group of individuals, including college deans, associated deans, department heads, mathematics teachers, experienced teachers from schools of applied science and engineering, as well as representatives from industries.

The chosen locations and individuals are relevant to the research objectives for several reasons. Firstly, the Ethiopian Science and Technology University represents a valuable case study due to its influence and potential impact on the higher education system in Ethiopia. By focusing on this university, the study can assess the effectiveness and practicality of implementing an industrial mathematics curriculum at a prominent institution. Secondly, involving faculty members, industry professionals, students, and policymakers ensures a comprehensive perspective in curriculum development. Faculty members can provide insights into the existing mathematics curriculum while industry professionals can offer their expertise to bridge the gap between academia and industry needs.

The industries were purposefully chosen through consultation with the public relations departments of each company, while academic participants were selected based on their expertise in curriculum development within their respective fields of study. By including a diverse range of participants and focusing on Ethiopian Science and Technology University, the study intends to develop a comprehensive curriculum that meets the requirements of industries in Ethiopia while also considering the local context and national priorities for science and technology education.

1.7. Significance of the Study

Currently, the Ethiopian higher education system places the utmost importance on providing science and technology education, as mandated by the government policy of maintaining a (70:30) ratio of science and technology students to social science students. This policy, along with the accompanying guidelines, has caused a significant number of students to pursue fields such as science, technology, and engineering in higher education. The introduction of new and revised curricula within science, technology and engineering institutions, including the two science and technology universities, has been instrumental in educating students in these disciplines (Salmi, Sursock, & Olefir., 2017).

The curriculum reforms signify positive progress toward achieving the goal of producing an adequate number of science and technology students, specifically in the field of industrial mathematics. However, previous experiences in Ethiopia indicate a lack of substantial expertise in research related to mathematics education as a whole, and curriculum development in particular. Therefore, the findings of this study are of significant value in contributing to the body of knowledge and empirical evidence on mathematics education and curriculum development processes, specifically within the Ethiopian context and the two sites of this study.

The research will also be advantageous for Mathematics educators and students as it will familiarize them with current information concerning the necessary knowledge, skills, and attitudes crucial for industrial mathematics in both present-day and future contexts. This will help them tailor their activities in curriculum development, teaching methodologies, and assessment strategies to align with the evolving landscape of this field. Furthermore, policymakers and planners will benefit from a deeper understanding of the essential components of present and future Mathematics education. This insight will enable them to incorporate vital inputs into their policy decisions and planning processes. Since industry serves as the end-user of graduates from industrial mathematics programs, they will also gain valuable insights into the teaching practices and implications for the Mathematics profession within science and technology universities.

The citations included throughout the material and the comprehensive literature review in Chapter Two offer diverse perspectives and approaches that underpin the development of industrial mathematics and general mathematics education curricula. These references improve understanding of the subject matter and provide a solid foundation for further research and practice in this field.

1.8. Structure of the Thesis

The thesis is structured as follows:

Chapter 1: Introduction and Research Approach

The first chapter focuses on the background and of the study, problem statement, research question, and the purpose of the study, the scope of the study, and significance of the study

Chapter 2: Literature review

In this chapter the review of the literature is presented, covering the main aspects and themes related to the study namely, science and technology, opportunities and challenge in Ethiopian higher education, relationship between science, technology, engineering and mathematics, curriculum development and implementation in Ethiopian Higher education particularly industrial mathematics curriculum in Ethiopian Science and Technology.

Chapter 3: Theoretical framework

The chapter investigates into the theoretical foundation of the study concerning the APOS Theoretical framework for Research and Curriculum Development in Industrial Mathematics Education. Within this chapter, the discussion revolves around the use of the APOS theory in industrial Mathematics, exploring its components such as theoretical analysis, design and implementation, as well as data collection and analysis.

Chapter 4: Research Methodology

The fourth chapter reports on the research paradigm and design used in the study, procedure for selections of sites and participants, data collection and the ethical issues.

Chapter 5: Data Presentation and Analysis

In this chapter the gathered date were presented by classifying in to quantitative and quantitative data analysis. The quantitative part used survey questions to collect data and data were presented using tables and graphs and the qualitative data's were collected using open-ended questions, focus group discussions and document review.

Chapter 6: Discussion of the Finding

The sixth chapter of the study delves into the discussion of presenting a curriculum guide for industrial mathematics in Ethiopian science and technology universities. This is achieved by incorporating examples from various industrial mathematics programs that are specifically chosen for this purpose.

Chapter 7: Summary of the Research Findings, Conclusion, and Recommendations

The last chapter gives a summary of the study and recommendations that are informed by the drawn conclusions are made.

CHAPTER TWO REVIEW OF RELATED LITERATURE

2.1. INTRODUCTION

In this section, the literature review concentrates on science and technology university education, giving special attention to industrial mathematics education and curriculum development. Initially, it examines into fundamental concepts and considerations regarding science and technology in university education and the process of curriculum development. Following that, it investigates into more specific aspects concerning industrial mathematics education and the formulation of its curriculum. The literature review draws from a variety of primary and secondary sources. Primary sources consist of journal articles (research-based), government policies, proclamations, and conference reports. Secondary sources encompass books and encyclopedias. The literature reviewed does not offer universally accepted definitions of the key terms in this study; therefore, the researcher applied the most relevant definitions.

Additionally, the utilization of abbreviations and acronyms is prevalent, with abbreviations denoting shortened forms of words or phrases (e.g., Ph.D. for "Doctor of Philosophy") and acronyms elucidating the meaning of each letter in the acronym (e.g., APOS for A-action, P-process, O-object, and S-schemas). Concerning the research methodology, a sequential mixed-method approach is adopted to explore the requirements of stakeholders in the industrial mathematics curriculum. This involves conducting a quantitative analysis followed by a qualitative analysis. The literature review highlights the pragmatism and practicality of the study, indicating that various ideas and hypotheses about the nature of reality are equally valid.

The literature review is structured into four main sections. The first segment provides a thorough overview of the concepts and challenges associated with science and technology in higher education. The second portion focuses on the concepts and issues concerning curriculum development in the realm of higher education. The third section summarizes the developmental process of the industrial mathematics curriculum. Lastly, the fouth section deals with the graduate employability skills.

2.2. Science and Technology University/Higher Education

2.2.1. Definition of Science and Technology (S & T)

Scholars have provided various definitions for science and technology, sometimes considering them as separate entities and others as interconnected activities. The International Technology Education Association (ITEA) defines science as the investigation of the natural world, while technology encompasses the human capacity to alter and enhance that world (ITEA, 2002; as cited in Kiyici & Kiyici, 2007). Although science and technology are distinct, they are mutually dependent. Technology extends beyond applied science, and science differs from applied technology. When technology is used to manipulate the natural world, it influences scientific knowledge. Science relies on technology for the development, testing, experimentation, verification, and application of its natural laws, theories, and principles. At the same time, technology depends on science to understand the structure and functioning of the natural world. On the other hand, according to UNESCO, the term "science and technology" (S&T) refers to a combination of activities aimed at generating, sharing, and applying knowledge related to technology. This includes various activities such as research and experimental development, scientific and technological services, innovation, and the dissemination of new ideas. In Ethiopian national innovation policy for science and technology, science and technology are seen as activities that contribute to the analysis of the relationship between technology and the economy, as well as to promote development. These activities involve identifying and improving traditional technologies, selecting and transferring modern and suitable technologies, establishing infrastructure for scientific and technological advancements, training a skilled workforce and making use of the results of research and development (NSTIP, 2010). This definition aligns with the definition of UNESCO because it includes research and development, technology transfer, and scientific and technological services or infrastructure. The Ethiopian Higher Education Proclamation, in its revised version, defines higher education as an educational program in the arts, social sciences, and science and technology, provided to undergraduate and graduate students through various delivery modes (Gazette, 2019). In Ethiopia, universities specializing in science and technology are now included in the category of higher education institutions. Unlike in the past, where the definition of higher education did not incorporate science and technology programs, this study recoginized these universities as integral parts of higher education. Therefore, the policies and reviews pertaining to the higher education sector are now applicable and relevant to science and technology universities as well.

2.2.2. Opportunities and Challenges in Ethiopian Higher Education

The Ethiopian government has made substantial efforts to improve higher education in the country. As part of these efforts, they have planned to establish 11 new universities, increasing the total number of public universities that accept Grade 12 students to 44. Additionally, there are 94 private university colleges and universities focused on higher-level human development initiatives in Ethiopia. The government has also implemented a student admission ratio, aiming at a distribution of 70% technology and science students to 30% social sciences and humanities students (MOE, 2020). Due to the significant growth of the higher education system, it faces various challenges that need to be addressed. These challenges include the need for more staff members, especially those with Ph.D. qualifications, and the necessity to prioritize their career development. Additionally, there is a need for an increase in the availability of books and the construction of more laboratories to meet the growing demands. The main challenges facing by the higher education system relate to the qualifications and expertise of academic staff. Ensuring that faculty members have the necessary qualifications and skills is crucial to maintaining the quality of education. Another challenge is to ensure the quality and relevance of science and technology programs. It is important that these programs align with current industry demands and advancements. Finally, it is necessary to enhance the research capacity of universities to foster innovation and contribute to knowledge creation (Salmi, Sursock, & Olefir, 2017). The scientific research output of Ethiopian Higher Education is low. The findings reveal that out of the output of the scientific research, agricultural research is (42%), medical and health science is (28%), natural science research is (18%), engineering research is (12%) and social science business and law are (9%) (Salmi, Sursock, & Olefir, 2017). Based on the data provided, it can be observed that research in mathematics falls within the category of natural science research output; most of the 18% of the natural science research output was accounted for by chemistry, physics, and biology, but research in mathematics is insignificant. The Ministry of Science and Higher Education (MOSHE, 2019) has identified several challenges in the research landscape of Ethiopia. These challenges include a shortage of qualified researchers and a lack of research experience. There is also a lack of proper mentoring for young researchers, which hinders their growth and development. Additionally, there is limited capacity to effectively manage research projects. Another significant challenge is the brain drain phenomenon, as skilled researchers often seek opportunities abroad. Collaboration within and between researchers and research groups is limited, mainly due to the absence of an effective platform that facilitates interaction and collaboration between different stakeholders, such as sector ministries, research institutions, universities and NGOs. Research efforts in Ethiopia are often fragmented, project-based, non-thematic, and monodisciplinary, lacking a holistic approach. The quality and relevance of research output is another concern. There is a lack of adequate research infrastructure and a scarcity of funding. Lastly, the dissemination and use of research evidence for policy-making purposes is weak, which limits the impact of research on society (MOSHE, 2019). The graduation rate for undergraduate higher education students is alarmingly low at 79 percent. Several factors contribute to this lack of success, including poor instruction quality, the limited relevance of higher education courses, the overall quality of students enrolled in higher education, and low teaching standards. To address and enhance these quality assurance mechanisms, the Ethiopian Higher Education system has implemented various strategies such as curricula harmonization, modular teaching, continuous assessment, and peer teaching (MOE, 2018). This allows flexibility, as students can progress at their own pace and focus on topics that interest them. By implementing modular teaching, the Ethiopian Higher Education system aims to provide students with a more dynamic and custimized learning experience.While these initiatives have been implemented, the 2018 MOE (Ministry of Education) report highlights that they have had limited positive impact on the core processes of teaching, learning, and continuous assessment in higher education institutions. This suggests that while the strategies hold promise, further efforts are needed to fully improve the quality of education in Ethiopian higher education institutions. It is a continuous process that requires ongoing evaluation, adjustments, and support from all stakeholders involved. However, there is still work to be done to fully realize the potential impact of these strategies and improve the core processes of teaching, learning, and continuous assessment in higher education institutions. Teachers teach as they were taught and have less experience implementing the continuous assessment method. Furtheremore, the student's teacher evaluation mechanisms affect the assessment of the learning process. The Ethiopian government plans to reach a middle income category and achieve 22% gross enrollment by 2025, but the available resources and the current situation of the country do not allow 22% gross enrollment to be achived by 2025 (MOE, 2018).

In his review of the challenges in Ethiopian Higher Education, Boateng (2020) identifies several problems. These include financing and the disparity between student enrollment and teaching staff, as evidenced by the student-teacher ratio. Another issue is the lack of adequately qualified staff to fill vacant positions in Higher Education Institutions (HEIs). Furtheremore, there is an infrastructure deficit, characterized by limited lecture rooms, computer laboratories, libraries, and their collections. Furthermore, there is a lack of generators to meet the power needs of HEIs during periods of erratic power cuts. These challenges are prevalent in higher institutions due to various factors, such as political instability, economic crises, the impact of COVID-19 and change in the educational system.

2.2.3. The Relationship between Science, Technology, Engineering, and Mathematics

In the revised Ethiopian Higher Education Proclamation, Higher Education means educational programmes in arts, social science, and science and technology offered to undergraduate and graduate students who attend degree programmes (Gazette, 2019). On the basis of this proclamation, the Ethiopian science and technology universities under this study were governed by the Higher Education proclamation in which all regulations and guidelines are implemented. The Ethiopian science and technology universities had the following programmes applied science and engineering programmes. However, science and technology fields of study are not only classified under these two disciplines.

According to the Massachusetts Department of Education (MDE, 2006), science, engineering, and technology have specific definitions. Science is the pursuit of knowledge about the natural world and often requires the development of innovative tools to find answers. Engineering, on the other hand, involves utilising scientific discoveries to create solutions and designs that fulfil societal needs. Finally, technology encompasses the actual products and processes that emerge from engineered designs. In summary, science seeks understanding, engineering applies scientific findings, and technology represents the tangible outcomes of engineered solutions. Mathematics is vital for bridging the gap between science and technology, providing a fundamental tool for scientists and engineers alike. It allows for precise analysis and prediction, facilitating the formulation and resolution of intellectual and practical inquiries. Neunzert & Wolters (2015) assert that mathematics plays a crucial role in a range of technology fields. These include process and product simulation, system optimization and design, data management and utilization, virtual material design, biotechnology, and health-related applications. Therefore, mathematics has become indispensable for technological advancements in these areas. For a long period, natural scientists have used mathematics as a resource and as a language in which to formulate their theories, and it has formed the basis for the computations of the world's engineers. Integration of mathematics with computer science has elevated mathematics to the rank of technology. In a certain respect, the computer is the purest form of mathematics turned technology (Neunzert & Wolters, 2015). The relationship between mathematics and computers indicates the importance of integrating the curriculum of industrial mathematics with computer applications for science and technology universities. However, mathematics programmes were not yet established as independent academic programmes in one of the science and technology universities (AASTU) under this study; rather, mathematics serves as a support course only. At the second university, namely ASTU, there are BSc, MSc, and Ph.D. programmes in applied mathematics. Here, mathematics graduates are trained to fill the vacancy of mathematics teachers in higher education and secondary schools. In both institutions, no industrial mathematics programme is offered. In this regard, this study focuses on the importance of establishing an industrial mathematics curriculum for science and technology universities to solve real-world industrial problems using different mathematical techniques. However, industrial mathematics alone does not solve the problems of industries; requires the knowledge of other fields of study, such as computer science, engineering, basic science, and business and management courses.

In the Ethiopian engineering higher education system, under the science and technology programme, there is no distinction between technology and engineering as separate fields of study. The definition of technology and its connection to science have been subjects of debate in literature. Engineering is often seen as an intermediary in this debate. Engineering is defined differently from technology in that it focuses on the profession of developing and producing technology, whereas technology encompasses a broader user dimension. Another distinction is that engineering involves both practical intervention in reality and the scientific study of that intervention. This places engineering alongside natural and human/social sciences. These distinctions have implications for how technology education is positioned in the curriculum. One approach is to teach technology and engineering as a combined subject called 'Technology and Engineering Education' (ETE), while another option is to integrate technology, engineering, and science teaching altogether (Vries, 2011). Technology literacy is a significant concern at various school levels, particularly as modern technological advancements continue to progress. It involves the ability to effectively use, manage, and comprehend technology, essentially serving as an introduction to technology education within the school curriculum. The International Technology Education Association (ITEA, 2007) envisions technology education gaining prominence in the future, similar to the importance placed on subjects like English or science.In conclusion,it is necessary to identify the meaning and purpose of each term (science, engineering, and technology) and their relationship when developing a curriculum. In Ethiopia, Science and Technology Universities are teaching both engineering and applied science as a core course of Science and technology. However, classifications of science and technology fields are not restricted only to the engineering and applied science fields of study. According to the OECD (2007a), the field of science and technology is classified as follows:

Table 2. 1 Field of Science and Technology in the Frascati Manual

Natural Sciences	**Engineering and Technology**	**Medical and Health Sciences**	**Agricultural Sciences**	**Social Sciences**	**Humanities**
Mathematics	Civil engineering	Basic medicine	Agriculture, Forestry and Fisheries	Psychology	History and Archaeology
Computer and information sciences	Electrical engineering, Electronic engineering, Information engineering	Clinical medicine	Animal and Dairy science	Economics and Business	Languages and Literature
Physical sciences	Mechanical engineering	Health sciences	Veterinary science	Educational sciences	Philosophy, Ethics, and Religion
Chemical sciences	Chemical engineering	Medical biotechnology	Agricultural biotechnology	Sociology	Arts
Earth and related Environmental sciences	Materials engineering	Other medical sciences	Other agricultural sciences	Law	Other humanities
Biological sciences	Medical engineering			Political science	
Other natural sciences	Environmental engineering			Social and economic geography	
	Environmental biotechnology			Media and communications	

Source: **Field of Science and Technology Classification in the Frascati Manual (FOS 2007)**

As observed in Table 2.1, there are six classifications of the field of specialization of science and technology. The two sciences and technology universities under this study are classified in the first two classifications, namely Natural Sciences and Engineering and Technology Fields of study. Table 2.2 indicates the academic programme classifications of the two science and technology.

Table 2. 2ASTU and AASTU Academic Programs

ASTU	AASTU
1. School of Applied Natural Sciences Programmes ♦ Applied Biology ♦ Applied Chemistry ♦ Applied Geology ♦ Applied Mathematics ♦ Applied Physics	1. College of Applied Natural Sciences Programmes ♦ Food Science and Nutrition ♦ Industrial Chemistry ♦ Geology
2. School of Civil Engineering and Architecture Programmes ♦ Architecture ♦ Civil Engineering ♦ Urban Planning and Design	2. College of Civil Engineering and Architecture Programmes ♦ Architecture ♦ Civil Engineering ♦ Mining Engineering
3. School of Electrical Engineering and Computing Programmes ♦ Computer Science and Engineering ♦ Electronics and Communication Engineering ♦ Electrical Power and control Engineering	3. College of Electrical and Mechanical Engineering Programmes ♦ Electrical and Computer Engineering ♦ Electro-Mechanical Engineering ♦ Mechanical Engineering ♦ Software Engineering
4. School of Mechanical, Chemical, and Materials Engineering Programmes ♦ Chemical Engineering ♦ Materials Science and	4. College of Natural and Social Science ♦ MBA in Industrial Management ♦ MBA in Construction Management

Engineering ♦ Mechanical Design and Manufacturing Engineering ♦ Mechanical Systems Engineering ♦ Thermal and Aerospace Engineering	
	5. College of Biological and Chemical Engineering Programmes ♦ Biotechnology ♦ Chemical Engineering ♦ Environmental engineering

Source: ASTU & AASTU official web site

As we can see from the above two tables, Ethiopian science and technology universities need to revise their academic programmes based on internationally recognised fields of study. Since the majority of the population (more than 80%) in Ethiopia lives in rural areas where the life of the farmer is based on agriculture, the needs for food and health are priorities for the people. In order to ensure adequate food production and healthcare services, it is imperative that we have well-trained agricultural experts and healthcare professionals. The health and well-being of the population are essential for transitioning from an agriculture-based economy to an industry-led economy. The mission of two science and technology universities, AASTU and ASTU (2010), is to provide top-quality education and training in strategically prioritized science and technology disciplines that align with the national economic demand. This focus on education and training will help meet the requirements for skilled individuals in the fields of agriculture, healthcare, and other relevant sectors. The UNESCO Science Report highlights the essential characteristics that a world-class university needs to possess by 2030. These include having a significant number of talented faculty and students, as well as enjoying self-governance and administrative autonomy. Academic freedom, including the freedom of faculty members to engage in critical thinking, is also crucial. Empowering young researchers to lead their own laboratories and providing ample resources for a comprehensive learning and research environment are additional requirements.

Unfortunately, many universities do not currently meet these criteria, as stated by UNESCO in 2015. Thus, the two science and technology universities should work to achieve the ranking requirements(to become world-class universities). The industrial mathematics curriculum is one of the programmes that benefit the universities by promoting research and development in the country and around the world with the minimum investment. Aziz and Bahar (2015) emphasize the significance of mathematics within science and technology universities, comparing it to the "software" that drives these fields. They assert that technology involves applying scientific knowledge to address challenges in commerce and industry. Science, on the other hand, entails the development, testing, and enhancement of models that predict the behavior of systems. In this context, mathematics serves as the language used to articulate and describe these models. In summary, mathematics plays a critical role in enabling scientific and technological advancements.

2.3. Curriculum Development in Science and Technology University

The Development Plan for the Ten-Year Perspective (2021–2030) The 2030 Pathway to Prosperity of the Ethiopian Government focuses on areas to achieve the development plan through innovation and technology. To promote innovation and technology, specific goals have been outlined. These goals include the establishment of a digital economy, the enhancement of national scientific research and technological capabilities, and the support of research and development efforts aimed at solving problems and improving production, productivity, and service provision. Additionally, the objectives aim to foster job creation and capital formation through technology-based initiatives while also ensuring the development of systems that safeguard technology and data security (FDRE, 2021). The German Ministry for Education and Research has identified mathematics as a strategic objective in their efforts to bolster Germany's innovative prowess as a technology nation. They have highlighted the importance of mathematical modeling, simulation, and optimization in research and development as a new technological domain. The ministry recognizes that research and innovation serve as the cornerstone for overall societal prosperity (Neunzert & Wolters, 2015, p. 9). Research in industrial mathematics has now become popular in developed countries, providing a direct benefit to the economy by putting the research results directly into practise with industry partners. In Africa, objectives that enhance innovation and technology are set, but appropriate curricula to achieve these goals are not developed.

A recent review of the literature on curriculum development in science and technology universities needs to look at the world today, in which the national economy is rapidly changing amid societal and environmental challenges. According to the report by UNESCO(2002) report on higher education, the globalisation of the world's economy and a growing acceptance, society needs highly skilled and competent knowledge workers.The core concern in curriculum development is determining the appropriate content and methods that are deemed essential for addressing the current and future challenges faced by students in their lives. This process involves making decisions about objectives, taking into account the characteristics of learners, selecting instructional content and strategies, designing appropriate assessments, and identifying necessary learning resources, including information technology (IT) and media. The goal is to organize all of these components into a cohesive and practical structure (Mesfin, 2016). Curriculum development is a comprehensive process that encompasses various stages, including evaluation, planning, creation, implementation, and ongoing maintenance of the curriculum. An important aspect of this process is to ensure that stakeholders, who are involved in shaping the curriculum, demonstrate a strong commitment to and sense of ownership for it. This ensures that all parties involved actively engage and take responsibility for the curriculum (Pree, 1987).

In Ethiopian Science and Technology Universities, the curriculum development processes are carried out within the parameters of the Vision and Mission of Science and Technology University. The Ethiopian Higher Education Roadmap for 2030 introduces a holistic and competency-based approach to education that goes beyond simply addressing what needs to be learned, but also emphasizes how it can be learned. This approach includes a focus on practical life skills and aesthetic content, which contribute to the development of problem-solving abilities. The roadmap recognizes the importance of incorporating creativity and nurturing creative minds within the curriculum (MOE, 2018).Article 20/9 of Proc. 1152/2019, under the sub-article Curriculum, states: "Applied science universities may develop curriculum that can be jointly offered with the industry and may offer dual degrees." According to Article 20/4 of the Proclamation of Higher Education on "Curricula Common," institutions having similar mission and vision and responsible for its implementation can develop the same curriculum jointly (Gazette, 2019). Based on these two sub-articles, the two Sciences and Technology universities, together with industries, may develop an industrial mathematics curriculum in their institutions.

2.3.1. Challenges in the Development of the Curriculum of Ethiopian Higher Education

Problems in curriculum development frequently emerge due to discrepancies between the intended curriculum (which includes policy, vision, rationale, and the underlying philosophy of the curriculum), the implemented curriculum (how the curriculum is actually interpreted and applied by school administrators and teachers in the teaching process and classroom practices), and the attained curriculum (the actual learning experiences of students, shaped by the defined learning outcomes). These gaps between the three aspects of the curriculum can pose challenges in effectively aligning educational goals with instructional practices (Pree, 1987). Howson, Keitel, & Kilpatric (2008) categorized the challenges to developing a curriculum into four categories: psychological, practical, power, and value barriers. Value barriers describe the diversity of beliefs and interests among people. These disparities can have a variety of origins, including political, religious, educational, and socioeconomic factors, and will have a great impact on how individuals respond to suggested the educational innovation suggested. Power barriers were frequently followed by changes in power dynamics, which were important for innovations. By doing so, the central government's powers were strengthened, while some of the teacher's authority was reduced. Parents, students, and employers want more. Psychological barriers: One of the hardest difficulties to clear is having failed at innovation in the past. Another significant barrier to developing a curriculum is the lack of incentives. Melese and Tadege (2019) have confirmed that several factors contribute to the poor quality of education and contribute to the inadequate design, development, implementation, and evaluation of the curriculum in Ethiopian higher education. These factors include the country's low economic level, which makes it challenging to provide necessary infrastructure and logistical support. Additionally, the teaching profession has not received sufficient attention from political authorities, and there is a sense of disengagement among teachers and students from their respective responsibilities. Moreover, teachers often lack the necessary pedagogical skills. Melese and Tadege (2019) further highlight that the use of English as the language of instruction from secondary to tertiary education, administration provisions, staff quality, evaluative systems, academic freedom, and political factors all significantly contribute to the current state of the educational system in Ethiopian higher education. The educational policy was designed and prepared by experts in educational fields at the national level, but when the policy is interpreted into the school curriculum, it loses its originality, as stated in the policy. The top-down process of curriculum development in higher education remains the same in science and technology universities. Sometimes, personal needs allow or reject the process of introducing the new curriculum.

In Ethiopia, the process of developing curricula was occasionally carried out without taking into account societal needs. The UNESCO report highlights that in numerous African countries, the objectives of education often fail to align with the needs, goals, and aspirations of the society. As a result, the process of creating a curriculum for higher education encounters a challenge, as it involves designing and implementing a curriculum that does not necessarily reflect the society's goals. Although the two science and technology universities examined in the study share a common mission of providing "world-class education" based on the UNESCO science report, their ranking does not reflect this mission. The report emphasizes the goal of transforming these universities into world-class institutions by 2030, which includes having a significant number of talented faculty and students, as well as enjoying self-governance and administrative autonomy. It also highlights the importance of academic freedom, empowering young researchers to lead their own laboratories, and having ample resources for a comprehensive learning environment and cutting-edge research. However, despite these aspirations, the two universities do not appear in the rankings that assess their status as world-class institutions. The policy mandate in Ethiopia dictates that science and technology universities should enroll students in a ratio of 70/30, prioritizing engineering and science fields over social sciences. However, this policy has resulted in a significant number of graduates who are unable to find employment, creating a current problem in Ethiopian higher education. The curricula followed by these universities do not sufficiently address employability and other lifelong learning skills among graduates. Additionally, universities seem to lack strategies and tactics to incorporate information technology effectively into their learning programs. The existing link between universities and industries is deemed insufficient, meaning that students do not have enough exposure to the real-world work environment and the expertise of industry professionals (MOE, 2018).A challenging area in the field of Engineering education curriculum development and implementation in Ethiopian higher institutions is that curriculum development initiatives come from top to bottom, with less emphasis being given to stakeholders, teachers, and students; a shortage of qualified teaching staff; a low standard of the teaching-learning process; and teacher and student behaviour (Silesh, 2016). According to the researcher's considerable experience with higher education curriculum development, all of the issues listed above are still present in science and technology universities. The Ethiopian educational roadmap for 2030 proposes competence-based education for higher education. On the other hand, the curriculum in Ethiopian higher education lacks clarity in terms of competencies. The organization of modules within the curriculum is considered weak, and the teaching methods predominantly revolve around traditional lecture-based approaches, with less emphasis on alternative methods. Furthermore, the world of work is not fully aware of the shift towards competence-based curricula that higher education institutions are making (MOE, 2018). As per the UNESCO report, education goals in numerous African countries may not effectively align with the needs, goals, and aspirations of society. Consequently, the development of curricula in higher education encounters a challenging situation where it becomes necessary to plan and design curricula based on goals that do not necessarily reflect those of society (UNESCO, 2015). To effectively tackle the challenge of higher education in Ethiopia, the Ministry of Education must take steps to strengthen and standardize the mathematics curriculum. In this regard, a mathematics harmonization team conducted an examination of the course offerings at various national universities and identified several inconsistencies and irregularities. These include variations in the required credit hours for different courses, discrepancies in the list of supportive courses, mismatches between the course descriptions and the provided materials, inclusion of course materials and codes that surpass the level of a Bachelor of Science degree, lack of clear objectives, learning outcomes, teaching-learning strategies, and assessment methods. Additionally, poorly written course objectives and the presence of less significant general education courses in certain departments are among the issues that require attention and resolution (AAU, 2009). After four years, the Ministry of Education (2013) prepared another harmonized mathematics to correct the following irregularities. Mismatch in the flow of students from their home countries to other countries; course descriptions and student competency are not adequately defined; courses are not presented in order of increasing complexity; students study time, learning outcomes, teaching-learning, and assessment techniques are not included; and a professional profile is not described.

2.3.2. The Model of Curriculum Development in Science and Technology

The development of curriculum is influenced by various factors such as approach, style, and source. In general, there are two main approaches to curriculum development: scientific/technical and non-technical/humanistic (Talla, 2012). For this particular study, scientific or technical procedures are preferred to select appropriate curriculum development modes for Ethiopian higher education institutions.

The scientific or technical approach to curriculum development follows a rational and systematic procedure that emphasizes effective and rigorous planning in order to achieve desired outcomes. This approach places importance on evaluating the attainment of goals through a systematic evaluation process. Several scientific models of curriculum development exist, including the Tyler Model, the Taba Model (also known as the Grass-roots rationale), the Saylor and Alexander model, and the Hunkins decision-making model (Talla, 2012). Ethiopian higher education institutions are currently undergoing educational reforms in various areas, including access, equity, unity in diversity, quality, relevance, efficiency, research, technology transfer, community service, and financing. However, the previous education system faced numerous challenges in implementing these reforms. One of these challenges was the quality of higher education, which did not adequately focus on developing employability skills and lifelong learning abilities among graduates. Universities were found to lack strategies and tactics for designing programs that incorporate extensive use of information technology for learning purposes. Additionally, there was an evident lack of sufficient collaboration between universities and industries (MOE, 2018). In addition to the lack of quality, there were also challenges related to the relevance of higher education, such as the quality of teaching that is the result of the shortage of qualified academic staff and the lack of adequate and well-established laboratories and workshops; the modular approach to the old structure of the curriculum;(knowledge-based) and the need for a new one; competency-based education; the stakeholders not yet being aware of competency-based curricula; and insufficient computer skills and research skills. All these is identified as major deficiencies among higher education graduates (MOE, 2018).

The competency-based curriculum development model is an instructional approach that is commonly used to teach practical skills rather than abstract concepts. Competency-based education emphasizes achieving specific learning outcomes and focuses on mastering skills at the learner's own pace, rather than within a predetermined timeframe. This approach often aligns with workplace needs and is characterized by self-paced learning, which requires investment in time and resources. However, in a country that is still in a development stage, challenges must be addressed to overcome these resource limitations. Opponents of competency-based education (CBE) in higher education curricula express concerns that it can be excessively prescriptive, overly focused on skill development, and may potentially undermine the academic nature of higher education (Kouwenhoven, 2020). On the other hand, Competency-Based Education (CBE) provides the business community with more confidence that universities are preparing their graduates and future employees with the necessary knowledge, skills, and abilities to contribute effectively to the workforce.To address the challenge related to a of higher education curriculum that is not geared towards the development of employability and other lifelong learning skills among graduates, Addis Ababa Science and Technology University planned to develop its curriculum using "outcome-based curriculum development" models. The model was based on the vision and mission of the university. Spady (1994, p.12.) defines outcome-based education as:

"Outcome-based education means clearly focusing and organizing everything in an education system around what it is essential that all students are able to do successfully at the end of their learning experiences. This means starting with a clear picture of what it is important for students to be able to do, then organizing the curriculum, instruction, and assessment to make ensure that learning ultimately happens".

Table 2. 3Process of Outcome-Based Curriculum Development

Steps	Steps of Outcome-based Curriculum Development
Step1	Vision and Mission of the University
Step2	Program Educational Outcomes(POE)
Step3	Program Outcome(PO)
Step4	Course Learning Outcomes (CLO)
Step5	Content Selection (CS)
Step6	Content Organizations(CO
Step7	Selection of teaching-learning Methods
Step8	Selection of Assessment and Evaluation

Table 2. 4The Curriculum Development Processes Stated by Hilda Taba

Steps	Curriculum Development Processes (Taba)
Step1	Diagnosing needs
Step2	Formulating specific objectives
Step3	Selecting content
Step4	Organizing content
Step5	Selecting and organizing learning experiences
Step6	Evaluation
Step7	Checking for balance and sequence

Tables 2.3 and Table 2.4 shown above are the two processes of the curriculum development process that are applicable to most academic programmes. Integrating the two models has a great advantage in that the other model fills the concept missed by one. The fundamental belief of outcome-based education is to generate individuals who can showcase their abilities and competencies in specific areas of education through tangible evidence. For an industrial mathematician, this means competencies in solving the

problems of the industry using mathematics and other necessary disciplines as defined by the profession and industrial needs at the beginning level upon completing an industrial mathematics programme.

<u>Curriculum Development and Review Cycle AASTU</u>

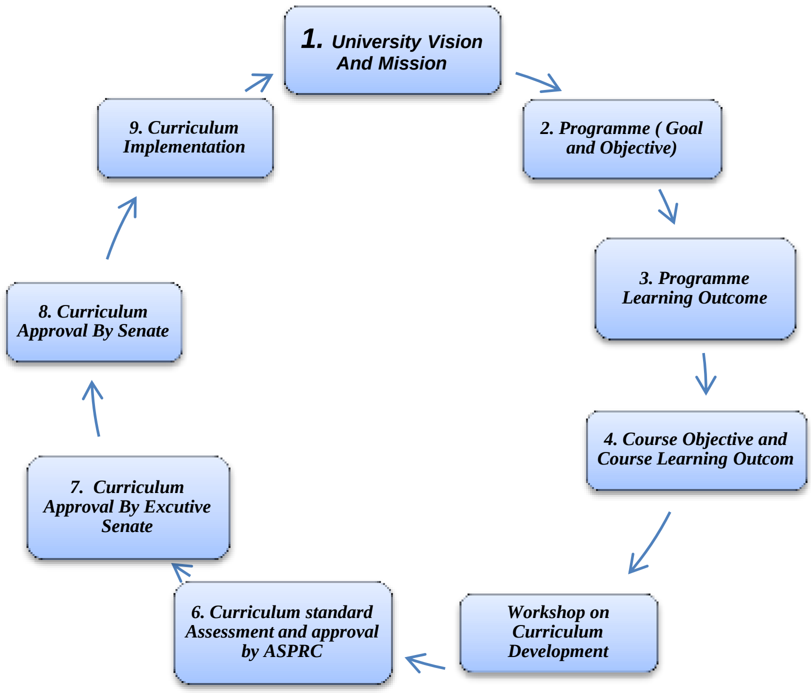

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Figure 2. 1 Outcome -based curriculum development process.

(Sources: AASTU Curriculum Development and Review)

The Addis Ababa Science and Technology Universities use an outcomes-based curriculum development process to fulfill their vision and mission. They incorporate Taba's model of curriculum development as shown in Table 2.4. However, the current curriculum development process lacks a detailed analysis of how content is selected and organized. In terms of mathematics curriculum development, the current theoretical framework follows the APOS theory, which emphasizes constructing knowledge through an Action-Process-Object-Schema theory. The objective of this framework is to support the learning experiences of students in a manner that promotes the development of new mental objects, processes, and schemes through the process of construction. This process encompasses various activities including generalization, interiorization, encapsulation, coordination, and reversal as identified by Mudrikah (2016).By utilizing the APOS theory, the curriculum development and research in mathematics education at the universities aim to promote students' active engagement in the learning process, facilitating the formation of new mental structures, and fostering the development of mathematical understanding.

2.4. Industrial Mathematics Curriculum for Science and Technology

2.4.1. Definition of Industrial Mathematics

Scholars define industrial mathematics on the basis of different scenarios. In this study, we will classify the definitions of industrial mathematics based on the educational level, their uses, problems that arise from industry, different disciplines, industry-university links, and research problems. Some of the definitions of industrial mathematics are summarised below.

According to Stull (1961), industrial mathematics at the high school and vocational education levels can be defined as the practical application of mathematical concepts to address the everyday problems encountered in industrial settings. This course involves solving problems related to fractions, decimals, money, percentages, linear measures, board measure, square measure, cubic measure, and a comprehensive study of typical shop formulas. The adoption of this definition of industrial mathematics will guide the future development of the mathematics curriculum at the Ethiopian Technical and Vocational Training College, which currently does not include mathematics in its curriculum. Industrial mathematics, in the opinion of Stockie (2017), can be defined as the combination of industry and mathematics. The term "industry" refers to a broad range of non-academic users of mathematics, including businesses in the public and private sectors, governmental organizations, healthcare facilities, foundations, and charitable causes. In this context, mathematics has a broad scope that includes both pure and applied mathematics and all mathematical methods that can be applied to solve practical problems. Industrial mathematics (IM) is divided into three main categories by Stockie.

i) Mathematics IN Industry (MII): performed by nonacademic mathematicians who work as employees of a company.

⇒ Goal: advances in products or processes

ii) Mathematics FOR Industry (MFI): performed by academic mathematicians as part of a collaboration with a company.

⇒ Goal: advances in mathematics and products/processes

iii) Mathematics INSPIRED BY Industry (MIBI): refers to the mathematical study of problems arising in industry, but within an academic setting, largely insulated from demands, pressures, and constraints of the industry.

⇒ Goal: advances in mathematics

Finally, the above definitions of industrial mathematics are combined and defined as follows. $IM = MII \cup MFI \cup MIBI$

According to Deshpande (2021), industrial mathematics is a subdivision of applied mathematics that differs from the broader field by its primary focus on resolving problems originating from the business sector. While applied mathematics encompasses theoretical concepts from various fields such as physics, biology, social science, and computing, industrial mathematics specifically addresses issues that arise in industry and aims to provide practical and cost-effective solutions. In other words, industrial mathematics is concerned with finding the most efficient strategies to address business-related challenges. Applied mathematics, computer, and engineering sciences are all incorporated into the topic of industrial mathematics, according to Tsetimi (2016). It includes a variety of fields with an industry focus, including business and computer science. The objective is to give students the skills necessary to solve problems that happen in the real world and in business by applying a variety of mathematical methodologies. From an African perspective, industrial mathematics is considered as a tool to support national development in areas like life expectancy and health, education and years of schooling, and per capita income. This is especially true in Nigeria. Bohun

(2014) recognizes the challenge in defining Industrial Mathematics and distinguishes it from Applied Mathematics, which primarily focuses on using mathematics as a tool for analysis. In a broader sense, Industrial Mathematics can be understood as the field of mathematics that encompasses all research efforts aimed at addressing problems posed by industrial applications. In summary, the definition of industrial mathematics depends on the country's industrial development and the use of mathematics for research and development.

Definition of Industry

The term "industry" is used to refer to a broad variety of economic operations, according to the Ethiopian economic Registration and Business Licencing Proclamation (2010). This covers both the production of goods and the usage of machinery powered by motors or other sources. It also includes tasks related to engineering, service delivery, service development, and agricultural development. The Science and Technology Innovation Policy Directive defines the word "Industry" as encompassing the manufacturing, construction, transport, communication and handicraft industries (NSTIP, 2010). According to the Organization for Economic Cooperation and Development (OECD) in 2008, the term "industry" was interpreted extensively to encompass any economic or socially valuable activity, including the service industry. This definition applies to both the public and private sectors.The definition of industry indicates the various sectors in industries with varied needs that require different disciplines to solve problems in industries. Therefore, the definition of industrial mathematics is of multidisciplinary subjects that integrate many fields of study. In the next section, the meaning of industrial mathematics is summarised in the context of this study.

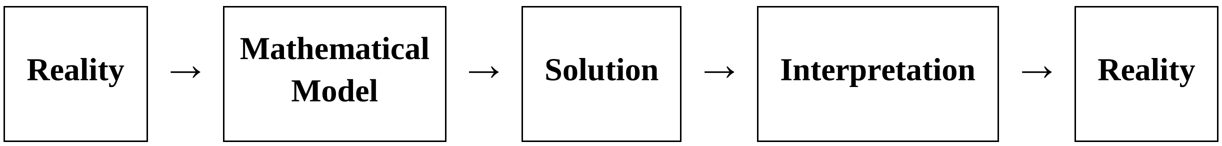
2.4.2. Industrial Mathematics Curriculum Development Process

In this section, the industrial mathematics curriculum development process in science and technology universities will be discussed. Before dealing with the concept of curriculum development in industrial mathematics, it is important to define the terms "industrial mathematics" and "industry" in this study context.

Industrial mathematics in this study is defined as a multidisciplinary subject (involving several academic disciplines or professional specialisations) that includes Applied Mathematics courses, theoretical topics from physics, biology, economics, and engineering disciplines, including industry disciplines like business and computer science, to train students to apply different mathematical techniques to solve problems arising from the industry. The definition of industry in this study agrees with the definition of industry in which industry is conceptualised in terms of all the manufacturing and non-manufacturing stakeholders influenced by the university-industry links.

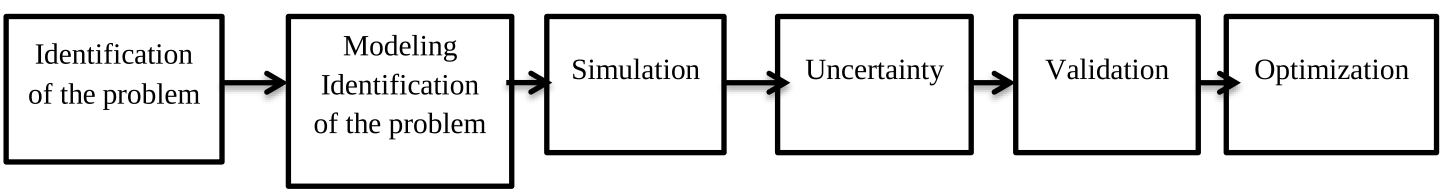
The OECD report from 2008, which focuses on mathematics in industry, proposed that the development of industrial mathematics curricula should aim to equip students for careers that combine mathematics and industry. To achieve this goal, these curricula should emphasize a strong foundation in mathematics, as well as other complementary knowledge beyond mathematics. They should be adaptable yet held to rigorous quality standards. Additionally, the curricula should prioritize industry-driven problems and foster students' scientific curiosity. Lastly, they should be designed to showcase the exciting research prospects and benefits that arise from the interaction between mathematics and industry. In this regard, as an example, institutional design of higher education of the industrial mathematics curriculum in Portugal is focused not only on mathematics but also on engineering, economics, science, management and accounting. One of the challenges in African mathematics education was the lack of contact with the application of mathematics to the benefit of society. However, in Nigeria, an industrial mathematics curriculum was developed to improve the national economic development of the country in the fields of health, agriculture, education, and industries (Tsetimi, 2016).

The primary aims of industrial mathematics are as follows: to comprehend real-world industrial problems initially presented in non-mathematical terms, to convert these problems into a suitable mathematical framework through mathematical modeling, to identify potential solutions using appropriate analytical and numerical methods, to verify the accuracy, validity, and dependability of the obtained solutions, and ultimately, to interpret or implement the findings in relation to the original real-world industrial problems. To fulfill these objectives, industrial mathematics and its applications address the problems in the following sequential manner, as outlined in Thapa's work in 2005.



The prosperity of society can be achieved through research and development if mathematics is used as a key to science and technology education. In line with the main objective of industrial mathematics, the European Road Map for Mathematics in Industry outlines the following strategic objectives: to establish Europe as the leading and most competitive knowledge-driven economy globally, capable of achieving sustainable economic growth while simultaneously creating more and higher quality jobs, and fostering greater social cohesion. This plan aims to position Europe at the forefront of the global economy by leveraging the potential of mathematics in driving innovation, competitiveness, and societal progress (Neunzert & Wolters, 2015).

To implement this strategic goal, the European Science Foundation (ESF, 2010) designed its industrial mathematics curriculum based on the following necessary steps to solve industrial problems:



These steps were important in the development of industrial mathematics curriculum to select and organise the courses and the contents of the courses. Each step of problem-solving requires corresponding courses to be completed. In this study, during the content analysis of industrial mathematics, the theoretical framework and the problem solving procedures mentioned above should be integrated into the curriculum development process.

2.4.3. Why Industrial Mathematics for Ethiopian Universities?

Presently, in Ethiopia, there exists a disparity between universities and the industry sector regarding their understanding and utilization of technology. To address the challenges associated with comprehending and implementing technology, it is imperative to enhance the relationship between universities and industry. This enhancement should involve a reciprocal exchange of technological knowledge and expertise. Joint efforts should concentrate on identifying technologies and their origins, gaining practical understanding through hands-on experience, and adapting these technologies accordingly. This approach, as highlighted by Salmi, Sursock, and Olefir in 2017, is crucial for bridging the gap between academia and industry in Ethiopia's technological landscape. The study highlights the significance of the two science and technology universities in the Ethiopian national industrial strategy, as the country strives to achieve its goal of becoming a middle-income economy by 2025. These universities play a critical role in this strategy by prioritizing applied research and facilitating the transfer of technology to various industries.However, they are limited in their academic programmes to applied science and engineering fields of study only, and most of the science and technology fields of study are still not included in their academic programmes. As stated in the Frascati Manual (FOS 2007), the classification of fields of science and technology is categorized into six principal areas of study. These areas include natural sciences, engineering and technology, medical and health sciences, agricultural sciences, social sciences, and humanities.More than 80% of the population in Ethiopia lives in rural areas in farming and pastoral communities. In 2020, 19 % of the population lived below the poverty line due to lack of food, shelter and health. Therefore, the need for medical and health sciences and agricultural sciences faculty in Ethiopian science and technology universities is crucial. Moreover, the two universities, which are situated around the industrial parks where the government wants to involve graduates in internships, research, and technology transfer programmes, are a general belief that mathematics is useful for companies to improve and increase their production. However, a lack of awareness of the use of mathematics in industries and higher institutions is one of the existing challenges in developing a mathematics curriculum in Ethiopia.

The decision to choose for an industrial mathematics curriculum instead of an applied mathematics curriculum is justified by the following distinctions, as outlined by Malik (2016):

1. Applied mathematicians do not recognize the distinction between pure and applied mathematics, whereas pure mathematicians do. However, industrial mathematics incorporates both pure and applied mathematics, with the latter being particularly relevant for addressing industry-specific problems.

2. The majority of applied mathematics is considered "applicable," meaning it has the potential to be applied but may not have been utilized yet. On the other hand, industrial mathematics has its own industry-centered applications and focuses on resolving problems posed by companies and technical organizations of an economic nature. This distinction serves as the second major difference between applied mathematics and industrial mathematics.

These differences contribute to the preference for an industrial mathematics curriculum, as it specifically caters to the application of mathematics in industry-related contexts. Thus, from the point of view of human creativity, industrial mathematics is one of the most exciting, adventurous, and joyful activities mathematicians can find. Despite the above differences between the two disciplines, graduates students of applied mathematics in Ethiopia are employed only as high school teachers; they are not employed in the industrial sectors, and most industries and government organisations lack awareness of the job specifications of mathematicians in their companies.

The primary goals underlying the importance of industrial mathematics in science and technology universities can be summarized as follows:

1. Converting technical, organizational, and economic problems initially presented in non-mathematical language into mathematical problems.

2. Finding solutions to these problems through the application of mathematical techniques or approximate methods, which may be analytical or numerical in nature, and subsequently interpreting the results in relation to the original problems.

3. Establishing connections between the field of mathematics and the practical world by acquiring knowledge of problems faced by companies and leveraging ideas and methods from mathematics.

These objectives reflect the need for industrial mathematics to bridge the gap between theoretical mathematics and practical industry challenges, as emphasized by Malik in 2016.

2.4.4. Who Learns Industrial Mathematics?

Industrial mathematics is a field of study that offers courses and programs for graduates at the BSc/BA, MSc/MA, and Ph.D. levels who pursue careers in industry where their mathematical skills are applicable. It is worth noting that these graduates may originate from disciplines other than mathematics. Furthermore, academic mathematicians, including professors and students, who engage in collaborative projects with industry also benefit from the knowledge and skills offered by industrial mathematics, as identified by Arnold in 2002. Higher Education Institutions (HEIs) in Tanzania and Rwanda have established partnerships with HEIs in Finland to collaborate on the training of postgraduate students (at the master's and Ph.D. levels) and the retraining of academic staff in the field of industrial mathematics. This collaboration aims to enhance the knowledge and skills of students and faculty in the application of mathematics to industry (Masanja, 2010).

At the University of Peradeniya in Sri Lanka, students who meet certain criteria are eligible to enroll in the M.Sc. in Industrial Mathematics program. The minimum requirement for admission is a B.Sc. Special Degree in Mathematics or a B.Sc. Special/General Degree with Mathematics as a subject. Alternatively, candidates with equivalent qualifications recognized by the Postgraduate Institute of Science are also eligible. Proficiency in English is essential, as the program is conducted in English (Ishak M. , 2010). The European Science Foundation (ESF) is responsible for formulating the curriculum for the Master's program in industrial mathematics, ensuring that it meets international standards. To be eligible for admission into this program, candidates must have completed 180 ECTS (European Credit Transfer and Accumulation System) of undergraduate study at the university level, typically through the completion of a bachelor's degree. These requirements are specified in the ESF's guidelines published in 2010.

2.4.5. Industrial Mathematics Programs and Programme Aims of Some Selected Countries

A) BSc. Program in Industrial Mathematics

(https://aliceisaacuniversityedu.com/course/b-sc-industrial-mathematics/)

1. B.sc. Industrial Mathematics Curriculum of Nigeria

The B.Sc. Industrial Mathematics Curriculum in Nigeria strives to attain the subsequent goals:

• Enhance students' capacity to utilize their knowledge and skills in mathematics to address both theoretical and practical problems.

• Provide students with versatile skills that can be applied in mathematics-related careers as well as other fields.

• Foster an appreciation for the importance and relevance of mathematics across various contexts, encompassing social, economic, environmental, and industrial domains.

- Provide students with advanced technical skills to utilize mathematical solutions to address challenges in both industry and society at large.

2. BSc. Industrial Mathematics: Kenya

(Bachelor of Science in Industrial Mathematics in Kenya (tertiaryinstitutions.com))

Program Objectives:

• To cultivate well-rounded researchers who possess contemporary knowledge and grasp the interplay between mathematics and business.

• equip students with skills in analysis, logical thinking, and abstract reasoning.

• Prioritize mathematical modeling and computational techniques within the program.

3. BSc. in Industrial Mathematics -Malaysia

(https://science.utm.my/wp-content/uploads/2018/12/UG-HANDBOOK-2018_2019.pdf)

Program objectives:

• equip graduates with the knowledge, skills, and attributes essential for a thriving professional career.

• Produce competent mathematicians capable of pursuing careers in relevant fields.

• To enhance personal and professional growth by fostering the development of soft skills.

• Instill a strong sense of ethics, a positive mindset, and a commitment to society.

4. BSc in Industrial Mathematics and Computer Science with Industrial Experience – Manchester

(https://www.manchester.ac.uk/study/undergraduate/courses/2023/00490/bsc-computer-science-and-mathematics-with-industrial-experience/course-details/COMP10120#course-unit-details)

Program objectives:

• To foster the acquisition of practical knowledge and skills in the fields of computer science and mathematics through the integrated honors degree program.

• To enable students to develop the necessary skills to utilize mathematical models in simulations that evaluate real-world scenarios, such as stress analysis in structures and bridges, airflow over airplane wings, or financial modeling.

5. B.Sc. in Mathematics with Computer Applications – India

(https://ethirajcollege.edu.in/wp-content/uploads/2021/07/Ssmaths_with_ca.pd)

Program objectives:

• Establish a solid foundation in both mathematics and computer applications.

• To cultivate a mathematical mindset, which including problem formulation and solving, analytical skills, and a commitment to precision

• To foster an appreciation for mathematical techniques, advanced programming skills in higher level computer languages, and a capacity for research in both mathematics and computer applications.

6. BSc Mathematics and Statistics –Manchester

(https://www.manchester.ac.uk/study/undergraduate/courses/2024/07101/bsc-mathematics-and-statistics/course-details/#course-profile)

Program objectives:

• This highly adaptable single honors degree program is specifically designed for individuals who anticipate using statistics in their future professional endeavors.

• To promote the development of skills in problem formulation, issue analysis, and interpretation of scientific data using appropriate statistical techniques.

• To establish a solid foundation in probability, statistics, and mathematics, which will serve as a basis for more advanced and technologlcally driven work in the future?

7. BSc. In Business and Industrial Mathematics- Sri Lanka

(Business and Industrial Mathematics (cinec.edu))

This degree program lasts four years and helps students locate an internship during the first six months of their final year. The industry has many employment openings in business and industrial mathematics, but there is currently a lack of skilled workers to meet its current and future workforce needs.

B) Master's Program in Industrial Mathematics

1. M. Sc. (Industrial Mathematics with Computer Application)- India

(https://nowrosjeewadia.mespune.org/course/m-sc-industrial-mathematics-with-computer-application/)

Program objectives:

• equip students with a solid foundation in fundamental mathematical concepts, procedures, and a comprehensive understanding of the vast capabilities of mathematical tools and techniques.

• Recognize the broad range of topics within the field and develop mathematical tools that can be utilized in further scientific research in various domains.

• Facilitate holistic growth in students by developing their expertise in mathematical modeling, problem solving, artistic creativity, and communication skills, essential for diverse job roles.

• Foster a positive mindset towards mathematics as a captivating and valuable field of study.

2. Master of Science (Industrial Mathematics) : Malaysia

Centre for Mathematical Sciences - Master of Science (Industrial Mathematics) by Mixed Mode (ump.edu.my)

Program objectives:

• To incorporate comprehensive coverage of two subspecializations, specifically applied and industrial mathematics, within the Master of Science in Industrial Mathematics program.

i) Data Computing, and

ii) Computational mathematics.

• To emphasize and support the utilization of simulation and big data computing, which are fundamental aspects of the industrial revolution.

• To enable students to combine theoretical knowledge with practical application, while also developing proficiency in essential computational tools.

• To promote student engagement, participants in the program are required to complete a project dissertation centered on a chosen applied and industrial challenge.

3. Master of Business & Science in Industrial Mathematics- USA

(Master of Business & Science in Industrial Mathematics – Department of Mathematical Sciences (rutgers.edu))

The purpose of the program

• to relate to what a scientist can know, what an executive can manage, and what an engineer can design.

• Using the methods and concepts of applied mathematics to analyse subtle interactions, vast amounts of data, and complicated systems

4. Center for Industrial Mathematics and Statistics (CIMS) -USA

(www.wpi.edu/+CIMS)

The purpose of the program

• To encourage university-business-government-industry partnerships for research in mathematics and statistics.

• Increase the knowledge required to handle today's complicated problems and provide solutions using appropriate statistics and mathematics.

• Provide the opportunity to get practical company experience through projects and internships that increase their competitiveness in the employment market of today.

• Improves companies technological competitiveness and assists them in meeting their needs for mathematical answers.

• The industrial projects in mathematics and statistics that CIMS offers offer a distinctive education for successful careers in business, higher education, and industry.

5. Master's degree program in Mathematics and Statistics

(https://www.manchester.ac.uk/study/undergraduate/courses/2023/07102/mmath-mathematics-and-statistics/#course-profile)

The purpose of program

- The programme will enhance students' ability to and analyse interpret data using the right statistical techniques.

- To deepen your understanding of specialised areas to the point that you are able to pursue postgraduate studies, carry out research, or work as a specialised mathematician.

- Acquire fundamental knowledge and skills in basic mathematics, probability, and statistics, and the basis for more advanced work later on.

2.4.6. Value of Industrial Mathematics

Few fields of human endeavor have had as much impact on life as mathematics (ESF, 2012). Mathematics, a vibrant academic discipline, continues to evolve and extend into various other fields, including industrial mathematics, which is now being explored in the mathematical sciences. Industrial mathematics is a specialized field of study within the mathematical sciences that holds significant applications for national development. Its scope extends across disciplines such as Accounting, Management Sciences, Business Administration, Economics, Mathematical Physics, Computing, and Engineering. The multidisciplinary nature of industrial mathematics makes it an essential tool for driving national progress (Tsetimi, 2016). The emergence of industrial mathematics as a field of study has opened opportunities for industries to evaluate new tools, design innovative products, control production processes, forecast sales and staffing needs, and create career pathways for employees to progress into leadership roles. Implicit in all these activities is a constant focus on delivering high-quality products and services to customers (Malik, 2016). When looking at it from a research standpoint, industrial mathematics is highly significant due to its ability to tackle issues that are related to various industries and provide practical solutions. These solutions often involve finding the best methods that are both efficient and cost-effective. The exceptional efficiency and effectiveness of these solutions have solidified industrial mathematics as an essential tool in the emerging technology fields of the present era. From an educational perspective, learning about industrial mathematics has a positive impact on analytical skills.

According to a study conducted by Damlamian, Rodrigues, and Sträßer (2013), the importance of mathematics in contemporary societies becomes clear. For instance, the page rank algorithm used by Google relies on eigenvectors in high-dimensional linear algebra. The Global Positioning System (GPS) incorporates concepts from geometry, linear algebra, and coding theory. Cryptography plays a fundamental role in modern society. Weather forecasting combines mathematical modeling and the computational power of high-speed computers. Statistics is a valuable tool for interpreting data. Additionally, mathematical principles, such as quaternion-based rotations, are crucial in computer animation. These examples demonstrate the wide-ranging applications of mathematics in practical and technological contexts, highlighting the significance of studying industrial mathematics for enhancing analytical skills.Furthermore, Sergeeva (2020) explains that future architects and civil engineers should possess knowledge in various fields, including linear algebra and analytical geometry, mathematical analysis, probability theory and mathematical statistics, mathematical modelling, and numerical methods. Deshpande (2021) suggests that operational research, a mathematical concept, is used in the transportation sector for purposes such as traffic management, logistics, network flow, terminal layout, and location planning. Modeling and simulation techniques are used in the aerospace industry for tasks such as charging spacecraft (Dudon, 2011). When looking at opportunities related to industrial mathematics in Europe, the integration of national indicators at a European level has the potential to create the most diverse, innovative, and efficient mathematical institutions globally. This collaboration presents an opportunity to focus some of this potential on finding solutions to societal and industrial challenges. However, we are not aware of any model of industry-mathematics collaboration that has not been adopted in some European nations. The best models may be distributed throughout Europe, taking into account the diversity and wealth of many European countries and using current expertise. There are several opportunities in the field of industrial mathematics, such as enhancing the global economy's competitiveness, addressing real-life problems in a relevant and effective manner, increasing the participation of mathematicians in industrial projects, sharing existing experiences and knowledge, establishing networks and databases for industrial problems, developing new mathematical and statistical approaches to handle the growing amount of data in various fields, enabling smart economic performance and sustainability through industrial and applied mathematics, and fostering strong confidentiality in industrial research (ESF, 2010).

2.4.7. Factors Influencing the Implementation of Industrial Mathematics

In this section, the experiences of different countries in implementing industrial mathematics curricula will be reviewed in terms of factors influencing the implementation process and the remedial measures they took to overcome these challenges. The challenges they encountered and the way they treated them are benchmarks for developing the new curriculum in Ethiopian science and technology universities. Some of the factors that influence the implementation of industrial mathematics are the following . One of the most challenging aspects for a mathematician is defining the requirements of a real problem. Often, the user or customer may not have a clear idea of what the final solution should look like, and it is the mathematician's responsibility to decipher and understand the problem at hand. In some cases, it is the customers themselves who identify the problems that need to be addressed.

Some of the possible difficulties in teaching and learning industrial mathematics identified by Milner (2000) were classified into three categories: difficulties with the courses of industrial mathematics, difficulties for teachers, and difficulties for students.

- Difficulties with industrial mathematics course content are finding the ‘right’ industrial problems, and some of the industrial problems are beyond the student's level.
- The difficulties for teachers are a lack of qualifications and an interest in offering all the courses by themselves.
- Difficulties for students are: the course needs a varied background like science and engineering, and students with different backgrounds enroll with different problems. (Milner, 1994)

In the same literature, the following possible solutions were recommended: assign more than one faculty member to teach industrial mathematics courses (one person teaches the model and the mathematical theory, and the others teach the numerical solution, programming, and production of graphics output and its interpretations); provide tutoring sessions for students on the software package; and provide another working code for certain numerical algorithms and allow students to modify them.

In a study conducted by Gemechu, Mogiso, and Husen (2021), several challenges were identified in the mathematics curriculum of Ethiopian higher education. These obstacles included students performing below average in mathematics, having inadequate background knowledge to comprehend mathematical concepts, and displaying limited conceptual understanding and problem-solving skills. Therefore, the researchers recommended a change in teaching mathematics in higher education, which needs technology to support learning and improve the quality of mathematics. Kahsay (2017) identified the major influential factors that affect university-industry links as those that directly or indirectly affect the implementation of industrial mathematics curricula in industries and universities and are characterised as motivation and willingness to collaborate with industries in research and innovation (university characteristics), lack of readiness and motivation to particpiate in partnerships, lack of willingness to invest in research and development (industry characteristics), and the legal and policy environment (government behaviour and operation in universities and industries).

2.4.8. Mechanisms of Promoting Mathematics in Industry

According to OECD (2009), the following mechanisms for promoting mathematics in industry were reported. Some of the mechanisms were classified as academic initiatives and academic-industrial collaborations.

2.4.8.1. Academic Initiatives

2.4.8.1.1. Interdisciplinary Research Centers within Academia

These Centers provide a significant advantage through facilitating numerous academic and industrial scientific interactions. This not only enhances the productivity and practical relevance of the Center members' mathematical work, but also prevents duplication of efforts and promotes networking with researchers located at a distance. Additionally, these Centers serve as important initial points of contact for industrial researchers in need of mathematical guidance.

2.4.8.1.2. Targeted Academic Positions/Faculty Positions/

A faculty position in industrial mathematics gave opportunities to focus on the job and facilitate a working environment for academic staff, industry professionals, and students.

2.4.8.1.3. Curriculum Reform and Student Projects

According to OECD (2009) reports on mechanisms of promoting mathematics in industry, students are unable to understand the societal worth of their mathematical abilities because universities in many nations, for a variety of reasons, are unable to give courses on the applications of mathematics in the real world. By allowing industrial initiatives to be included in the curriculum and by reforming the curriculum, this problem can be solved quite quickly. Ethiopian science and technology universities should offer undergraduate and graduate-level curricula with industry projects that include industrial mathematics as part of the curriculum.

2.4.8.1.4. Student Modeling Weeks

Modeling Weeks is a highly popular Mathematics in Industry event among academics because it was one of the first initiatives to recognize the significance of mathematics in the industrial sector and its appeal to both undergraduate and graduate students. The term "modeling" in this context primarily refers to the process of translating real-world industrial problems into mathematical formulations. However, the emphasis is not only on formulating the problems, but also on mathematical and numerical analysis, as well as validation. For many students, participating in a modeling week provides them with their first exposure to witnessing the practical application of mathematics in real-world situations.

2.4.8.1.5. Conferences

The establishment of networks within the international community of industrial mathematics is facilitated by conventional research conferences with a focus on mathematics in industry. Their primary responsibility is to spread novel theoretical concepts and their practical applications as a result of all types of industry partnerships.

2.4.8.2. Academic – Industrial Collaboration

2.4.8.2.1. Workshops

Perhaps the quickest way for academics to respond to industry-assisted issues is through the quick adoption of a small, informal workshop. In these workshops,industry researchers present an issue or set of challenges, while academics may suggest pertinent mathematical approaches. There may be breakout sessions afterward, but there should always be a conclusion that summarises the knowledge and opportunities gained and results in a written report.

2.4.8.2.2. Study Groups

Study groups have become a regular and increasingly popular component of the global industrial mathematics landscape. The typical structure involves a group of 4 to 10 industrial researchers presenting their specific problems to an audience comprising academic mathematical scientists, including students, on the first day. A key aspect of these study groups is that the academics, numbering around 10 for each problem, choose the problems that pique their interest and collaborate with the industrialists in separate rooms for the following 2-3 days to brainstorm potential solutions. On the final day, a reporting-back session takes place, and ideally, a comprehensive report is prepared for each industrialist within one to two months after the completion of the Study Group.

2.4.8.2.3. Internships

Although internships have been commonly utilized in various scientific disciplines, including mathematics, at both undergraduate and graduate levels, the implementation of internships in the field of industrial mathematics is a relatively recent development.

2.4.8.2.4. Teamwork

Building strong relationships between academia and industry is a huge benefit for organisations that are large and resourceful enough to fund teamwork projects.

2.4.8.2.5. Networks

Networks, which are frequently run jointly by academic and industrial committees, are in a prime position to educate funding organizations and the government about regional research and training strengths and weaknesses.

2.4.8.2.6. Facilitation

The idea of having facilitators who act as intermediaries between industry and academia is gaining increasing recognition globally. However, one of the challenges associated with these facilitators is funding. Since they don't fit into the traditional roles of full-time researchers or administrators, it becomes difficult to define a well-defined career path for them. To address this issue, one solution is to utilize facilitators as part-time consultants, as this aligns with their qualifications and expertise. By adopting this approach, the problem of funding can be alleviated.

2.4.8.2.7. Publicity

Publicity plays a crucial role in engaging both academic and industrial communities, and the following list mainly targets this objective. Various activities have been undertaken to enhance publicity, such as publishing authentic case studies in scholarly journals, maintaining a comprehensive website with news and media coverage, distributing newsletters, establishing an institutional repository, raising awareness about the problem-solving capabilities of mathematics, forming a committee to identify strategic areas and promote collaboration among stakeholders, and generating global publicity about past, present, and future study groups, as well as other events and reports. To encourage the integration of mathematics in industries, ESF (2010) suggests several mechanisms. Firstly, academic institutions and companies should establish effective communication channels and promote best practices globally, transcending geographical and scientific boundaries, utilizing networks and digital technologies. Secondly, it is recommended that the mathematical community collaborate with the industry to establish a dedicated journal for industrial mathematics and contribute to the Digital Mathematics Library. Additionally, academic institutions and industry should facilitate the mobility of employees between academia and companies. Lastly, the mathematics community and industry should collaborate on application-themed competitions to explore and capitalize on real-world opportunities. However, some of the factors that affect the university-industry link in Ethiopia can be broken down into characteristics of the university and the industry. For example, universities tend to lack motivation and willingness, an academic core that is capable and engaged, committed leadership, adequate funding for research, and supportive policies. Industry characteristics are the elements outside the control of the university. The collaboration between industry and universities is influenced by key factors related to the industrial sector. These factors include the willingness and enthusiasm of the industry to form partnerships with universities, specifically in areas of research, innovation, and technology transfer. Additionally, the presence of sufficient infrastructure and qualified personnel for research and development, investment in research activities, and the industry's capacity to effectively adopt and utilize new knowledge and technologies are significant determinants of this partnership (Kahsay, 2017).

2.5. **Graduate Employability Skills**

The government established ten industrial park projects near the top ten universities in the country to promote internships, research, and employment opportunities. To strengthen the connections between Ethiopian science and technology universities and the industry, they should integrate innovation into their curriculum and reassess their teaching methods to focus on the specific skills required by the industry. The development of these skills is crucial for improving employment prospects and driving productivity and growth. However, it is worth noting that education and training systems do not always equip individuals with the necessary skills to thrive in the job market. A challenging area in the field of the development of Ethiopian Higher Education curriculum development is that it is not geared toward the development of employability and other lifelong learning skills among graduates (MOE, 2018). In order to ensure the maintenance of quality standards in universities, the Ministry of Education plans to implement a university ranking system. This system will rely on various indicators of key performance outcomes to assess the universities. These indicators include factors such as the publication of research in reputable journals, the development of patented technologies, the enrollment of students, the success rate of graduates in exit exams, the employability of graduates, and the number of international students attracted to the universities. The introduction of this ranking system aims to provide a comprehensive evaluation of universities and foster a culture of continuous improvement in the higher education sector(MOE, 2018). Graduate unemployment and low productivity will continue to be a national issue until stakeholders (universities, labour market institutes, industries, and professional groups) take integrated steps to improve employability (Tesfamariam & Jeilu, 2021). Therefore, employability skills are increasingly becoming a vital factor in curriculum development and implementation programmes. According to the findings of Demissie et al. (2021), several factors have been identified as significant predictors of graduate employment outcomes in Ethiopia. These factors include demographic characteristics, curriculum characteristics, institutional culture, graduate characteristics, economic and labor market conditions, as well as global and emerging issues. The conclusions drawn from this study suggest that these various factors have a substantial impact on the future prospects of employment for graduates in Ethiopia. The curricula for Mathematics in Ethiopian Higher Education institutions have been found to lack the identification of employability skills. As a result, stakeholders have expressed dissatisfaction with the quality of graduates. This issue arises from the fact that a significant number of graduates are unable to contribute effectively without additional training to meet the requirements of applied technical and communication skills. This indicates the need for a revision in the curricula to address these shortcomings and ensure that graduates are adequately prepared for the demands of the job market. According to SIAM's (1994) Report on Mathematics in Industry: The Job Market of the Future Preparing for Iindustry Employment Industrial experience can be acquired through a summer job, an internship, a cooperative employment program, a postdoctoral, or an industrial project. The ability to learn another discipline and to communicate with its practitioners is important; computational skill is important; and practise in all forms of communication (reading, speaking, listening, and writing) can be achieved by contacting a potential employer. The following Table 2.5 describes the components of each skill and the teaching strategies to develop the skills.

Table 2. 5Components and Teaching Strategies for Developing Employability Skills

Employability skill	Element (Skills that graduate think is important)	Teaching Strategies
1. Communication	♦ Listening and understanding ♦ Speaking clearly and directly ♦ Writing to the needs of the audience ♦ Negotiating responsively ♦ Reading independently ♦ Empathizing ♦ Speaking and writing in languages other than English ♦ Using numeracy ♦ Understanding the needs of internal and external customers ♦ Persuading effectively ♦ Establishing and using networks ♦ Being assertive ♦ Sharing information	➢ Writing and presenting ➢ written and verbal reports ➢ Role plays ➢ Demonstrations ➢ Working in groups
2. Team work	♦ Working across different ages irrespective of gender, race, religion or political persuasion ♦ Working as an individual and as a member of a team ♦ Knowing how to define a role as part of the team ♦ Applying team work to a range of situations, e.g. futures planning, crisis problem solving ♦ Identifying the strengths of the team members	➢ Team or group projects Learning sets ➢ Group discussion ➢ Syndicates ➢ Communities of practice

	♦ Coaching and mentoring skills including giving feedback	
3. Problem solving	♦ Developing creative, innovative solutions ♦ Developing practical solutions ♦ Showing independence and initiative in identifying problems and solving them ♦ Solving problems in teams ♦ Applying a range of strategies to problem solving ♦ Using mathematics including budgeting and financial management to solve problems ♦ Applying problem solving strategies across a range of areas ♦ Testing assumptions taking the context of data and circumstances into account. ♦ Resolving customer concerns in relation to complex projects issues	➢ Case studies ➢ Simulations ➢ Investigative projects and research ➢ Using various problem solving tools and techniques ➢ Developing or designing models ➢ Problem solving in teams and networks ➢ Decision making activities
4. Initiative and enterprise	♦ Adapting to new situations ♦ Developing a strategic, creative, long term vision ♦ Being creative ♦ Identifying opportunities not obvious to others ♦ Translating ideas into action ♦ Generating a range of options ♦ Initiating innovative	➢ Brainstorming activities ➢ Designing innovative and creative practices and solutions ➢ Initiating change /designing change processes ➢ Simulation activities, ➢ such as improving productivity

	solutions	
5. Planning and organizing	♦ Managing time and priorities- setting time lines, co-coordinating tasks for self & with others ♦ Being resourceful ♦ Taking initiative and making decisions ♦ Adapting resource allocations to cope with contingencies ♦ Establishing clear project goals and deliverables ♦ Allocating people and other resources to tasks ♦ Planning the use of resources including time management ♦ Participates in continuous improvement and planning processes ♦ Developing a vision and a proactive plan to accompany it ♦ Predicting - weighing up risk, evaluate alternatives and apply evaluation criteria ♦ Collecting, analysing and organising information ♦ Understanding basic business systems and their relationship	➢ Research and data collection ➢ Developing action plans ➢ Planning and organizing events ➢ Time management activities ➢ Goal setting activities and scheduling tasks ➢ Collecting and analyzing information
6. Self-management	♦ Having a personal vision and goals ♦ Evaluating and monitoring own performance ♦ Having knowledge and confidence in own ideas and visions ♦ Articulating own ideas and visions	♦ Development of portfolios ♦ Work plans ♦ Using log books to record time management skills and monitor own performance ♦ Career planning exercises

	♦ Taking responsibility	
7. Learning	♦ Managing own learning ♦ Contributing to the learning community at the workplace ♦ Using a range of mediums to learn - mentoring, peer support and networking, IT, courses ♦ Applying learning to 'technical' issues (e.g. learning about products) and 'people' issues (e.g. interpersonal and cultural aspects of work) ♦ Having enthusiasm for ongoing learning ♦ Being willing to learn in any setting - on and off the job ♦ Being open to new ideas and techniques ♦ Being prepared to invest time and effort in learning new skills ♦ Acknowledging the need to learn in order to accommodate change	➢ Reflective journals log books, diaries ➢ Mentoring and coaching activities ➢ Self-evaluation tools
8. Technology	♦ Having a range of basic IT skills ♦ Applying IT as a management tool ♦ Using IT to organise data ♦ Being willing to learn new IT skills ♦ Having the physical capacity to apply technology e.g. manual dexterity	➢ Using the Internet, ➢ Intranets ➢ Using ICT skills to complete activities ➢ Industry relevant software, technology and equipment

Sources: Elements of Employability from Department of Education Austria ,2006 and Teaching strategies by Manivannan & Suseendran (2017

Summary

The literature review chapter covers topics related to Science and Technology, Higher Education in Ethiopia and Curriculum Development in Industrial Mathematics: The discussion delves into the landscape of higher education in Ethiopia, particularly focusing on science and technology universities. The definition and scope of Science and Technology (S & T) are outlined to provide a foundational understanding of the field. The review addresses the opportunities and challenges within the Ethiopian higher education system, emphasizing the need for quality assurance and improvement efforts. The interconnection and significance of Science, Technology, Engineering, and Mathematics (STEM) are explored to highlight their interdisciplinary nature. Reference is made to the Frascati Manual regarding the classification in the fields of Science and Technology. The process and importance of curriculum development within Science and Technology universities are discussed, focusing on enhancing educational quality and relevance.

The concept of Industrial Mathematics is introduced, along with its development process and significance for Ethiopian universities. A comparison of Industrial Mathematics programs and aims in selected countries is presented to highlight global trends and developments. The value of Industrial Mathematics in addressing industry challenges is explored, along with factors influencing its effective implementation.

Mechanisms for promoting Mathematics in Industry are discussed to underscore the importance of numeracy skills in professional settings.The importance of Graduate Employability Skills is emphasized, indicating the relevance of Industrial Mathematics in preparing students for the workforce.

Overall, the summary provides a comprehensive overview of key themes related to Science and Technology Higher Education and the integration of Industrial Mathematics into curriculum development processes, addressing challenges, opportunities, and the practical applications of mathematics in industry to enhance graduate employability skills

CHAPTER-3: THEORETICAL FRAMEWORK AND ITS DESCRIPTION

3.1. Introduction

Curriculum development is centered on the enhancement and introduction of new elements into the educational system. This is a lengthy process, particularly when it comes to developing generic curricula that go beyond a specific local context. It involves incorporating desires and ideals into a cyclical process of design, implementation, and evaluation with the objective of achieving tangible outcomes in practice (Celia & Elize , 2014). Hilda Taba, a former student of Tyler, presented a sophisticated version of his curriculum development procedure in 1962. This version consisted of seven key steps: 1) Identifying the needs of the learners, 2) Establishing clear objectives, 3) Choosing appropriate content, 4) Structuring the content in a logical manner, 5) Selecting suitable learning experiences, 6) Arranging the learning experiences effectively, and 7) Determining what to evaluate and how to evaluate it (Jon & Joseph, 2015).

The following were the components of the curriculum development cycle adapted by Celia and Elize (2013).

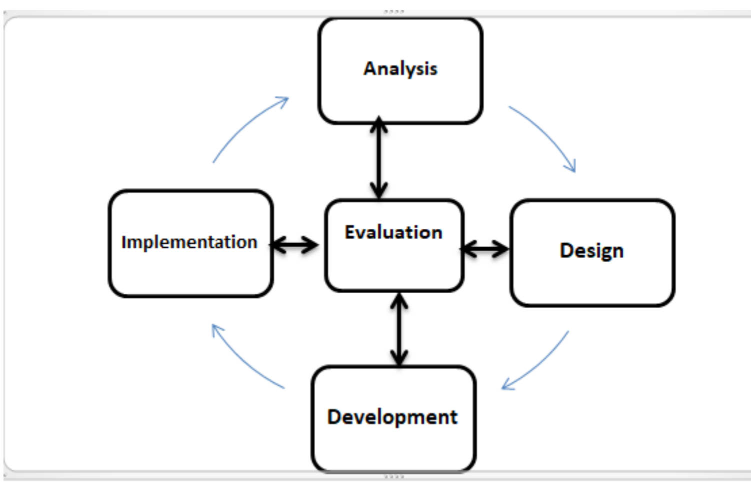


Figure 3. 1 Curriculum developments Cycle

Curriculum development is an iterative process in which analysis, design, development, implementation, and evaluation occur continuously and interactively. Typically, the process begins with an examination of the current educational environment and the establishment of objectives for the desired change or innovation. During this initial phase, key activities such as problem analysis, context analysis, needs analysis, and analysis of the existing knowledge base are conducted (Celia & Elize, 2014). In this study, barriers to curriculum development in Ethiopian higher education were examined, strengths and limitations of the mathematics curriculum of existing universities were examined, the need for mathematical specialties was assessed, problems in industries were identified, the value of industrial mathematics was determined, which parts of industrial mathematics were appropriate for science and technology universities, and in general a gap analysis was performed. Based on the needs assessment conducted, this study utilizes the APOS theoretical framework for researching and developing the industrial mathematics curriculum. Subsequently, the upcoming section will investigate into a discussion of the theoretical framework for curriculum development.

3.2. APOS Theoretical framework for Research and Curriculum Development

The present study has involved the APOS theory, which is linked to the research and development of mathematics education curricula. APOS stands for action, process, object, and schema and serves as a theoretical framework that sheds light on effective learning of mathematical concepts. Originating from Jean Piaget's constructive theory of learning and later refined by Ed Dubinsky, the APOS Theory focuses on constructing cognitive process models of individuals as they learn mathematical concepts. These models are then employed in creating instructional materials and evaluating students' progress and challenges in solving mathematical problems (Arnon et al., 2014).

The APOS Theory can be considered a strictly developmental perspective, an evaluative tool with analytical precision, or even both (Bredenbach, 1992; Weller and Dubinsky, 2013, 2011, as cited in Arnon et al., 2014). According to Schoenfeld (2000), models and theories in mathematics education must fulfill eight criteria, namely descriptive power, explanatory power, scope, predictive power, rigor and specificity, falsifiability and replicability, and multiple sources of evidence, often referred to as "triangulation." These criteria are essential for assessing the effectiveness and utility of models and theories in the realm of mathematics education.

The APOS Theory exhibits characteristics that align with the criteria for mathematics education as outlined by Dubinsky (1999). These include the ability to make predictions, provide explanatory insights, apply to a wide array of phenomena, facilitate the organization of thoughts on learning phenomena, aid in data analysis, and offer a common language for discussing learning processes. Ed Dubnisky gives the following meaning to the question "What is APOS?"

> 'An individual's mathematical knowledge is their tendency to respond to perceived situations of mathematical problems and their solutions by reflecting on them in the social context and constructing or reconstructing mathematical action, processes, and objects and organizing them in schemas to use in dealing with situations.' (Ed Dubnisky,1994.p4.)

In this study, the APOS theory of research and curriculum development has included a variety of pedagogical tools and research methods in which instructors have improved their professional development careers in terms of teaching learning and research development in mathematics education.

3.2.1. Why APOS theory of Research and Curriculum Development?

The reasons why the APOS theory is being used to develop industrial mathematics curricula in Ethiopian science and technology universities are as follows.First, the previous curriculum development processes in Ethiopian universities were simply reproductions of curricula from other universities, lacking clear explanations of the theoretical foundations. The curriculum offered followed a top-down approach and did not adequately address the demands of stakeholders. Moreover, the quality of mathematics instructors and research practices were sub-par. According to Asila et al. (1997), in certain circumstances, an event or discovery is so significant that it cannot be assimilated into the existing paradigm, leading to the development of a new program. Dissatisfaction with the current paradigm has reached a point where finding solutions to specific problems (often fundamental to the subject) has become challenging or even impossible.

The APOS theory serves as a philosophical and theoretical framework for a scientific discipline. It involves the formulation of hypotheses, laws, and generalizations, as well as the conduction of experiments to support them. In a broader sense, any philosophical or theoretical framework that fits this definition can be considered as an embodiment of APOS theory. As APOS theory encompasses a comprehensive research stance, it is often referred to as a paradigm. This is due to several reasons: (1) it differs from the majority of mathematics education research in terms of its theoretical approach, methodology, and the types of results it yields, (2) it includes interconnected theoretical, methodological, and pedagogical components, (3) researchers continue to utilize it to address various issues related to the learning of different mathematical topics, and (4) it encourages the scientific community to actively seek solutions for questions that arise from the theory itself (Arnon et al., 2014). Therefore, the development of the industrial mathematics curriculum based on APOS involves three stages: theoretical analysis, instruction design, and data analysis to develop the industrial mathematics curriculum. These three components can be applied to develop industrial mathematics curricula, as explained in the following section.

3.2.2. Cycle of APOS theory of Research and Curriculum Development

Research focuses on how people learn (or don't learn) mathematics as well as what happens inside a person's mind when attempting to comprehend a mathematical concept. The goal of curriculum development is to enhance the content and/or delivery of a curriculum; classroom dynamics, social pressure for change, and its effects are all aspects of development.

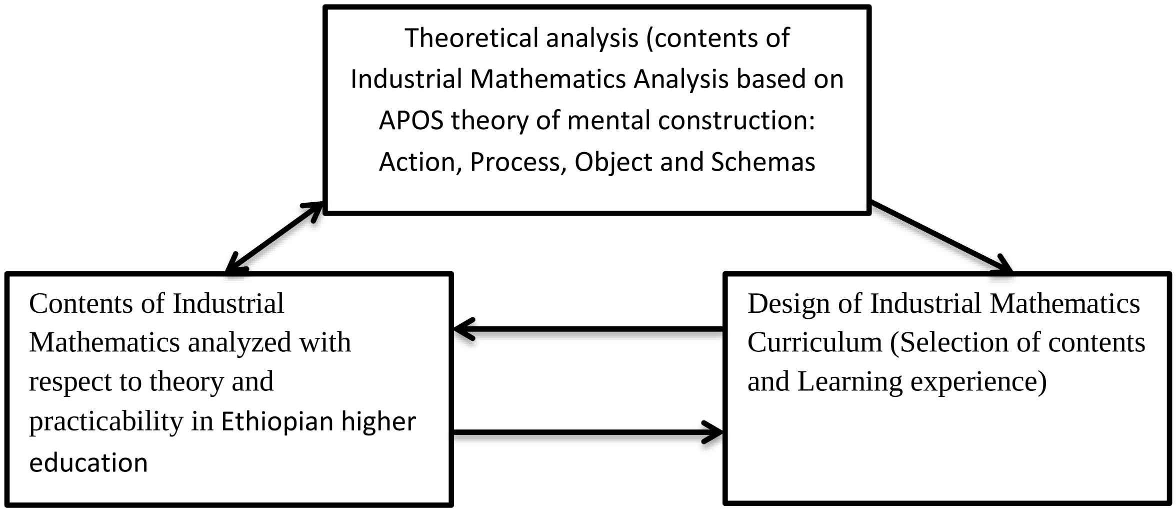


Figure 3. 2 Cycle of APOS theory of research and curriculum development

The one-way arrow represents the theoretical analysis which entails the description (genetic decomposition) of mental structures and mechanisms that might be useful in the development of a mathematical concept. Theoretical analysis can be achieved by developing and implementing instructional strategies that are informed by it. The third stage involves gathering and analyzing facts, comparing them with the constructs posited in the genetic decomposition, and drawing a conclusion. These three elements form a cycle that is repeated until there is alignment between genetic decomposition and empirical evidence. It is important to note that genetic decomposition may be open to contestation.

The study described aims to produce a guideline for developing industrial mathematics curricula for undergraduate programs at science and technology universities in Ethiopia, based on the best selected curriculum for Ethiopian industrial development. The researcher intends to accomplish this by analyzing data obtained from questionnaires and group discussions. The international standard will be compared to documents from selected industrial mathematics curricula to ensure compliance. To effectively structure content and learning experiences in the field of industrial mathematics, the combination of inductive content analysis and the APOS theory of research and curriculum development in mathematical education is employed.

Within the larger framework of the APOS Paradigm for Research and Curriculum Development in Mathematics Education, two specific categories can be identified for this study: the APOS paradigm for Industrial Mathematics Education Research and the APOS paradigm for Industrial Mathematics Education Curriculum Development. These categories serve as valuable tools for conducting research and designing curricula specifically tailored to the needs of industrial mathematics education.

In summary, this passage provides an overview of the role of theoretical analysis and genetic decomposition in the development of mathematical concepts. It also outlines the approach used in this study to develop curricula for undergraduate programs in industrial mathematics.

1. APOS paradigm for research in industrial mathematics education:

The APOS paradigm for industrial mathematics education offers effective methods for helping students grasp mathematical concepts. It leverages various pedagogical strategies such as cooperative learning, small-group problem solving, and lecturing. The analytical research question in mathematics education aims to address two key points: (1) Did students successfully develop the necessary mental models through theoretical analysis? (2) How well did students comprehend mathematics? If the answer to the first question is negative, instructional methods are studied and revised. If the answer to the first question is positive but the second question is negative, the theoretical analysis is reconsidered and adjusted accordingly (Arnon et al., 2014).

2. APOS paradigm for industrial mathematics curriculum development:

Curriculum development entails enhancing the content, delivery, dynamics of the classroom, and considering social pressures and implications of change. Drawing upon the APOS paradigm for research in industrial mathematics education, the industrial mathematics curriculum's content and learning experiences are carefully selected, sequenced, and organized. This approach ensures that the curriculum aligns with the principles and goals of the APOS paradigm, enhancing the overall effectiveness of the educational program.

3.2.2.1. Theoretical analysis

The goal of the theoretical analysis of industrial mathematics curriculum for science and technology universities is to select and organise curriculum materials based on genetic decompositions in which students build certain mental constructions (Action, Process, Object, and schema). The analysis begins with the application of a general theory of learning, which is usually a problem-solving strategy used in solving industrial-based challenges and is greatly influenced by the researchers' personal knowledge of the notion, as well as previous learning and teaching experience.

The following are some of the basic questions that need solutions under theoretical analysis:1)What is the best way to create a theoretical perspective? 2)What is the connection between this hypothesis and what actually occurs? 3)To what extent can theoretical analysis produce an exact or even approximate picture of what is going on in learners' heads? 4) What does it mean to grasp the concept? And 5)How can a student construct that understanding?

How is industrial mathematics knowledge constructed?

According to Dubinsky (1994), reconstruction in a context comparable to, but distinct in fundamental ways from, a problem previously addressed leads to the development of mathematical knowledge. The reconstruction is not exactly the same as before; it may include one or more breakthroughs to a higher level of sophistication. This was related to Piaget's assimilation and accommodation dichotomy. Assimilation refers to the cognitive process of integrating new information into existing schemas by modifying the new information to fit well with pre-existing knowledge. On the other hand, accommodation is the process of adjusting and reorganizing cognitive schemas in response to new information. If the existing cognitive structure cannot accommodate new knowledge, assimilation becomes impossible. In such cases, accommodation is necessary to adapt and incorporate the new information effectively. (Piaget's Schema & Learning Theory: Fascinating Experiments (positivepsychology.com).

These two processes are very important in designing industrial mathematics curricula because, as beginners, we need to see the previous and current curricula. The former helps us assess our current level of understanding and implement the curriculum. The latter indicate the present knowledge related to the field of industrial mathematics in the Ethiopian context.

Mental constructions from learning mathematics

Interiorized actions become processes, which are then encapsulated to form objects. Decapsulated objects are returned to the process where they were generated. Finally, schemas can be used to group activities, processes, and objects together.

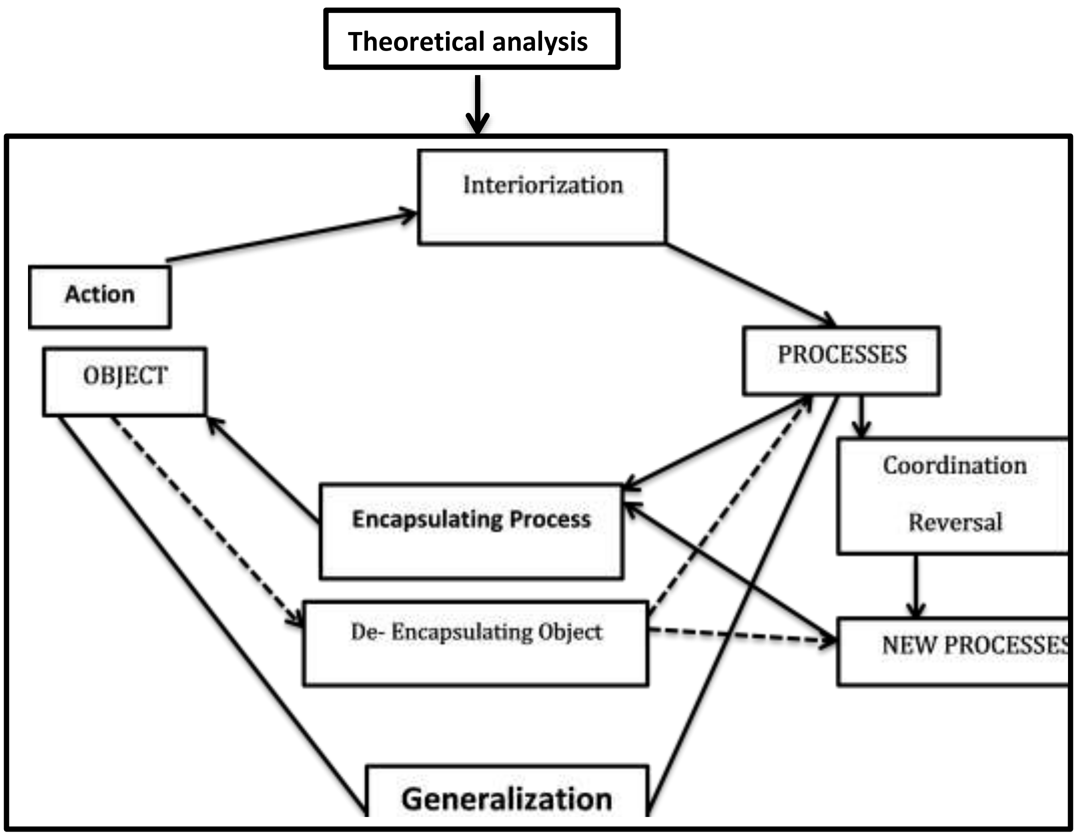


Figure 3. 3 The genetic decompositions of mental construction

Actions interiorize to give process. Processes can form another new process by coordinating and reversing processes. Process encapsulated to form objects. Conversely, objects are de-encapsulated to form processes.

The three components of the research cycle influence each other, as shown by the arrows in Fig. 3.3 above. Theoretical analysis guides the planning and delivery of education by focusing on activities that promote the mental constructions that the analysis requires. Students will learn how to create Actions, interiorize them into processes, encapsulate processes into objects, and coordinate two or more processes to create new processes through activities and exercises.

The Action-Process-Object-Schema (APOS) theory is a learning theory that focuses on the development of individuals' mathematical thinking. The APOS theory describes the four phases of mathematical understanding as follows (Syamsuri, Purwanto, Subanji, & Santi, September 2017).

Action: An action refers to a transformation that occurs when an individual reacts to external stimuli. It is considered an action when a student provides accurate examples for a given proposition.

Example of Action:

- The child learns addition by counting using physical objects like sticks or stones to represent quantities.
- Moving abacus beads to understand addition and subtraction.

Process: When an individual repeat and contemplates an action, they may integrate it into a mental process. A mental process is a cognitive framework that performs the same operation as the action, but entirely within the individual's mind. An indication of a mental process is the ability of students to construct mathematical equation models using any variable.

Example of a Process:

- Mentally adding or subtracting numbers without the need for physical manipulation.
- Solving a long division problem using a step-by-step procedure.

Object: When an individual recognizes a process as a whole, understands that transformations can affect that entirety, and is capable of constructing such transformations (either explicitly or in their imagination), we consider that the individual has encapsulated the process into a cognitive object. For instance, students have the ability to generate alternative representations from mathematical equation models to establish connections with other information in the given proposition.

Examples of an object:

- Viewing numbers as abstract entities with properties like odd or even, prime or composite.
- Manipulation of variables in algebraic expressions without relying on physical representations.

Furthermore, the following are examples of genetic decompositions from various publications that show how content is chosen and organised for research purposes and how successfully achieved objectives are chosen for the curriculum.

3.2.2.2.1.Examples of Genetic Decompositions

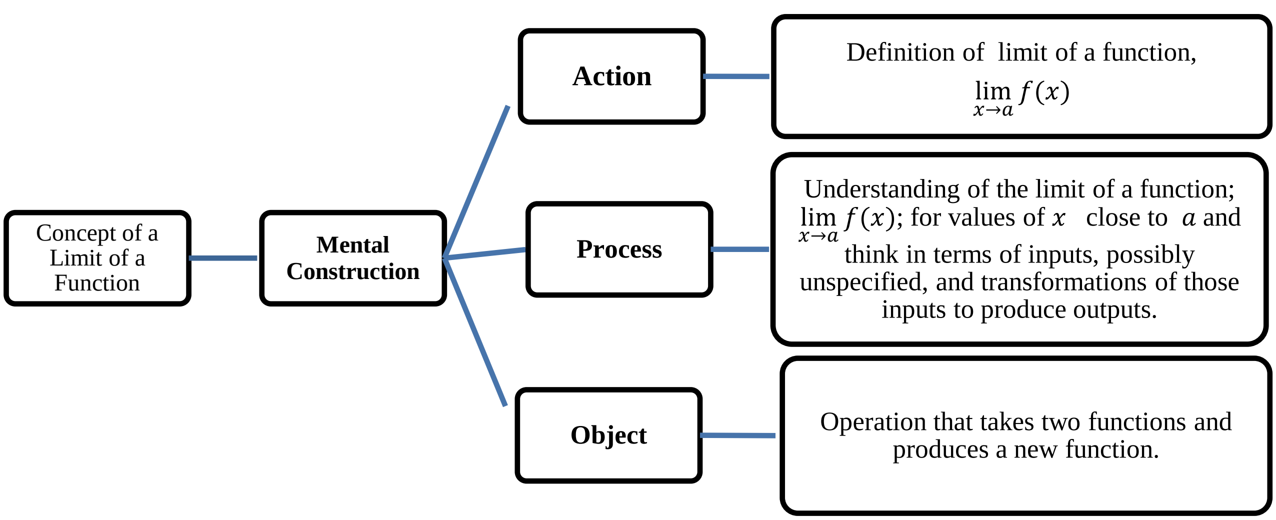


Figure 3. 4 Genetic decomposition of the concept of a limit of a function

Source: (Maharaj, An APOS Analysis of Students' Understanding of the Concept of a Limit of a Function, 2010)***, An APOS Analysis of students' understanding of the concept of a limit of a function***

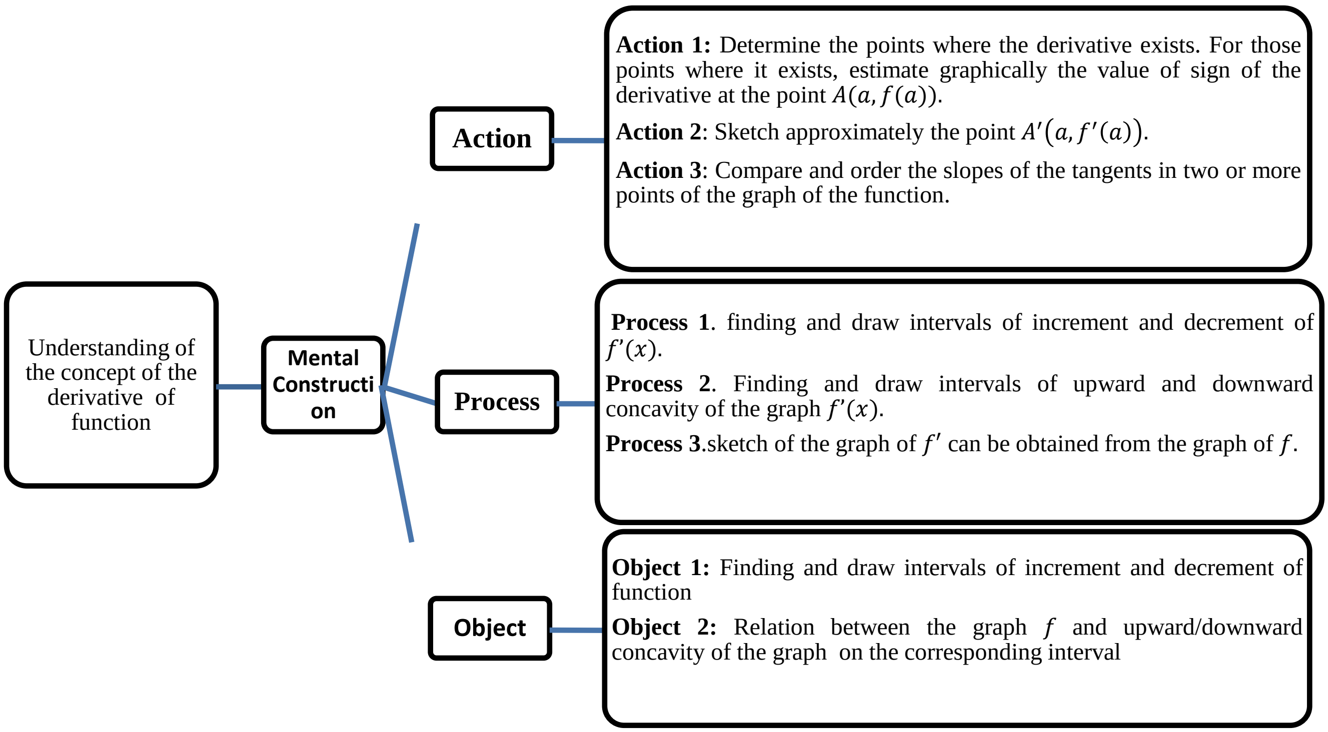


Figure 3. 5 Genetic decomposition of understanding the concept of a derivative of function

Source: (Borji , Font , & Alamolhodaei, Application of the Complementarities of Two Theories, APOS and OSA, for the Analysis of the University Students' Understanding on the Graph of the Function and its Derivative, 2018) Application of the Complementarities of Two Theories, APOS and OSA

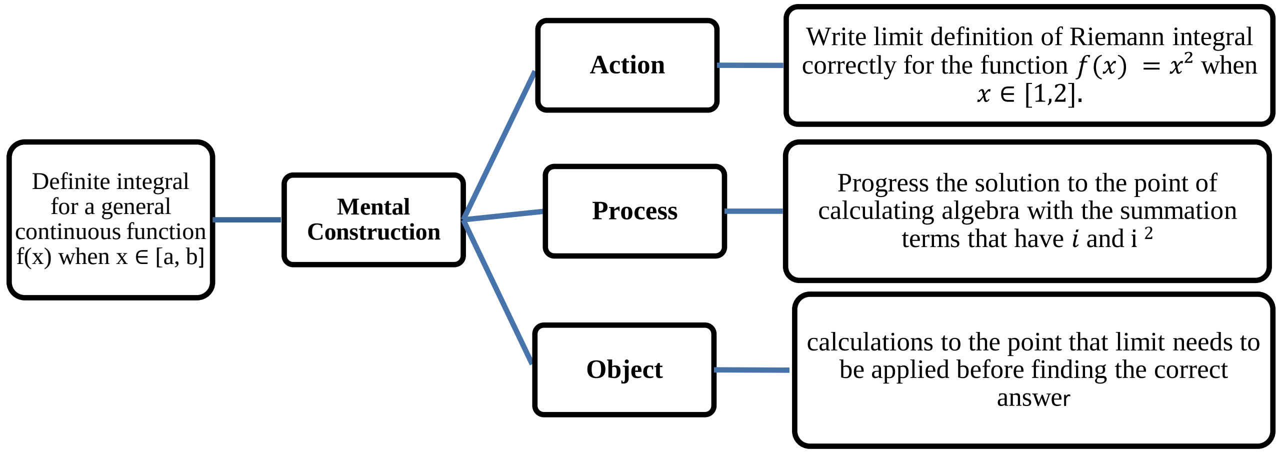


Figure 3. 6 Genetic decomposition of understanding the concept of integral of function

Source: Tokgoz (2016) Evaluation of Engineering & Mathematics Majors' Riemann integral definition Knowledge by utilizing APOS Theory

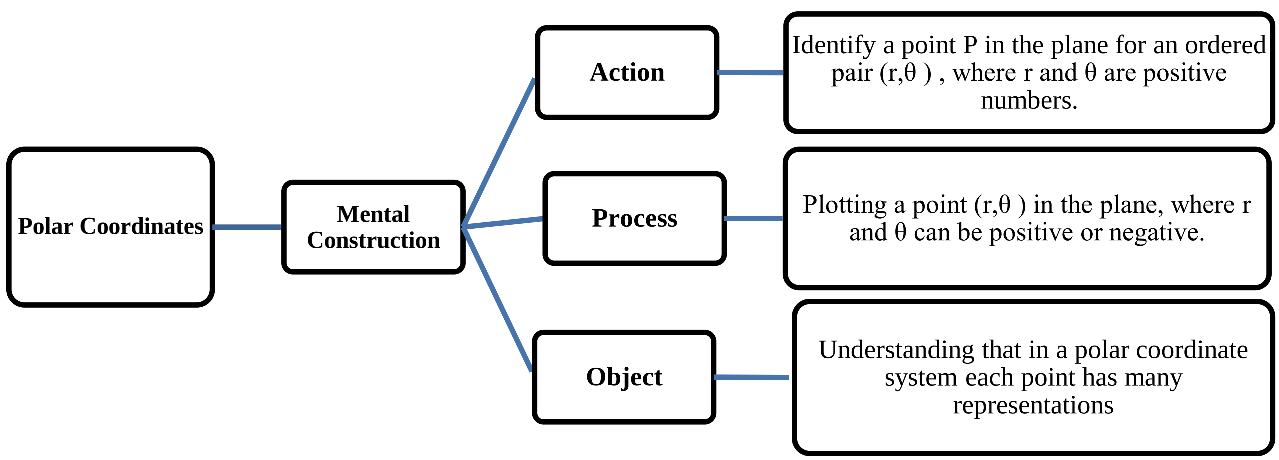


Figure 3. 7 Genetic decomposition of understanding the concept of Polar Coordinates

Source: Borji & Gr. Voskoglou, Applying the APOS Theory to Study the Student Understanding of Polar Coordinates, 2016

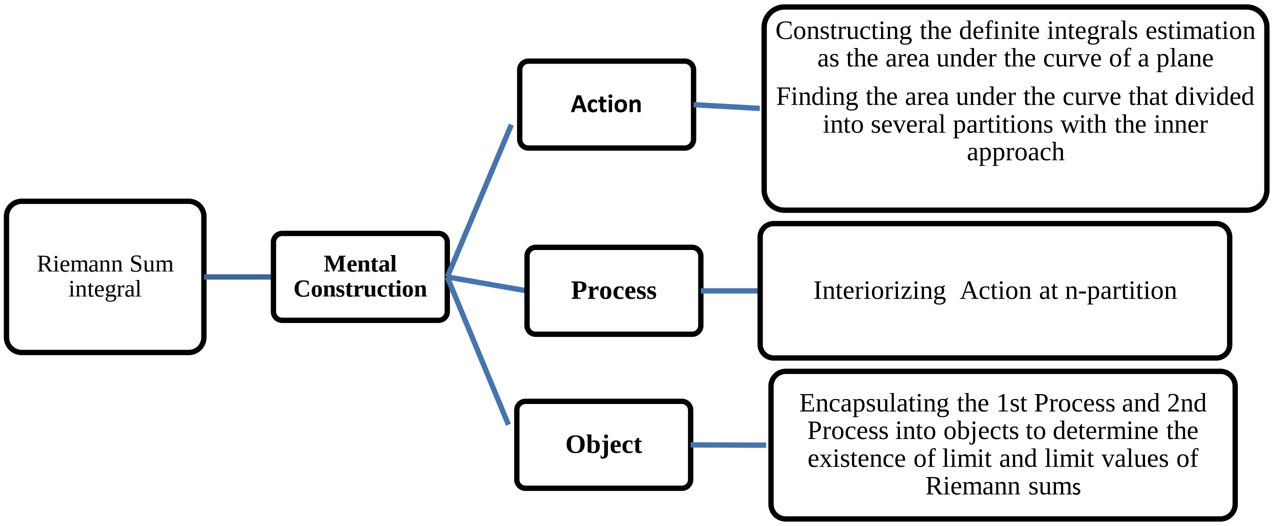


Figure 3. 8 Genetic decomposition of understanding the concept of Polar Coordinates

Source :Nisai, Waluya & S Marian (2020): Implementation of APOS theory to encourage reflective abstraction on the Riemann sum

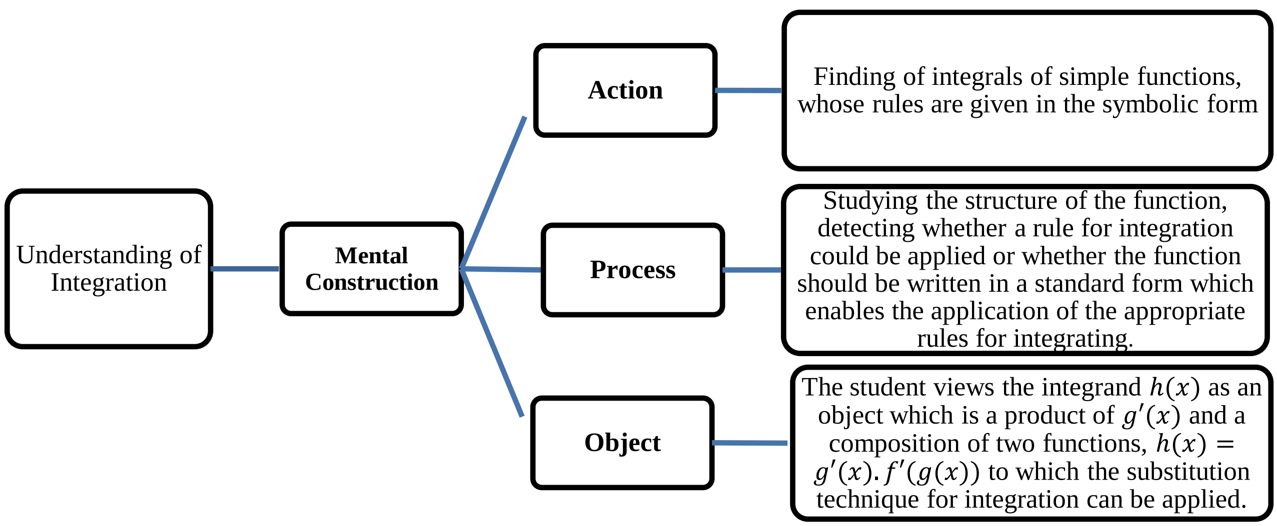


Figure 3. 9 Genetic decomposition of the concept of understanding of integration

Source: (Maharaj, An APOS Analysis of Natural Science Students' Understanding of Integration, 2014)

Genetic decompositions of matrix, determinant, and systems of linear equations

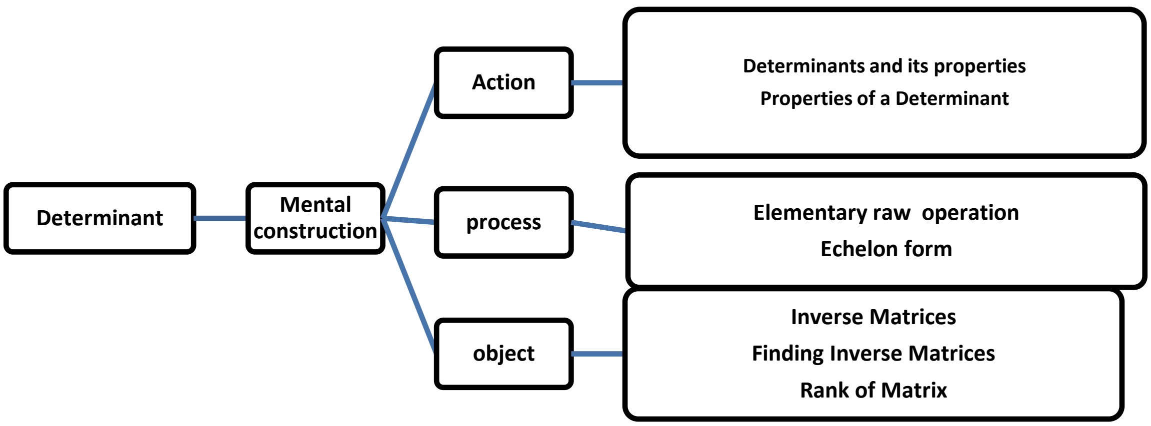


Figure 3. 10 Modified Genetic decompositions of the determinant of matrix

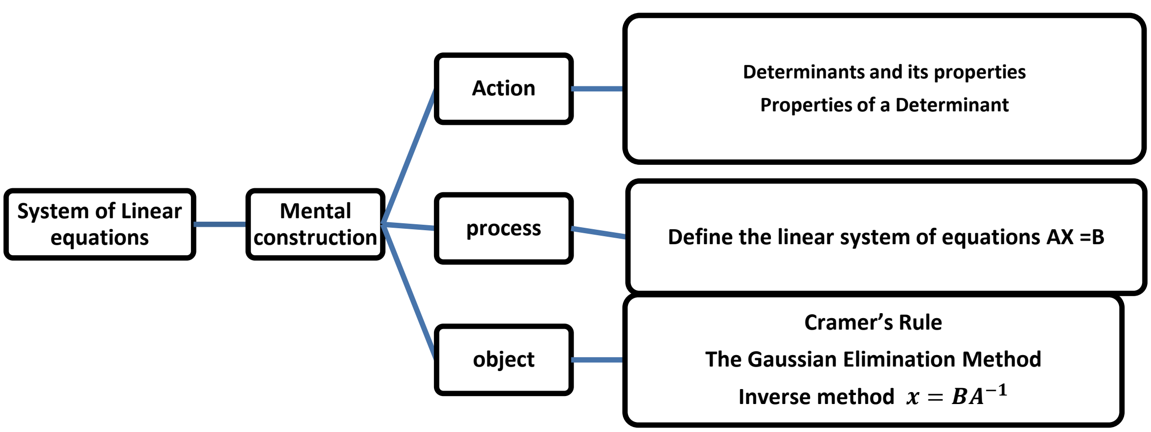


Figure 3. 11 Modified Genetic decompositions of Linear Equation System

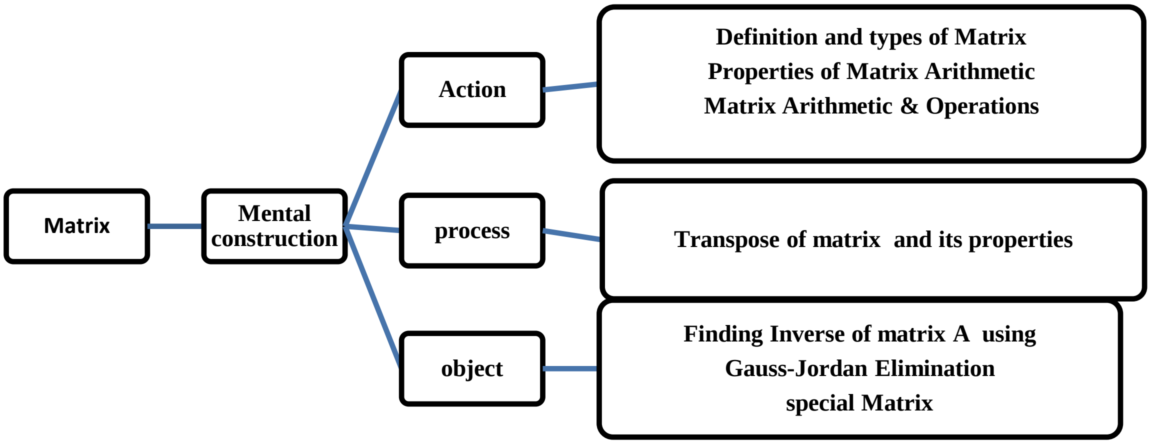


Figure 3. 12 Modified Genetic Decompositions of Matrix Algebra

In conclusion, the examples presented from various publications demonstrate how content selection and organization are crucial for research purposes and the development of curriculum. For the concept of a limit of a function, understanding starts with an action-oriented perspective, where individuals can manipulate an explicit expression and substitute values of x close to a in the function. As they progress, individuals with understanding of the process can construct mental processes to handle values of x near a and think in terms of inputs and transformations to produce outputs.Additionaly, situations arise where individuals need to apply various actions and processes, such as operations that combine functions to create a new function. Similarly, in the definition of the derivative of a function at x using the tangent of its graph, individuals begin with actions to connect two points on the curve and the calculate the slope of the corresponding chord. Through interiorization, these actions become a process for calculating the slope of a secant line as the point b approaches a. Eventually, this process is encapsulated into two objects, namely the tangent line at the point (a, f(a)) and the slope of the tangent line, which is the derivative of the function at x = a.

These examples, the concept of a limit of a function, the definition of the derivative of a function at x using the tangent of its graph , the definite integral for a general continuous function f(x) when x [a, b] ,polar coordinates, Riemann sum, understanding of integration, matrix, determinant and system of linear equations emphasize the importance of a systematic approach to curriculum development that considers the actions, processes and objects underlying each concept. By carefully selecting and organizing content, students can develop a deep understanding of mathematical concepts and their applications. This approach fosters the development of critical thinking skills and the ability to apply mathematical principles in various contexts.

3.2.2.2. Design and Implementation of Instruction

The second element of the framework revolves around the process of designing and executing instructional practices guided by theoretical analysis. The implementation phase often involves the utilization of the ACE teaching cycle, an instructional approach that facilitates the construction of the cognitive frameworks necessary for genetic decomposition. The ACE Teaching Cycle comprises three main components: Activities, Classroom Discussions, and Exercises. These components work together to create a comprehensive pedagogical strategy (Arnon et al., 2014). This aspect of the framework focuses on teaching and learning the industrial mathematics curriculum at science and technology universities (Arnon et al., 2014).

Design and implementation of the industrial mathematics curriculum

The APOS theory framework for research and curriculum development has guided the current study to analyse different countries (developed and developing) undergraduate and graduate industrial mathematics curricula. Based on the basic research questions raised in the study, the issues related to research in mathematics, teaching and learning of industrial mathematics, and curriculum development required a theoretical framework that indicated the direction of the research.

The APOS Theory centers around understanding the mental processes individuals go through while learning a mathematical concept. This theory is leveraged to develop instructional materials and assess students' progress and challenges when faced with mathematical problems. Ed Dubinsky, in collaboration with members of the Research in Undergraduate Mathematics Education Community (RUMEC), including former students of Dubinsky, played a crucial role in creating the APOS Theory (Arnon et al., 2014). According to the framework, the evolution of a mathematical concept can be understood as a transition from an initial action-based understanding (intra-operational) to a more refined and interconnected understanding (inter-operational) through a process known as interiorization, which involves reflective abstraction. The outcome of this progression is a well-developed cognitive process (trans-operational) that can be represented as an object. The framework also emphasizes that these object representations can be revisited and transformed back into processes when needed. Schemas, which consist of coordinated actions and processes, can similarly be organized into objects (Cottrill, 2003).Dubinsky (2014) translated Piaget's "Interiorized operations" as Processes, "translation" as the APOS mental process of "interiorization," "Material" action as "Action," and "System" as a "Schema". The Action-Process-Object-Schema (APOS) theory is a learning theory that focuses on the development of individuals' mathematical thinking. The APOS theory describes the four phases of mathematical understanding as follows (Syamsuri, Purwanto, Subanji, & Santi, September 2017).

3.2.2.2.1. Activities

The initial phase of the ACE teaching cycle involves engaging students in interactive activities that are designed to facilitate the development of the cognitive structures proposed by genetic decomposition. These activities encourage students to work collaboratively in teams, with the main objective being to promote reflective abstraction rather than solely focusing on obtaining correct answers. Reflective abstraction draws upon Piaget's concept of general coordination of actions, where the internalization of knowledge takes place. As per the theory, there are five forms of reflective abstraction:

interiorization, encapsulation, de-encapsulation, coordination, and reversal. These different types contribute to the cognitive growth and understanding of the subject matter.

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In advanced mathematical thinking, reflective abstraction is used. There are four steps to our educational method to encouraging conceptual thinking in mathematics. First, watch students while learning a certain topic or group of topics to see how their conceptual frameworks, or idea images, are growing. Second, analyse the data and, based on these findings, the theory presented in this work, and the designer's knowledge of the mathematics involved, create a genetic decomposition for each issue of concern that reflects one possible way a subject can construct the concept. Third, create activities and situations that will encourage students to produce the specific reflective abstractionrequired. Construct activities and create scenarios that will encourage students to make the specific reflective abstractions that are required. Fourth, continue the process as long as possible or until stabilisation occurs, modifying the genetic decomposition and the educational treatment (if it does) (Dubinsky, p. 120).

The design and implementation of industrial mathematics instructions involve various activities, including:

1. Utilizing existing resources like carefully structured books or materials as a foundation for an activity or course.

2. Presenting the problem statement in a general manner and providing 3-4 relevant articles or sources.

3. Incorporating case studies into classroom discussions and assigning open-ended problems for team-based assignments outside of class.

4. Introducing only the problem statement to encourage students to explore and devise their own solutions.

5. Directing students to important concepts or courses in related disciplines or other disciplines and promoting active problem-solving rather than passive learning. While

opinions on the role of books may differ, there is a consensus on the need for shared resources for industrial problem-solving(Nigam & Rodrigues, 2013).

3.2.2.2.2.The Classroom Discussion

During the classroom discussion phase, students engage in collaborative discussions led by the instructor within small groups. These discussions revolve around paper and pencil tasks that complement the lab activities completed in the previous activities phase, as well as calculations assigned by the instructor. The purpose of these discussions and in-class work is to provide students with an opportunity to reflect on their previous work, particularly the activities conducted in the lab. As the instructor guides the discussion, they may offer definitions, explanations, and present an overview to help tie together the concepts and ideas that the students have been exploring and working on. This part of the cycle specifically focuses on the undergraduate industrial mathematics curriculum at the university level (Arnon et al., 2014). Industrial mathematics is an interdisciplinary field that focuses on real-world challenges. As a result, teaching industrial mathematics connects mathematics in the workplace with school mathematics. One of the problems in teaching industrial mathematics was that the mathematician did not fully know the industrial context of the mathematics they taught in university, and industrial experts were also not aware of what mathematical concepts they used in their working conditions. To minimise these gaps, university-level teaching and learning are organised in order to make industrial mathematics visible through the following mechanisms: (1) Collaborate with teachers and experts in other disciplines to expose mathematics in context. (2) Open some black boxes(refers to a testing strategy in which internal operations are not taken into account.The inputs and outputs are highlighted.) at every level (e.g., at the undergraduate level, write your own Differential equation solver to understand the software black box). (3) Share and disseminate good examples, e.g., on the Web. (4) Stimulate, encourage, and reward curiosity (Nigam & Rodrigues, 2013). Students can acquire skills and knowledge in the following areas, partially in connection with specialised scientific courses and partially in specialised modules: Presentation and lecture techniques, Project development, Methods of scientific work, Industry-relevant software tools, History of science and mathematics and Professions and professional practise. Moreover, practical work: A computer lab, work on smaller projects within a modelling lab, and, if applicable, laboratory courses in the technical subject are mandatory and students may complete a professional internship of several weeks to gain insight into future mathematical professional practise. (University of Bremen 2021).The role of technology in teaching learning mathematics nowadays becomes an important part of the higher education program. The students are also aware of the new technology and are eager to use it. Therefore, the higher education curriculum development process should include technology as a teaching method.

In order to better understand the role of technology in the educational interfaces between industry and mathematics, for instance, it may be useful to make a distinction between technology created and used to help industry do its job—often referred to as "indutech" (Industrial technology)).—as well as "edutech," or educational technology, which was developed specifically to support the teaching and learning of mathematics and its use, for example, in industry. (Damlamian , Rodrigues, & Sträßer, 2013). Mathematics-specific software applications are tools with the ability to increase students' conceptual understanding mathematical modeling, visualization and simulation. Educational technologies like: Teaching management systems, dynamic learning tools such as GeoGebra, Desmos, Matlab, etc. are recommended for teaching mathematics in higher education (Nantschev , et al., 2020). In Ethiopian higher education, MATLAB software supported learning in teaching Applied Mathematics II for Engineering and science students in university (Gemechu, Mogiso, & Husen, 2021). Because communication skills are crucial for employment in industry, it is desired to have these abilities taught and mastered in all areas of education and training. Effective communication and cooperation are fundamental and integrated aspects in the practical application of mathematics in industry.

• Incorporating real-world problem scenarios into mathematical education at all levels can serve as a means to teach mathematics within its contemporary context. Such problem-based approaches heavily rely on effective communication throughout the learning process.

• Teaching communication skills, including listening, writing, speaking, and utilizing communication technologies, naturally complement the mathematics learning process.

• Assessing communication skills, encompassing listening, writing, speaking, and utilizing communication technologies, naturally align with mathematics assessments.

• Collaborative learning should be introduced in primary education and fostered as part of lifelong learning. For instance, activities like planning and creating healthy soft drinks in primary school, analyzing strategic games or simulating operating a small business in secondary education, and tackling real industrial problems in tertiary education serve as illustrative examples. (Damlamian, Rodrigues, & Sträßer, 2013)

In the teaching and learning of industrial mathematics at the University of Wolverhampton, students are entitled to:

1) Students will be provided with a digital copy of all course materials created by the lecturer. Each module will have a dedicated section on the Wolf platform that contains links to the module guide, lecture slides and notes, workshop and tutorial exercises, assessment briefs and marking criteria, as well as mock test papers.

2) Certain programs offer regular online formative assessments accompanied by constructive electronic feedback to supplement your independent study and gauge your progress within the module. For example, the Wolf platform or a topic-specific system may administer weekly multiple-choice tests. In other modules, Wolf is utilized for formative learning activities, and your instructor may provide feedback on your performance during scheduled meetings, tutorials, or workshops.

3) Students will have the chance to engage in online collaboration with their peers within the learning cohort. Each module on the Wolf platform will feature a Course Café, allowing communication and discussion among colleagues regarding the module content. Furthermore, certain modules may offer forums or wikis specifically designed for discussing coursework tasks, sharing notes, and providing support materials. These platforms may also encourage active participation and contributions from students.

4) Students will have the chance to engage in electronic Personal Development Planning (ePDP) as part of their course. At each level of the course, there will be a module dedicated to developing skills in ePDP. Throughout the duration of the course, students

will create an e-portfolio using the PebblePad platform. In certain modules, PebblePad will serve as the submission system for assignments, allowing students to build a portfolio that showcases their skills to potential employers.

5) All face-to-face sessions within each module offer opportunities for interactive learning. These sessions encompass workshops, seminars, tutorials, and meetings. Additionally, certain modules and subject areas may offer additional support sessions, known as surgeries, where students can seek extra help and guidance. (Wolverhampton, 2017).

3.2.2.2.3. Homework Exercises

Homework exercises, the third part of the cycle, consist of fairly standard problems designed to reinforce the computer activities and the classroom discussion. The exercises help to support the continued development of the mental constructions suggested by the genetic decomposition. They also guide students to apply what they have learned and to consider related mathematical ideas. The ACE Cycle and its relationship to genetic decomposition are illustrated. The third part of the cycle consists of fairly standard problems designed to reinforce the computer activities and the classroom discussion. The exercises (assessment and evaluation) help to support the continued development of the mental constructions suggested by the genetic decomposition (Arnon et al., 2014). More recent evidence (Manivannan & Suseendran, 2017) proposes that another course design and delivery mechanism (model) between university and industry was the model for the design and delivery of courses in the programme, inspired by the Plan-Do-Study-Act (PDSA) cycle: "Plan (selection of stakeholders involved, definition and joint discussion of course objectives, contents, and participations of the stakeholders in the course (iterative process to reach that), planning Resources , After the first cycle, plan the actions decided in the previous cycle.

Do (Course delivery) Study (Assessment of the accomplishments of the objectives, inputs by teachers and industrial participants, and Analysis of the results)

Act (Decide the actions to modify the course in the next edition based on the previous analysis of the result). "A successful partnership requires a good fit between the expectations, the time scales, and the expertise of the partners. A project that is undertaken jointly must be properly structured, and the partners must share a reasonable expectation that it is necessary. In designing curriculum, the collaboration of universities and industry in teaching and training could be in one of the following aspects:

a) Industry participation in academic planning and course design

b) In-kind support by industry (donation of equipment, student scholarships, teaching grants)c) Placement of staff by industry at the university as part-time professors, visiting professors, or executives in residence

d) Industry provision of on-the-job training opportunities (co-op programmes, summer jobs) and of part-time work opportunities

e) Delivery of specialised courses by universities (continuing education, executive development, customised specialised programmes)

f) Participation of university professors in industry-led professional development activities, faculty consulting in industry, participation on company boards, and other industry-driven committees (Sintayehu & Banbul, 2017)

3.2.3. Assessment and Evaluation in Industrial mathematics

Mehrens and Lehmann (1991) used the terms evaluation and assessment, which are occasionally used interchangeably, but most users make distinctions among them. Evaluation has, for instance, been defined in a variety of ways. Evaluation is "the process of delineating, obtaining, and providing useful information for judging decision alternatives. A second popular concept of evaluation interprets it as the determination of the congruence between performance and objectives.. Other definitions simply categorise evaluation as professional judgement or as a process that allows one to make a judgement about the desirability or value of something. One can evaluate either qualitative or quantitative data. Thus, measurement is not the same as evaluation. Two students may obtain the same measure (test score), but we might evaluate those measures differently. The term assessment is also used in a variety of ways. Much of the time, the word is used broadly, like evaluation, or it is often used to indicate the use of both formal and informal data-gathering procedures and the combining of the data in a global fashion to reach an overall judgement. At times, assessment is used more particularly to refer to the clinical diagnosis of an individual's problems. It is important to point out that people are never measured or evaluated and instead, their characteristics or properties are measured or evaluated, such as, their scholastic potential, knowledge of algebra, honesty, perseverance, ability to teach, and so forth. This should not be confused with evaluating the worth of a person. Teachers, parents, and students do not always seem to keep this distinction clearly in mind (Mehrens & Lehmann, 1991).

According to the OECD (2013), the terms evaluation and assessment can be distinguished as follows:

- Assessment pertains to the evaluation of individual students' progress and their attainment of learning objectives. It encompasses assessments conducted within the classroom setting, as well as large-scale external assessments and examinations.
- Evaluation, on the other hand, relates to the assessment of the effectiveness of schools, school systems, policies, and programs as a whole. It involves judgments regarding the overall performance and impact of educational institutions and initiatives.

Evaluation and assessment are frequently used to inform the formulation of policies, curricula, planning, reporting, improvement initiatives, budgeting decisions, resource allocation decisions, and performance management. (OECD, 2013).

The APOS conception can be designed for assessment in item form. In the industrial mathematics curriculum different assessment mechanisms are employed to support the continued development of the mental constructions suggested by the genetic decomposition. The APOS theoretical framework's viewpoint on assessment is that it should focus on two types of questions: 1) Has the student developed the mental constructions (particular actions, processes, objects, and schemas) that the research requires, and 2) Has the student learned the mathematics in the course? Positive responses to the first type of question allow one to claim that they have acquired mathematics based on these mental creations. This enables us to assess knowledge that the second type of question might not cover, albeit indirectly (Dubinsky, 1999). One very important aspect of industrial mathematics is the quality of the teaching assistant, who also grades the homework (Friedman, 1994).

The following are some Assessment techniques used in teaching learning Higher education programs:

i) Capstone courses that tie together different parts of mathematics;
ii) Comprehensive exams that examine advanced parts of a student's major;
iii) Core exams that cover what all mathematics majors have in common;
iv) Diagnostics exams that help identify students' strengths and weaknesses
v) Employer advisors to ensure compatibility of courses with stakeholder needs;
vi) Feedback from graduates concerning the benefits of their major program
vii) Focus groups that help faculty identify patterns in student reactions;
viii) Group projects that engage student teams in complex tasks;
ix) Individual projects which lead to written papers or oral presentations;
x) Interviews with students to elicit their beliefs, understandings, and concerns;
xi) Journals that reveal students' reactions to their mathematics studies;
xii) Oral examinations in which faculty can probe students' understanding;
xiii) Performance tasks that require students to use mathematics in context;
xiv) Research projects in which students employ methods from different courses;
xv) Samples of student work performed as part of regular course assignments
xvi) Senior seminars in which students take turns presenting advanced topics;
xvii) Senior theses in which students prepare a substantial written paper in their major;
xviii) Visiting committees to periodically assess program strengths (A.Steen, 1999)

<u>Assessment methods of Industrial Mathematics</u>

- Assignments – the coursework for this program typically includes task-based and report-based assignments. Students are often required to write reports documenting the process of developing solutions for various tasks. Additionally, it is common practice to ask students to reflect on their learning experience as part of the coursework, using the following approach.

- Case studies- realistic scenarios are utilized as the basis for the learning activities in this program. Through case studies that are suitable for the specific topic areas, students have the opportunity to enhance their skills in analysis, application, and evaluation. These case studies enable students to apply their knowledge and develop critical thinking abilities in practical contexts..
- Practical exercises – Tutorials and workshop sessions play a vital role in facilitating the comprehension and application of knowledge in practical settings. These sessions provide opportunities for students to utilize a range of IT tools, contributing to the development of practical skills..
- Portfolios or e-portfolios are collections of work samples that showcase the achievements and progress of students. They serve as effective assessment tools by providing multiple examples of work, allowing students to assess their own learning and growth over a period of time.
- Formal presentations are an integral part of this program, where students may be expected to deliver presentations to tutors or the entire class. These presentations can involve demonstrating practical work, showcasing projects or developments, or presenting the findings of a study. They serve as a significant means of assessing and evaluating students' communication skills.
- Examinations and time-constrained assessments (tests) play a crucial role in assessing students' breadth of knowledge. These assessments may adhere to traditional formats or be administered online. They are designed to evaluate the extent to which students have acquired a comprehensive understanding of the subject matter.
- In group project work, assessments are designed to ensure that individual contributions are adequately recognized and reflected in the grading process. Various mechanisms are implemented to achieve this, such as employing peer assessment to evaluate the individual contributions of group members. Additionally, individuals are encouraged to engage in personal reflection, both on the process and the final product of the group project.

- Peer-group assessment involves the use of student feedback, particularly in group assessments, to identify and evaluate each student's individual contribution to the collaborative work. This process allows for the assessment of each student's efforts, skills, and overall contribution within the group project.
- Individual Project Work - Every course mandates the completion of at least one module of individual project work, wherein students undertake a significant task on their own. This form of work is facilitated through either scheduled meetings with an assigned project supervisor or by attending seminars.
- Work-based assessments are employed to evaluate the student's work-based modules and to facilitate feedback from the organizations where they are placed for work experience. Typically, these assessments are utilized for students who are engaged in part-time courses while also being employed in the industry, or for students undergoing a placement. (Wolverhampton, 2017)

Based on the APOS theory of research and curriculum development, industrial problem solving follows the following problem solving procedure: Industrial Mathematics and its Applications (IMA) deals with the problems in the following order:: (THAPA, Industrial Mathematics Concepts, Algorithms and Complexity, 2005)

Reality → **Mathematical Model** → **Solution** → **Interpretation** → **Reality**

Summary

In this study, the initial phase of curriculum development involved conducting essential activities including problem analysis, context analysis, needs analysis, and evaluation of the existing knowledge base (Celia & Elize, 2014). The study examined the first research question regarding the strengths and limitations of the current mathematics curriculum, as well as the second question on challenges related to curriculum development and implementation in industrial mathematics. This examination was carried out by investigating participants' practices in curriculum development and review programs, identifying barriers to curriculum development, and incorporating mathematics specialists in industries. The analysis of the current mathematics curriculum at Ethiopian universities was based on specific criteria such as the curriculum's content, teaching and learning methods, practical application in solving real-world problems, and opportunities for graduates in the job market.

Furthermore, the study addressed the third and fourth research questions which focused on mechanisms for promoting industrial mathematics within industries and the advantages of utilizing Industrial Mathematics to enhance career development in terms of research, teaching, training, and mentorship. Lastly, the study explored the final research question concerning the selection of industrial mathematics content utilizing the APOS theory framework in research and curriculum development. Within this framework, the content and learning experiences were structured based on the Action-Process-Object-Schemas approach.

CHAPTER FOUR: RESEARCH METHODOLOGY

4.1. Introduction

The purpose of this study was to examine and understand issues and challenges related to the development and implementation of curricula in science and technology universities. This was done to establish a strategic framework for designing and implementing industrial mathematics curricula tailored to Ethiopian science and technology universities. To achieve this goal, the researcher selected a research approach that was aligned with the research questions and objectives of the study. It was crucial to understand the stakeholders' requirements and opinions regarding to develop a framework for new industrial mathematics curriculum and their understanding of its interpretation. In this study, a mixed sequential explanatory method was employed, which involved two science and technology universities in Ethiopia. Through this approach, the researchers aimed to examine the process of developing and implementing the industrial mathematics curriculum within the context of these universities. This chapter offers a comprehensive explanation and description of the research methodology and design utilized in this particular study.

4.2. Research Paradigm and Design

4.2.1. Research Paradigm

A paradigm can be defined as a perspective or framework through which we understand and study various phenomena. It encompasses a range of concepts, including our worldview, accepted scientific knowledge, preferred methods of investigation, shared beliefs, and problem-solving approaches. In the context of research, a paradigm guides researchers in how they approach their work and determines accepted practices within a specific research community (Cohen, Manion, & Morrison, 2018). One paradigm suggested for conducting mixed-methods research is pragmatism (Creswell, 2014). Pragmatism does not adhere to a specific philosophical system. Instead, it emphasizes the practicality and usefulness of different methods and approaches. In the context of mixed methods research, pragmatism allows researchers to freely draw from both quantitative and qualitative assumptions and methods based on the specific needs and goals of their study. This flexible approach enables researchers to combine the strengths of both approaches to gain a more comprehensive understanding of their research topic.

In general, adopting a pragmatism paradigm in mixed-method research means that researchers are not bound by rigid methodologies or theoretical frameworks. Instead, they have the freedom to choose and integrate different methods and assumptions based on what is most appropriate for their particular research question or problem.

4.2.2. Research Design

The research design is a crucial aspect of a study as it determines how evidence is gathered and utilized to address the research goals, objectives, and questions. It acts as a logical framework that connects these elements to the collected data and the resulting conclusions (Creswell, 2014). The research design serves as a comprehensive plan and basis for approaching, operationalizing, and investigating the research problem or issue at hand. It outlines the specific approach, theory, and methodology that will be employed. Additionally, it specifies the types of data needed, the instruments to collect them, and the target population or sample. The research design also delineates how the collected data will be analyzed, interpreted, and reported. Moreover, it includes the warrants or justifications that support and defend the derived conclusions from the research. Lastly, the design evaluates the validity and reliability of each research element, thus establishing the level of confidence that can be placed in the findings (Cohen, Manion, & Morrison, 2018).

4.2.2.1.Sequential Explanatory Mixed Method

Mixed method research designs refer to the systematic approaches used to gather, analyze, and integrate both numerical and qualitative data within a single investigation or a chain of studies with the intention of comprehending a research issue (Creswell, 2012). The focus of this study was to explore the perspectives of stakeholders regarding the development process and practices of the new Industrial Mathematics curriculum in two intentionally selected science and technology universities in Ethiopia. To gather comprehensive information from various stakeholders, including industries and governmental organizations, the quantitative data collection method was deemed more reliable than the qualitative method, as it allows for broader coverage across all sectors examined. This approach ensures the study's transferability, enabling generalizations to be made. Following the collection and analysis of quantitative data from science and technology university teachers, managers, and industry experts, a subsequent qualitative data collection was carried out, supplemented by document analysis of industrial mathematics curricula from diverse African and European countries.

The choice of research methods should be predominantly influenced by substantive research questions and not only by methodological and epistemological considerations alone (Ahsbahs, Knipping, & Presmeg, 2015). In this study, the first four questions are dealt with through the quantitative analysis of stakeholder needs, while the fifth question focuses on the content analysis of the industrial mathematics curriculum. Using a mixed-method research approach allows researchers to capitalize on the advantages of both quantitative and qualitative data (Creswell, 2012). By combining these two types of data, there is a synergy that goes beyond what could be obtained from each component individually, resulting in a more comprehensive understanding and enhanced insights (Cohen, Manion, & Morrison, 2018). This collaborative approach acknowledges that the combination of quantitative and qualitative methods can yield greater value than their sum as separate components (1 + 1 = 3).

In this specific study, the term "understanding of the industrial mathematics curriculum development process and its implementations" pertains to acquiring a more comprehensive comprehension of the procedures and choices involved in developing the industrial mathematics curriculum and its actual application. This encompasses identifying the strengths and weaknesses encountered throughout the development of the curriculum and emphasizes the factors that have a positive or negative influence on its progression, ultimately affecting its practical implementation at both the BSc. and MSc. levels. The perspectives of stakeholders within the industrial mathematics education system in Ethiopian Science and Technology Universities, particularly those from the two sites included in the study, are taken into account to explore this understanding.

4.2.2.2.Rationale of Mixed Design Method

Mixed-method research design is a research approach that revolves around addressing a specific research problem, where methods and theories are chosen and employed based on their suitability and relevance to the current study (J. Privitera & Ahlgrim-Delzell, 2019). The strengths of a mixed-method approach to research are particularly apparent in this scenario. For example, when examining a new learning environment in school practice, there is typically limited existing knowledge regarding its effects. As a result, formulating effective hypotheses to guide quantitative research before entering the empirical field becomes quite challenging. Furthermore, qualitative research can be utilized to enhance the insights gained from quantitative monitoring studies, as there are numerous theories in mathematics education that can be applied on a more detailed level. In the larger context, qualitative studies have the potential to contribute to the creation of new learning environments, such as a fresh industrial mathematics curriculum within these environments. These new learning environments can then be systematically examined using quantitative methods (Kelle & Buchholtz, 2015).

This study aimed to gain insight into the development process and practices of the new industrial mathematics curriculum. Specifically, it focused on understanding these aspects from the viewpoints of stakeholders within two carefully chosen science and technology universities in Ethiopia.To obtain sufficient information from different stakeholders (industries and government organizations), the quantitative data collection method is more reliable than the qualitative method and covers all sectors in the study. This ensures the transferability (generalizations) of the study. After collecting and analyzing quantitative data from science and technology universities, teachers, managers, and industry experts followed up with qualitative data collection and analysis from different industrial mathematics curricula in various countries in Africa and Europe. The limitations that can be observed in using qualitative or quantitative methods can be improved by using mixed method methodology (Ahsbahs, Knipping, & Presmeg, 2015).

A sequential quantitative-qualitative design involves conducting a quantitative study initially to identify problem areas and research questions that can be further explored using qualitative data and methods. This approach is particularly useful for addressing challenges encountered in quantitative research, such as the potential lack of clarity in statistical findings, which may require additional contextual knowledge from a qualitative study to be adequately understood. Additionally, the quantitative sub-study within this design can facilitate systematic case comparisons in the subsequent qualitative study by determining criteria for case selection and providing a "qualitative sampling frame." This approach helps mitigate a significant threat to the validity of qualitative research, which is the potential focus on remote or marginalized cases (Cohen, Manion , & Morrison, 2018). For a number of reasons, Creswell (2012) advises using a mixed-method approach: First, whenever a mix of quantitative and qualitative data is needed to solve the study topic. Second, when utilising the benefits of both qualitative and quantitative data is desired. Thirdly, when it is necessary to examine both the qualitative and quantitative results of a study in order to create a thorough grasp of social processes. Last but not least, there are instances in which neither a qualitative nor a quantitative technique by themselves is adequate to handle the research problem or fully address the research objectives. Given the research questions and objectives of the study, mixed methods research is deemed more appropriate to conduct a comprehensive investigation. This approach enables the exploration of data collected from individuals who are directly or indirectly engaged in the curriculum development processes and those who are currently experiencing it at the institutional level. By combining both qualitative and quantitative methods, the study can delve deeper into the research questions and ultimately achieve its set objectives.

4.3.Procedures for Selecting the Sites and Participants

The initial phase of data collection involved the decision about which sites to select and which to involve in the questionnaire and/or in focus group discussions. This was a very crucial stage in determining whose ideas, perceptions, experiences, and attitudes will be most important to answer the research questions and achieve the research objectives. Finally, the decision was made according to the criteria described below.

4.3.1. Site Selection

The two science and technology/engineering institutions, namely Addis Ababa Science and Technology University (AASTU) and Adama Science and Technology University (ASTU), were deliberately selected as sites for the study in anticipation of the availability of sufficient numbers and appropriate participants within these institutions. Although the two institutions currently share some common culture of higher education at present, they are also different in some respects. It is generally believed that each institution has its own unique culture and that specific cultures are shaped by the shared experiences of participants.

The two purposely selected sites are more or less similar in their vision and mission since they both are obliged to enforce their activities on the basis of the education policy (MOE, 1994) and the higher education proclamation 650/2009 (GAZETTE, 2014). Although they are different in their previous experiences of providing science and technology and engineering education, at present they all stick to using the reformed engineering and applied science education curriculum, which was developed under the support of the former Engineering Capacity Building Program (ECBP), and are expected to make progress in that provision (Mesfin, 2016). However, they are different in their geographic location, historical background, experience in providing science and technology/engineering education, the number and level of qualification of their teaching staff, and the physical and other resources at their disposal. For instance, Addis Ababa Science and Technology University is somewhat younger in terms of the length of time they have existed as science and technology/engineering education institutions and in terms of their experiences in providing science and engineering education. However, ASTU has a long and rich history of providing engineering education that dates back to the late 1950s. However, at present, they are all involved in providing undergraduate engineering courses and applied science in different fields of study based on the ideas of the reformed engineering education framework, which was initiated by the Engineering

Capacity Building Programme (ECBP). To obtain reliable data on the topic under study and to have a better understanding of it, it was necessary to involve purposely selected participants from each of the selected sites. Table 4.1.

Table 4. 1 Cross tabulation of Research Site with corresponding Institutions

	Research Site			
Institutions	ESTU	Industry(Gov.)	Industry(PLC)	Total
Airlines	0	5	0	5
AASTU	66	0	0	66
ASTU	46	0	0	46
Breweries company	0	0	6	6
Electric Power	0	5	0	5
Metal Industry	0	16	4	20
Road Administration	0	5	0	5
Sugar corporation	0	0	5	5
Telecommunication	0	5	0	5
Total	112	36	15	163

The criteria and reasons for the selection of the above institutions were based on their purpose and relationship with the Universities of Science and Technology. The two science and technology (S&T) universities, namely AASTU and ASTU, were selected because the government considers them central to the national industrial strategy and the goal of becoming a middle income economy by 2025. The Addis Ababa Science and Technology University (AASTU) in this study is now represented as ESTU-1, upgraded from an Institute of Technology, and the Adama Science and Technology University (ASTU) is now represented as ESTU-2, split from a comprehensive university. After a few years of operation, the two universities were moved from the Ministry of Education to the Ministry of Science and Technology to allow different ways of managing staff and admitting students. These two universities are expected to focus on applied research and technology transfer (Salmi, Sursock & Olefir, 2017). The seven governmental and private industries were selected under the guidance of the Offices of University Industry Linkage (UIL) and Technology Transfer (TT) based on their active collaborations with the two Universities. Some of the activities or projected interactions between the academics and industries were as follows. Through UIL and TT consulting projects between universities and sugar corporations on runoff and sediment load estimates; a consultancy project with breweries share companies on fermentation process optimisation; providing technical training for Electric Power Corporation; and another training programme conducted on mechatronics and advanced industrial automation delivered to metal industry workers (AASTU, 2020).

4.3.2. Participant Selection for Individuals and Groups

There are many actors in the industrial mathematics curriculum development process and its practises; given the aim of the research, capturing the ideas of stakeholders was included in this research. Since the programme is new, the primary focus was given to academic communities (Applied Science and Engineering Instructors) and industrial experts to serve as crucial participants in this research, the curriculum development process and its practises. Teachers are the ones who implement the curriculum and industries are the ones who are expected to be affected by the curriculum to result in the desired outcomes. Therefore, teachers who were purposely drawn from the two sites of higher education institutions of science and technology were invited to participate in the questionnaires and focus group discussions. The second important participant in this research is industry experts, who are closely working with the two science and technology universities. In this curriculum development process, industry professionals are expected to be involved from the beginning to the implementation stage of the industrial mathematics curriculum development process. Data were also collected from purposely selected representatives of industry for their previous and present knowledge, acquaintance, and proximity to the subject being studied. The details of the sample selected are as follows: The selected dean of the college, the department heads, and the experienced teaching staff of the School of Applied Natural Sciences, School of Civil Engineering and Architecture, School of Electrical Engineering and Computing, School of Mechanical, Chemical and Materials Engineering, College of Natural and Social Sciences, and College of Biological and Chemical Engineering of the two institutions are included as participants in this study. Focus on teachers of mathematics areas was made because they are the primarily responsible for the industrial mathematics curriculum as separate fields of studies within the science and technology universities education system and are available within the two institutions selected for this study. Experienced teachers from each of the fields of study who are believed to have a better experience and the ability to share their lived experiences in the curriculum development process and in implementing the reformed curriculum were selected using the purpose sampling method. Access to the participants was provided through the deans of the respective institutions upon receiving a letter from the vice president of the academy office of Addis Ababa Science and Technology University and the office of the University-Industry linkage Directorate of Addis Ababa Science and Technology University **(see Appendix –G & H).** Deans and department heads were also participants in this research because of their proximity to the curriculum development process and their participation in its practices within their respective institutions both in teaching and in leading.

4.3.2.1.The Study Participants' Profiles

As already discussed, the study was conducted in two phases:first quantitatively and then qualitatively. Instructors were involved in both phases whileIndustry experts were involved in the first phase only. Based on the information acquired during the focus group discussion and from the survey questionnaire, the profiles of the participants are presented as follows:

4.3.2.1.1. Instructors' profiles

As explained earlier, instructors were involved in both phases of the study. In addition toThe instructors who participated in the first phase were a small sample of instructors.in the second phase of the study, as its purpose was purposive sample data gathering. The profiles of these instructors and industry experts are summarised in Tables 4.1 and Table 4.2, respectively.

Table 4. 2 Instructors Research site, Departments, Education and services Years

Research Site	Department	Educational level	Respondents Service Years <=5	6-10	11-15	16-20	>=21	Total
ESTU-1	Mathematics	Ph.D.		2	2	2	0	6
		Second Degree		7	6	1	1	15
	Applied Science	Ph.D.		3	7	3	2	15
		Second Degree		3	3	0	3	9
	Engineering	Ph.D.		3	3	3	3	12
		Second Degree		4	1	2	2	9
	Total	Ph.D.		8	12	8	5	33
		Second Degree		14	10	3	6	33
		Total		**22**	**22**	**11**	**11**	**66**
ESTU-2	Mathematics	Ph.D.	0	0	2	4	3	9
		Second Degree	2	2	7	2	0	13
	Applied Science	Ph.D.	0	1	5	4	2	12
		Second Degree	1	1	1	1	0	4
	Engineering	Ph.D.	0	2	1	1	1	5
		Second Degree	1	1	1	0	0	3
	Total	Ph.D.	0	3	8	9	6	26
		Second Degree	4	4	9	3	0	20
		Total	**4**	**7**	**17**	**12**	**6**	**46**

Key: ESTU (Ethiopian Science and Technology University) , ESTU-1 : refers to one of the science and Technology university and ESTU-2 : stands for the second one.

Table 4.2 describes the profiles of the instructors involved in the study. In total, one hundred and twelve instructors from two universities participated in the study. As the table shows, 112 instructors who were from the disciplines of applied mathematics (38%) (Differential Analysis, Numerical, Algebra, Optimisation, Modelling, and Mathematics Education), from the disciplines of applied sciences 36% (Industrial Chemistry, Physics, Biotechnology, Food science, Statistics and English) and from Engineering 26% (Civil, Electrical, Mechanical, Electro-mechanical, Computer, Architecture, Water and Sanitary, Environmental and Chemical Engineering) participated in the study. The levels of education of the instructors ranged from second degree to PhD; 53% of them were Ph.D. holders and 47% of them were second degree holders. Regarding the teaching experiences and services in the university of these instructors, the sample ranged from those who taught for just one year to those who taught for more than 20 years in a university context. The majority of the instructors, 108 (96%) of them, have served more than five years in a university or in industry.

4.3.2.1.2. Profile of Industry Professionals

Table 4. 3 Cross tabulation of Research Site, Departments, and Educational Status

			Respondents Service Years					
Research Site	Department	Education	=< 5	6-10	11-15	16-20	>= 21	Total
Industry(G)	Engineering	First Degree	7	13	1	0	1	22
		Second Degree	3	2	2	3	3	13
		Total	10	15	3	3	4	35
	Management	First Degree	0	0	1	0	1	2
		Second Degree	0	2	0	0	1	3
		Total	0	2	1	0	2	5
	Total	First Degree	7	13	2	0	2	24
		Second Degree	3	4	2	3	4	16
		Total	10	17	4	3	6	40
Industry(P)	Engineering	First Degree	0	2	0	0	0	2
		Second Degree	1	0	3	1	1	6
		Total	1	2	3	1	1	8
	Management	Second Degree	2	0	0	0	1	3
		Total	2	0	0	0	1	3
	Total	First Degree	0	2	0	0	0	2
		Second Degree	3	0	3	1	2	9
		Total	3	2	3	1	2	11

Table 4.3 (above) shows the industry professional departments (field of study) and their educational level with service years. The research site covers governmental industries (G) and private limited companies (P)) that have strong industry-university links. The industrial sites are found in Addis Ababa and Adama. The industries were chosen based on their ties to both science and technology universities, as well as those that signed memoranda of understanding with both institutions and currently have joint research and academic programmes with the two universities. In Ethiopia, many industrial parks were developed near the top ten universities in the country. Most of the industries and industrial parks are located near the two science and technology universities due to their proximity to the capital city and their infrastructure development. From industries, participants were 85% from the field of engineering and 15% from the field of social science (Management). Out of the total participants, (69%) were Engineers from government institutions, (16%) were from private industries, and 15% were from the field of social sciences. Participants from the fields of Engineering have the following

positions: expert on university and research institutes training, vehicles and fabrication products assistant researcher, Senior Electrical engineer, Senior Mechanical Engineer, Senior Manufacturing Technology Engineer, Design Engineer, Innovation section leader at research and development, Project Coordinator, Geothermal Power Engineer, Power System Planning Electrical Engineer, Generation Engineering Design, Senior and junior Training Developer, RAN optimization Specialist, optimization Engineer, Electrical Engineer, Maintenance Engineer and Assistance Safety Manager, IT project Manager and Data Management. Participants from the fields of social science have the following job positions: Total Productivity Management Facilitator, Human resource management (HRM) Executive officer, supervisor, administration, finance & procurement supervisor, and Branch Manager and Service head.

Table 4. 4 Frequency of Respondents Position with their respective institutions

	Research Site			
Current Position	ESTU	Industry (Gov.)	Industry (PLC)	Total
Associate Deans	8	0	0	8
College Deans	7	0	0	7
Department Heads	13	0	0	13
Directorates	10	0	0	10
HLM	0	3	5	8
LLM	0	17	4	21
MLM	0	16	6	22
Teachers	72	0	0	72
Vice President	2	0	0	2
Total	112	36	15	163

Key: HLM= Higher Level Management, MLM = Middle Level Management, LLM=Lower level management

The institution's position was a key factor during curriculum development and review programmes because they were the first to be exposed to them. They are occasionally anticipated as powerful individuals, both positively and negatively. In Ethiopia, the researcher's long-standing stance is linked to the winning ideologies of the political parties. Consequently, the ideologies of the parties also influenced the educational systems. Positions in academic institutions are consequently also subject to this pressure.

4.4. Data Collection Methods and Techniques

Data collection procedures pertaining to the research questions and objectives were collected from different sources using different data collection strategies. Primary data were collected using questionnaires (see Appendices C and D) and focus group discussions. Secondary data were obtained from written and recorded documents that included policy materials, curricular documents, and industrial mathematics curricula from different countries.

4.3.3. Getting Ready for Data Collection

For conducting the research within the selected science and technology universities, governmental organisations, and industries, primarily a letter of request was secured from Addis Ababa Science and Technology University Vice President for Academic Office and University-Industry Linkage Directorate (see Appendix-E). At the initial stage of contact with personnel in the research sites, a copy of the letter was delivered to Adama Science and Technology University Academic Vice President for Research, and the vice presidents forward copies of the letters to all purposely selected school deans, departments, and experienced staff through the heads.

Likewise, the University-Industry Linkage Directorate assigned thirteen purposely selected industries that have a potential participant in the curriculum development programme, and the same copy of the letter was delivered to the appropriate offices (e.g., public relations office, human resource development office) of each of the industries. Out of thirteen industries, ten, in which the researcher and the University-Industry Linkage Directorate thought that they were the most significant employers or consumers of mathematics, were contacted with the anticipation of questionnaires as key informants in each of the industries. From here, the letter was forwarded to the persons who were considered knowledgeable on the subject of the study by the officer in charge (see, for example, Appendix-F).

The vice president and directors of the academic institutions were contacted at the initial stage of data collection within the sites because they are the highest administrative officials responsible for academic matters within those institutions. After the researcher introduced himself and explained why he was there and what he needed, the officials signed and forwarded the same letter that carried a short memo, their signature, the names of the deans with whom the researcher should contact, and the institution's stamp on it to the deans (see Appendix-E). A photocopy of the signed letter was again delivered to each of the deans. As the researcher delivered the letters to the respective deans, he also introduced himself and briefly explained the title and purpose of his research, and he ultimately told each of them that he needed them to fill out the questionnaires with two options: one with a printed copy and the other on a Google Form. Each of the deans received a copy of the signed letter that had been photocopied. Most of the participants, whom the researcher contacted, were willing to fill out the questionnaires through the Google form, and some of the respondents preferred printed questionnaires, but three of the respondents who preferred the printed copies forgot to fill out the questionnaires. For the respondents who were unable to fill out the printed copies, the researcher provided them with Google Form questionnaires through their email by taking the respondents e-mail address and phone number to remind them to fill out the form with their permission. The selection of the teachers from applied science and engineering schools began and continued with the advice of the deans and department heads. The deans and department heads were purposely selected by the researcher because they were appropriate persons for leading curriculum development programmes in their respective fields of study. In other cases, they directed the researcher to the department heads for carrying out the selection of the participants. The department heads and the deans also identified the names of appropriate people whom they thought were knowledgeable on curriculum development and who had more experience in practising it for the questionnaires. Having secured the names of the possible "would-be" candidates, the researcher went to each teacher's office to ask for their permission and willingness to answer the survey questions. Many of them responded positively to his request. Soon after, he introduced himself and briefly explained the title and the purpose of his research to them.

Focus group discussions with mathematics teachers were also conducted by negotiating with the head of the department of mathematics and dean of the College of Natural Science and Social Sciences during their meeting. They provided the researcher with an opportunity to present the research proposal and discussion points to the staff. While some of the representatives opted to participate in the group discussion, others pointed out and picked those they thought had better knowledge of the subject under study. The second discussion group was conducted on the day the department organised a PhD curriculum development programme in applied mathematics at Addis Ababa Science and Technology University. Participants in this programme were invited from different universities in the country and stakeholders from industries and government organisations. The researcher purposely planned the discussion by preparing questions related to curriculum practise in Ethiopian Higher Education and the needs assessment of the stakeholders for the purpose of mathematics in industries. All the stakeholders' presentations and comments were relevant to the "Industrial Mathematics Curriculum "need for Ethiopian science and technology universities. The reports on relevant issues to this study are included.

The survey questions were conducted from the beginning of November, 2021, to the first week of December, 2021. During this period, the researcher submitted the consent letter to authorised personnel for permission; sometimes this took more than a week for a decision because industries and government organisations evaluate the contents of the questionnaires related to their institution's policy on providing institutional information that does not harm their institution. Two of the industries refused to provide information about their company; one industry asked the researcher to modify two items that were expected to be company secrets and accepted the rest of the items in the questionnaires. However, the modified questions did not affect this study, and the researcher accepted their modification.

4.3.4. Strategies for Data Collection

Three different types of data collection strategies were used in this study: questionnaires, group discussion, and document analysis of various types and natures. These are described below.

4.3.4.1.Data Collection Procedures for the Quantitative Phase

4.3.4.1.1. Questionnaire

Written questionnaires can be distributed to a large number of people, including those who live in distant locations, potentially saving a researcher travel expenses or lengthy telephone calls. Also, participants can respond to questions with anonymity—and thus with some assurance that their responses won't come back to haunt them. Accordingly, some participants may be more truthful than they would be in a personal interview, especially when addressing sensitive or controversial issues (Leedy, Jeanne, & Laura, 2021). In this study, different kinds of written questions were developed and distributed to the participants. The written questionnaires give time to read and think about how to respond to each item with free will. The following types of questionnaires are used to collect participants' responses: dichotomy, check list, four, five, Five and nine-point rating scale, Closed and Open questions.

Dichotomous questions are used, and then it is desirable to use several questions to gain data on the same topic in order to reduce the problem of respondents 'guessing' answers. A checklist is a list of behaviours or characteristics for which a researcher islooking. The researcher—or, in many studies, each participant—simply indicates whether each item on the list is observed, present, or true, or, in contrast, is not observed, not present, or not true. A rating scale is more useful when a behaviour, attitude, or other phenomenon of interest needs to be evaluated on a continuum of, say, "inadequate" to "excellent," "never" to "always," or "strongly disapprove" to "strongly approve." (Leedy, Jeanne, & Laura, 2021).(Refer appendix-C and D)

4.3.4.2.Data Collection Procedures for the Qualitative Phase

Purposeful sampling is the research term for qualitative sampling. In purposeful sampling, researchers deliberately choose people and locations to discover or comprehend the primary phenomenon (Creswell, 2012). In the focus group discussion, the participants and research site are selected based on the conditions favourable to obtaining reliable information when the participants are ready for discussion. The researcher arranges time with the school head and department head to use the school's weekly meeting time for the discussion.

4.3.4.2.1. Focus Group Discussions

The qualitative data for this study were gathered through seminar-style focus group discussions with Applied Science and Applied Mathematics instructors. The researcher will introduce the objectives and basic research questions to the participants. At the beginning, the researcher prepared semi-structured interview questions for the participants. After conducting a questionnaire, he recognised that focus group discussions provided better information than interviews. Since the majority of respondents were unfamiliar with the study's findings, the focus group discussion provided a chance for participants to express their thoughts and get fully engaged in debate.The essential points brought up by the focus group discussants were noted down by the researcher, and when a notion was unclear, the discussants were questioned about it. The focus group discussions (FGDs) were restricted to professors in applied science and applied mathematics groups; data saturation was noticed, and the focus group discussants then presented fresh ideas.(Appendix-E)

4.3.4.2.2. Document Review

The study also gathered additional data from printed and other recoded documentary sources, such as course catalogues, framework directives, yearbooks, Society for

Industrial and Applied Mathematics (SIAM) and OECD-Reports, industrial mathematics curricula of ten different countries, and other pertinent materials. These resources proved to be of great use to the researcher as he looked into the perspectives, contexts, orientations, and objectives of curriculum creation in general as well as the procedures and practises of industrial mathematics curriculum development in particular. The general and specific contextual information for this study were provided by context-specific materials like the Ethiopian Education and Training Policy (ETP), the Growth and Transformation Plan (GTP), the Education Sector Development Plans (ESDP-V), proclamations, and many other documents of this type and Curriculum in higher education. Obtaining related literature on industrial mathematics and mathematics in industrial application in Ethiopian higher education context was one of the limitation of this study to undertake document evaluation.

4.4.Data Collection and Analysis in APOS theory

A genetic decomposition is nothing more than a theory without empirical approval, hence the data collecting and analysis step is crucial for APOS-based research. Finding the answers to two questions is the purpose of data analysis.

(1) Did the students appear to create the mental structures that the genetic decomposition described?

(2) How well did the students understand the concept? (Arnon, et al., 2014)

Different tools are used to explore these two issues. Depending on the objectives of the research, examaminations, audio and/or recorded semi-structured interviews, and written surveys may be employed. The technique may include things like textbook analysis, classroom observations, and historical and epistemological research. Examples from the literature are provided to illustrate the many instrument types that can be employed in the methodological design of a research project. In each of these cases, the analysis is triangulated through joint research, in which researchers discuss findings until they come to an agreement on how to interpret them, and/or by utilising various research tools in a single study (Arnon, et al., 2014).

The following data collection instruments are proposed for APOS-based research conducted to obtain empirical evidence on the contents of industrial mathematics selected based on preliminary genetic decompositions:.

Interviews

Interviews are the most important means by which data is gathered in APOS-based research.

- An interview can be used to evaluate mathematics performance across various teaching philosophies and assess students' attitudes.
- The major goal is to find out if students have employed the mental constructs suggested by the genetic decomposition used in a certain research.
- Subjects for interviews may be chosen based on their answers to a written questionnaire or previously given test, teacher comments, or a combination of these factors. (Arnon, et al., 2014)

The goal is to compare the thinking of students who struggled with that of students who excelled by accessing data that displays a variety of arithmetic performance on various mathematical problems. By comparing these discrepancies, the researchers can decide whether the mental constructions required by the theoretical analysis account for disparities in performance or whether alternative mental constructions that are not taken into account by the theoretical analysis are required.. (Arnon, et al., 2014)

Written questions

Written questions in APOS-based research are carefully crafted to help gather evidence for the existence of the mental constructions predicted by the preliminary genetic decomposition and to suggest changes to the pedagogical strategies and/or the genetic decomposition when these constructions are absent. Additionally, they enable researchers to concentrate on the elements of knowledge building that they are researching. The written questions should be organised based on the genetic decompositions. 1) Construction of Process conceptions 2) Check for interiorization of Actions, 3) To determine whether encapsulation had occurred; and 4) How a genetic decomposition informs the design of written instrument questions (Arnon et al., 2014).

Classroom Observations

When the training is not founded on pedagogical components connected to APOS Theory or is carried out by instructors with little to no familiarity with this technique, classroom observations might produce fascinating data. Despite the fact that APOS Theory was included into the course design, the classroom observation revealed that the design of the course lacked some key components of an APOS-based pedagogical technique (Arnon, et al., 2014).

Textbook Analyses

Textbooks can be analyzed to account for the pedagogical strategy followed,

- To identify which conclusions, laws, and theorems employ the idea, and
- To determine whether the notation used may affect students' understanding..
- All of these factors can be helpful when examining student answers and can be applied to guide data interpretation.
- Two genetic decompositions were suggested for the given mathematical idea. They discovered evidence for one of the genetic decompositions but not the other when they analysed student data.
- One of the preliminary genetic decompositions that they proposed started with a previously constructed (general) concept Object and built on that by de-encapsulating it and coordinating the underlying Process with the related Processes concept. (Arnon, et al., 2014)

In general, APOS-based research seeks to explore and clarify how individuals create their grasp of mathematical topics rather than classifying pupils into groups. A method like this, which incorporates prompts and follow-up inquiries, enables the interviewer to watch the development process as it takes place. The data is organised so that the researchers can use it quickly after the instruments have been administered.

In this study and many other APOS studies, the organisation and analysis steps described and illustrated in this section are frequently used to test the validity of the genetic decomposition. For example, if there is a mathematical concept that some students seem to understand but others struggle with, the researcher uses the data to see if the difference can be explained in terms of the presence or absence of one or more specific mental structures and/or relations between men. If so, then evidence supports the existence of these structures in the genetic breakdown. Researchers may need to reevaluate the genetic decomposition if this doesn't appear to be the case..

APOS-Based Research's Scope and Constraints

The following types of questions are frequently considered in research investigations when APOS Theory is employed as an analytical tool:

- How might an understanding of the concept be constructed by students?
- What are the mental constructions involved in the development of a Schema and its components?

Some auxiliary questions can be used to help in answering the main questions or can aid in making suggestions for didactical approaches based on research.

Examples are the following:

- What are the prerequisite concepts necessary to construct understanding of a particular mathematical concept? (Content selection)
- How is a particular conception characterized in the learning of a particular concept? (SELECTION OF LEARNING EXPERINCES)
- How is the transition from one conception to another characterized? (From Action to process , from process to object and which genetic decomposition coordinated to form schemas)

- What are some pedagogical strategies that can help students in the mental construction of a particular concept? (Students centered learning approach) (Arnon, et al., 2014)

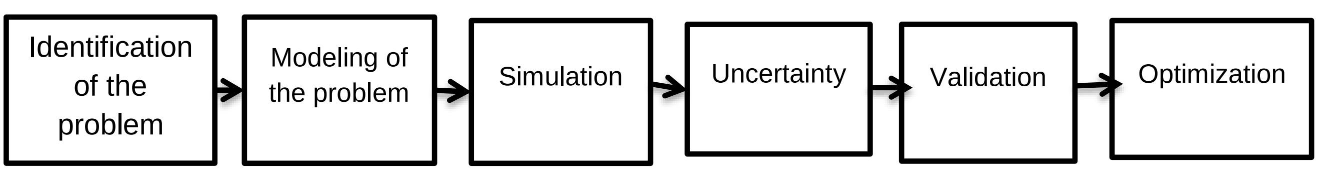
This does not mean that the research questions have to follow a specific format if APOS Theory is used but rather emphasizes the kind of phenomena that arise in working with this paradigm.

The following are examples of topics that could be researched using APOS Theory:

- The use of APOS Theory to find out how mathematicians perceive the mathematical concepts they teach
- Strength and stability of constructions of mathematical concepts learned using an APOS-based learning sequence
- How to teach APOS Theory to pre or in-service teachers, so as to help them to use APOS Theory methodology in their practice.
- Is APOS Theory applicable /adaptable to other humanistic or scientific domains? (Arnon, et al., 2014)

The research trend using APOS Theory indicates that the construction of mathematical concepts will continue to be studied using the lens of APOS Theory, and more research questions will be added to the repertoire as researchers discover the need for them.

According to The European Science Foundation (ESF), the necessary steps to solve an industrial problem are listed as follows: (ESF, 2010)



These procedures are crucial for choosing and organising the courses and their course materials when developing an industrial mathematics curriculum. For each step in the problem-solving process, corresponding courses are required. The theoretical framework and the aforementioned methods for solving problems should be integrated into the process of developing curricula, according to this study's content analysis of industrial mathematics.

The branches of applied mathematics such as numerical methods, optimisation, statistics, differential equations, and mathematical modelling will need to sufficiently integrate into the Industrial Mathematics curriculum in order to successfully transfer mathematics to another field of study.

4.5.Data Analysis

Descriptive statistics like percentage and mean were used to analyse the data with the help of SPSS. For the open-ended question, analysis was conducted with the help of an Excel Spreadsheet. The Google Form questionnaires were saved as Excel documents, and from the open-ended responses, identify common responses, arrange them into one common theme, code each theme with a number or letter to count using an Excel formula, and finally convert the frequency into proportion to calculate the percentage responses on each item and make an analysis based on the results obtained.

One must comprehend the measurement scale indicated by the numbers in order to analyse Likert data appropriately. Numbers assigned to Likert-type items indicate a "greater than" relationship; the exact magnitude of the greater association is not implied. Because of these conditions, Likert-type items fall into the ordinal measurement scale. Descriptive statistics recommended for ordinal measurement scale items include a mode or median for central tendency and frequencies for variability (Boone & Boone, 2012). As shown in Table 4.6 (below), the 4-point Likert-type items range from Not significant (1) to Very significant (4) for each question. The respondents mean score values for each question are calculated, and the analysis of each question is compared to the following Likert scale analysis results:

<u>Mean Score Calculation</u>

a) For 4-point Likert scale $4 - 1 = \frac{3}{4} = 0.75$ and to obtain the first interval add 0.75 0n 1 and we got $[1,1.75]$ and continue in similar procedure for the next interval i.e. ,

$1.75 + 0.75 = 2.50$

i. $[1.00, 1.75]$ - Not – Significant

ii. $[1.76, 2.50]$ - Little - Significant

iii. $[2.51, 3.25]$ - Significant

iv. [3.26,4.00] – Very -Significant

1. For a 5-point Likert scale, to get the first interval, add this value to the minimum value (1 = strongly disagree) and Maximum Value (5= strongly agree), [1, 1.8]. Similar to getting the next interval, add 0.8 to the right end point of the interval, i.e., the next interval is [1.81, 2.60]. The mean score obtained by software was compared with the newly obtained Likert scale (Boone & Boone, 2012) [1.00, 1.80]. strongly disagree
2. [1.81,2.60] – Disagree
3. [2.61,3.40] – Undecided
4. [3.41,4.20] – Agree
5. [4.21,5.00] - Strongly Agree

For comparing frequencies and mean scores of Likert scale all items corresponding to each respondents and compare with the percentage.

4.6.Ethical Considerations

The typical ethical standards, such as protection from harm, informed consent, and participants' rights to privacy and confidentiality about any personal information they may choose to provide, must be followed when conducting any mixed-methods research study (Leedy, Jeanne, & Laura, 2021). In addition, the researcher must acquire approval from the appropriate committee at their institution before conducting any research with humans or nonhuman animals, either from the institutional animal care and use committee or the IRB (Institutional Review Board) in the case of human volunteers (Leedy, Jeanne, & Laura, 2021). The research was done in adherence to UNISA's Policy on Research Ethics. The UNISA College of Education Ethics Committee approved this study on the following reference numbers: 2021/02/10/64126845/25/AM, Appendix-G.

On each informed consent, the researcher provided sufficient details about the study's goals, the procedures to be followed, the advantages of participating, and the reliability of the researcher. This knowledge made it simpler for people to willingly participate in the study as a result.

The researcher kept all data collected from study participants confidential. The researcher suppressed names and other details about study participants unless they gave their permission for the information to be revealed to a third party. In order to protect the privacy of information about responders, the researcher also kept the names of the participants from whom the data had been collected. To conduct research at the specific universities, clearance from the pertinent institutions must be obtained. Before performing the study, the researcher received formal approval from university officials in the various institutions, from industry Public relations (PR) offices up to the department where the relevant academic course was presented.

CHAPTER- FIVE
DATA PRESENTATION AND ANALYSIS

5.1. INTRODUCTION

The purpose of this study was to examine and understand issues and challenges related to the development and implementation of curricula in science and technology universities. This was done to establish a strategic framework for designing and implementing industrial mathematics curricula tailored to Ethiopian science and technology universities. Based on the information collected through a survey questionnaire, focus group discussions with selected participants, and a review of documents, this chapter provides a background on the study institutions and an analysis and interpretation of the data drawn from each of them. The researcher gathered data through questionnaires using both paper-based surveys and Google Forms. There was initial resistance from respondents to complete paper questionnaires. To address this resistance, the researcher prepared a Google Form to collect data and overcome the challenges faced with the paper-based method.

The chapter begins with the background of the study institutions, followed by an analysis of the views and opinions of academics and industry professionals as expressed in their responses to the questionnaire. The opinions and perceptions expressed in the responses to the questionnaire provide information on the background of the institutions. The findings of the study are organized and presented by representing each of the study sites (the two science and technology universities and industries) within which the study was performed and the new industrial mathematics curriculum will be developed and implemented. Structured questions, focus group discussion questions, and related document analysis of industrial mathematics curricula of different countries were used as tools for data collection. For open-ended item questions, the same thematic topics were identified and analyzed using Excel worksheet books to present the empirical data of each participant. The results presented in each of the subtopics were obtained from the analysis of the data from the questionnaire results obtained from the mathematics, applied science, and engineering teachers, deans, department heads, and selected industry personnel, including the focus group discussion of mathematics teachers. The data were analyzed following the procedure discussed in Chapter 4 and sorted, and for open-ended items, the data were grouped into various categories and themes.

5.2. Quantitative Analysis

5.2.1. Survey Questions

In these subsections, first the results of survey questionnaires are presented and analysed under the quantitative analysis parts, followed by those of the focus group discussions and review documents under the qualitative analysis parts. Responses to the survey questionnaire are located in the quantitative phase of the research design by comparing their responses with the rest of the respondents in terms of what opinion and what rating in the survey questionnaire were selected by the majority. Survey questionnaires are commonly used to gather data from a large sample size. Here are some reasons to choose survey questionnaires: They are ideal for collecting quantitative data that can be analyzed statistically. This data is beneficial for drawing generalizable conclusions and identifying trends. It is a cost-effective and time-efficient way to collect data from a large population. They can be distributed electronically, making it convenient for respondents to participate. Respondents may feel more comfortable providing honest feedback on sensitive topics when their responses are anonymous. Surveys allow for consistency in the data collection process, as all respondents receive the same questions. This helps in comparing responses across different groups.

5.2.1.1. Practice on Curriculum Development and Review Programs

In this section, participants were asked survey questions related to their practice in curriculum development and reviewing programmes in their fields of study. For the purpose of analysis, the previous practices of the participants in the development of curriculum and review programmes in their respective subject areas and their level of participation (the role of the participants, leader, facilitator, secretariat and member) were extracted from each participant. The following table shows the percentage of crosstabulations of respondents with respect to the research sites. In the process of curriculum development, the faculty organise a working group that is responsible for curriculum development, called the curriculum development and review committee. The committee had a leader who organized and led the group; facilitators are a group of people who are responsible for gathering information and facilitating resources for the group; and members are active groups of the committee responsible for selecting and organising the content and learning experience of the curriculum.

Table 5. 1 Cross tabulation of Research Site and Participation level of Participation

Research Site	Participated	Level of Participations									
		Leader		**Facilitator**		**Secretary**		**Member**		**Total**	
		F	%	F	%	F	%	F	%	F	%
ESTU	No	0		0		0		0		29	41%
	Yes	17	18%	17	18%	2		47	51%	83	90%
	Total	17		17		2		47		112	
Industry	No	0		0				0		41	59%
	Yes	3	15%	3	15%			3	6%	9	10%
	Total	3		3				3		51	
Total	No	0		0		0		0		70	43%
	Yes	20		20		2		50		92	57%
	Total	20		20		2		50		163	

ESTU= Ethiopian Science and Technology University

The prior experience of the participants with the development of curriculum and review programmes is shown in Table 5.1, along with their level of participation. For instance, of the 112 participants at the ESTU research site, 83 responded "Yes" to the question about their engagement in the formulation of curricula or programme reviews, while 29 said "No." Of those who answered positively, 47 were members of the active committee that choose and organise the curriculum's contents and learning experiences, while 17 were leaders (faculty or department heads), 17 were facilitators (teachers who communicate with accountable bodies to facilitate the process), and 2 were secretaries. For the industry research site, a total of 51 participants responded to the questionnaire about their participation in curriculum development or review of programmes: 9 indicated 'Yes' and 41 indicated 'No'. Of those who indicated in the positive, 3 were leaders (faculty or department heads), 3 were facilitators (teachers who communicate with responsible bodies to facilitate the process), and 3 were members (active members of the committees who select and organize the content and learning experience of the curriculum). Participants in the programme for developing and review curricula will provide accurate responses to each survey question. Participants and those who did not participate will share more information on what they know and do not know about curriculum development.From what I've noticed in the curriculum development and review program, a small group of members dominated the committee's work. This bias could potentially impact the program by allowing these few members to promote their own perspectives in the curriculum. Acknowledging this, the researcher utilized both of these situations to their benefit when designing the new curriculum.

5.2.1.2. Barriers to Curriculum Development

In this section, we shall look at the factors that influence participants' responses during curriculum development or review programmes. Table 5.2 shows the responses of academic communities to the question: Which of the following are the barriers you have come across in your work with curriculum development and review of new programmes at the university and how significant are they? The number and percentage of respondents to each statement are shown in Table 5.2, and the mean score for each statement is also indicated in the table. The mean scores are analysed based on the criteria set for the analysis of the Likert scale (page 108-109). The mean value indicates the mean score of the respondents for each statement.

Table 5. 2 Barriers to Curriculum development with respect to Mean Score and Frequency

Barriers		Responses				Mean
		NS	LS	S	VS	
1.Lack of time to fully participate in the program	F	17	33	44	18	2.56
	%	15.2	29.5	39.3	16.1	
2.Lack of interest to fully participate in the program	F	42	39	21	10	1.99
	%	37.5	34.8	18.8	8.9	
3. Inadequate background knowledge in curriculum development and review	F	28	23	30	31	2.57
	%	25.0	20.5	26.8	27.7	
4.Inadequate understanding of new technology	F	24	31	40	17	2.45
	%	21.4	27.7	35.7	15.2	
5.Lack of support within my organizations	F	16	26	41	29	2.74
	%	14.3	23.2	36.6	25.9	
6. The Curriculum is prepared by scholars selected from different institutions but not from diversified groups.	F	17	18	47	30	2.80
	%	15.2	16.1	42.0	26.8	

Key: VS= Very Significant, S= Significant, LS=Little Significant, NS= Not Significant

As illustrated in Table 5.2, the highest mean score in the above table was mean = 2.8. By Likert analysis, this score indicates the significance of barriers to curriculum development and review programmes because the curriculum was prepared by scholars selected from different institutions but not from diversified groups. This reflects the considerable attention that must be paid to a stakeholder of the programme, and curriculum development groups should include a diversified group. The second significant barrier assigned was a mean score of 2.74: the lack of support from their organisation. The result was in line with earlier literature (Melese and Tadege, 2019), which confirmed that the low economic level of the country made it difficult to provide the infrastructure and logistical services needed to support the educational system in Ethiopia. The third significant barrier assigned a mean score of 2.57 was that the instructor's background knowledge in curriculum development and review programmes was not satisfactory. This barrier has been found to be critical because, without knowing the theories and processes of curriculum development, the expected quality of education cannot be achieved as planned. The fourth significant barrier, with a mean score of 2.56, was the lack of time to fully participate in the programme. The rest of the statements, including inadequate background knowledge in curriculum development and review (mean score = 2.55) and a lack of interest to fully participate in the programme (mean score = 1.99), were considered less significant barriers. These barriers mirrored those identified by Melese and Tadege (2019): the disengagement of teachers and students in their respective tasks and a lack of pedagogical skills. In response to the above question, the majority of those surveyed indicated that the barriers indicated above were significant. In addition to the psychological barriers to the curriculum development process, as suggested by (Howoson, Keitel, & Kilpatric, 2008), which include the lack of incentives that reduce educational innovation, the Ethiopian science and technology universities in the current study have highlighted the lack of interest and support from the government as hindrances to curriculum development. The power barriers to the curriculum development process, also identified by (Howoson, Keitel & Kilpatric, 2008), are characterized by a power dynamic in which the central government's authority is strengthened while the authority of teachers and stakeholders is diminished. In Ethiopian science and technology universities, the curriculum is prepared by scholars selected from a limited number of institutions, rather than from diversified groups, as illustrated in item 6. In my opinion, involving a diverse group in the curriculum development process can sometimes lead to the inclusion of numerous courses from various interest groups, resulting in an abundance of courses that do not align with the curriculum. Including many courses from different fields can extend the duration needed to complete the curriculum. To address this issue, the group should come to a consensus before curriculum development begins. In the next section, we explore the demand for mathematics specialties in industries and examine the factors that influence companies to employ mathematicians.

5.2.1.3. Employing Mathematics Specialty in Industry

To assess the kinds of position and job descriptions of mathematics graduates in industry or government organisations, the following two questions were prepared and distributed to industry professionals. Do you have mathematical specialists in your company? What are the problems with industries employing mathematicians? The responses to the first question are shown in Table 5.3, and the responses to the second question are indicated in Table 5.4.

Table 5. 3 The industries Experts responses

		Industries Experts Responses		
Research Site	Name of industry /organization	No	Yes	Total
Industry G	Aviation Academy	5(14.3)%	0	5(13.9%)
	Electric Power	5(14.3)%	0	5(13.9%)
	Engineering group	9(25.7%)	0.0%	9(25.0%)
	Metal Industry	6(17.1%)	1(10.0%)	7(19.4%)
	Road Administration	5(14.3)%	0	5(13.9%)
	Telecommunication	5(14.3)%	0	5(13.9%)
	Total	35	1	36
Industry P.L.C	Motors P.L.C	4 (26.7%)	0	4 (26.7%)
	Sugar corporation	1 (6.7%)	0	1 (6.7%)
	Breweries company	6 (40.0%)	0	6 (40.0%)
	Sugar corporation	4 (6.7%)	0	4 (26.7%)
	Total	15	0	15

As shown in Table 5.3, out of 35 government and industrial participants, only 1(10%) of the respondents said 'yes' to this question. It is apparent that the need to have mathematicians in Ethiopian industries was not reflected in these results. This is in contrast to reports that revealed that the need for mathematicians in the industry was growing significantly, as captured in mathematics employers' data from the Society of Industrial and Applied Mathematics (SIAM) annual survey, which classified employers by broad Industrial categories. The SIAM survey report indicates how mathematics influences industrial activities in developing countries. Based on the response in Table 5.3 above, industry professionals were asked a dichotomy question and an open-ended question about the reasons why their organizations did not employ mathematics specialists. During the data collection phase, participants were associating mathematicians with the financial system in their organization, but the tasks related to industrial mathematics go beyond this scope. The following table shows the responses of industrial experts to each statement.

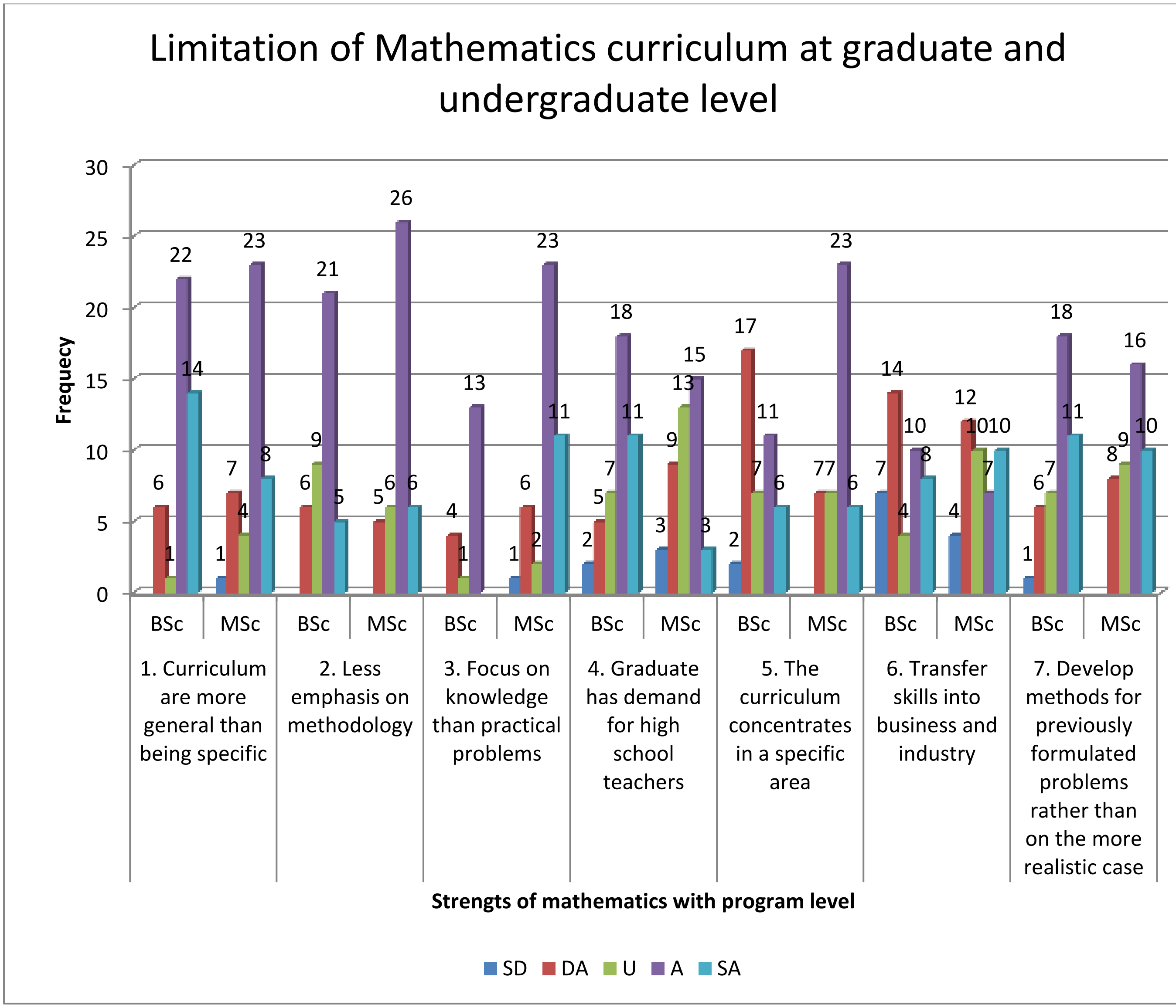
Table 5. 4 The industries Experts responses on mathematics specialty barriers

Statements		Responses		
		No	Yes	Total
1. Lack of technical mathematical ability	F	36	15	51
	%	70.6	29.4	100
2. Salary policy based on money return	F	41	10	51
	%	80.4	19.6	100
3. Bureaucratic procedure	F	32	19	51
	%	62.7	37.3	100
4. Officers is not often a judge of mathematical ability	F	33	18	51
	%	64.7	35.3	100
5. Lack of supervision knowledge of this type of personal	F	24	27	51
	%	47.1	52.9	100

As illustrated in Table 5.4, in response to Statement 5, more than half of the respondents (52.9%) pointed to their organizations lack of knowledge in supervising mathematicians. However, supervision by an individual of adequate mathematical background provides a job in mathematics, and the mathematicians have been appraised for their job (Fry, 1991). The bureaucratic procedure (37.3%) and decision making of the officers based on mathematical ability (35.3%) were the reasons for not having mathematics specialties in their organisations. These results corresponded with open-ended responses such as "no need for mathematicians for our institution", "no related positions for such a profession", "I did not see a need for mathematicians; perhaps their role would be better suited to other areas", and "the role of mathematicians in industries like motor maintenance companies is not clear and the profession is unknown". The findings revealed that the new industrial curriculum should consider the status of industry professionals' understanding of the need for mathematicians in industries. This is despite the mathematics professional vacancy posted by the Ethiopian government and private companies (Ayalew, 2016) listing the following positions: Teacher at Primary or Public Elementary & Secondary Schools, Colleges & Universities, ICT Technician, Human Resource Personnel, Worker at Ethiopian Airlines, National Intelligence Bureau (Security), Admission Officer (Registrar), Expert at Anti-Corruption Office, Expert at Sport & Youth Bureau, Planning and Data Organisation personnel at Finance Bureau, Worker at Ethiopian Shipping Authority, Legal Methodology Officer at Trade Revenue Office, and a Trade & Transport Expert at Micro and Small Enterprises. Based on my previous perspective and the literature, mathematicians are believed to be suitable for any role in an industry or organization. This biased notion stems from my belief that mathematics forms the foundation of every discipline, influenced by my experience with the importance placed on mathematics. However, my expectations were not reflected in the research findings presented in Table 5.3.

5.2.1.4. Limitations and Strengths of Modular Curriculum of Mathematics

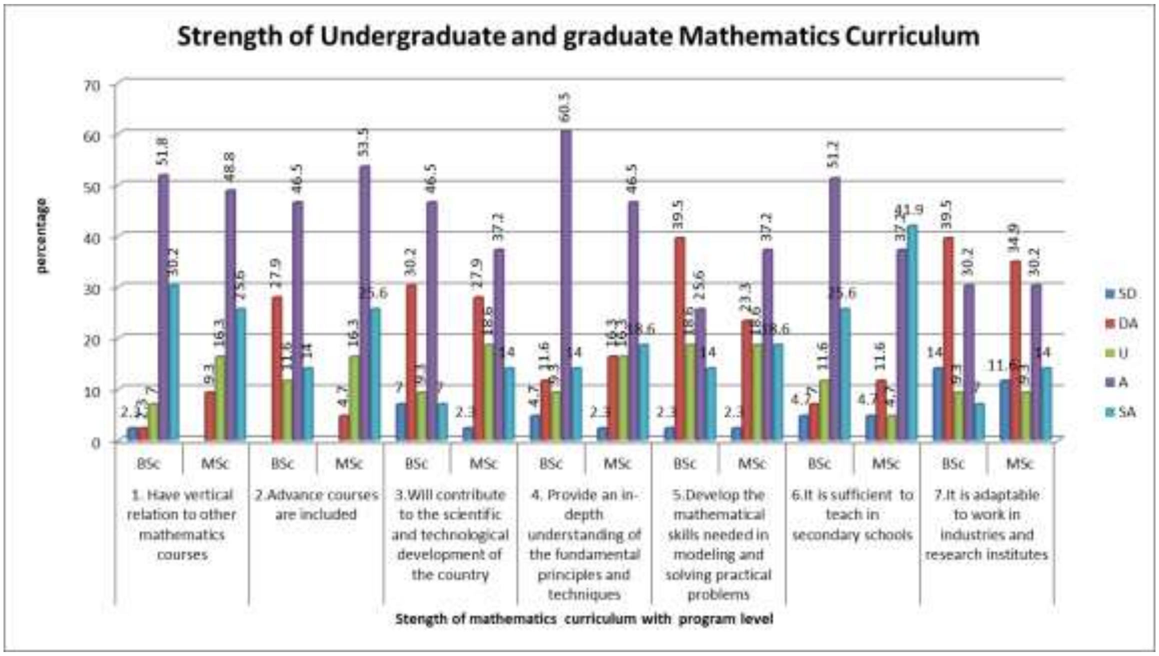
To assess the gap in the existing mathematics curriculum of undergraduate and graduate programmes in science and technology universities, the following Likert-type items were prepared and distributed to mathematics instructors of the universities under study. The frequency of the respondents on each item was indicated using bar graph in academic levels.



Key: SA = Strongly agree, A = agree, U = undecided, D = disagree, SD = strongly disagree

Figure 5. 1 Instructors response on the limitations of mathematics

The limitations of the mathematics curriculum at the graduate and undergraduate levels are presented in figure 5.1. As shown in Figure 5.1, the responses of instructors on the BSc. The mathematics curriculum was reported as follows: 14 of them indicated "strongly agree" 22 showed "agree", whereas 6 disagreed with it, and 2 of the participants could not decide on the statement that the curriculum was more general than being specific. The same statement applies for the MSc. In the program, 8 of them indicated that they "strongly agree", 23 showed that they "agree", while 7 disagreed with it, and 1 said "strongly disagree." Four of the participants could not decide on the statement. The second statement was that the curriculum gave less emphasis to methodology. Responses from respondents to the BSc. mathematics programme was reported as 5 "strongly agree" and 21 “agree”, while 6 “disagreed” with it and 9 of the participants could not decide on the statement. For the identical statement regarding graduate programmes, 6 "strongly agree" 26 of them indicated that they "agreed" with the statement, while 5 disagreed," and 6 of them "undecided" on the statement. The third statement, focused on knowledge rather than practical problems, and the fifth statement the curriculum concentrates on a specific area of knowledge for BSc. Programme were reported as 13 and 11, "agreed", while 4 and 17 "disagreed" with the statement, and 1 and 7 of the participants could not decide on the statements, respectively. However, 6 of them "strongly agree" on the fifth statement. For the MSc. Programme, 11 and 6 of the respondents responded "strongly agree" , 23 and 23 responded " agree", while 6 and 7 "disagreed" with them, and 2 and 7 of the participants could not decide on the statements, respectively. The fifth and seventh statements about limitations of the mathematics curriculum in both programmes to transfer skills into business and industry and develop methods for previously formulated problems rather than on the more realistic case were asked, and the responses were reported as follows: for the BSc. Programme, 8 and 11 said "strongly agree", 10 and 18 "agreed" , whereas 14 and 6 disagreed, 7 and 1 "strongly disagreed," and 4 and 7 of the participants could not decide on the statements, respectively. For the MSc. Programme, 10 and 10 of the respondents answerd "strongly agree" and 7 and 16" answered agree", while 12 and 8 "disagreed" with them, and 10 and 9 of the participants could not decide on the statements, respectively.



Key: SA = Strongly Agree, A = Agree, U = Undecided, D = Disagree, SD = Strongly Disagree

Figure 5. 2 Percentage of respondents on the strength of the mathematics curriculum

The mathematics instructors from the two study institutions were asked to rate the strength of the mathematics curriculum at the graduate and undergraduate levels, as shown in Figure 5.2. Seven expected strengths of the existing university mathematics curriculum for graduate and undergraduate programs were provided as major rating points to evaluate the curriculum. The first statement, which described the vertical relationships of the content of the mathematics curriculum among different course levels, received agreement from 82% (indicating "Strongly agree" + "Agree") of the respondents for the BSc Program and 74.4% for the MSc Program. However, for the BSc program, 4.6% responded disagreed, and for the MSc program, 9.3% responded disagreed on the existence of vertical relationships in the content of mathematics at the two levels. Regarding the second statement on the strength of mathematics curriculum contents at the two levels, the respondents' ratings were as follows: for the BSc program, it received "strongly agree" 14%, "agree" 46.5%, "undecided" 11.6%, and "disagree" 27.9%. For the MSc program, the ratings were "strongly agree" 25.6%, "agree" 53.5%, "undecided" 16.3%, and "disagree" 4.7%.

The third statement, which assessed the contribution of mathematics courses to the scientific and technological development of the country, received the following ratings for the BSc. Program: "strongly agree" 5%, "agree" 46.5%, "undecided" 9.3%, "disagree" 30.2% and "strongly disagree" 4.7%. For the MSc. program, the ratings were: "strongly agree" 14%, "agree" 37.2%, "undecided" 18.6%, "disagree" 27.9%, and "strongly disagree" 7%. Regarding the fourth statement, which evaluated the strength of the existing mathematics curriculum in universities, the course contents provide an in-depth understanding of the fundamental principles and techniques for both programs were assessed as follows for the BSc. Program: "strongly agree" 14%, "agree" 60.5%, "undecided" 9.3%, "disagree" 11.6%, and "strongly disagree" 4.7%. For the MSc. program, the ratings were: "strongly agree" 18.6%, "agree" 46.5%, "undecided" 16.3%, "disagree" 16.3%, and "strongly disagree" 2.3%. The fifth and seventh statements focused on the strength of the universities' mathematics curriculum in relation to industries. The ratings for the BSc. Programs were as follows: 41.8% and 53.5% "disagree", 18.6% and 9.3% "undecided", and 39.6% and 37.2% "agree" for the two statements, respectively. For the MSc. program, the ratings were: 25.6% and 46.5% "disagree", 18.6% and 9.3% "undecided", and 55.8% and 44.2% "agree" for the two statements, respectively. The sixth statement, which assessed the sufficiency of the mathematics curriculum contents for teaching in secondary schools and higher institutions, received the following ratings for the BSc. program: "strongly agree" 25.5%, "agree" 51.2%, "undecided" 11.6%, "disagree" 7%, and "strongly disagree" 4.7%. For the MSc. program, the ratings were: "strongly agree" 41.9%, "agree" 37.2%, "undecided" 4.7%, "disagree" 11.6%, and "strongly disagree" 4.7%. The findings highlight the rationale behind the Ethiopian Ministry of Education initiative to organize a modular standardized mathematics curriculum in 2013. The goal was to address several inconsistencies and deficiencies in the existing curriculum, which included the following irregularities.

1. Mismatch in Student Mobility: The flow of students from their home countries to other countries was not effectively facilitated due to various factors.

2. Inadequate course descriptions and student competency definitions: The curriculum lacked clear and comprehensive descriptions of courses, as well as defined student competencies.

3. Lack of an organized sequence of courses: The curriculum did not present courses in a logical order of increasing complexity.

4. Lack of proper consideration for study time, learning outcomes, teaching-learning approaches, and assessment techniques.

5. Absence of a professional profile: The curriculum did not provide a description of the expected professional attributes of graduates (MOE, 2013).

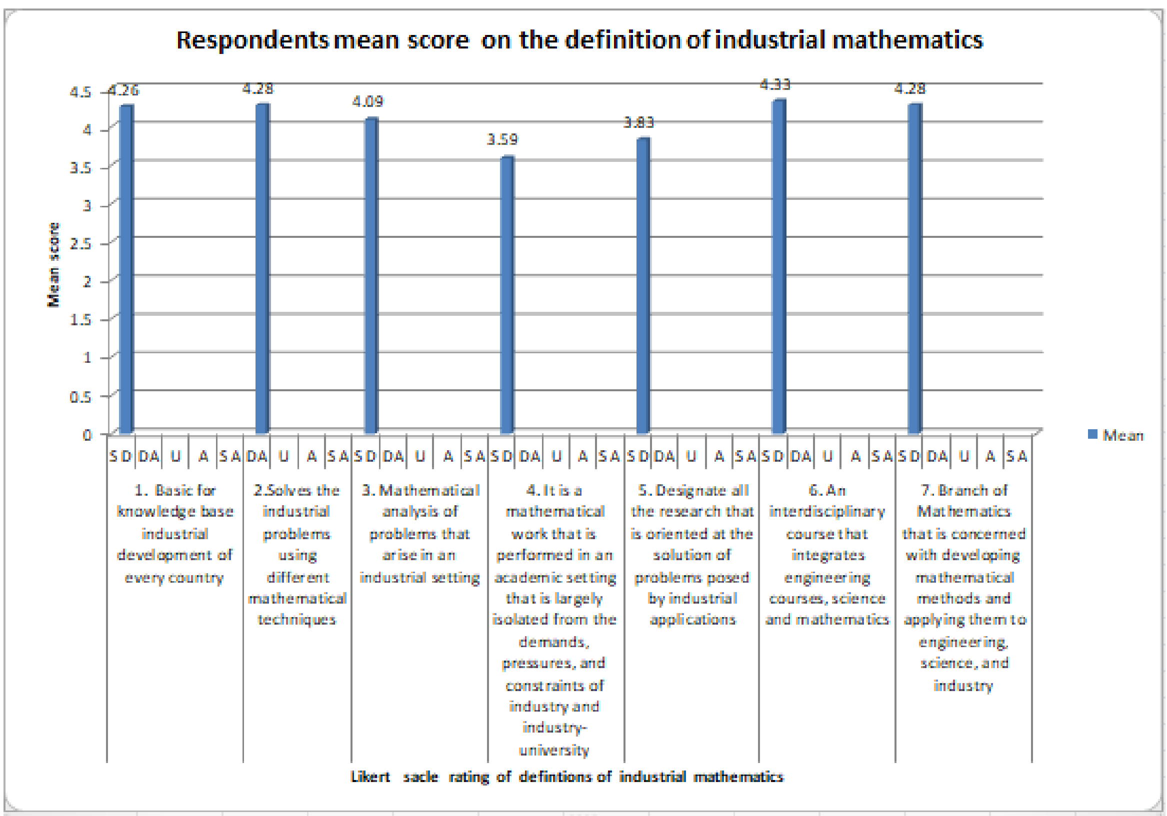
The study's results on the strengths and weaknesses of the existing mathematics program offered at Ethiopian Science and Technology Universities indicate that most criteria focus on content organization, methodology, application in industry, and job prospects. From my evaluation, the necessity for a unified modular curriculum stemmed from the irregularities outlined in points one through five above, which had already been addressed in the previous curriculum review back in 2009 (AAU, 2009). In my assessment, these issues are likely to persist in the upcoming curriculum review. This research can act as a fundamental basis for the forthcoming curriculum review of Ethiopian universities.

This study confirms the necessity of improving the current mathematics curriculum in Ethiopian universities. The existing curriculum was more general in nature, placing less emphasis on methodology and practical problem solving. Furthermore, it mainly focused on theoretical knowledge rather than practical applications. Graduates from this curriculum mainly found employment as high school teachers. To address these limitations, the revised curriculum aims to concentrate on specific areas of mathematics, enhance the transferability of skills to business and industry, and develop methods to tackle real-world problems.

5.2.2. Industrial Mathematics Curriculum for Science and Technology Universities

5.2.2.1. Definition of Industrial Mathematics

Before proceeding to the development of a new industrial mathematics curriculum for science and technology universities, it is critical to grasp what the subject under consideration means and to make participants aware of what is meant by industrial mathematics. After understanding industrial mathematics, the participants were able to provide reliable answers to all of the study's questions. The following table indicates the understanding of university instructors and industry professionals about the definitions of industrial mathematics. The finding also shows the mean score value of each statement on the definitions of industrial mathematics given by the respondents.



Key: SD= Strongly disagreed, DA = disagree, U = undecided, A = agree, SA = strongly agree

Figure 5. 3 Mean score value of "Industrial Mathematics" Definition

According to Figure 5.3, of the 163 respondents, 112 instructors and 51 industry experts participated in rating each of the seven statements. The first statement, 'industrial mathematics is basic for the knowledge base of industrial development in every country,' received a mean score of 4.26 based on Likert scale analysis. This score falls within the interval [4.20, 5.00], indicating a strong unanimous agreement among all respondents. The second statement defines industrial mathematics as a subject that solves industrial problems using various mathematical techniques. With a mean score of 4.28, the respondents also 'strongly agree' with this statement. Similarly, for the sixth and seventh definitions of industrial mathematics, namely that it is an interdisciplinary course integrating engineering, science and mathematics, and a branch of mathematics concerned with developing and applying mathematical methods in engineering, science, and industry, received mean scores of 4.33 and 4.28, respectively. Again, the respondents 'strongly agree' with these statements based on Likert analysis. The third, fourth, and fifth statements received mean scores of 4.09, 3.59, and 3.83, respectively, indicating agreement among the respondents. Combining all the definitions, Stockie (2017) defines industrial mathematics by incorporating the use of mathematics into three categories. Industrial Mathematics (IM), which includes mathematics performed by non-academics; Mathematics for Industry (MFI), conducted by academic mathematicians in collaboration with companies to advance mathematics and improve productivity; and Mathematical Analysis in Industry (MIB), which involves mathematical work performed in an academic setting, largely isolated from industry demands and constraints. This study focuses specifically on the definition of Mathematics for Industry (MFI), where academic mathematicians collaborate with companies to advance mathematics and enhance productivity. Researcher defines industrial mathematics as an interdisciplinary field that integrates various mathematical disciplines such as differential analysis, numerical optimization, modeling, simulations, statistics, computer science, engineering, and financial mathematics

5.2.2.2. Assessing Major Industrial Issues or Topics Used Mathematics

This section examines the experiences of industry professionals and academicians with research or projects related to various industrial issues or topics that require different mathematical techniques. Table 5.5 presents the responses of the academic community and industry professionals on the main industrial issues that require mathematics. Of the 163 participants, 13 individuals, consisting of 4 industry experts and 9 instructors, were unable to respond to the questions. The specific question asked was: "What are the main industrial concerns or subjects on which your department collaborates with industries or academic institutions. What mathematical ideas did you use for the most important problems in the industry?" Of the total of participants, 150 responded to the questions, including 103 instructors and 47 industry experts. The number of responses for each industrial issue was recorded in an Excel spreadsheet. Participants were asked to select one or more of the six mathematical concepts provided for each industrial problem. The selection of these six mathematical concepts was based on a review of the literature and was limited to the mathematical concepts taught in Ethiopian universities that are expected to be known by all respondents. Table 4.5 shows the percentage of the total number of respondents who selected each mathematical concept for specific industrial issues.

Table 5. 5 Major types of industrial issues and Mathematical concepts

		Mathematical concepts					
	INDUSTRIAL ISSUE OR TOPICS	**Differential**	**Numerical**	**Statistical**	**Computational**	**Discrete**	**Optimization**
No1.	Investigative projects and research from industry	13%	22%	13%	18%	11%	22%
No2.	Using various problem-solving tools and techniques to solve problems in industry	14%	16%	20%	18%	11%	20%
No3.	Developing or designing models related to industrial Problems	19%	18%	17%	18%	7%	19%
No4.	Simulation activities, such as improving productivity,	14%	18%	14%	19%	12%	23%
No5.	Initiating change and designing in industrial processes	18%	19%	18%	18%	10%	16%
No6.	Industry-relevant software, technology, and equipment	11%	17%	19%	23%	13%	17%

As illustrated in Table 5.5, six industrial issues or topics with six different mathematical concepts with percentages of responses from respondents were presented. Analyses of each industrial topic were presented as follows:

1. Investigative projects and industry research

The survey results show that participants from both academic institutions and industries commonly selected numerical analysis, optimization, and computational methods as their focus areas. The percentages for these areas were 22%, 22%, and 18%, respectively. These findings are consistent with the SIAM reports, which state that numerical analysis is considered essential in all applications (SIAM, 2017). Furthermore, in the proceedings of a conference on promoting undergraduate research in mathematics, Heinricher and Suzanne (2007) observed that industry projects typically required a combination of probability, statistics, differential equations, numerical analysis, and optimisation. The conference suggests that a broad range of mathematical skills and techniques are often needed in practical industry applications.

2. Using various problem-solving tools and techniques to solve problems in industry

The findings in Table 5.5 show that, the participant selection of mathematical concepts to industrial issues that various problem-solving tools and techniques to solve problems in industry was ranked from first to sixth based on the following categories with their corresponding percentages: statistics (20%), optimization (20%), computational methods (18%), and numerical analysis, differential and discrete. The result consistent with the ESF (2010) report, the curriculum of industrial mathematics aims to enhance the students' mathematical and computational abilities, enabling them to solve industrial problems and engage in development tasks in innovative ways.

3. Developing or designing models related to industrial problems

Differential (19%), Optimization (19%), Numerical analysis (18%) and Computational (18%), respectively, are the mathematical concepts chosen by the respondents to develop or design models related to industrial problems.

4. Simulation activities, such as improving productivity.

The participant selection ranked Optimization (23%), Computational Methods (19%) and Numerical Analysis (18%) as the top choices, respectively. Modelling and Simulation play a crucial role in comprehending industrial processes or products. In recent years, simulation has gained significance due to its ability to design and validate various scenarios without necessitating physical alterations to the original system or substantial financial investments (SIAM, 2017).

5. Initiating change or designing industrial processes

The mathematical concepts selected by respondents for initiating change or designing industrial processes were numerical analysis (19%), differential equations (18%), statistics (18%), and computations (18%).

6. Industry-relevant software, technology, and equipment

The last industrial topics "Industry relevant software, technology and equipment "used the following mathematical topics computations (23%), numerical analysis (19%), statistics (17%) and optimisation (17%).

The aim of these sections is to assess the respondents' mathematical knowledge in their respective fields and their companies' mathematical requirements. The number of participants who responded to the above-mentioned questions is as follows: 5 participants from the road administration, 5 from the aviation industry, 6 from a brewery company and 5 from an electric authority. In the subsequent sections, the findings present the responses of industry experts based on their companies' utilization of mathematical concepts in research or projects. The industrial topics or issues represented by No. 1 include investigative projects and research in industry; No. 2 involves utilizing various problem solving tools and techniques to address industry challenges; No. 3 focuses on the development or design of models related to industrial problems; No. 4 encompasses simulation activities aimed at enhancing productivity; No. 5 involves initiating change and designing industrial processes; and No. 6 revolves around industry-relevant software and technology.

Road Administration

In this subsection, participants were assigned from the Road Research and Development Institute. Five researchers and development professionals responded to the question. Which mathematical ideas did you employ for the most important problems in the industry? Table 5.6 indicates lists of mathematical concepts with corresponding industrial issues or topics illustrated above by codes No.1–No.6.

Table 5. 6 Road administration Selection of mathematical concepts for industrial issues

		Industry Experts responses						
	Road Administration (5)	**No1**	**No2**	**No3**	**No4**	**No5**	**No6**	**Total**
1	Differential Equation	0	2	1	1	1	1	6
2	Numerical analysis	1	1	1	1	2	2	8
3	Statistical analysis	5	4	2	1	3	2	17
4	Computational methods	0	0	2	2	1	2	7
5	Discrete Mathematics	0	1	0	1	1		3
6	Optimization	0	0	1	4	2	1	8
	Total	6	8	7	10	10	8	49

As Table 5.6 illustrates, road administration respondents selected statistics as the mathematical concept chosen most frequently for the six topics related to industrial issues. Additionally, both numerical analysis and optimization were equally popular choices for these six industrial topics. Within this institution, the respondents prioritized two industrial issues. Specifically, 10 participants selected simulation activities, such as improving productivity, while another 10 participants chose to initiate change and design industrial processes. For the industrial issue, where simulation activities were selected, 4 participants rated optimization as the corresponding mathematical concepts. In contrast, for the second industrial issue regarding initiating change and designing industrial processes, 3 participants opted for Statistical Analysis. Additional data on the topic can be found in the table. Furthermore, Deshpande (2021) suggests that operational research, a mathematical concept, is employed in the transportation sector for purposes such as traffic management, logistics, network flow, terminal layout, and location planning. Furthermore, Sergeeva (2020) explains that future architects and civil engineers should possess knowledge in various fields, including linear algebra and analytical geometry, mathematical analysis, probability theory and mathematical statistics, mathematical modeling and numerical methods.

In summary, statistical analysis was the mathematical concept most frequently selected (chosen by 17 respondents) in road research and development institutions, followed by optimization and numerical methods, each of which was selected by 8 respondents.

Aviation Industry

Ethiopia's growth in the aviation industry was dynamic. Therefore, the use of mathematics in the aviation industry promotes research and development in this field. The following table shows five aviation academic training developers who responded to the industry's issue using mathematics..

Table 5. 7 Aviation industry Selection of mathematical concepts for industrial issue

	Aviation industry (5)	**Industry Experts responses**						**Total**
		No1	**No2**	**No3**	**No4**	**No5**	**No6**	
1	Differential Equation	1	1	2	1	1	3	9
2	Numerical analysis	3	1	1	1	2	1	9
3	Statistical analysis	2	3	2	2	2	1	12
4	Computational methods	2	3	1	2	3	1	12
5	Discrete Mathematics	2	1	2	2	2	4	13
6	Optimization	1	1	2	2	2	2	10
	Total	11	10	10	10	12	12	65

As depicted in Table 5.7, the respondents identified three subjects as the main mathematical concepts used in their work. These subjects include discrete mathematics (selected by 13 respondents), computational methods (chosen by 12 respondents) and statistics (also selected by 12 respondents). Of the three main concepts, discrete mathematics was the first choice of respondents. In relation to this topic, four participants associated it with industry-related software, technology, and equipment in their respective companies. Additionally, for industrial issues No. 1, No. 3, No. 4, and No. 5, two respondents selected discrete mathematics for each topic. However, only one respondent chose discrete mathematics for the second industrial problem. Moving on to the second major mathematical concept, 12 respondents from the aviation industry selected computational methods. Among these 12 respondents, 3 chose computational methods for the first industrial issue, 3 for the second, 1 for the third, 2 for the fourth, 3 for the fifth and 1 for the sixth industrial issue. In particular, three respondents selected computational methods as their major mathematical concept for two specific industrial topics: No. 2, which focuses on using various problem solving tools and techniques in the industry, and No. 5, which emphasizes initiating change and designing industrial processes. In addition to the mathematical concepts chosen in the airline industry, Deshpande (2021) suggests the use of operational research for tasks such as managing routing and flight plans, crew programming, and revenue management. Operational research is an interdisciplinary field that combines elements of mathematics, statistics, physics, engineering, economics, and the social sciences to solve real-world business problems. Furthermore, computational fluid dynamics finds application in aircraft and automobile design (Anjali, Deepanshi, Manimala, & Sherry, 2020). Additionally, modeling and simulation techniques are employed in the aerospace industry for tasks such as spacecraft charging (Dudon, 2011).

In general, the data indicate that discrete mathematics, computational methods, and statistics were the prominent mathematical concepts utilized in the airline industry. These concepts were applied in various aspects of industrial problem solving and technological advancement.

Breweries share company

These institutions included national alcohol and beer beverage companies that are working with university communities on different projects. Six participants were involved in answering the question: Which mathematical ideas did you employ for the most important problems in the industry? The following table, 4.8, indicates the frequency with which the respondents selected the main mathematical concepts for the corresponding industrial problems.

Table 5. 8 Brewery company Selection of mathematical concepts for the industrial Issues

		Industry Experts responses						
	Brewery share company(6)	**No1**	**No2**	**No3**	**No4**	**No5**	**No6**	**Total**
1	Differential Equation	1	3	1	3	1	0	9
2	Numerical analysis	0	4	2	1	1	0	8
3	Statistical analysis	5	4	2	2	1	2	16
4	Computational methods	3	0	1	1	3	3	11
5	Discrete Mathematics	0	1	1	2	1	2	7
6	Optimization	1	1	2	3	3	0	10
	Total	10	13	9	12	10	7	61

As shown in Table 5.8, the respondents from the beverage company selected statistical analysis as their primary mathematical concept, with a count of 16. Computational methods and optimizations were also chosen, with counts of 11 and 10, respectively. In terms of statistical analysis, five respondents assigned this subject to investigative projects and research within their company. Furthermore, 4 respondents used statistical analysis for various problem solving tools and techniques in the industry. Two respondents selected statistics as their major subject for developing or designing models related to industrial problems, specifically focusing on simulation activities to improve productivity, as well as industry-relevant software, technology, and equipment. Moving on to the second mathematical concept, 11 respondents from the beverage company selected computational methods. For the first industrial issue, which involves investigative projects and industry research, 3 respondents employed computational methods to solve related problems. One respondent applied this concept for developing or designing models related to industrial problems (No. 3). In addition, three respondents each utilized computational methods for simulation activities (no. 4), initiating change and designing industrial processes (no. 5), and industry-relevant software and technology (no. 6).

In general, the main industrial problems that frequently required the use of mathematical concepts were as follows: using various problem-solving tools and techniques to solve problems in the industry (No. 2), selected by 13 respondents; simulation activities, such as improving productivity (No. 4), chosen by 12 respondents; initiating change and designing industrial processes (No. 5), chosen by 10 respondents; and investigative projects and research from the industry, also chosen by 10 respondents. These industrial problems and the corresponding mathematical concepts served as resources for developing a new industrial mathematics curriculum in science and technology universities.

Electric power

The Ethiopian Electric Power (EEP) is responsible for generating, transmitting and wholesale electricity to the whole country and to neighboring countries. Participants in this institution are assigned from the Department of Electrical Power Research and Development and are expected to answer the question, which mathematical ideas did you employ for the most important problems in the industry? The following Table 4.9 indicates the frequency of respondents assigning mathematical concepts for the corresponding industrial problems.

Table 5. 9 Electric Power Authority selection of mathematical concepts for industrial issues

		Industry Experts responses						
	Electric Power (5)	**No1**	**No2**	**No3**	**No4**	**No5**	**No6**	**Total**
1	Differential Equation	2	2	2	1	2	2	11
2	Numerical analysis	3	3	3	1	2	1	13
3	Statistical analysis	3	3	3	1	2	1	13
4	Computational methods	3	3	3	1	1	2	13
5	Discrete Mathematics	1	0	0	2	0	2	5
6	Optimization	3	3	3	3	1	3	16
	Total	15	14	14	9	8	11	71

As depicted in Table 5.9, the frequency of responses for the six main industrial issues and their corresponding mathematical concepts were as follows: optimization (16), numerical analysis (13), statistics (13), and computational methods (13), for industrial topics ranging from No. 1 to No. 6. For the mathematical concept of optimization, of the 5 respondents, it was selected as a major concept for various industrial issues: No. 1 (3 respondents), No. 2 (3 respondents), No. 3 (3 respondents), No. 4 (3 respondents), No. 5 (1 respondent) and No. 6 (3 respondents). On the other hand, numerical analysis, statistical analysis, and computational methods were equally selected as the main mathematical concepts for all industrial issues, and the specific number of selections for each industrial problem can be found in Table 5.9. For the Electric Power respondents, the main industrial problems selected were investigative projects and research (15 respondents), using various problem solving tools and techniques to solve industry problems (14 respondents), and developing or designing models related to industrial problems (14 respondents). These findings provide valuable feedback for the development of industrial mathematics in science and technology universities.

In summary, the results indicate that in the Road Administration institutions, statistics (17 respondents), optimization (8 respondents) and numerical analysis (8 respondents) were the main mathematical concepts utilized. The corresponding industrial topics selected were simulation activities (10 respondents) and initiating change and designing industrial processes(10 respondents). In the aviation industry, the main mathematical concepts selected were differential mathematics (13 respondents), statistics (12 respondents), and computational methods (12 respondents). The corresponding industrial topics were initiating change and designing industrial processes (12 respondents), industry-relevant software and technology (12 respondents), and industry-related research projects and research (11 respondents). Brewery companies prioritized statistics (16 respondents), computational methods (11 respondents), and optimization (10 respondents) as the main mathematical concepts. The corresponding industrial topics chosen were using various problem solving tools and techniques to solve industry problems in the industry (13 respondents) and simulation activities, such as improving productivity (12 respondents). Lastly, within the Electric Power industry, optimization (16 respondents), statistics (13 respondents) and computational methods (13 respondents) were the major mathematical concepts selected. The corresponding industrial topics were industry investigative projects and research from the industry (15 respondents), using various problem-solving tools and techniques to solve problems in the industry (14 respondents), and developing or designing models related to industrial problems (14 respondents).

5.2.2.3. Mechanisms of Delivery of Industrial Mathematics Courses

The industry requires highly skilled mathematical scientists who can effectively utilize modern mathematical analysis techniques, stay up-to-date with the latest advancements in scientific computing, and possess knowledge of numerical algorithms. In addition, these scientists must understand and respect the specific demands of the industry and have received adequate training to translate industrial problems into mathematical concepts. It is only through the expertise of such individuals that groundbreaking ideas can be generated, thus shaping future trends (OECD, 2008). Solving industrial problems successfully requires the collaboration of experts in various disciplines. To incorporate industrial issues into the new industrial mathematics curriculum, it is crucial to establish a comprehensive delivery system. The integrated approach aligns with the standardization of the undergraduate program and emphasizes the adoption of a modular teaching approach within Ethiopian higher education institutions. By employing cooperative training, which involves a partnership model between educational institutions and industry workplaces, joint training provision can be achieved (MOE, 2020).

Table 5.10 provides information on the responses obtained from industry experts and university instructors regarding the inclusion of industry elective courses in industrial mathematics programs. Respondents were asked to indicate all relevant courses that would be appropriate for the industry. The table shows the collective feedback obtained from these professionals.

Table 5. 10 Percentage of respondents who chose the mechanisms of delivery courses

	Mechanisms of Delivery Courses	Respondents			
		Industry Experts		Instructors	
1	Industry will design the courses as per requirements.	21	19%	72	26%
2	Industry will select the candidate and organise special training.	36	32%	72	26%
3	Industry will develop their own courses and deliver them through subject experts.	31	28%	67	24%
4	Industry will develop student projects.	23	21%	66	24%

The data presented in Table 5.10 reveal that 32% of industrial experts prefer the method used by the industry to assign candidates and organize special training in collaboration with universities. Similarly, 26% of the instructors agreed with the experts' preference for such delivery mechanisms. The second mechanism of course delivery, selected by 28% of industry experts, involves industry developing their own program and having it delivered by subject experts. Among the instructors, 26% also chose this selection, indicating that industry will design courses according to industry requirements.The findings in line with OECD (2008) reports that to develop new mathematical technologies for specific industries, joint teams or "collaborators" consisting of experts from both academia and industry are utilized. These teams should be problem-oriented rather than project-oriented, with a focus on long-term goals rather than short-term ones.

As per Article 21:3 of the Higher Education Proclamation No. 650/2009, the curriculum delivery should be research-oriented, up-to-date, and the teaching-learning process should be regularly revised in its structure, methods of delivery, and assessment tools. This article emphasizes the importance of selecting delivery methods that are study-based. In my own experience, the delivery method did not prioritize graduate employability skills. However, in this study, the delivery methods did incorporate employability skills.

In the upcoming sections, namely 5.2.2.4 and 5.2.2.5, the factors influencing the implementation of the industrial mathematics curriculum in higher learning institutions, as well as in companies and university-industry partnerships, will be explored. Additionally, Section 5.2.2.5 will provide an examination of the mechanisms employed to promote mathematics.

5.2.2.4. Factors affecting the implementation of Mathematics Curriculum.

This section presented the responses of instructors and industry experts to the question “What are factors that influence the implementation of mathematics curricula at the Ethiopian Science and Technology University?. Responses were classified as industrial activities, university-industry activities, and institutional (academic) activities. The third activity is the most difficult for the implementation of the industrial mathematics curriculum. Because it was the primary accountable body for establishing and implementing the curriculum, it was presented as institutional (academic) activities.

Table 5. 11 Factors affecting Implementations of Industrial Mathematics

	Responses				
	S D	**DA**	**U**	**A**	**SA**
Industry activities	P(%)	P (%)	P (%)	P (%)	P (%)
1. Industry expert lack of mathematical background	12.3%	23.9%	19.6%	29.4%	14.7%
2. Industry awareness in using research result	0.6%	19.2%	15.3%	53.4%	21.5%
3.The necessary investment in mathematics	1.3%	7.0%	28.5%	43.7%	19.6%
4. Do not fully know the industrial context	0.0%	4.6%	25.2%	49.0%	21.2%
University-Industry Factors					
5.Poor university-industry link	2.5%	6.1%	16.0%	44.2%	31.3%
6.Lack of knowledge in importing technology	1.2%	11.0%	22.1%	49.1%	16.6%
Academic Factors					
7. Lack of trained man power in the field	0.7%	4.8%	17.8%	48.6%	28.1%
8. Insufficient information about the graduate	2.5%	9.8%	20.9%	49.7%	17.2%
9. Pedagogical practice	2.5%	5.5%	16.6%	55.2%	20.2%
10. Universities do not have industrial strategy	0.7%	4.0%	20.0%	56.0%	19.3%

Key: SD= Strongly disagreed, DA = disagree, U = undecided, A = agree, SA = strongly agree

Table 5.11 shows that the anticipated influences for the implementation of the mathematics curriculum can be divided into three groups: institutional or academic factors, university-industry linkages factors, and industrial factors to consider.

Industrial Factors

Table 5.11 presents the distribution of responses from the survey participants. Approximately 44.1% of the respondents agreed with the statement that "Industry experts lack mathematical background", indicating that this was a perceived issue. Around 19.6% of the respondents neither agreed nor disagreed with the statement, while 36.2% expressed disagreement with the statement. This disagreement highlights the importance of solid mathematical background for industrial professionals. Regarding the statement "Industry awareness in using research results", the majority of the respondents, accounting for 74.9%, agreed with this assertion. A small percentage of academics and industry professionals, specifically 15.3%, did not express any specific opinion on the matter. However, 19.2% of the respondents disagreed with the statement. The majority of respondents, which included 63.3%, agreed that financial support was necessary to introduce industrial mathematics into Ethiopia. Kahsay (2017) points out that inadequate funding and research infrastructure hinder the development of high-quality relevant research outputs and graduates in the academic field of Ethiopia. This is consistent with the findings of the study, since nearly 70.1% of academics indicated a lack of complete understanding of the industrial challenges. Therefore, based on the data from this study, it can be inferred that factors such as industry experts' lack of mathematical knowledge (44.1%), limited awareness in utilizing research findings (74.9%), insufficient investment in mathematics (63.3%) and incomplete comprehension of the industrial context (70.2%) significantly impact the implementation of curricula.

University-Industry Factors

According to the data presented in Table 5.11, more than 75% of the respondents agreed with the statement "poor university-industry links" as a contributing factor. This finding is consistent with Kahsay's (2017) report, which identifies several factors that influence the university-industry link in Ethiopia. These factors can be categorized into two main components: university characteristics and industry characteristics. On the university side, key factors include a lack of motivation and willingness to collaborate, an engaged and capable academic core, committed leadership, adequate research funding, and supportive policies. These aspects play a significant role in shaping university-industry relationships.

On the industry side, factors that influence the linkage are beyond the control of the university. They include the willingness of the industrial sector to engage in research, innovation, and technology transfer collaborations with universities. Additionally, the availability of research and development infrastructure and personnel, investment in research and development activities, and the absorptive capacity of the industry are determining factors in the establishment of successful university-industry partnerships. Furthermore, within the surveyed participants, 65.7% acknowledged that a "lack of knowledge in importing technology" was an influential factor in collaboration between universities and the industry. In contrast, 12.2% did not perceive this as a significant factor and 22.1% remained neutral on the matter. These findings emphasize the importance of addressing various factors that affect university-industry linkages to foster effective collaboration and knowledge exchange between the two entities.

Academic Factors

According to the data provided in Table 5.11, the majority of respondents either agreed or strongly agreed on four critical issues that their universities are responsible for, which hinder the implementation of industrial mathematics curricula. These issues include a lack of trained personnel in the field (76.7%), insufficient graduate information (69.9%), ineffective pedagogical practices (75.4%), and universities lacking an industrial strategy (75.3%). These findings imply that the development and successful implementation of industrial mathematics in Ethiopia require effective planning. Furthermore, the study highlighted various industry factors that influence the implementation of mathematics curricula. These include the industry experts' lack of mathematical background, industry awareness of utilizing research findings, inadequate investment in mathematics, and the academic sector's limited understanding of the industrial context..

5.2.2.5. Mechanisms of promoting Mathematics in Industries

The primary focus of an industrial mathematician is problem-solving rather than simply applying a predetermined set of mathematical concepts. According to SIAM (1998), a successful student experience in this field involves tackling significant problems and generating solutions that are beneficial in practical applications.

This section aims to provide a comprehensive overview of the implementation of mathematics in industry. Its purpose is to provide a clear and easily accessible list of strategies and mechanisms to promote mathematics in the industrial sector.

Table 5.12 illustrates various successful mechanisms categorized into two groups: university activities and university-industry collaboration activities. University activities encompass several initiatives, such as establishing start-up mechanisms, developing educational programs that align with the objectives of all involved parties, creating interdisciplinary research centers, incorporating faculty positions in industrial mathematics, offering consulting services, and implementing successful industrial mathematics projects within Ethiopian industries. The second were university-industry collaboration activities: Trust and openness between the two parties; supervision of students; fellowships or practicums; establishment of study groups from industry and university communities; technology translators; and personnel exchange.

Table 5. 12 Percentage of respondents on Mechanisms of Promoting Mathematics in Industry

		Responses				
	Mechanisms for promoting Mathematics in industry	**UIM**	**SIM**	**MIM**	**IM**	**VIM**
	University Activities	**%**	**%**	**%**	**%**	**%**
1	Initiates existing relationships	1.8	4.3	4.3	42.9	46.6
2	Educational programmes that satisfy the missions of all parties	0	2.5	7.4	47.2	42.9
3	Interdisciplinary research	1.2	1.8	9.8	38	49.1
4	Faculty Positions for Industrial Mathematics	5.5	4.3	23.9	39.9	26.4
5	Consultancy service	0	3.7	13.5	55.2	27.6
6	Use of a successful completed industrial mathematics project	0.6	5.5	19.6	52.8	21.5
	University-Industry Activities					
7	Trust and openness	1.2	3.1	9.3	40.1	46.3
8	Supervise students	0	3.7	9.9	49.4	37
9	Fellowships or Practicums	1.8	3.7	9.8	46.6	38
10	Study groups	0.6	6.7	14.7	44.2	33.7
11	Technology translators	0.6	5.5	17.2	47.9	28.8
12	Personnel exchange	0	1.8	19.6	51.5	27

Key: UIM=unimportant, SIM= slightly important, MIM=moderately important, IM=important, VIM=very important

Universities Activities

It appears in Table 5.12 that of the academic institutions that were responsible for the programme, 89.5% of the respondents agreed with the importance of the startup programme, which is an academician's attempt to initiate the existing relationship between academics and industry professionals. The second mechanism to promote mathematics in industry was the organization of educational programmes that would satisfy both parties; 90.1% of the respondents agreed with the importance of this statement. The third statement, "Interdisciplinary research," was another mechanism that promotes mathematics in industry. 87.1% of the respondents agreed with this statement. The fourth statement is the faculty position for industrial mathematics, in which, out of the total respondents, 23.9% of them give it a moderate importance mechanism rating. 66.3% of the respondents rated the statement as important or very important. In line with this statement, the OECD (2008) suggested that the need for faculty positions in industrial mathematics at universities can serve as the starting point for collaborations, encourage industrial problem solving in a classroom setting, and adapt academic curricula to the demands of industry. Successful academic mathematicians may have the opportunity to pursue their interest in industrial challenges in these settings and provide an efficient and direct transfer of industrial demands to academic research and instruction. The fifth and sixth statements were accepted by more than half of the respondents. Consulting work and project work are probably the distinguishing features of industrial mathematics (SIAM, 1987). The findings of this section have considerable implications for promoting mathematics in industry. Initiating existing relationships by academic institutions, preparing and implementing educational programmes that satisfy the missions of all parties, establishing an interdisciplinary research center, providing faculty positions for industrial mathematics and consulting services for industries, and using a successful completed industrial mathematics project are important institutional activities.

University-Industry Activities

As shown in Table 5.12, the first statement, "Trust and openness" on both sides, was an important issue for 86.4% of the respondents. For the statements "Supervise students" (86.4%) and "Fellowships or Practicums" (84.6%), the respondents considered them important for the promotion of mathematics in industries if they were done by both parties. As Table 5.12 shows, 79.9% of the respondents agreed on the importance of establishing study groups between universities and industries to promote mathematics. The study groups with industry are long meetings in which industrialists, mathematicians, and other scientists work intensively on problems proposed by the industrialists. ESF (2010) recommends that as a strategic road map to promote mathematics in industries, academic institutions, and industry must facilitate employment mobility between academia and companies. Therefore, 78.5% of the respondents agreed with the importance of this statement. ESF (2010) recommends the following mechanisms to promote mathematics in industries: Academic institutions and companies must communicate and promote best practices across nations and disciplines via networks and digital technologies, create a journal devoted to industrial mathematics, contribute to the digital mathematics library, and facilitate employment mobility between academia and companies. There is satisfactory agreement between the findings; it seems to suggest that trust and openness are important between the two parties to create good collaborations; instructors and industry professionals should supervise students; fellowships or practicum should be arranged by both institutions; study groups are groups of industrialists, mathematicians, and other scientists who work intensively on problems proposed by the industrialists; technology translators; and personnel exchanges between two parties are the major university-industry collaborations for promoting mathematics in industry.

5.2.2.6. Values of Industrial Mathematics

Industrial mathematics has emerged as a crucial component in developing technological fields in the new millennium because of the following areas: simulation of processes and products; optimisation, control and design; uncertainty and risk; data management and exploitation; virtual material design; and food, biotechnology, and health. These areas include the simulation of processes and products, optimization, control and design, uncertainty and risk analysis, data management and exploitation, virtual material design, and food, biotechnology, and health (Neunzert & Wolters, 2015). Having these in minds, the value of deploying industrial mathematics programmes in science and technology universities has its own benefits in research and development.

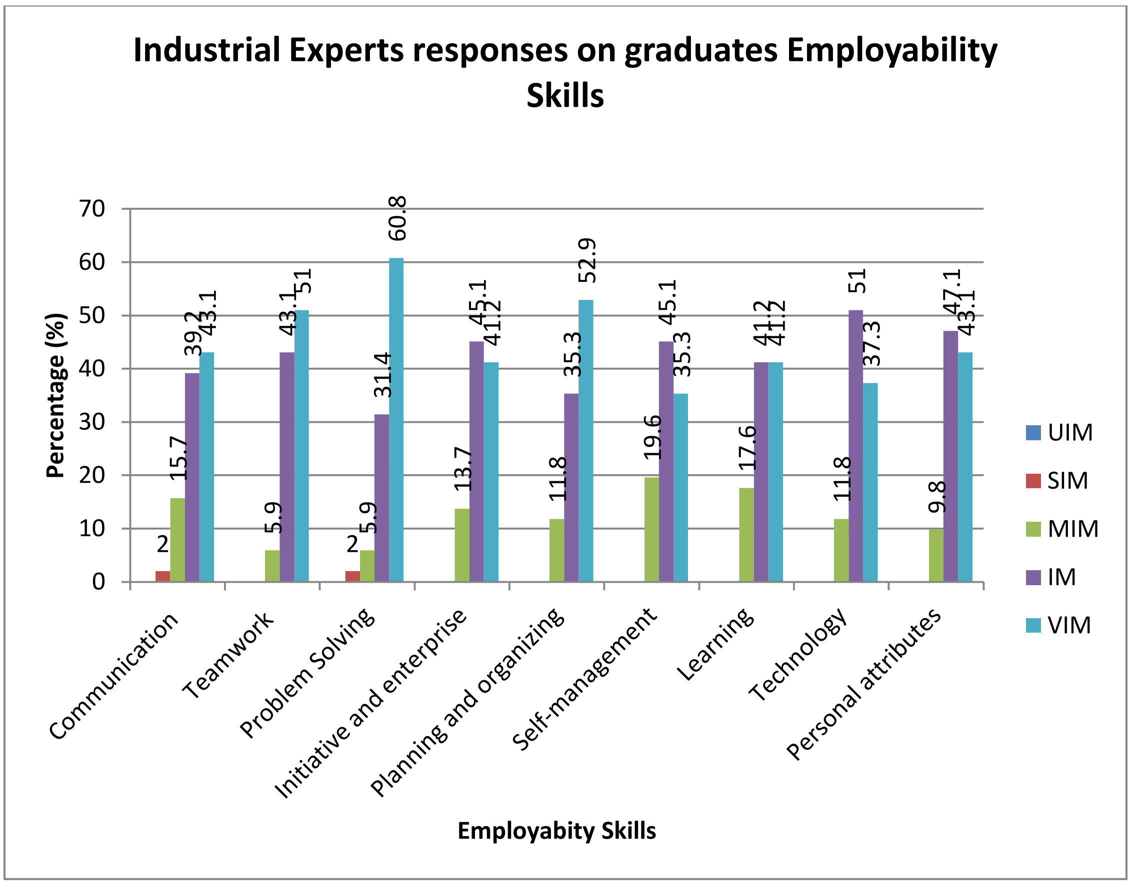
Table 5. 13 The percentage of respondents that value the of industrial mathematics

	Benefits gained	Beneficiaries				
		Teachers	Students	Industry experts	Industry	University
1	Academic Rank (AR)	77%	45%	33%	26%	48%
2	Publication(Pub)	73%	47%	46%	27%	60%
3	Patent	56%	45%	63%	56%	53%
4	Financial gain	60%	38%	57%	74%	53%
5	Academic achievement	69%	72%	25%	11%	42%
6	Job opportunity	36%	79%	44%	19%	13%
7	Improve production and services	10%	9%	33%	85%	29%
8	Use innovation from the academia	35%	31%	44%	63%	45%
9	Job appraisal	48%	34%	53%	33%	28%
10	Global rank	23%	13%	17%	61%	89%
11	Increase export productions	4%	1%	16%	94%	12%

The value of industrial mathematics is demonstrated through research and teaching, providing numerous benefits to all stakeholders involved, including teachers, students, industry experts, industries, and universities. Teachers experience the benefits of academic recognition and publication more frequently than other stakeholders. The benefits of professional patents are distributed among industry experts (63%), teachers (56%), and students (45%). Patents in industrial mathematics are received in Europe. The Fraunhofer Institute for Industrial Mathematics has attracted over 81 million euros' worth of industrial projects through its research, as well as nearly 51 million euros' worth of publicly sponsored projects. In the past three years alone, they have successfully completed more than 700 industrial projects (Neunzert & Wolters, 2015). Table 5.13 indicates that the financial benefits of research and teaching in industrial mathematics are mainly enjoyed by industry (74%), teachers (65%), industry experts (57%) and industries (53%). However, students (38%) are at a disadvantage in terms of financial gain.

5.2.2.7. Employability Skills Needed for Graduate of Industrial Mathematics

To incorporate employability skills into the industrial mathematics curriculum of universities of science and technology, a scale ranging from unimportant (1) to very important (5) was used in Figure 5.4 to assess the responses of industrial experts regarding nine foundational skills. It has been observed that the two harmonized modular mathematics curricula of undergraduates for Ethiopian higher education institutions do not clearly emphasize employability skills, leading to dissatisfaction among stakeholders regarding the quality of graduates. This dissatisfaction can be attributed to the large number of graduates who require additional training to meet the applied technical and communication skill requirements and become productive in their roles.



Keys:UIM=Unimportant,SIM=Slightlyimportant,MIM=Moderately important, IM=Important,VIM=Very important

Figure 5. 4 Industrial Expert's responses on graduates Employability Skills

Communication skills

As can be seen in Figure 5.4, (82.3%) of the respondents consider communication skills to be important as graduation skills. Similarly, communication and writing skills are selected as banking employability skills (Banbul & Sintayeh, 2017). To improve communication skills in industrial mathematics , teaching strategies such as writing and presenting written and verbal reports, role plays, demonstrations, and group work can be encompassed (Manivannan & Suseendran, 2017). In terms of future recommendations, it would be beneficial to provide students with more opportunities to present their findings verbally, whether from a project or individual work. Although arranging group work for students can be challenging, it is an area that we would like to focus on developing (Peter & Jeff, 2017). Effective communication abilities that strengthen the employability of graduates incorporate skillful listening and comprehension, clear and direct verbal expression, customized writing content catering to diverse target audiences, practiced negotiation skills, independent reading proficiency, empathy towards others, multilingual proficiency in speaking and writing, proficiency in numerical reasoning, understanding the requirements of both internal and external clients, persuasive aptitude, efficient networking establishment and utilization, assertiveness, and efficient sharing of information.

Teamwork

In Figure 5.4, it was discovered that the majority of industrial respondents (94.1%) recognized the importance of teamwork. Teaching strategies to improve teamwork were suggested by Peter and Jeff (2017) and included team or group projects, group discussions, syndicates, and communities of practice. Skills and qualities desired by employers encompass working across different ages, regardless of gender, race, religion, or political persuasion; functioning as both an individual and a team member; understanding how to define a role within a team; applying teamwork to various situations, and such as futures planning and crisis problem-solving; identifying team members' strengths; and possessing coaching and mentoring skills, including the ability to provide feedback. Proficiency in teamwork is a crucial skill for mathematicians working in the industry, and one of the responsibilities of a faculty advisor is to observe and guide the team-building process.

Problem solving

The main objective of this study was to identify real-world problems and utilize various mathematical techniques to solve them effectively. As a result, graduates in industrial mathematics will possess the ability to recognize problems and translate them into mathematical terms to find solutions. Consequently, a significant majority of industrial experts (92.2%) agreed with this assertion. Graduates will not only recognize the fundamental skills they have acquired, but also demonstrate proficiency in developing innovative and creative solutions, devising practical approaches, displaying independence and initiative in problem identification and resolution, collaborating on problem-solving tasks, employing diverse strategies for tackling problems, utilizing mathematics, including budgeting and financial management, to address complex issues, applying problem-solving strategies across multiple domains, critically evaluating assumptions considering the contextual information and data, and addressing customer concerns related to intricate project matters. In terms of teaching strategies that enhance problem-solving skills, they encompass employing case studies, simulations, investigative projects, and research; utilizing various problem-solving tools and techniques; developing or designing models; engaging in team-based problem-solving and networking activities; and participating in decision-making exercises (Manivannan & Suseendran, 2017, pp. 107-108)

Initiative and enterprise

A significant proportion of respondents (86.3%) agreed on the importance of initiative and enterprise as fundamental skills that graduates in industrial mathematics are expected to possess. These graduates should be equipped with the ability to adapt to new situations, develop long-term strategic visions, demonstrate creativity and identify opportunities that may not be apparent to others, translate ideas into actionable plans, generate multiple options, and initiate innovative solutions. Teaching strategies to develop these skills include brainstorming activities, designing innovative and creative practices, and finding effective solutions. Furthermore, implementing change and designing change processes, as well as engaging in simulation activities to improve productivity, are recommended approaches (Manivannan & Suseendran, 2017).

Planning and organizing

According to Figure 5.4, of the 51 participants, 45 (88.2%) agreed on the importance of planning and organizational skills for graduates in industrial mathematics. Teaching strategies that promote the development of these skills include research and data collection, action plan development, event planning and organization, time management activities, goal-setting exercises, task scheduling, and information collection and analysis (Manivannan & Suseendran, 2017).

5.2.2.8. Industrial Mathematics for Science and Technology Universities

In this section, respondents were asked to choose an industrial mathematics program for Ethiopian science and technology universities, considering the current developments in the country. The objective of this study is to design a curriculum that aligns with the Human Resource Development strategies for human resource development of the Ministry of Science and Technology and to focus on modifying the balance of the enrollment numbers of higher education students in favour of the science and technology human resource development needs of science and technology of the country and to conduct practical training in cooperation with industry (MOSHE, 2019). Therefore, Table 5.14 shows the selection of an undergraduate and graduate industrial mathematics program for Ethiopian science and technology universities that aims to develop a curriculum appropriate for the country's industrial development.

Table 5. 14 Selections of Undergraduate and graduate Program

BSc. Selection	Respondents Selections		
	Industry Experts	Academics	Total
BSc. Industrial Mathematics With Computer Applications	33(1st)	69(1st)	102(1st)
BSc. Industrial Mathematics and Statistics;	24(3rd)	54(2nd)	78(2nd)
BSc Industrial Mathematical Modeling	25(2nd)	47(3rd)	72(3rd)
MSc. Selection	Respondents Selections		
	Industry	Academics	Total
MSc. Industrial Mathematics With Computer Applications	37(1st)	81(1st)	118(1st)
MSc. Industrial Mathematics and Statistics	33(2nd)	67(3nd)	100(2nd)
MSc Industrial Mathematical Modeling	29(3rd)	70(2rd)	99(3rd)

As evident in Table 5.14, both respondents unanimously selected industrial mathematics with computer applications as their top choice for both graduate and undergraduate programs. The second and third choices varied, as indicated in the table mentioned earlier. However, when considering the total responses for both programs, the ranks were determined as shown above. The initial selection, BSc in Industrial Mathematics with Computer Applications (Appendix-1F), aligns with the curriculum of India, while BSc in Industrial Mathematics and Computer Science with Industrial Experience - Manchester (Appendix-1E) aims to reflect the vision, mission, and industrial development objectives of Ethiopian Science and Technology Universities. The second choice, BSc in Industrial Mathematics and Statistics - Manchester, is suitable for a career in data analysis. The third choice, BSc in Industrial Mathematical Modeling, focuses on research and development of industrial problems. The table above describes the selection of the Master program.

5.2.2.9. Job Opportunities for Graduates of Industrial Mathematics

In this section, a list of job opportunities for graduates of industrial mathematics was compiled on the basis of experiences from different countries. Respondents were then asked to indicate job vacancies related to the field in their respective institutions. The table presented below displays the frequency of responses for each listed job opportunity, taking into account that the respondents had the opportunity to select more than one option. For coding purposes, the respondents' choices were assigned numbers ranging from 1 to 9, as demonstrated in Table 5.15 on the Excel worksheet. The "COUNTIF" formula was utilized to track the number of times each job opportunity was selected by the respondents from their institutions. Responses from instructors and industry experts were classified and compared with the total number of responses received.

Table 5. 15 Jobs Selected by Academics and Industry Experts for Graduates

	JOB OPPORTUNITIES	Instructors	Rank	Experts	Rank	Total	Rank
1	Operational Research Analysts	**84**	**2**	**37**	**1**	**121**	**2**
2	Scientific programmer	**62**	**6**	**19**	**7**	**81**	**6**
3	Data analyst	**85**	**1**	**37**	**1**	**122**	**1**
4	Financial Analysts	**63**	**5**	**32**	**3**	**95**	**4**
5	Production line optimization	**83**	**3**	**31**	**4**	**114**	**3**
6	Risk management	**60**	**7**	**28**	**5**	**88**	**5**
7	Software testing and verification	**55**	**8**	**24**	**6**	**79**	**8**
8	University Instructor	**79**	**4**	**1**	**8**	**80**	**7**
9	High School Teacher	**47**	**9**	**1**	**8**	**48**	**9**

As shown in Table 5.15, industry experts selected the following job opportunities that their companies require: operational researcher (37), data analyst (37), financial analyst (32), and production line optimization (31) respectively. On the other hand, the instructors selected the following job opportunities: data analyst (85), operational research analyst (84), production line optimization (83), and university instructor (79). Therefore, the new curriculum of industrial mathematics must consider the vacancies for graduates in industries. In the next section, the qualitative analysis parts of open ended data, the result of the focus group discussion, and the document analysis parts will be presented and analyzed.

In conclusion, while efforts are being made to provide efficient and relevant mathematics curricula in Ethiopian science and technology universities, significant challenges remain to be addressed. These challenges include a lack of background knowledge in curriculum development and review, a lack of understanding of new technology, and inadequate support within organizations. Ethiopian science and technology universities can contribute to the education of students for careers in industrial mathematics by addressing these difficulties. Although the current mathematics curriculum offers certain advantages by providing students with a strong foundation in mathematical concepts and skills, there are also drawbacks that need to be addressed. By designing industrial mathematics curricula in consultation with industry representatives, the program can better prepare students for rewarding careers as mathematicians in the industry.

5.3. Qualitative Analysis

5.3.1. Open ended Questions

To gather the opinions of the respondents on specific research questions, additional open-ended question items were prepared and distributed. The researcher thoroughly reviewed the open-ended responses of each individual respondent, repeatedly reviewing them. The main themes from each respondent's responses were appropriately highlighted by the researcher, condensing them into manageable portions to present and analyze the data to answer the research questions. The researcher selected and identified the themes based on his prior teaching and learning experience.The interpretation of the open-ended data involved creating tables displaying the percentage of respondents' reactions to corresponding themes, accompanied by a summary of the respondents' responses to each question. The questionnaires included both closed-ended and open-ended items. This combination allowed predetermined closed-ended responses to provide valuable information to support theories and concepts in the literature. Additionally, open-ended responses provided insights into the reasons behind closed-ended responses and any additional comments that extended beyond closed-ended questions (Creswell, 2014).

5.3.1.1. Barriers in Curriculum Development and Review Programs

Awareness of barriers to curriculum development and review programmes will help to successful development of the new curriculum (Howoson, Keitel, & Kilpatric, 2008). According to MOE (2010), the quality of Ethiopian higher education showed that the challenges of higher education quality were imposed on the curriculum development process: “The curricula of higher education institutions were not geared toward the development of employability and other lifelong learning skills among graduates. Universities did not seem to have strategies and tactics to prepare programs that require intensive use of IT for learning purposes. The existing university-industry links were found inadequate and therefore students did not have ample exposure to real-world of work as well as the teaching of practitioners from industry. ‘Thus, it appeared that educators from colleges of applied science and engineering expressed their personal perceptions about the barriers of curriculum development and review programmes as follows.

> *The practice of curriculum development in Ethiopian higher education follows a top-down approach, most of the time curriculum development was not based on theory(theories of curriculum development), simply it was prepared by selection of content and copying curriculum of others within the countries or abroad from sister university, curriculum development is influenced by the need of teachers especially PhD programmes focus on the teachers interest and ability to implement but not on the need of the stakeholder, no need assessment done at all. If it has done, it was not properly organised, the works of curriculum focused to dig out information up to the selection of the course content and teaching methodology. This leads to copy-pasting curriculum from other foreign institutions with different levels of economic developments. Top officials from higher institutions showed little commitment to the curriculum development process.*

> *Mathematics instructors were responded that curriculum development in mathematics is highly influenced by the "political system". Understanding of the university's top management about the newly developed programme was one of the discouragement factors for the development and review of the curriculum. One respondent suggested that assessing the need and demand of the programme takes time to complete.*

The instructors' comments on the challenge of curriculum development in Ethiopian higher education were significant for its development and implementation. Instructor responses were a basic factor because they were a key person in the use of the new curriculum in industrial mathematics.

5.3.1.2. Employing Mathematician in Industry

In the report on industrial mathematics, the issues related to hiring mathematicians in the workplace were described, highlighting the fact that employment officers were not always qualified to assess the mathematical abilities of candidates (Fry, 1941). The officers' abilities in hiring mathematicians reflected in the finding shown in Table 5.3, the quantitative analysis in result table 5.3 showed that 1% of the respondents answered "Yes" to the question of having mathematical specialties in their company, while 99% answered "No". For those who responded "No", additional comments were solicited through an open-ended question asking about the problems in employing mathematicians in industries. The following are industry experts' responses to this question: 1) Lack of Awareness: Industry respondents claimed that they were unaware of the relationship between universities and industries, as well as the demand for mathematicians in their institutions. Due to this lack of awareness, they felt desperate for a job without considering the potential benefits of hiring mathematicians; 2) Misunderstanding of Job Roles: Respondents from automobile assembly companies stated that they were not aware of the need for mathematicians in their company, possibly because they believed that their functions could be better suited to other areas. Some of them were unaware of the profession itself and assumed that studying mathematics was not crucial for their companies. 3) Irrelevant job requirements: Since the job requirements in their companies did not involve mathematics, there was no position specifically designated for a mathematics specialist. The absence of a clear role for mathematicians in their organizations led to a perception that extensive mathematical understanding was not necessary; 4) Emphasis on Engineered Expertise: The respondents' responses suggested that the business sector, due to a lack of awareness about the significant gains from studying mathematics, did not demand extensive mathematical understanding. Instead, they valued engineering expertise above mathematical specialization. These responses highlight the challenges faced by industries in employing mathematicians, including lack of awareness, misconceptions about the role of mathematicians, and inadequate job requirements. It is essential that industries recognize the value that mathematicians can bring to their organizations in terms of problem solving, data analysis, and decision-making. Increasing awareness and fostering collaboration between universities and industries can help address these issues and create more opportunities for mathematicians in the workplace.

5.3.1.3. Improving the Existing Mathematics Courses in the Universities

This section presents the participants' responses to open-ended questions aimed at assessing their opinions on how to improve the existing mathematics courses at universities. Of the 70 engineering and applied sciences instructors, 40 provided suggestions in response to this question. Similarly, of the 51 mathematics instructors, 34 responded and of the 51 industry professionals, 32 provided their opinions. The researcher thoroughly reviewed each individual respondent's open-ended questions multiple times. The researcher then identified and highlighted the main themes within four categories: curriculum revision, needs assessment, application, and methodology. The process of categorizing the main themes allowed the researcher to appropriately capture the responses within manageable portions of the themes, which were then presented and explained to address the research question. The findings of the open-ended data are displayed in Table 5.16, which includes the percentage of respondents' reactions to the corresponding themes. A summary of the responses of the respondents to each question is also provided. By categorizing the responses and analyzing the common themes, the researcher was able to identify patterns and trends in participants' suggestions for improving the existing mathematics courses at universities. This approach helps in understanding the collective opinions and areas that need attention in order to enhance mathematics education. Please note that the specific details of Table 5.16, including the themes, percentages, and summary of responses.

Table 5. 16 Frequency & Percentage of respondents on themes of improvement

		Respondents			
	Theme	App. & Engineers	Math Instructors	Industry Experts	Total
1	Curriculum revision	8(20%)	10(29%)	2(6%)	20(19%)
2	Need assessment	9(23%)	6(18%)	2(6%)	17(16%)
3	Application	8(20%)	11(32%)	16(50%)	35(33%)
4	Methodology	15(38%)	7(21%)	12(38%)	34(32%)
		40	34	32	106

As shown in Table 5.16, out of 162 participants, 106 responded to the question. Among these respondents, there were 40 applied science and engineering instructors, 34 mathematics instructors, and 32 industry experts. Below is a summary of the responses provided by the applied science and engineering instructors.

1. Curriculum revision (8/40 = 20%):

Among the 70 applied science and engineering instructors, 40 of them commented on the question about improving the courses. Of these 40 respondents, 20% suggested the need for curriculum review. They emphasized the importance of updating applied mathematics courses by incorporating examples from different fields of study and industries. They also emphasized the need for content modification to address the problem-solving needs of employers in the industry. In addition, they recommended periodic curriculum revisions.

2. Stakeholder Needs Assessment (9/40 = 23%):

Nine respondents highlighted the importance of conducting "needs assessments" that involved industry and all stakeholders before developing the curriculum. Some suggested a "design-based curriculum" that is tailored to industry needs. One respondent mentioned that the needs assessment should begin by defining the graduate profile and identifying the required courses to achieve it. They proposed breaking down general courses and aligning them with industry needs, using practical applications with the help of software, and establishing strong links with industry.

3. Applications (8/40 = 20%):

The participants emphasized the inclusion of applicable mathematics content that helps solve real-world and industrial problems. They suggested that assessments should incorporate exercises and term papers that focus on applying mathematical concepts to practical situations. It was recommended that courses be relevant and meaningful and closely aligned with current demands and findings in both industry and educational institutions.

4. Methodology (15/40 = 38%):

The respondents highlighted various suggestions for improving the teaching methodology. These included having professionals (teachers) from the same department teach the same courses from outside the country, allowing instructors to acquire the latest skills from industry experts through online courses. They also recommended organizing workshops in collaboration with stakeholders, using high-quality teaching materials and tools, improving the student-teacher ratio, and designing courses and teaching methods based on the needs of modern technology. These summarized responses from applied science and engineering instructors provide insight into their perspectives on improving mathematics courses. They emphasize the importance of curriculum revision, needs assessments, practical applications, and improved teaching methodologies. Incorporating these suggestions can contribute to the overall improvement of mathematics education in the field of applied science and engineering.

Mathematics Instructor Responses:

1. Curriculum Revision (10/34 = 29%):

Mathematics instructors agreed on the need for curriculum revisions. They suggested including new concepts that are industry-based and highlighting the importance of mathematics as a tool for problem solving. They emphasized the necessity of incorporating a computer application curriculum to enhance practical applications.

2. Stakeholders' Needs Assessment (6/34 = 18%):

Mathematics instructors emphasized the importance of basing mathematics education in universities on industry demand rather than on the interests of curriculum developers. Some respondents suggested conducting detailed research to identify the main limitations and prioritize areas for improvement. They highlighted the need for a more relevant curriculum and recommended sharing experiences from other countries, considering that mathematics education development is a global and competitive field. It was suggested that the curriculum should be revised according to market needs in collaboration with potential employers, while strengthening university-industry linkages. One instructor proposed incorporating indigenous mathematics knowledge that reflects the lives of learners and society.

3. Application (11/34 = 32%):

Mathematics instructors emphasized the need for practical applications in the curriculum. They made suggestions such as incorporating content that arises from practical problems, fostering collaboration between the university and industries to solve real-world problems, integrating the course objectives with real application problems, promoting interdisciplinary cooperation with other disciplines and industries, and including industrial problems and solutions in the textbook and curriculum. Many instructors recommended the development of an "industry-based curriculum" specifically for higher education in Ethiopia.

4. Methodology (7/34 = 21%):

Mathematics instructors highlighted the importance of supporting mathematical teaching with practical examples. They emphasized the necessity of integrating course objectives with real-life application problems, especially those related to industrial problem solving content within the curriculum. These responses from mathematics instructors shed light on their perspectives on curriculum revision, needs assessment, application of practical examples, and teaching methodology. Their suggestions emphasize the need for relevance, practicality, industry orientation, and collaboration between academia and industry to enhance mathematics education.

Industry experts Responses

Industry experts have provided valuable feedback on university mathematics courses, focusing on the practical application of mathematics in various industries. Instead of purely theoretical teachings, experts emphasize the importance of applying mathematical concepts to drive industrial progress. Some experts recommend a more academic approach to mathematics courses, with a strong emphasis on applying mathematical knowledge to solve practical problems in the workplace. They suggest incorporating practical examples from real-world industries such as engineering and applied science to help students understand how mathematics can be used in different fields. Academicians also stress the need to promote the practical usefulness of mathematics courses beyond numbers and calculations. They suggest introducing new concepts of industrial mathematics and the extensive promotion of these courses in industrial organizations. This entails highlighting the benefits of the courses and demonstrating how the principles taught can be implemented in real-life industrial settings. To create high-quality course curricula and training materials, industry professionals advise conducting research beforehand. They believe that appropriate curriculum design will benefit students and all stakeholders involved. Practical training and internship programs are also recommended to develop effective programs in professional disciplines. Additionally, experts suggest incorporating applicable mathematical concepts that aid in the analysis and synthesis of products using scientific methods. This approach would contribute to the redesign and improvement of products in various industries. Considering the time constraints in both educational institutions and industry settings, it is recommended to offer different industry case study courses that focus on short and precise problem solving steps. In doing so, students can gain practical skills relevant to their chosen fields. However, experts acknowledge that for those primarily focused on productivity, an engineering course may cover the necessary applications of mathematics and other useful subjects. Engineering integrates various mathematical concepts and provides a comprehensive understanding of their practical applications.

In summary, industry experts advocate for mathematics courses that prioritize practical application and problem solving in real-world contexts. By incorporating practical examples, promoting the usefulness of courses, and designing appropriate curricula, universities can better prepare students for success in various industries.

The following Table 5.17 indicates the participants' recommendations on some additional course content to include improving the existing university mathematics curriculum.

Table 5. 17 Courses Proposed by Responders to Enhance the Existing Mathematics

Applied and Engineer	Mathematics	Industry Experts
• Mathematical modeling • Simulations • PDE • Optimization with software • Advanced numerical analysis • Mathematical physics • Business mathematics • Quantitative analysis (operational research) • Econometrics • Computational mathematics • Applied Mathematics • Statistics • Mathematics in programming	• Financial mathematics, • Mathematical biology • Numerical simulations • Optimization • Modeling • Software Matlab & Python • Numerical analysis • Fluid dynamics • Cryptography • Actuarial mathematics • Computer algebra • Designed based on Model-eliciting activities • **Design computer based curriculum** • Applied mathematics • Control theory • Industrial mathematical with modeling • Coding and algorithm development • Computational mathematics • Industrial mathematics • Mathematical modeling,	• Data science / data mining /forecasting • Statistics for engineers • Calculus , • Geometry • Apparatus design and reaction engineering • Simulation

- Differential
- Combinatorial design
- Actuarial mathematics

As can be seen in Table 5.17, the list of courses shows what the respondents felt would improve or promote mathematics research in an industrial setting. As a result, this study reveals that some of the courses listed above will be integrated into the newly developed industrial mathematics curriculum.

5.3.1.4. Joint Programs

The Ethiopian education policy encourages joint programs among institutions, allowing each institution to develop curricula for their academic programs (Gazette, 2019). In this context, participants in the study were asked to explain their views on the advantages of having a joint program. Specifically, applied and engineering instructors provided their responses.

<u>Applied and Engineering Instructors' Responses</u>

From the analysis of open-ended items, 48 out of the 70 respondents who answered the question "If your response to question number 2.8.1.1 is "Yes," what are the benefits of having joint curriculum?". However, after filtering out repetitive suggestions from the 48 comments, 32 unique comments were identified. The following are the responses from instructors at applied and engineering colleges, as summarized in Google form.

- ♦ *It enables us to have good teachers.*
- ♦ *The curriculum's development starts with addressing real problems and is based on common interests.*
- ♦ *It allows students to be exposed to real case studies and the latest industry insight.*
- ♦ *Mutual benefits include the exchange of experienced or reputable professionals from both the university and the industry.*
- ♦ *Provides opportunities to utilize resources.*

- *It is a win-win situation for both the university and the industry.*
- *It can be helpful in dealing with industry problems using mathematical applications, which enhance the productivity of core industries in the country's development.*
- *Because it is a multidisciplinary course, it acts as a bridge.*
- *It aims to ensure comprehensive teaching, addressing timing issues in industry.*
- *It will improve existing problem solving methods.*
- *Checking the curricula to be in line with international standards, such as the ABET standards.*
- *"It contributes to the development of both parties and the economy.*
- *It is beneficial to prepare a more productive curriculum.*
- *An important section could be included in the course if it is developed in a joint way.*
- *They can identify the real problems (gaps) on both sides.*
- *modern capabilities for all types of digital communication*
- *The industries can benefit from the trainees*
- *Staff Exchange and Knowledge Transfer*
- *Practically applicable curriculum can be designed.*
- *to develop mutual understanding and benefits as well as create job opportunities.*
- *It strengthens the curriculum and its acceptance.*
- *because it is an important discipline for science.*
- *help to see things from a different perspective*
- *Graduates will be directly involved in industry matters.*
- *Uniformity, easy credit transfer, and consistency*
- *Will generate competent graduates who will support the industry.*
- *It can create shared values.*
- *may solve the core problem;*
- *It is possible to fill the gap between trainers and employers.*

- *Its application in modeling the spatial distribution of life and multidisciplinary approaches that solve problems in different disciplines*
- *The instructors will have a practical understanding of the problems.*
- *The courses will be geared to the competencies required by industry.*

In summary, the responses from applied and engineering instructors highlight the advantages of joint programs, including improved collaboration, increased specialization, diversified perspectives, improved networking opportunities, quality assurance, efficient resource utilization, and improved recognition and accreditation. These benefits contribute to a more comprehensive and enriched learning experience for students. Additionally, joint programs provide opportunities for the use of shared resources, allowing universities and industries to make the most efficient use of their assets. This collaborative effort leads to a win-win situation for both the university and the industry, as they can leverage each other's strengths and expertise. Another advantage of joint programs is the exchange of potential teachers between institutions. This allows a diverse range of perspectives in teaching and exposes students to different teaching methods. It also provides an opportunity for students to be exposed to real case studies and the latest industry insights, making their education more relevant and valuable. Furthermore, joint programs facilitate the development of a curriculum based on real industrial problems and common interests. This approach ensures that the curriculum is aligned with the industry needs, enhancing the practical application of knowledge and skills acquired by students.

Quality assurance is another crucial aspect of joint programs. By developing the curriculum collaboratively, it becomes easier to ensure compliance with international standards. Uniformity, easy credit transfer, and consistency are promoted, allowing students to have a continuous academic experience while ensuring that the program meets the industry expectations. One of the significant advantages of joint programs is their multidisciplinary nature. This makes them an effective bridge between academic knowledge and industry needs. For example, a joint program that combines science, technology, and mathematics can provide solutions to industry problems through mathematical applications, ultimately improving productivity. The development of joint programs also fosters strong university-industry linkages. By identifying and addressing real-world problems together, both parties can contribute to the improvement of the industry and focus on areas that require attention. The industry can benefit from trainees through staff exchange and knowledge transfer, while instructors gain a practical understanding of industry problems, enabling them to better prepare students for the workforce.

In general, joint programs strengthen the curriculum by making it more relevant and practical. They help to develop mutual understanding and create job opportunities for graduates, who can apply their skills directly to industry matters. Additionally, joint programs encourage individuals to see things from different perspectives and focus on their areas of application, resulting in better results for both the university and industry.

Mathematics Instructor Responses

Having a joint program offers several advantages for employees, employers, and researchers, particularly for mathematics instructors. These advantages include collaborative research, solving practical industrial problems, transfer of knowledge between science and engineering students, sharing ideas on new technology, and utilization of potential candidates from both institutions. These responses from mathematics instructors highlight the various ways in which joint programs benefit both instructors and the industry. The collaborative nature of these programs fosters research, problem solving, knowledge transfer, and the utilization of diverse talent, ultimately leading to advancements and growth in the field of mathematics and its applications in industries. The following are responses to this question from mathematics instructors taken from the Google form summary.

- *It has advantages for employees, employers, and researchers.*
- *For collaborative research and to solve practical industrial problems*
- *Transfer of knowledge between science and engineering students. If science and engineering students can work together, they can invent a big technology that will improve Ethiopia's economy through industry development.*

- *We can use potential candidates from both institutions.*
- *to get real data from industry and model problems*
- *It will be a problem-based curriculum.*
- *The industry expertise mainly identifies the industry problem and lacks Mathematical tools to overcome it. The mathematician has detailed knowledge of general mathematical concepts but lacks specific industrial problems. So, jointly develop the curriculum to address and improve the industrial productivity challenge.*
- *Share experience, build graduates with practical activities and job opportunities, and lay a foundation for the development of the country.*
- *Efficient utilisation of human and material resources, acceleration of capacity building in institutions, and strengthening of knowledge and technology transfer*
- *better understanding and trust between two parties;*
- *Because the curriculum is developed by interdisciplinary professionals.*
- *Analyze the gap that has to be covered in the education system*
- *It simply fits the industry's curriculum best to the market.*
- *Show the application of mathematics in technology.*
- *Students, after completing their studies, will apply their knowledge in the industries, and industries will also benefit by increasing their quality.*
- *It helps to graduate professionals who can solve problems in industry.*
- *Universities can produce skilled industrial mathematics graduates.*
- *solving real problems, productivity, and profit*
- *It will be convenient because stakeholders clearly know the problems that exist.*
- *We will be able to force the courses based on the real problems of the industry.*
- *It paves the way for the best curriculum design.*
- *The cooperative work between science and technology universities and industry is important.*

- *The graduate will gain knowledge of industrial problems. And helps to connect graduates with industries.*
- *creates job opportunities and enhances industry-university linkage;*

The collaboration between industry experts and mathematicians in the jointly constructing the curriculum brings together the unique expertise of both parties. Industry experts have a deep understanding of the specific challenges faced in the industrial sector, but may lack the mathematical skills required to solve them. On the other hand, mathematicians possess extensive knowledge of general mathematical concepts but may not have direct insight into industrial problems. By collaboratively constructing the curriculum, industrial productivity challenges can be effectively addressed. This partnership strengthens the transfer of knowledge and technology between academia and industry, fostering the sharing of experiences and best practices. Graduates of such programs are equipped with practical skills in the real world that improve their employment opportunities and contribute to the development of the industry. The collaborative development of the curriculum also allows for the effective utilization of material and human resources, laying the foundation for national development. By aligning the curriculum with the needs and challenges of the industry, all parties involved can have their interests taken care of in a shared curriculum. As students complete their education and enter the workforce, they can apply the knowledge and skills they have acquired to improve the quality and efficiency of their respective industries. Graduates from joint programs, especially those with a focus on industrial mathematics, are highly qualified individuals who excel at finding solutions to actual challenges faced in the industry. The comprehensive understanding of the challenges facing all stakeholders paves the way for a curriculum designed to address these challenges effectively. This ensures that the curriculum serves its intended purpose and prepares graduates to make significant contributions to their industries. In general, the collaborative construction of the curriculum in joint programs brings together the expertise of industrial professionals and mathematicians, bridging the gap between theoretical knowledge and practical application. By integrating industry-specific challenges with mathematical concepts, these programs produce graduates who can provide innovative solutions to real-world problems, thus improving efficiency and profitability in various industries.

Industry Professional Responses

Only 16 of the responses to question 2.8.1.3 of the questions from the 51 industry experts that participated are reflected below. The question was "If your response to question number 2.8.1.1 is "Yes", what are the advantages of having a joint curriculum?" The following are the responses of the industry experts.

- *Sometimes, providing a chance to industry instructors lets students focus and get the right way of understanding the course.*
- *The application of mathematics focuses on improving industrial problems.*
- *for the development of both parties (fruitful outcomes);*
- *knowledge transfer and sharing*
- *It ensures that what is developed in academia is applicable to the industry.*
- *To improve industrial development and to provide advanced services and increase the capital of industries.*
- *To improve industry production rate and quality of products*
- *It can solve the gap between theory and practice.*
- *To support or adjust industries need with curriculum*
- *Having Applicable Curriculum In Both Sides & It Give The Chance For Customizing What The Industry Needs*
- *Taking Industry Scenarios into the Course*
- *The curriculum development will focus on both the industry situation and the academic area.*
- *Pass for implementation of industrial mathematics*
- *Information sharing know how to facilitate problem solving mechanisms and used for industrial research*
- *Course contents can be enriched by real problem-solving case studies*
- *Problems Will Be Solved Easily Through Digitalization, Creating Easy Problem-Solving Opportunities, & Provide Better Opportunities In Problem Solving*

A collaborative program provides instructors with the opportunity to actively engage in industry activities, which in turn benefits students by enabling them to focus on and fully comprehend the course material. Through this collaboration, the program can address specific industrial issues, and the application of mathematics is tailored towards solving these problems. This approach ensures that the industry receives cutting-edge solutions and experiences increased production. The involvement of industry experts is crucial, as they possess a deep understanding of the challenges faced by the industry. Their expertise allows them to provide relevant information and insight, bridging the gap between theoretical knowledge and practical application. By collaborating with academia, industry experts ensure that the knowledge generated in the academic setting is practical and useful for the industry, effectively closing the theory-practice divide. Joint programs have a positive impact on the development of both academia and industry. By incorporating mathematics into industry practices, these programs foster knowledge exchange and sharing, increasing industry capital, and improving production rates and product quality. The application of mathematics in industry contributes to its advancement and competitiveness.

In summary, collaborative programs that integrate mathematics into industry practices benefit both academics and industry professionals. They provide instructors with practical experience and allow students to grasp the course material more effectively. Furthermore, the collaboration addresses specific industrial issues and ensures that the application of mathematics is directly relevant to solving real-world problems. By sharing knowledge and promoting the use of mathematics in industry, these programs enhance production rates, improve product quality, and contribute to the overall development and competitiveness of the industry.

5.3.1.5. Industry Issue with the Corresponding Mathematical Concepts

This section highlights the input and suggestions provided by different participants in relation to research and projects related to industrial issues. Here are some of the responses from the participants, categorized by their respective backgrounds.

Applied Science and Engineering Instructors Responses:

- One respondent proposed the inclusion of building information modeling (BIM) that uses mathematical software in the newly developed curriculum. This suggests the importance of integrating technology and mathematical tools into industrial applications.
- From the School of Management and Business, one respondent suggested including business courses such as profitability, asset management, production chain control, and effective labor and resource utilization. This emphasizes the importance of incorporating business principles and practices into an industrial mathematics curriculum.
- In terms of physical lab courses, the instructors mentioned numerical analysis, computational methods, and differential equations as essential mathematical concepts. This shows the relevance of mathematical techniques and problem-solving approaches in real-world industrial scenarios.
- Mathematics instructors:
- The mathematics instructors recommended integrating specific mathematical concepts to address industrial issues. These suggestions included mathematical modeling, biomathematics, fractional calculus (both variable-order and constant order differential and integral equations), and analysis. This highlights the importance of mathematical techniques in understanding and solving complex problems in industrial settings.
- In addition, the instructors suggested incorporating a programming course related to MATLAB and other computing software, which is typically covered in computational methods. This acknowledges the importance of computational tools in industrial mathematics and their applications in data analysis and problem solving.

Industry professionals:

- Industry professionals have put forward several recommendations for the new curriculum. They suggested including courses that aid in technology selection, specifically through the Alliance of Technology Transfer Professionals (ATTP). This highlights the importance of considering technology transfer and innovation in the industrial mathematics curriculum.

- The professionals also emphasized the integration of programming skills into the curriculum, recognizing the growing importance of coding and its applications in industrial settings. They further suggested that projects be focused on work process flow, matrix analysis, and probability, indicating the need for practical hands-on experiences relevant to industrial problem solving.

5.3.2. Focus Group Discussion

This section provides an overview of the findings of the focus group discussions on the new curriculum for industrial mathematics in Ethiopian science and technology universities. Initially, the researcher's primary method for data collection was conducting face-to-face interviews. However, after piloting this approach, it was found to be ineffective in gathering sufficient information from the participants due to the novelty of the topic. As a result, the researcher decided to switch to a different data collection tool. Focus group discussions are more suitable for obtaining in-depth qualitative insights. Here are some reasons to choose focus group discussions: Focus groups provide rich, qualitative data that can uncover underlying motivations, attitudes, and perceptions of participants. This depth of insight is valuable for understanding complex issues. Participants can interact with each other, leading to the emergence of new ideas and perspectives. This group dynamics aspect can offer a deeper understanding of the topic. Focus groups allow researchers to explore topics in greater detail, probe responses, and clarify ambiguous answers. This flexibility enables a more comprehensive analysis of the subject matter. In a focus group, researchers can observe non-verbal cues like body language, tone of voice, and facial expressions, providing additional context to participants' responses.

Instructors expressed positive opinions about the curriculum, particularly with respect to its development and review. They also discussed their admiration for the teacher-led effort in designing the curriculum. The quantitative phase of the study revealed several benefits of implementing an industrial mathematics program at these universities. Participants reported that the program increased the roles of students, teachers, and industry experts in research and teaching-learning processes. Here are some specific advantages of having this program in Ethiopia:

1. Teachers gained benefits in terms of academic rank (77%) and increased publication (73%).

2. Students had better job opportunities (79%) and improved academic achievement (72%).

3. Industry experts received patents (63%) for their innovations.

4. Industrial mathematics had a positive impact on export products (94%) and boosted production and services (85%).

5. For universities, it improved their global ranking (89%) and increased publications (60%).

Based on the results of the quantitative investigation, the researcher led the focus group participants in suggesting improvements to the new industrial mathematics curriculum at Ethiopian Science and Technology University. These suggestions aim to further support the curriculum and align it with the research findings.

Point of Discussions

1. Do you think that the mathematics course you took at the university level is sufficient to solve problems of industry? Engineering? Applied Science? Yes/No

2. If the response is Yes/No, can you mention some of the strength/limitation of Mathematics curriculum related to problems in industry? Engineering? Applied Science?

3. What are the roles of academician (mathematician, engineers, and applied science scholars)/Industry expert implementing industrial mathematics curriculum in Ethiopian Science and Technology Universities/ In Ethiopian industries?

4. What are the factors that influence the implementation of industrial mathematics in an Ethiopian university? Industries? Regarding: Teaching learning? What is the relationship between the university industry?

5. What are the values of implementing industrial mathematics in enriching careers in terms of research? Teaching &training? Mentorship/advisor? Job opportunity?

6. Which industrial mathematics curriculum do you recommend for the Ethiopian Science and Technology University?

Participant 1. "In practice, in Ethiopia, curriculum is developed from upper level to lower level. This is the first time I have experienced a curriculum development initiative arise from a teacher, and I admire this initiative. Therefore, I support such a curriculum development method from the lower level or from stakeholder to upper-level management. However, my fear is how much higher-level management supports such initiations. "

Participant 2: "The development of the Ethiopian curriculum is politically motivated. Therefore, it is better to cross the line and show the importance of the new curriculum to promote industrial development in Ethiopia".

The third participant said, "It is better to conduct a stakeholder need assessment and a gap analysis of the need for the new industrial mathematics curriculum."

Participant 4. 'He strongly comments to publish on the APOS theory of curriculum development and research on mathematics education.'

Participant 5. 'To integrate disciplines from different fields of study, think of the mechanism to organise these groups in the same framework.'

Participant 6.. " Consider the quality monitoring of the curriculum you recommend to the universities of science and technology in Ethiopia. Briefly describe the profile of graduates who will work in industries. '

Participant 7. 'The curriculum should choose an industrial project, an internship programme, place students in industries and integrate students in a fellowship and an industrial practicum programme in order to implement this programme in Ethiopian industries.'

In the discussions, the instructors mentioned many advantages of the development of an industrial mathematics curriculum for Ethiopian Science and Technology Universities, which include industrial mathematics:

- is helpful to industry and research universities.
- Contributions to filling the gaps that were observed between industry and universities.
- is used as input for the development of the nation by providing graduates in this discipline.
- demands for an assessment tool that is being used to determine programme development, so the curriculum is applicable.
- It helps to work together for professional development.
- encourages students to learn mathematics.
- is very important for problem solving and increased productivity in industries.
- links people's knowledge with technology;

The researcher posed the question to the participants about the extent of the roles of academicians (mathematicians, engineers, and applied science scholars) and industry experts in implementing the industrial mathematics curriculum in Ethiopian Science and Technology Universities and Industries. Instructors emphasized that instructor participation in curriculum development should have commenced from the need assessment stage and continued throughout the curriculum development and implementation stages. They highlighted that instructors, who are the main people responsible for the program, play a crucial role in curriculum development. The focus group discussion emphasized that the motivation and active participation of instructors in the curriculum development process positively influence the importance of industrial mathematics curricula for science and technology universities.

In terms of the usefulness of instructors' activities, the discussions identified three categories: research, teaching, and learning, and providing community services through the programs. The focus group participants expressed their view that the industrial mathematics program should primarily focus on identifying and defining problems in industries and translating them into mathematical terms for solution. This collaborative approach that involves multiple participants in the field provides an opportunity for instructors to actively engage in mathematics research and teaching.

The discussion leaders also emphasized the importance of need assessment activities and gap analysis in effectively implementing industrial mathematics within Ethiopian economic development standards. However, the findings from the quantitative phase of the study indicated that the implementation of industrial mathematics was influenced by three key activities: industry activities, university-industry activities, and academic activities. These activities must be considered in the curriculum process. Furthermore, a significant number of instructors expressed the usefulness of the new industrial mathematics curriculum in acquiring more knowledge in the field, solving real-life problems in society, and improve collaboration across various disciplines and industries.

The instructors in the focus group discussions expressed their concern that the Ethiopian curriculum development process is politically motivated. However, they emphasized the importance of transcending political divisions and focusing on the significance of the new curriculum in promoting industrial development in Ethiopia. They observed that curriculum development in Ethiopia tends to follow a top-down approach, with limited involvement of teachers and senior management. The instructors also highlighted the need for higher-level management support for such initiatives and expressed the belief that industrial mathematics should be integrated with other disciplines from different fields of study. They discussed the importance of organizing these groups within a framework that contributes to common goals.

During the focus group discussions, the instructors discussed the mechanisms of implementing the industrial mathematics program in Ethiopian industries. Some of the suggested mechanisms included facilitating field visits for students, selecting industrial-based projects as part of the curriculum, providing internship programs, arranging student placements in industries, and embedding students in fellowship and industrial practicum programs. Most of the participants confirmed that the new proposed industrial mathematics curriculum in Ethiopian Science and Technology universities should have to facilitated mathematics research in industry.

In the next sub-section, the industrial mathematics curricula of different countries were examined, focusing on their program aims and the career opportunities they offer for students in undergraduate and graduate programs. The selection of these countries was based on their proximity to Ethiopia and their status as benchmark countries for the current educational reform in Ethiopia. Three industrial mathematics programs were chosen for Ethiopian science and technology universities based on the quantitative findings.

5.3.3. Document Review

5.3.3.1. Industrial Mathematics Program for Science and Technology

In this section, a comparison and analysis of industrial mathematics courses was conducted from different countries. Some countries were specifically selected for potential future collaborations. Malaysia, for example, was chosen because it served as a reference country for Ethiopian educational reforms. The curricula of other countries were assigned based on the quantitative data findings.

The purpose of this section was to provide an accurate and unbiased description of the courses, avoiding any preconceptions of the researcher. Quantitative analysis showed that both groups of respondents ranked "BSc. in Industrial Mathematics with Computer Applications" and "MSc. in Industrial Mathematics with Computer Applications" as their top choices. These choices formed the basis for comparing industrial mathematics curricula from other nations and selecting content suitable for Ethiopian Science and Technology universities.

The researcher examined industrial mathematics programs in select African nations, including Nigeria and Kenya, in universities, colleges, and institutes. Kenya was chosen because of its proximity to Ethiopia, while Nigeria was selected because of the numerous institutions offering industrial mathematics courses there.

In pursuit of improving the educational system aligned with the country's vision and development objectives, the Ministry of Education, specifically the Education Strategy Center, looked at Malaysia and Vietnam as international models for Asian nations. These two countries were known for their high-performing educational systems according to PISA scores (MOE, 2018). As a result, Malaysia's industrial mathematics curriculum was included for comparison.

Based on the results of the quantitative analysis, the undergraduate and graduate programs were similarly ranked as the first choice. However, they differed in their rankings for the second and third programs. Academics rated "BSc. in Industrial Mathematics and Statistics" second, while industry professionals ranked "BSc. in Industrial Mathematical Modeling" third, and vice versa for each program.

Table 5. 18 Undergraduate Industrial Mathematics, Program Aims and Careers

	Programs	**A degree program in Industrial Mathematics was aim to:**	**Careers opportunities**
1	B.sc Industrial Mathematics Curriculum of ***<u>Nigeria</u>*** (Appendix-A)	• To develop the ability to apply their mathematics knowledge and skills to the solution of theoretical and practical problems in mathematics • To acquire a variety of transferrable abilities that are useful in both jobs involving maths and jobs involving other subjects. • To foster an understanding of the value of mathematics in a range of contexts, including social, economic, environmental, and industrial. • To acquire highly technical skills in using mathematical solutions to problems with both industry and society.	• Mathematician, • Data Analyst, • Epidemiologist, • Quantitative Analyst, • Financial Analyst • Risk Analyst • Business Analyst **https://aliceisaacuniversityedu.com/course/b-sc-industrial-mathematics/**

2	BSc. Industrial Mathematics: ***Kenya*** (Appendix –B)	❖ Creating multidisciplinary researchers with current expertise in the field and an understanding of the connections between mathematics and business. ❖ Students will gain knowledge of analysis, logical thought, and abstract reasoning. ❖ The program puts emphasis on mathematical modeling and computational techniques.	❖ Systems Engineering ❖ Researchers ❖ Scientific computing Financial industry and Automotive companies Bachelor of Science in Industrial Mathematics in Kenya (tertiaryinstitutions.com)
3	**BSc. in Industrial Mathematics -*Malaysia* (Appendix-D)**	♦ To provide graduates with the information, abilities, and qualities necessary for a successful professional life. ♦ To produce qualified mathematicians who can work in related fields. ♦ Advance professionally by developing your soft skills. ♦ Promote a high standard of ethical behaviour, an optimistic outlook, and societal commitments.	❖ Quality assurance manager ❖ Production control engineer ❖ Planning officer ❖ Statisticians, ❖ Operations research ❖ Sales and marketing executives ❖ Financial executives ❖ Administrative officers Academicians ❖ Researchers https://science.utm.my/wp-content/uploads/2018/12/UG-HANDBOOK-2018_2019.pdf
4	BSc in Industrial Mathematics and Computer Science with Industrial Experience – ***Manchester*** (Appendix –E)	One can learn and develop practical knowledge and abilities in both computer science and mathematics through this combined honours degree programme. It covers the skills required to use mathematical models in simulations that	❖ Actuary, ❖ AI Engineer , ❖ Banker , ❖ Cloud Computing Engineer

		assess actual circumstances, including stress analysis in structures and bridges, airflow over aeroplane wings, or financial modelling. Between your second and third years of study, you will complete a one-year work placement in industry as part of the program's industrial experience component. Students with work experience tend to score better on final exams and have more definite views about their future career paths.	❖ Cyber Security Analyst ❖ Data Analyst ❖ Games Designer and/or Developer ❖ Software Engineer ❖ Web Designer and/or Developer (https://www.manchester.ac.uk/study/undergraduate/courses/2023/00490/bsc-computer-science-and-mathematics-with-industrial-experience/course-details/COMP10120#course-unit-details)
5	B.Sc. in Mathematics with Computer Applications (Appendix –F) – ***India***	The B.Sc. degree programme is structured to provide a foundation in both mathematics and computer applications, as well as a mathematical attitude towards problem formulation and solving, analytical skills, and a desire for accuracy. It also emphasises an appreciation of mathematical techniques, higher level computer language programming skills, and research aptitude in both mathematics and computer applications.	(https://ethirajcollege.edu.in/wp-content/uploads/2021/07/Ssmaths_with_ca.pd
6	BSc Mathematics and Statistics -***Manchester*** (Appendix –G)	Those who anticipate using statistics in their future professional career should particularly choose this very flexible single honours degree programme. They will get the ability to formulate and analyse issues, as well as interpret scientific data using the proper statistical techniques. Basic knowledge and skills in probability, statistics, and mathematics	Finance, industry, computing (including operational research), management, Administration, Statistics, teaching (schools and colleges), and postgraduate study **https://www.manchester.ac.uk/study/undergraduate/courses/2024/07101/bsc-**

		serve as the foundation for later, more technologically advanced work.	**mathematics-and-statistics/course-details/#course-profile**
7	BSc. (Hons) In Business And Industrial Mathematics- **Sri Lanka**	The Ministry of Higher Education and the University Grants Commission of Sri Lanka have authorised CINEC Campus's BSc (Hons.) in Business and Industrial Mathematics programme. This degree programme lasts four years, and CINEC always helps students locate an internship during the first six months of their final year. The industry has many employment openings in business and industrial mathematics, but there is currently a lack of skilled workers to meet its current and future workforce needs.	• Research and Financial analysts, • Corporate Finance executives and investment executives. **The target job market includes** • Finance companies, • Insurance companies, • Research Companies, • Software Companies, • Industrial companies in the corporate Business division of any other organization Business and Industrial Mathematics (cinec.edu)

According to Table 5.18, the industrial mathematics programs of Nigerian universities offer a wide range of courses beyond industrial mathematics. These programs also include subjects like computer science, accounting and finance, business management, and economics, and even certain engineering areas such as production engineering. By studying accounting and finance, industrial mathematics students gain the necessary skills to contribute to the management of the country's resources. The government relies on economic indices and analysis to aid in planning and resource allocation (Tsetimi, 2016). It is feasible to adjust the Nigerian industrial mathematics curriculum to meet the requirements of Ethiopia's industrial growth. This can be achieved by considering two options: introducing industrial statistics courses instead of the current Nigerian focus topics, and modifying mathematics courses to tackle industrial challenges. The order of the curriculum can be determined by identifying and formulating problems, engaging in mathematical modeling, and conducting simulations.

The primary goal of the Kenyan Industrial Mathematics course is to provide students with the necessary skills and knowledge to develop mathematical models and apply them to solve problems in various fields including engineering, science, medicine and other social domains. The course emphasizes the use of computational techniques and mathematical models to address social challenges. To achieve this, students are required to take advanced courses in mathematics, optimization, and computational techniques that are directly relevant to industrial investments. In addition, students have the opportunity to enroll in specialized courses in financial marketing, accounting, and physics. The Kenyan curriculum covers a wide range of subjects that are highly applicable to the workplace. Accordingly, it would be beneficial to modify the Kenyan industrial mathematics program to align it with the industrial progress in Ethiopia.

The structure of the Malaysian Industrial Mathematics program is designed in a way that allows for connections to be formed with educational institutions in other countries. This is achieved through the provision of transfer credits for courses that are comparable both domestically and globally, and by facilitating opportunities for students to undergo industrial training abroad. To ensure that the Malaysian Industrial Mathematics curriculum is aligned with the economic requirements of Ethiopia, it is essential to assess the courses that are directly relevant to the Ethiopian industry. Moreover, dividing the Malaysian industrial mathematics program into separate tracks for computer science and statistics could prove to be advantageous.

The University of Manchester's BSc in Industrial Mathematics and Computer Science programme offers a valuable blend of mathematical and computer science knowledge and skills. This programme equips students with the experience needed to apply mathematical models effectively in simulations that mirror real-life scenarios. Examples of such simulations include stress analysis in structures and bridges, airflow calculations for aircraft wings, and financial modeling. The curriculum encompasses a wide range of essential mathematical concepts and places significant emphasis on the importance of formulating abstract problems. In addition, it promotes the principles of formal evidence and rigorous argumentation. Additionally, the programme incorporates fundamental principles of software engineering and programming from the field of computer science.

In conclusion, comparative analysis of industrial mathematics programs in Nigeria, Kenya, and Malaysia provides valuable insight into aligning the curriculum with the industrial growth needs of Ethiopia. Nigerian universities' programs offer a diverse range of courses beyond industrial mathematics, including computer science, accounting and finance, and engineering. By incorporating industrial statistics courses and modifying mathematics courses to address industrial challenges, the Nigerian curriculum can be adapted to meet Ethiopia's requirements. The Kenyan Industrial Mathematics course focuses on equipping students with the skills to develop mathematical models and apply them to solve problems in various fields. The curriculum covers a wide range of topics applicable to the workplace, making it desirable to modify it to align with Ethiopian industrial progress. The Malaysian Industrial Mathematics program has a well-structured framework that fosters connections with educational institutions in other countries and facilitates industrial training abroad. To meet the economic requirements of Ethiopia, it is important to evaluate the courses that are relevant to the Ethiopian industry and consider dividing the program into computer science or statistics tracks. These findings suggest that a comprehensive approach that involves the integration of various disciplines, such as mathematics, computer science, and statistics, can better prepare students for the industrial challenges of the future. By adapting and aligning the curriculum, countries like Ethiopia can effectively address the needs of their growing industries. The BSc in Industrial Mathematics and Computer Science programme at the University of Manchester offers a unique combination of mathematical and computer science knowledge and skills. This programme provides students with the necessary expertise to effectively apply mathematical models in simulations that accurately reflect real-life situations. For example, students learn to perform stress analysis on structures and bridges, calculate airflow patterns on aircraft wings, and perform financial modeling. The curriculum covers a wide range of essential mathematical concepts, placing a strong focus on problem formulation and the ability to tackle abstract problems. It also emphasizes the principles of formal evidence and rigorous argumentation. In addition, the programme integrates fundamental principles of software engineering and programming from the field of computer science. As a result, graduates are well prepared to address various industrial challenges by leveraging their mathematical and computational skills.

Table 5. 19 MSc. Industrial Mathematics, program aims and Careers

	MSc Programs	Program Aims:	Careers opportunities
1	M. Sc. (Industrial Mathematics with Computer Application)- India	1) Provide students with adequate knowledge of fundamental concepts, procedures, and a comprehensive understanding of the immense strength of mathematical concepts, tools, and techniques, as well as instruction on how to apply these concepts through modelling, problem-solving, and interpretation. 2) reflecting the topic's breadth and creating mathematical tools for further scientific research in diverse domains. 3) Improving students' entire growth and giving them the mathematical modelling expertise, problem-solving know-how, artistic creativity, and communication skill required for varied job roles. 4) Enabling learners to adopt a favorable mindset towards mathematics as a fascinating and worthwhile field of study.	➢ IT expert ➢ Data analyst ➢ Software Engineer (https://nowrosjeewadia.mespune.org/course/m-sc-industrial-mathematics-with-computer-application/)
2	Master of Science (Industrial Mathematics) : Malaysia	Program Description Applied and industrial mathematics are covered in-depth in two sub-specializations of the Master of Science in Industrial Mathematics, respectively (i) Data Computing, and (ii) Computational Mathematics. The programme supports simulation and big data computing, two pillars of the Industrial Revolution 4.0 (IR 4.0). The curriculum has a strong emphasis on embedded case studies, which allow students to combine theory and application while also using crucial computational tools including Python, R Language, VBA, EXCEL, Matlab, TORA, Minitab, and KNIME. Every student in the programme must also finish a project dissertation based on a selected applied and industrial challenge. The programme is designed for recent graduates and working professionals, particularly those with non-mathematics degrees, who want to improve their knowledge and skills in one of the several sub-specializations. Applicants are encouraged from candidates with a first degree in any of the following fields: statistics, mathematics, finance, economics, computing, engineering, or the sciences, as well as strong proficiency in undergraduate mathematics courses.	• Academician • Cryptographer • Investment Analyst • Quantity Surveyor Acoustic • Data Analyst • Inventory Control • Statistician • Consultant • Data Engineer • Machine Learning Engineer • Software Engineer • Actuarial • Data Scientist • Mathematical Modeler Centre for Mathematical Sciences - Master of Science (Industrial Mathematics) by Mixed-Mode (ump.edu.my)

3	Master of Business & Science In Industrial Mathematics- USA Rutgers, The State University of New Jersey	A postgraduate course in industrial management is called M.Sc. Industrial Mathematics, or Masters of Science in Industrial Mathematics. Industrial mathematics relates to what a scientist can know, what an executive can manage, and what an engineer can design. The methods and concepts of applied mathematics can be used to analyse subtle interactions, vast amounts of data, and complicated systems. The M.Sc. in Industrial Mathematics programme typically lasts two academic years, but this might vary from university to institute and some may even provide part-time options. The course is career-oriented and is divided into four semesters in the syllabus.M.Sc. Industrial Mathematics Eligibility	Master of Business & Science in Industrial Mathematics – Department of Mathematical Sciences (rutgers.edu) • Product Manager • Biology Researcher • Teacher & Lecturer • Market Research - Manager • Industrial Relations Manager • Science Adviser • Business Analyst Manager • Quantitative Marketing Analyst • Professor/Asst. Prof./Lecturer • Project Manager • Analyst
4	Center for Industrial Mathematics and Statistics (CIMS)- WPI)- USA	The Center for Industrial Mathematics and Statistics (CIMS) ❖ To promote collaborations between the university and business, government, and industry for research in mathematics and statistics ❖ Businesses and industries are faced with increasingly complicated difficulties, and these problems are frequently solved using sophisticated mathematics. The staff and students affiliated with CIMS have the knowledge necessary to tackle the complex issues of today and offer answers utilising pertinent statistics and maths. ❖ The Centre gives undergraduate and graduate students the chance to get practical company experience through projects and internships that increase their competitiveness in the employment market of today.. ❖ Additionally, it improves businesses' technological competitiveness and assists them in meeting their needs for mathematical answers. The industrial projects in maths and statistics that CIMS offers offer a distinctive education for prosperous careers in business, higher education and industry..	www.wpi.edu/+CIMS • Actuarial Mathematics • Applied Statistics • Applied Mathematics • Financial Mathematics • Mathematics for Educators • Mathematical Sciences
5	Master's degree	This flexible single-honors undergraduate Master's	https://www.manchester.ac.uk/s

	program in Mathematics and Statistics / Overview	degree programme will frame and analyse topics as well as interpret scientific data using the appropriate statistical approaches if you plan to use statistics in your professional career. Your education in these specialised fields is sufficiently in-depth to enable you to pursue postgraduate studies, engage in research, or work as a specialised mathematician. A core of basic mathematics, probability and statistics provides you with the fundamental knowledge and skills, and the basis for more advanced work later on.	tudy/undergraduate/courses/2023/07102/mmath-mathematics-and-statistics/#course-profile

According to Table 5.19, the Indian M. Sc. (Industrial Mathematics with Computer Application) program aims to prepare students for various job opportunities that involve using computer science and technology to solve mathematical problems or for further studies and research in mathematics. The curriculum not only focuses on developing professional skills and problem-solving abilities using computing sciences but also covers the fundamental aspects of mathematics and computer science disciplines.

In Malaysia, the Master of Science in Industrial Mathematics offers two sub-specializations: Data Computing and Computational Mathematics, which both emphasize applied and industrial mathematics. This program provides training in simulation and big data computing using computational tools like Python, R Language, VBA, EXCEL, Matlab, TORA, Minitab, and KNIME. Students are also required to complete a project dissertation on applied and industrial problems. It is worth noting that this program is open to both non-mathematics degree holders and first-year students with a strong undergraduate mathematics background.

In the United States, the Master of Business & Science in Industrial Mathematics program focuses on industrial management, data analysis, interaction analysis, and complex system analysis. These programs typically offer part-time options and span two academic years that consist of four semesters. The specific requirements for this program may vary. The Center for Industrial Mathematics and Statistics (CIMS) in the United States aims to foster collaborations between universities, businesses, government, and industry in the field of mathematics and statistics research. The center utilizes advanced mathematics to address complex problems and provide solutions. It offers practical experience to students, enhances their competitiveness, and contributes to companies' technological competitiveness. Finally, the Master's degree program in Mathematics and Statistics from Manchester, UK offers a comprehensive single-honors program that covers various topics and statistical approaches relevant to professional work. This program prepares students for postgraduate studies, research, and careers as mathematicians. However, it is suggested that it would be beneficial to include industrial mathematics curricula from more developed nations alongside the mentioned programs. On the basis of the evidence presented, it is apparent that Ethiopian science and technology universities are involved in developing new industrial mathematics. When creating new curricula, researchers must adhere to theories of curriculum development in mathematics education. In the study mentioned, the APOS theory was used for research and curriculum development in industrial mathematics. The next part of the study includes a sample curriculum guide for undergraduate industrial mathematics in science and technology universities.

In conclusion, the information provided in Table 5.19 and the accompanying details highlight various master's degree programs in industrial mathematics in different countries. These programs aim to equip students with the skills and knowledge necessary to pursue careers in fields that utilize mathematics, computer science, and technology for problem solving and research purposes. The Indian M. Sc. program focuses on both professional skills in computing sciences and fundamental aspects of mathematics and computer science. This ensures that students are well prepared for employment opportunities or advanced studies in mathematics. The Malaysian Master of Science program offers sub-specializations in Data Computing and Computational Mathematics, with a strong emphasis on applied and industrial mathematics. Students are trained in simulation and big data computing using various computational tools. The program is open to students with or without a mathematics degree, provided that they have a solid background in undergraduate mathematics. The Master of Business & Science in Industrial Mathematics program in the United States focuses on industrial management, data analysis, and complex systems analysis. These programs often allow for part-time study options and have varying requirements. They provide students with the skills necessary for success in industrial careers. The Center for Industrial Mathematics and Statistics (CIMS) in the United States serves as a hub for collaboration between universities, businesses, government, and industry in the research and application of mathematics and statistics. The center is dedicated to using advanced mathematics to solve complex problems and improve technological competitiveness. The Master's degree program in Mathematics and Statistics from Manchester, UK, offers an extensive curriculum that prepares students for postgraduate studies, research, and careers as mathematicians. However, it is suggested that including industrial mathematics curricula from other developed nations would further enhance the program's effectiveness and relevance. Moreover, evidence suggests that Ethiopian science and technology universities are actively involved in the development of new industrial mathematics. Researchers in mathematics education should consider utilizing curriculum development theories such as the APOS theory to ensure effective and comprehensive curricula. The inclusion of a sample curriculum guide for undergraduate industrial mathematics in science and technology universities further contributes to improving the field in Ethiopia.

5.4. Summary

This chapter provided a comprehensive analysis of the data collected through questionnaires, focus group discussions, open-ended questions, and review of documents. The researcher gathered data through questionnaires using both paper-based surveys and Google Forms. There was initial resistance from respondents to complete paper questionnaires. To address this resistance, the researcher prepared a Google Form to collect data and overcome the challenges faced with the paper-based method.

This chapter is divided into three sections, each addressing specific aspects of the research. The first section focuses on the analysis of data collected from questionnaires. These data provide valuable information on insights into the perceptions and experiences of individuals about the industrial mathematics curriculum. By analyzing the responses to the questionnaire, the study can identify the strengths and weaknesses of the current curriculum, allowing for a critical evaluation of its effectiveness. The second section comprises the analysis of data obtained from focus group discussions and document reviews. This study investigates the implementation of industrial mathematics programs in different countries, examining relevant materials from science and technology universities, industries, and government organizations. The exploration involves an examination of documents that provide insights into the structure, content, and practices of these programs. By studying these materials, the research aims to gain a comprehensive understanding of how industrial mathematics programs are implemented in different countries and the involvement of key stakeholders such as universities, industries, and government bodies. Based on my experience, the curriculum development process was previously carried out by representatives chosen from various institutions; however, the selection process was biased and influenced by their positions within the universities. The researcher can draw meaningful comparisons and identify areas of focus in the guide of the new industrial mathematics development for Ethiopian universities. The third section delves into a detailed analysis of the industrial mathematics curriculum for Ethiopian science and technology universities. Here, the curriculum is evaluated by comparing it with reports from reputable organizations such as SIAM (Society for Industrial and Applied Mathematics), OCED (Organization for Economic Cooperation and Development), the Ethiopian curriculum development framework on applied mathematics curriculum, and relevant literature. This comparative analysis helps to ensure that the curriculum is aligned with international standards and best practices. However, the selection of benchmark countries within the Ethiopian educational system impacts the curriculum development process. For example, the university where I am currently employed introduced an outcome-based curriculum educational system that was not utilized in other universities in Ethiopia.Furthermore, the chapter explores the participants' understanding of industrial mathematics and compares it with different scholarly definitions. Researcher defines industrial mathematics as an interdisciplinary field that integrates various mathematical disciplines such as differential analysis, numerical optimization, modeling, simulations, statistics, computer science, engineering, and financial mathematics. This definition aligns with the programs chosen by Ethiopian universities of science and technology, ensuring that they cover the necessary topics and disciplines.

In addition, the chapter investigated mechanisms for promoting the use of mathematics in industry. It examined industrial topics and related mathematical concepts in selected industries and government organizations. By identifying these topics, the research aimed to bridge the gap between academia and industry, ensuring that the curriculum covered practical and applicable knowledge. Based on my observation, the majority of curricula in Ethiopian science and technology universities tend to emphasize theoretical aspects rather than incorporating practical skills. Consequently, graduates often face challenges in securing job opportunities. To enhance graduate employability skills, the chapter also addressed teaching strategies. We designed these strategies to equip students with the necessary skills and knowledge for successful careers in the industrial sector. By incorporating these strategies into the new industrial mathematics curriculum, Ethiopian science and technology universities can better prepare their graduates for the job market.

The curriculum of Industrial Mathematics in Nigeria and other mentioned countries can be tailored to align with the newly developed Industrial Mathematics curriculum in Ethiopian science and technology universities. This adaptation is informed by the specific needs of Ethiopian industrial stakeholders and is guided by the APOS theoretical framework discussed in Chapter Three. The course contents and educational strategies are carefully chosen and structured based on the principles of the APOS theory, which focuses on how students grasp mathematical concepts and shapes pedagogical innovations.

The objectives of the courses and the selection of course contents are driven by an analysis rooted in the APOS theoretical framework, emphasizing the Action-Process-Object-Schemas elements. The curriculum design and teaching practices are informed by the APOS framework, particularly in designing instructional activities through the ACE teaching cycle (Activities-Class discussion-Exercise) to foster the cognitive frameworks required for understanding mathematical concepts thoroughly.

Teaching methodologies and assessments that enhance students' employability skills are integrated into the instructional strategies guided by the APOS theory. The data collection and analysis phase, the crucial third stage in APOS-based research, aims to validate the effectiveness of the instructional approach. This phase addresses whether students are engaging with the material as expected and if learning outcomes meet the desired objectives. Adjustments to the instruction or theoretical framework are made based on these evaluations, with a continuous cycle of revision to enhance teaching practices and curriculum delivery.

This structured approach is applied throughout the selection and adaptation of Industrial Mathematics programs to ensure that the final curriculum aligns effectively with the needs and context of Ethiopian science and technology universities, fostering a comprehensive and tailored educational experience.

Research conducted utilizing the APOS Theory framework typically includes three main elements: theoretical analysis, which involves breaking down mental structures and mechanisms to explore how mathematical concepts are formed; developing and applying teaching methods based on this analysis; and gathering and examining data to compare with the initially hypothesized constructions, leading to potential revisions and adjustments to the genetic decomposition if needed. (Oktaç, Trigueros, & Romo, 2019)

Matthew Inglis (2015) endorses the idea proposed by Lakatos (1976) that a research program offers a more precise portrayal of the APOS theory's status, providing a beneficial framework for assessing its impact. Consequently, the M. Sc. program in Industrial Mathematics with Computer Application is designed to prepare students for positions that require the use of computer science and technologies in solving mathematical problems, or for pursuing advanced academic studies and research in mathematics integrated with computer science (Matthew, 2015)..

Overall, this chapter provided a detailed analysis of the current mathematics curriculum given in Ethiopian universities which is different from industrial mathematics under this study, identified strengths and weaknesses, compared it with international standards, defined the field of industrial mathematics, explored mechanisms for promoting its use in industry, and incorporated teaching strategies to improve graduate employability skills

CHAPTER SIX: DISSCUSION OF THE FINDING

6.1. Introduction

In this chapter, the study's main findings, which include the selection of an industrial mathematics curriculum for Ethiopian Science and Technology universities and the theoretical framework for research and curriculum development in mathematics education, were synthesized to create a curriculum guide for the undergraduate program in industrial mathematics. The guide incorporates components related to employability skills and teaching strategies for implementing these skills among graduates of industrial mathematics.

To develop industrial mathematics curricula, the study utilized APOS theory for research and curriculum development in mathematics education. This theory provided a framework for designing and structuring the curricula. Additionally, examples of applied mathematics courses were used in the study to illustrate the practical application of APOS theory in both research and curriculum development.

6.2.Selected Industrial Mathematics Program

Based on the survey findings and the quantitative analysis in Section 4.2.2.8, the preferred industrial mathematics programs for Ethiopian Science and Technology universities, as chosen by academic experts and industry professionals, are the BSc in Industrial Mathematics with Computer Applications, BSc in Industrial Mathematics and Statistics, and BSc in Industrial Mathematical Modelling. The selection of these programs was influenced by the employment opportunities available in their respective institutions. Example courses for these programs can be found in Appendix 1A-1G. In terms of post-graduate options, the majority of respondents selected the MSc in Industrial Mathematics with Computer Applications as their first choice out of 10 options. The MSc in Industrial Mathematics and Statistics and the MSc in Industrial Mathematical

Modelling were chosen as the second and third options, respectively, by both academic and industry respondents. However, their ranking varied between the two groups. Industry specialists ranked the MSc in Industrial Mathematics and Statistics as their second choice and the MSc in Industrial Mathematical Modelling as their third choice. Academicians, on the other hand, ranked them in the opposite order. These selected industrial mathematics programs are considered suitable for Ethiopian industries and government institutions. The following section will present an undergraduate industrial mathematics curriculum guide, which will be developed using the APOS theory of research and curriculum development in mathematics education.

6.3. Curriculum Guide of Industrial Mathematics Based on APOS Theory

The APOS theory, which serves as the underlying framework for research and curriculum development in industrial mathematics, encompasses three key components: theoretical analysis, design and implementation of instruction, and data collection and analysis. This study aims to focus on the first two components, namely the theoretical analysis and the design and implementation of instructional strategies and sample courses in industrial mathematics. Examples from previous research in these areas will be used to illustrate these components. The first part of the theoretical analysis entails a preliminary genetic decomposition, which aims to enhance students' conceptual understanding of mathematics to the level of mathematical concepts, comparable to the understanding of mathematicians. It is important to note that these proposed preliminary genetic decompositions have not yet been experimentally tested or either it was tested by others but it is new for others to implement with a new study group. The second component of the instruction design concentrates on methods to assist students in constructing these mental representations, based on the preliminary genetic decomposition. Table 6.1 provides an illustration of how the development of new industrial mathematics curricula for undergraduate science and technology programs in universities unfolds. The curriculum guide encompasses course content, specific objectives, and prerequisite knowledge required to learn each topic. The third part relates to the APOS theory of research and curriculum development, which is referred to as data collection and analysis in this study. This aspect is described in the research topics. The study also includes evaluation, instructional resources, and teaching methods that aim to enhance employability skills.

In the initial phase of the theoretical analysis within the APOS theory, several fundamental questions can be addressed, such as the most effective technique for developing a theoretical viewpoint, the relationship between this notion and the actual learning process, the accuracy of theoretical analysis in representing students' mental processes, the meaning of comprehension in relation to ideas, and how students can generate that understanding (Arnon et al., 2014).

Table 6. 1 Curriculum guide for undergraduate Industrial Mathematics Program

Topic 1 Concept of the Limit of a Function

Prerequisite knowledge

Review the following concepts from previous courses:

- *determining* the slope of a line
- *determining* the equation of a line
- *using* function notation for substituting into and evaluating functions
- *simplifying* algebraic expressions
- *factoring* expression
- *finding* the domain of functions
- *calculating* average rate of change and slopes of secant lines
- *estimating* instantaneous rate of change and slopes of tangent lines

Contents	Specific Objectives	Theoretical Analysis (Genetic-decomposition)	Design and implementation of instruction	Teaching strategies (enhancing employability skills)	Assessment	APOS research Question	Instructional Resources
Topic-1 Concept of the Limit of a Function	At the end of the lesson students will be able: • *Define* the limit of a function • *Express* limit explicitly	**Action:** An explicit expression to think about a limit of a function, $\lim_{x\to a} f(x)$, and can do little more than substitute values of *x* close to *a* for the variable in the expression $f(x)$ and manipulate it. It is considered an action to have better understanding of the limit of a function. **Process:** For example, an individual with a	**Activities** :Lecture When does limit exist? **1.** Let $f(x)=\frac{x^2-16}{x-4}$, Does $\lim_{x\to 4} f(x)$ exist? **2.** When does $\lim_{x\to 4} f(x)$ exist? **3.** Find the following limits **3.1.** $\lim_{x\to 3} g(x)$, if $g(x)=\frac{x^2+9}{x-3}$	• Cooperative learning • Discussion • Presentation	**1)** Group discussion of 5/6 students for testing the understanding level of a student **2)** Additional practical work of interdisciplinary approach **3)** Written Test and/or Mid Term Test (not more than one or two for each course) **4)** Journal/Lecture/	Two basic questions in APOS are: (**1**) Did the students make the mental constructions called for by the theoretical analysis? (**2**) How well did the students learn the mathematical content? If the answer to	♦ GeoGebra ♦ Matlab ♦ ELearning resources ♦ Access to online resources ♦ PC tablet

Contents	Specific Objectives	Theoretical Analysis (Genetic-decomposition)	Design and implementation of instruction	Teaching strategies (enhancing employability skills)	Assessment	APOS research Question	Instructional Resources
	• *Evaluate* the limit at a given point • *Compute* limits of different functions	process understanding of the limit of a function $\lim_{;x\to a} f(x)$, will construct a mental process for values of x close to a and think in terms of inputs, possibly unspecified, and transformations of those inputs to produce outputs. **Object:** For example, for the concept of limit of a function, an individual may confront situations requiring him/her to apply various actions and/or processes. These could include thinking about an operation on two functions and producing a new function, such as in $\lim_{x\to 4^+} \frac{4-v}{\|4-v\|}$ or	**3.2**. $\lim_{x\to 1} \frac{\|x-1\|}{x-1}$ **4**. Refer to the graph of $f(x)$ **Class Discussion:** ♦ Free to discuss with other students sitting in addition to them. ♦ Use prescribed textbook ♦ Working together on their difficulty ♦ Activities and discussion followed after homework. **Homework** ♦ Tutorials a multiple choice questions (MCQs) test		Library notes **5)** Short Quizzes; **6)** Assignments	the first question is negative, then the instruction is re-examined and revised. If the answer to the first question is positive and the answer to the second question is negative, the theoretical analysis is reconsidered and revised. (Arnon, et al., 2014) ***a***) How should the teaching of the concept of a limit of a function be approached? ***b***) What insights would an APOS	

Contents	Specific Objectives	Theoretical Analysis (Genetic-decomposition)	Design and implementation of instruction	Teaching strategies (enhancing employability skills)	Assessment	APOS research Question	Instructional Resources
	• Define one sided limit	$\lim_{x \to 0^-} \left(\frac{1}{\sin x} \right)$. In order to operate on the one-sided limit of this new function, the process understanding must be encapsulated and converted to an object. **Schemas :** For example, the coherence might lie in the understanding that to determine the existence of a limit of a function $\lim_{x \to a} f(x)$, the following must be considered: input values to the left and right of a, the corresponding output values, and a means of transforming elements of the inputs into elements of the outputs.				analysis of the students' understanding of the concept of a limit of a function reveal? Aneshkumar Maharaj(2010) 1) To what extent do our theoretical ideas work? 2) How much mathematics are students learning? 3) What would it take to falsify specific conjectures or our theory in general? 4) Since data can come from this study but also from assessment	

Contents	Specific Objectives	Theoretical Analysis (Genetic-decomposition)	Design and implementation of instruction	Teaching strategies (enhancing employability skills)	Assessment	APOS research Question	Instructional Resources
						of student learning, which may not be part of this study, what is the appropriate use of these in drawing conclusions? (Asiala, 1996)	

Topic 2 Definition of the derivative of a function

Prerequisite knowledge

Review of the following concepts from previous courses and the previous

- Working with the properties of exponents
- Simplifying radical expressions
- Finding the slopes of parallel and perpendicular lines
- Simplifying rational expressions
- Expanding and factoring algebraic expressions
- Evaluating expressions
- Working with the difference quotient

Contents	Specific Objectives	Theoretical Analysis (Genetic-decomposition)	Design and implementation of instruction	Teaching strategies (enhancing employability skills)	Assessment	APOS research Question	Instructional Resources
Topic-2 Definition of the derivative of a function (using the tangent line at a point on its graph)	At end of the lesson students will be able • Compute the slope of a line between two given points • Sketch the curve of y= f(x) and	**Action:** Connecting two points $A(a, f(a))$ and $B(b, f(b))$ on a given curve $y = f(x)$ to construct its corresponding chord and the actions needed to calculate the slope $m = \frac{f(b) - f(a)}{b-a}$ of this chord. **Process:** Interiorization of the above actions to the process of calculating the slope of	**Activities** : 1. The students are working on the Limit process, where the point $B(b, f(b))$moving on the graph of f(x) approaches the fixed point $(a, f'(a))$, which means that the corresponding secant line approaches the tangent lines of the graph at point A. 2.Students draw the graph of $f(x)$ and its	• Cooperative learning • Discussion • Presentation Refer to chapter-2	1) Written Test and/or Mid Term Test (not more than one or two for each course) 2) Journal/Lecture /Library notes; 3) Short Quizzes;	Two basic questions in APOS are: (1) Did the students make the mental constructions called for by the theoretical analysis? (2) How well did the students learn the mathematical content? (Arnon, et al.,	♦ GeoGebra ♦ Matlab ♦ ELearning resources ♦ Access to online resources

	tangent line at a point • Define tangent line • Find equations of a tangent line • Determine the slope of a tangent line	a secant line at a point a as the second point b approaches it **<u>Object:</u>** Encapsulation of the above process in two objects, the tangent line at a point $(a, f(a))$ of the graph of $f(x)$ and the slope of the tangent, i.e. the derivative $f'(a) = \lim_{x \to a} \frac{f(x) - f(a)}{x - a}$ Of the function $f(x)$ at $x = a$.	tangent line at x=a ,calculate the slope of the tangent line and plot the point $(a, f'(a))$ in the coordinate syatem 3. Expanding the second procedure so that, to plot any point the form $(x, f'(x))$ when the graph of f(x) is given to draw the the graph of the function $f'(x)$ in the same coordinate system. **<u>Class Discussion:</u>** *Students express their ideas, thought, and understanding through reflection to the class and in a group discussion **Instructors led the discussion ***using soft ware sketch the graph of f and f"		4) Assignments; 5) An Open Book Test	2014) 3) To what extent do our theoretical ideas work? 4) How much mathematics are students learning? 5) What would it take to falsify specific conjectures or our theory in general? 6) Since data can come from this study but also from assessment of student learning, which may not be part of this study, what is the	

			Homework: *Using the graph of the function $f(x)$ and the values of f given in the table approximate the value of the derivatives of $f'(x)$ at $x = a$ ** Suppose that L is the tangent to the graph of $f(x)$ at the point (a,a) .Calculate the value of of $f\ '(a)$			appropriate use of these in drawing conclusions? (Asiala, 1996)	

Topic 3 Definite Integral (for a General Continuous Function f(x) when x ∈ [a, b])

Prerequisite knowledge

Review of the following concepts from previous courses:

- The concept of summation and properties of summation
- $\sum_{i=1}^{n} 1 = n$
- $\sum_{i=1}^{n} \mathrm{i} = \frac{n(n+1)}{2}$
- $\sum_{i=1}^{n} i^2 = \frac{(n+1)(2n+1)}{6}$
- The concept of anti-derivatives
- The concept of the limit function

Contents	Specific Objectives	Theoretical Analysis (Genetic-decomposition)	Design and implementation of instruction	Teaching strategies (enhancing employability skills)	Assessment	APOS research Question	Instructional Resources
Topic-3 Definite integral for a general continuous function f(x) when x ∈ [a, b]	At end of the lesson students will be able • Revise rule of summations • Define Riemann	**Action :** : Write the definition of the Riemann integral limit correctly for the function $f(x) = x^2$ when $x \in [1,2]$. **Process:** Progress the solution to the point of calculating algebra with the summation terms	**Activities :** i)Define the Riemann integral of the function $f(x) = x^2$ on the interval x$x \in [1,2]$ ii) Using the summation rule, expanded the summation of the function $\lim_{n\to\infty}\left(\sum_{i=1}^{n} f(1+i\Delta x)\Delta x\right) =$ iii) Using the summation rule find	• Cooperative learning • Discussion • Presentation	i) Written Test and/or Mid Term Test (not more than one or two for each course) ii) Journal/Lecture/Library notes; iii) Short Quizzes;	Two basic questions in APOS are: (1) Did the students make the mental constructions called for by the theoretical analysis? (2) How well did the students learn the mathematical	♦ GeoGebra ♦ Matlab ♦ ELearning resources ♦ Access to online resources

	sum • Compute the limits functions •	that have i and i^2 **Object:** calculations to the point that the limit must be applied before finding the correct answer **Schemas:** "Object" level and be able to find the right answer by applying the limit.	the sum of the $\sum_{i=1}^{n} 1$, $\sum_{i=1}^{n} i$ and $\sum_{i=1}^{n} i^n$ iv) Using limit theorem evaluate the limit of the given function obtained in step **Class Discussion:** • Instructors led discussion • Question and answer **Homework** **Repeat the procedure using the function** $\boldsymbol{f(x) = x}$ When $x \in [-1,3]$.	Refer to chapter-2	iv) Assignments; v) An Open Book Test	content? (Arnon, et al., 2014)	

Topic-4 Polar Coordinates

Prerequisite knowledge

Review of the following concepts from previous courses:

- Drawing an angle clockwise and counterclockwise in the plane; for example the difference between $\frac{\pi}{4}$ and $-\frac{\pi}{4}$
- Sketching graphs with trigonometric functions like

$y = \cos x$ $\quad$ $y = \sin 2x$

$y = \sin x$ $\quad$ $y = \cos 2x$

- • Compute the values of trigonometric functions like $\sin\frac{5\pi}{2}$, $\cos\frac{4\pi}{3}$, $\sin\frac{17\pi}{6}$, etc.
- Cartesian coordinates, for example plotting points (x, y) sketching line graphs and quadratic graphs in the plane,

Contents	Specific Objectives	Theoretical Analysis (Genetic-decomposition)	Design and implementation of instruction	Teaching strategies (enhancing employability skills)	Assessment	APOS research Question	Instructional Resources
Topic-4 Polar Coordinates	At the end of the lesson students will be able : • Define polar coordinate • Change polar coordinate to	**Action:** Identify a point P in the plane for an ordered pair(r, θ), where r and θ are positive numbers. **Process:** Interiorization of the above action into a *process* by plotting a point (r, θ) in the plane, where r and θ can be positive or negative. It is recalled that,	**Activities :** 1. Prerequisite knowledge (Cartesian coordinates, generalized angles, and trigonometric functions). 2. Identifying, plotting, and representing points of the plane by their polar coordinate and converting Cartesian to polar coordinate and	• Cooperative learning • Discussion • Presentation	a) Group discussion of 5/6 students for testing the understanding level of a student b) Additional practical work of interdisciplinary approach c) Written Test and/or Mid Term Test (not more than one or two	Two basic questions in APOS are: (1) Did the students make the mental constructions called for by the theoretical analysis? (2) How well did the students learn the mathematical content?	♦ Geo-Gebra ♦ Matlab ♦ ELearning resources

Contents	Specific Objectives	Theoretical Analysis (Genetic-decomposition)	Design and implementation of instruction	Teaching strategies (enhancing employability skills)	Assessment	APOS research Question	Instructional Resources
	Cartesian coordinate • Change Cartesian coordinate to polar coordinate • Sketch the graph of polar coordinate	when $r < 0$, then the point P is determined in a distance $\|r\|$ on the opposite side of the straight line determined by the angle θ **Object:** An *object* conception occurs when students encapsulate all the above cases ,thus understand that in a polar coordinate system each point has many representations **Schemas**: When the above actions, processes, and objects are organized in a coherent *schema*, then students become able to sketch polar equations.	vice versa. 3. Sketching graphs of polar equations in all quadrants of the plane **Class Discussion:** *Instructors guide students reflection **Working in a cooperative group *** Computer activities **Homework**	Refer to Chapter 2 for Employability skill Teaching Strategies	for each course) d) Journal/Lecture/ Library notes e) Short Quizzes; f) Assignments	(Arnon, et al., 2014)	♦ Access to online resources

Contents	Specific Objectives	Theoretical Analysis (Genetic-decomposition)	Design and implementation of instruction	Teaching strategies (enhancing employability skills)	Assessment	APOS research Question	Instructional Resources

Topic-5 Riemann sum

Prerequisite knowledge

Review the following concepts from previous courses:

- Areas of plane figure
- Area of region under any curve
- Properties of Summation
- Anti-derivatives

Contents	Specific Objectives	Theoretical Analysis (Genetic-decomposition)	Design and implementation of instruction	Teaching strategies (enhancing employability skills)	Assessment	APOS research Question	Instructional Resources
Topic-5 **Riemann Sum**	At the end of the lesson students will be able : • Estimate the area of irregular plane figure	**Action:** A1. Constructing the estimation of the definite integral as the area under the curve on a plane A2. Finding the area	**<u>Activities :</u>** *Worksheet-1 was designed to construct the mental mechanisms of Action-1, Action-2, and Action-3. **Worksheet-2	• Cooperative learning • Discussion	g) Group discussion of 5/6 students for testing the understanding level of a student h) Additional practical work of interdisciplinary	Two basic questions in APOS are: (1) Did the students make the mental constructions called for by the theoretical analysis? (2) How	♦ Geo-Gebra ♦ Matlab

	• Define partitions of the number system • Define upper sum and lower sum of the interval • State the properties of summation • Define the **Riemann Sum**	under the curve that divided into several partitions with the inner approach A3. Repetition of the A2 above with an outer rectangular approach to eliminate dependence on external cues **Process:** P1. Interiorizing the second action, A2, in n partition. P2. Interiorizing Action-3 on the n-partition **Object:** O1. Encapsulating the first process, **P1**, and second process, **P2**, into objects to determine the existence of limit and limit values of Riemann sums, and. O2. Encapsulating the	was designed to construct the mental mechanisms of Process-1 and Object-1, while ****Worksheet-3 was designed to construct the mental mechanisms of Process-2 and Object-1 **<u>Class Discussion:</u>** *Instructors identify students ability using prerequite knowledge **Small group instructor led discussion ***Instructors assist student individually or in a group.	• Presentation Refer to Chapter 2 for Employabilit y skill Teaching Strategies	approach i) Written Test and/or Mid Term Test (not more than one or two for each course) j) Journal/Lecture/ Library notes k) Short Quizzes; l) Assignments	well did the students learn the mathematical content? (Arnon, et al., 2014)	♦ ELearning resources ♦ Access to online resources

		1st, 2nd, and 3rd Process into objects **Schemas :** Thematization by applying the concept of Riemann sum to the function of distance to time and other mathematical situations	Homework				

Topic 6) Understanding of Integration

Prerequisite knowledge Review the following concepts from previous courses:	• *Composition of function*	• Areas of curves in the given interval
	• *the concept anti-derivative*	• *limit function*
	• *trigonometric function*	• Graph of function

Contents	Specific Objectives	Theoretical Analysis (Genetic-decomposition)	Design and implementation of instruction	Teaching strategies (enhancing employability skills)	Assessment	APOS research Question	Instructional Resources
Topic 6) Understanding of Integration	At the end of the lesson students will be able : • State the rule of integration • Integrate Composite function • Introduce chain rule	**Action conception**: Which enables the finding of integrals of simple functions whose rules are given in symbolic form? For example: $\int 3x^2\,dx$. **Process conception**: Studying the structure of the function, detecting whether a rule for integration could be applied or whether the function should be written in a standard	**Activities :**	• Cooperative learning • Discussion • Presentation	I) Group discussion of 5/6 students for testing the understanding level of a student II) Additional practical work of interdisciplinary approach III) Written Test and/or Mid Term Test (not more than	Two basic questions in APOS are: (1) Did the students make the mental constructions called for by the theoretical analysis? (2) How well did the students learn the mathematical content? (Arnon,	♦ Geo-Gebra ♦ Matlab ♦ ELearning resources ♦ Access to online resources

	• State rules of integration	form which enables the application of the appropriate rules for integrating. **<u>Object conception:</u>** For example, the student views the integrand $h(x)$ as an object which is a product of $g'(x)$ and a composition of two functions, $h(x) = g'(x).f(g(x))$ to which the substitution technique for integration can be applied.	**<u>Class Discussion</u>**: Homework		one or two for each course) IV) Journal/Lecture/ Library notes V) Short Quizzes; VI) Assignments	et al., 2014)		

In summary, the development process of the industrial mathematics curriculum is illustrated in Table 6.1. The selection of course content and objectives were guided by the APOS theory of research and curriculum development in industrial mathematics education. The curriculum also included assessments, teaching strategies aimed at improving employability skills, and instructional resources, all of which align with the theoretical framework established for this curriculum development.The APOS theory provided a comprehensive framework for research and curriculum development in industrial mathematics, comprising three main components: theoretical analysis, design and implementation of instruction, and data collection and analysis. This study focused primarily on the theoretical analysis and the design and implementation of instructional strategies and sample courses in industrial mathematics, utilizing examples from previous research in the field. The theoretical analysis begins with a preliminary genetic decomposition aimed at elevating students' conceptual understanding of mathematics to a level comparable to that of mathematicians. It is worth noting that these proposed genetic decompositions have yet to be experimentally tested or may be new for implementation with a new study group. The design of instruction then focused on methods to support students in constructing these mental representations based on the preliminary genetic decomposition. Table 6.1 provided an illustrative example of how new industrial mathematics curricula for undergraduate science and technology programs in universities can be developed. The curriculum guide specifies course content, specific objectives, and prerequisite knowledge necessary for each topic. The third component, data collection and analysis, aligned with the APOS theory and is outlined under the research topics. The study also incorporated assessment methods, instructional resources, and teaching strategies geared toward enhancing employability skills.

CHAPTER SEVEN: SUMMARY OF THE RESEARCH FINDINGS, CONCLUSION, AND RECOMMENDATIONS

7.1. INTRODUCTION

This chapter provided a summary of the main findings discussed in Chapter 4, which are based on the participants' statements, observations, and impressions of curriculum development, as well as a review of existing programs. The findings were collected from a variety of sources, including government institutions, private industries, and survey questionnaires. Additionally, input from academics and an industry professional was collected to supplement the data. Based on these findings, the chapter also offered recommendations for the development of an industrial mathematics curriculum. These recommendations included suggestions for collaboration between different disciplines within the same institutions, as well as opportunities for collaboration between science and technology universities and industries. Additionally, recommendations are provided to improve the key factors that influenced the curriculum development process. In essence, this chapter concluded the study by summarizing the major findings and providing actionable recommendations for the development of an industrial mathematics curriculum..

7.2. SUMMARY OF THE RESEARCH FINDINGS

The purpose of this study was to examine and understand issues and challenges related to the development and implementation of curricula in science and technology universities. This was done to establish a strategic framework for designing and implementing industrial mathematics curricula tailored to Ethiopian science and technology universities. On the basis of the findings of the study, a suitable industrial mathematics curriculum was recommended for universities specializing in science and technology. The study participants chose three undergraduate industrial mathematics programs, namely a BSc in Industrial Mathematics with Computer Applications, a BSc in Industrial Mathematics and Statistics, and a BSc in Industrial Mathematical Modelling. The selection of these programs was informed by the quantitative analysis conducted during the study. Through document analysis, it was determined that a BSc in Industrial Mathematics with Computer Applications aims to develop a mathematical attitude towards problem formulation and solving, enhance analytical skills and a desire for accuracy, foster appreciation for mathematical techniques, provide proficiency in programming using advanced computer languages, and cultivate research aptitude in both mathematics and computer applications.

(https://ethirajcollege.edu.in/wpcontent/uploads/2021/07/Ssmaths_with_ca.pd).

Another curriculum example is the BSc in Industrial Mathematics and Computer Science with Industrial Experience offered at Manchester Institution. This program aims to integrate mathematical and computer science knowledge and skills. It encompasses the knowledge and techniques necessary to implement mathematical models in simulations to evaluate real-world situations.

(https://www.manchester.ac.uk/study/undergraduate/courses/2023/00490/bsc-computer-science-and-mathematics-with-industrial-experience/course-details/COMP10120#course-unit-details)

As a result, the Ethiopian industry recognizes the value of graduates in industrial mathematics with a specialization in computer applications, who are equipped with both computer and mathematical expertise to address industrial challenges. The second option, a BSc in Industrial Mathematics and Statistics, further strengthens the capability to develop and analyze problems, as well as assess scientific data using appropriate statistical methods. This program establishes a solid foundation in probability, statistics, and mathematics, which is essential for tackling more technologically advanced tasks in the future.

(https://www.manchester.ac.uk/study/undergraduate/courses/2024/07101/bsc-mathematics-and-statistics/course-details/#course-profile).

Graduates of the BSc in Industrial Mathematics and Statistics program have the potential to work in various roles such as statisticians, data analysts, and industrial mathematicians within companies. On the other hand, the BSc in Industrial Mathematical Modelling program focuses on developing mathematical models to address industry-related issues and is particularly significant for research purposes. When participants were asked about suitable industrial mathematics programs at the graduate level, both academics and industry experts selected the following three master's programs: MSc. Industrial Mathematics and Statistics, MSc. Industrial Mathematics with Computer Applications, and MSc. Industrial Mathematical Modelling. However, this study primarily focused on the first two program choices, as graduates of these programs can be employed as statisticians and IT experts. Specific job descriptions for industrial mathematicians in Ethiopian industries are not yet well defined.

The main objective of this study was to examine and understand issues and challenges related to the development and implementation of curricula in science and technology universities. This was done to establish a strategic framework for designing and implementing industrial mathematics curricula tailored to Ethiopian science and technology universities. To achieve this goal, the research questions mentioned below were addressed. The subsequent analysis and interpretations presented in Chapter 4 led to the following major findings of the study.

Research Question-1

What are the limitations and strengths of the existing Mathematics Curriculum in promoting mathematics in industry?

7.2.1. Limitations of the Existing Mathematics Curriculum

The shortcomings of the previous mathematics curriculum highlight the prevalent reliance on traditional teaching methods, where instructors dominate class discussions (AAU, 2009). Teachers tend to instruct in a manner that aligns with their preferred teaching style, as the curriculum pays less attention to instructional approaches. This emphasis on traditional teaching methods discourages the inclusion of industrially oriented research in mathematics, resulting in a lack of practical applications. Consequently, the undergraduate mathematics curriculum tends to be more broad and generalized rather than specific. The study's findings indicate a lack of emphasis on the development of students' modeling and problem-solving abilities within BSc mathematics programs, confirming the results of the AAU survey. In the M.Sc. curriculum, the focus is on subject specialization, and research within the graduate program tends to prioritize literature reviews rather than problem solving in real-world contexts. The BSc and MSc mathematics programs in Ethiopian higher education primarily prepare graduates for careers as teachers in high schools, colleges, and universities. While there are Applied Mathematics programs that aim to train mathematicians for various roles in government agencies, the majority of graduates end up finding employment as primary and secondary school teachers.

Strength of the existing mathematics curriculum

The outcome of the study indicates a vertical connection between the undergraduate and graduate mathematics curricula. In both programs, there is an inclusion of advanced courses that contribute to the scientific and technological advancement of the country. These courses provide students with a comprehensive understanding of the fundamental principles and techniques of mathematics, equipping them with the necessary knowledge to teach mathematics in secondary schools and higher educational institutions in Ethiopia.

7.2.2. Improving the Existing Mathematics Courses in the Universities

What could be done to improve the curriculum?

The responses of the participants were categorized into four main themes: curriculum revision, need assessment, application, and methodology. This breakdown allowed manageable portions of the themes to be used in presenting and explaining the data to address the research question. According to OECD reports, curriculum reform should include industrial initiatives, such as need assessments, in order to address current issues with the mathematics curriculum. By incorporating examples from various disciplines of study and industrial challenges, applied mathematics courses can be modernized and better reflect employers' concerns in resolving industry challenges. Therefore, curricular modification is necessary. One of the debate topics raised by the participants was the teaching of mathematics. The present study, which is based on the APOS philosophy of research and mathematics curriculum development, emphasizes the interconnectedness between the theoretical, methodological and pedagogical aspects of education (Arnon, et al., 2014). Furthermore, respondents argued for ongoing modifications to the curriculum. General courses should be tailored to meet industry requirements, made practical through software usage, and connected to real-world applications. Higher-level mathematics courses should include term papers and relevant exercises in assessments, with a focus on practical application and relevance to the most recent industry requests and findings. To improve teaching quality, respondents suggested having professionals from the same department teach the same courses, learning the latest skills from industry experts, taking online courses, organizing workshops with stakeholders, using high-quality teaching tools and materials, improving student-teacher ratios, and designing courses and teaching methods according to industry standards. The findings presented in Section 4.2.3.2 of the Undergraduate Curriculum Guide of Industrial Mathematics Based on APOS Theory can assist Ethiopian universities of science and technology in designing better curricula. These findings provide valuable information and guidance for curriculum development in the field of industrial mathematics in Ethiopia.

Research Question-2

What are the problems related to the application of the industrial mathematics curriculum?

7.2.3. Barriers in Curriculum Development and Review Programs

Curriculum development in Ethiopian higher education usually follows a top-down approach, where curricula are often selected and copied from sister universities abroad. To improve the quality of higher education in Ethiopia, reforms must be implemented in several areas. It is important for university graduates to possess a balance of cognitive and noncognitive skills, as well as higher-order thinking abilities like critical, creative, and problem-solving thinking. Additionally, computer literacy should be prioritized. Malaysia's experience in these areas can provide valuable information (MOE, 2018).

The development of curricula in Ethiopia is influenced by the experience of Malaysia. The findings of this analysis highlight the importance of addressing the needs of teachers, particularly in Ph.D. programs, and focusing on their enthusiasm and capacity for implementation. It is crucial that the curriculum development process is well organized, taking into account factors such as course content and teaching approaches. Copying and pasting curricula from foreign institutions with differing levels of economic development is not a suitable approach. For example, in the context of the harmonized BSC degree in mathematics, improving the curriculum involves incorporating best practices from reputable European institutions to enrich the existing curricula developed by a group of national universities (MOE, 2013). The curriculum incorporating approach ensures that the curriculum reflects industry demands and aligns with international standards while maintaining a harmonised structure.

7.2.4. Employing Mathematician in Industry

The respondents provided several reasons for not employing mathematicians in their organizations. One main factor was lack of awareness regarding the relationship between universities and industries, as well as the demand for mathematicians in their institutions. This lack of knowledge made them believe that there was no need for mathematicians, leading to a sense of desperation for a job. In the case of automobile assembly firms, the respondents stated that they were unaware of the need for mathematicians in their companies. They may have believed that other areas would be more suitable for their jobs. Some respondents were unfamiliar with the profession of mathematicians and assumed that studying mathematics was not crucial for their companies. Since the job requirements did not involve mathematics, there was no position available specifically for a mathematics specialist. The awareness about the significant contributions of mathematics to the business sector resulted in a perception that extensive mathematical understanding was not in demand. Instead, respondents believed that engineering expertise was more relevant. Overall, the respondents' misconception and understanding regarding the benefits of studying mathematics for the business sector contributed to their reluctance to employ mathematicians in their organizations.

Research Question-3

How does a mathematician and industry expert work together to apply industrial mathematics in Ethiopian industries and in Ethiopian Science and Technology universities?

Definition of Industrial Mathematics

Before undertaking the development of an industrial mathematics curriculum, it is important to establish a common understanding of what exactly is meant by the term "industrial mathematics." In the context of Nigeria, industrial mathematics is considered a crucial component of national development, contributing to areas such as life expectancy, health, education, and income (Tsetimi, 2016). Another definition of industrial mathematics states that it involves the application of mathematical techniques to solve problems in an industrial setting. The definition stated above aligns with the concept of Mathematics IN Industry (MII) as described by Stocke. MII refers to the work of nonacademic mathematicians employed by companies, with the goal of advancing products or processes. Mathematics Inspired BY Industry (MIBI) is another term used to describe the study of industrial problems within an academic setting, separate from the practical constraints of industry. The goal in this case is to advance mathematics. This definition is similar to the respondents' definitions and represents mathematical work conducted in an academic setting, focusing on industry-related problems. In a broader sense, industrial mathematics encompasses all nonacademic end-users of mathematics, including companies, government agencies, hospitals, and nonprofit organizations. The field of mathematics involved can range from pure mathematics to applied mathematics, encompassing various techniques that can be employed to solve real-world problems.

In summary, industrial mathematics is an interdisciplinary subject that incorporates various mathematical fields, such as differential analysis, numerical optimization, modeling, simulations, statistics, computer science, engineering, and financial mathematics. It focuses on solving problems that arise in industry and is essential for national development and advancement..

7.2.5. Mechanisms of Delivery of Industrial Mathematics Courses

Successful resolution of industrial problems requires the collaboration of experts from various disciplines. Therefore, it is essential to establish a delivery system within the new industrial mathematics curriculum that effectively addresses these problems. In Ethiopian higher education, efforts have been made to standardize the curriculum of undergraduate programs and improve the quality of teaching and learning. This includes adopting a modular approach to course delivery, among other measures (MOE, 2013). Based on the findings of this research, several delivery mechanisms have been identified for the industrial mathematics curriculum. An approach is for the industry to select candidates and provide specific training. Industry professionals with expertise in relevant topics can then deliver the courses. Another approach involves designing the courses according to industry requirements and developing student projects that align with real-world industrial problems. These delivery mechanisms are intended to facilitate a practical and effective learning experience.

In summary, the collaboration of experts from multiple disciplines is needed to address industrial problems. Establishing a delivery system within the industrial mathematics curriculum, such as selecting candidates for industry-specific training, engaging topic specialists as course instructors, and incorporating practical projects, can greatly contribute to the successful resolution of these challenges.

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7.2.6. Factors Affecting Implementations of Industrial Mathematics

The factors influencing the implementation of industrial mathematics, as identified in Section 4.2.2.4, can be broadly classified into three categories: industrial factors, university-industry collaborations, and academic factors.

Industrial factors that impact the implementation of industrial mathematics include the lack of mathematical background among industry experts, limited awareness within the industry regarding the utilization of research findings, and inadequate funding for mathematics-related projects. Insufficient university-industry collaborations also play a role in hindering the progress of industrial mathematics. According to Kahsay (2017), this poor link is characterized by factors such as lack of motivation and willingness, absence of a competent and engaged academic core, weak leadership commitment, inadequate research funding, and lack of supportive policies.

Academic factors were also found to be influential in the implementation of industrial mathematics. Research findings indicate a shortage of trained personnel in the field, insufficient information on graduate-level pedagogical practices, and the absence of industrial strategies within universities.

7.2.7. Mechanisms of Promoting Mathematics in Industry

There were several successful mechanisms that have been implemented to promote mathematics in industry, as highlighted in Section 4.2.2.5. These mechanisms can be grouped into two categories: university activities and university-industry collaboration activities. University activities include establishing startup mechanisms, developing educational programs that align with the missions and visions of all involved parties, setting up interdisciplinary research centers, creating faculty positions specifically for industrial mathematics, providing consultancy services, and implementing successful industrial mathematics projects within Ethiopian industries. University-industry collaboration activities encompass building trust and openness between the two parties, facilitating student supervision, offering fellowships or practicum programs, establishing study groups composed of industry and university communities, deploying technology translators, and facilitating personnel exchange. According to the OECD (2009) global science forum report, academic initiatives for promoting mathematics in industry include establishing interdisciplinary research centers, creating targeted academic positions for industrial mathematics, reforming curricula and incorporating student projects, organizing student modeling weeks and conferences. The report also emphasizes the importance of enhancing academic-industrial collaboration through workshops, study groups, internships, teamwork, and networks. Additionally, conferences, student projects, student modeling weeks, and curriculum revisions are mentioned as effective methods in promoting mathematics in industry, although they were not specifically examined in the findings outlined in the OECD report.

Research Question-4

What benefits can be derived from deploying Industrial Mathematics to enrich careers in terms of professional development (research, teaching, training, and mentorship)?

The findings regarding the advantages of industrial mathematics provide valuable support to academic staff members, offering them opportunities for career advancement through academic rank and publication. According to Article 32-1 b) of the Higher Education Proclamation (2009), all academic staff members are required to engage in problem solving studies and research, as well as transfer knowledge and skills related to their area of expertise. This requirement ensures that your teaching is research-oriented, continuously updated and beneficial to the country. In Ethiopia, industrial mathematics has been used to facilitate applied research among academic staff members to further their professional development. As outlined in Section 5.2.2.6 under the topic of the value of industrial mathematics, students have greatly benefited from these programs in terms of academic success and job opportunities. Meanwhile, industry experts have made financial and intellectual gains from the research findings. Industries have seen increased productivity and services, increased exports, and higher profits. Universities have also seen improvements in their global rankings and increased publications. Over time, collaborative research conducted by study groups could lead to practical solutions for industry partners, potentially resulting in patent filings and substantial financial rewards. Therefore, the utilization of industrial mathematics not only supports academic staff members by enhancing their careers, but also contributes to the overall growth and prosperity of industries and universities alike.

From the research results concerning "Fellowships or Practicums" (84.6%), participants viewed them as vital for advancing mathematics within industries when both parties are actively involved. Internships represent practical learning opportunities that students undertake for academic recognition. Most academic disciplines mandate internships over practicums. Practicums serve as structured learning experiences obligatory in certain professions like education and medicine. Fellowships denote competitive academic programs extended to students, referred to as "fellows," aiming to pursue specialized research in their respective academic domains.

According to Matti, Matylda, & Godwin (2016), one of the main challenges facing East African industrial mathematics education lies in establishing connections between mathematics departments and other educational institutions. To address this issue, strategies include boosting the number of student projects, facilitating company placements, encouraging internships, promoting summer jobs, and fostering Master of Science thesis projects rooted in practical industrial applications. Successful collaboration practices between academic institutions and industries in East Africa encompass student exchanges, academic staff visits, coordination of student and faculty study groups, and organizing modeling weeks.

As identified by the OECD (2009), mechanisms for enhancing the role of mathematics in industry are categorized into academic initiatives and academic-industrial partnerships. Noteworthy forms of academic-industrial collaborations include workshops, study groups, internships, teamwork initiatives, facilitation efforts, and promotional activities.

Research Question-5

What parts of an industrial mathematics curriculum are the best models for Ethiopian industrial development?

The following findings show parts of an industrial mathematics curriculum that are the best models for Ethiopian industrial development.

According to the findings in Table 5.14 revealed, academic professionals and various industries have identified three industrial mathematics programs suitable for undergraduate and graduate programs offered by Ethiopian Science and Technology Universities. Total number of respondents to the selection of BSc. In industrial mathematics, the following were: BSc. Industrial Mathematics with Computer Applications (102 respondents), BSc. Industrial Mathematics and Statistics;(78 respondents), and BSc Industrial Mathematical Modeling (selected by (72 respondents). Similarly, MSc. Selection Total is MSc. Industrial Mathematics with Computer Applications (118 respondents), MSc. Industrial Mathematics and Statistics (100 respondents) and MSc Industrial Mathematical Modeling (99 respondents). This selection process aimed to address specific challenges faced by industry and government organizations, including road administration, the aviation sector, breweries, and electric power authorities. The unique problems of each industry were taken into consideration when choosing these programs, which have already demonstrated their effectiveness in problem solving. These selected industrial mathematics programs incorporate advanced mathematical principles such as statistics, optimization, numerical methods, computational methods, and discrete mathematics. By employing these mathematical approaches, companies can improve their operations and provide better services to their clients. However, to further enhance their utilization of mathematical ideas and promote innovation, it is essential for these industries to continue engaging in research and development through the field of industrial mathematics.

In summary, identified industrial mathematics programs serve as valuable tools for tackling industry-specific issues, leading to successful problem-solving outcomes. By continuing to leverage mathematical concepts and investing in research and development, industries can make further advancements and foster innovation in their respective fields.

7.3. RECOMMENDATIONS

Recommendation 1:

It is recommended to organize and carry out regular staff training workshops that align with curriculum development theories to improve the contens and methods of teaching the existing mathematics curriculum in Ethiopian universities.

Recommendation 2:

One of the study recommendations is the Undergraduate Curriculum Guide for Industrial Mathematics utilizing APOS Theory can provide valuable guidance as a foundational framework for Ethiopian universities focused on science and technology to enhance the design and implementation of more effective industrial mathematics curricula.

Recommendation 3:

Establishing a departmental study group consisting of representatives from various academic disciplines is recommended, such as algebra, numeric analysis, differential analysis, optimisation, mathematical modeling, and combinatory.

Recommendation 4:

To promote interdisciplinary collaboration, it is recommended to increase departmental study groups to the level of faculty members and establish a national African interdisciplinary research center in science and technology universities.

Recommendation 5:

To boost the competencies and expertise of academic faculty and other interested individuals, such as industry professionals, it is recommended that they undergo retraining in the field of industrial mathematics. This training can be offered jointly with reputable universities through online platforms at the Master's and Ph.D. levels. Alternatively, the two universities could collaborate to provide specialized training to interested candidates through a scholarship program at renowned European universities that boast a well-developed curriculum in this field.

Recommendation 6:

Policymakers and funding organizations should collaborate to support mathematics programs at Science and Technology Universities that foster innovation through research infrastructure. This can be achieved by establishing the Ethiopian Institute of Mathematics for Innovation, which coordinates clusters of excellence in industrial mathematics.

Recommendation 7:

To overcome geographic and scientific dispersion, academic institutions and companies must use networks and digital technology to share best practices between Ethiopian universities and disciplines. This can be achieved by encouraging researchers to adapt to different domains, establishing an industrial mathematics magazine, contributing to an African or Ethiopian digital mathematics library, and facilitating employment mobility between academia and industry.

Recommendation 8:

The responsibility of developing common curricula and educational programs in mathematics at the Ethiopian level should lie with mathematical societies and academic institutions. Regional expertise and specificity should be considered in this process. Academia should establish a pool of industrial mathematics experts, develop an Ethiopian curriculum for the subject, and create new criteria to assess and recognize careers in industrial mathematics.

7.4. CONCLUSION

The main conclusion drawn from the current research is that mathematics plays a crucial role in Ethiopia's ambition to become a middle-income country. However, the significance of mathematics as a tool for research and development is not fully recognized in various industries and academic institutions. It is becoming increasingly evident that mathematics has the potential to enhance competitiveness. The benefits of fostering a vibrant mathematical community that actively collaborates with business and industry are substantial and outweigh the relatively low costs associated with its maintenance. Nevertheless, these benefits can only be realized through the establishment of mathematics education and a coordinated community of industrial and applied mathematicians, both of which are vital for Ethiopia's economic growth, prosperity, and global competitiveness.

The purpose of this study was to examine and understand issues and challenges related to the development and implementation of curricula in science and technology universities. This was done to establish a strategic framework for designing and implementing industrial mathematics curricula tailored to Ethiopian science and technology universities.Education in industrial mathematics is crucial for Ethiopia's economic development. By developing mathematical reasoning, thinking, and an understanding of mathematics as the primary language of science and engineering, students can acquire the mathematical skills necessary to model and solve industrial problems. This enables them to participate in professional activities that support the nation's industrial development and prepares them for advanced studies in industrial mathematics and related fields. In summary, a robust industrial mathematics curriculum can equip Ethiopia's future workforce with the skills needed to drive industrial growth and achieve the country's economic goals.

7.5. LIMITATIONS OF THE STUDY

In this study, a mixed sequential explanatory method was used as it was considered suitable to investigate and explain the identified problem and to address the research questions at hand. However, certain limitations were encountered during the research process. One limitation was the scarcity of local research and materials on industrial mathematics education and curriculum development, making it challenging to incorporate them into the study. Furthermore, the selected semi structured interview method was found to be insufficient to obtain reliable information due to the novelty of the topic. As a result, the method was modified to a group discussion approach, allowing participants to provide more valuable feedback. Consequently, the researcher had to rely more on external resources for information. Another limitation was the unavailability of certain software, such as ATLASti, despite the researcher's awareness of their potential usefulness in data organization and analysis. Therefore, alternative methods, such as SPSS and Excel, were utilized instead.

7.6. AREA OF FUTURE RESEACH

The current study introduced a curriculum development framework utilizing the APOS theory for industrial mathematics research and curriculum development. The curriculum guide detailed in section 6.3 advocates for additional research investigating deeper into various industrial mathematics concepts, as elaborated in appendices 1A-1F (for the BSc. Program) and appendices 2A-2E (for the MSc. Program), tailored to the specific industrial progressions of individual nations.

Further investigation is needed to explore how the APOS theory for research and curriculum development can be applied to other subjects?

Will the APOS theory of curriculum development enhance teaching and learning of mathematics?

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Appendix1A. B.sc Industrial Mathematics Curriculum of Nigeria

https://aliceisaacuniversityedu.com/course/b-sc-industrial-mathematics/

In Nigeria, Industrial mathematics is defined as an interdisciplinary subject who comprises applied mathematics courses, computing and engineering disciplines including industry disciplines like business and computer science to train students to apply different mathematical technique to solve problems arising from industry.

A degree program in Industrial Mathematics will aim to:

- To develop the ability **to apply** their mathematics **knowledge and skills** to the **solution of theoretical and practical** problems in mathematics
- To develop a range of **transferable skills** of **value in mathematical** related and **non-mathematical related employment**
- To generate **an appreciation** of the importance of mathematics in an industrial, **economic**, **environmental** and **social context.**
- To develop **high technical abilities** in the applications of **mathematical solutions to real-world and industry problems.**

Career in industrial mathematics for degree program in Nigeria

- ❖ Mathematician ,Data Analyst ,Epidemiologist ,Quantitative Analyst ,Financial Analyst, and Risk Analyst or Business Analyst

Basic Admission Requirements

To be eligible for admission,

- ❖ Admission through U.M.E. shall take the student to 100 levels (In Ethiopia equivalent to first year students).
- ❖ Candidate is expected to pass both the UTME (ECLSE in Ethiopia) and the University screening test.

- Candidates with the Advanced Level in one or more relevant subjects (Mathematics, Further Mathematics, Physics and Chemistry) or
- Good diploma in Mathematics, Physics and Engineering are eligible to undertake the three- year degree program with entry at 200-level (In Ethiopia equivalent to second year students).
- Students can transfer into 200-Level (2nd Year) courses provided they have the relevant qualifications and the requisite CGPA.

Course Structure at 100 Levels (1st Year): Industrial Mathematics

Course Code	Course Title	Units/Cr.hr.	Status	LH	PH
MTH 101	Elementary Mathematics I	3	C	45	
MTH 102	Elementary Mathematics II	3	C	45	
MTH 103	Elementary Mathematics III	3	C	45	
STA 101	Probability I	3	C	45	
PHY 101	General Physics I	3	C	45	
PHY 102	General Physics II	3	C	45	
PHY 103	General Physics III	3	C	45	
CHM 101	General Chemistry I	3	C	45	
BIO 101	General Biology I	3	C	45	
GST 101	Use of English	2	C	30	
CSC 101	Introduction to Computer Science	2	C	30	
LIB 101	Library Studies	2	C	30	
	Total	**33**			

Course Structure at 200 Levels (2nd Year): Industrial Mathematics

Course Code	Course Title	Units	Status	LH	PH
MTH 201	Mathematical Methods I	3	C	45	
MTH 202	Elementary Differential equations I	3	C	45	
MTH 203	Sets Logic and Algebra I	3	C	45	
MTH 204	Linear Algebra I	2	C	30	
MTH 205	Linear Algebra II	2	C	30	
MTH 207	Real Analysis I	3	C	45	
CSC 201	Computer Programming I	4	C	60	
MTH 209	Introduction to numerical analysis	3	C	45	
STA 211	Probability II	4	C	60	
GST 01	Communication Skills	2	C	30	
GST 202	Nigerian People and Culture	2	C	30	
EPS 201	Entrepreneurship Studies I	2	C	30	
MTH 210	Vector Analysis	2	C	30	
	Total	**37**			

Course Structure at 300 Levels (3rd year): Industrial Mathematics

Course Code	Course Title	Units	Status	LH	PH
MTH 311	Introduction to Industrial Mathematics	3	C	45	

STA 321	Distribution Theory III	2	C	30	
MTH 302	Ordinary Differential Equations II	3	C	45	
MTH 315	Financial Mathematics	3	C	45	
MTH 316	Introduction to Operations Research	3	C	45	
MTH 312	Mathematical Computing I	3	C	30	15
MTH 319	Numerical Analysis I	3	C	30	15
MTH 308	Mathematical Modeling I	3	C	45	
MTH 320	SIWES	8	C	120	
EPS 301	Entrepreneurship Studies II	2	C	30	
	Total	**34**			
	Elective Courses				
MTH 309	Discrete Mathematics	3	E	45	
MTH 319	Mathematical Computing II	3	E	45	
STA 311	Probability III	3	E	45	
	Total	**9**			

Electives should be selected from Year III courses in Physics, Computer Science, Economics and Accounting.

Course Structure at 400 Levels (4th Year) : Industrial Mathematics

Course Code	Course Title	Units	Status	LH	PH
MTH 425	Control Theory and Project Management	2	C	30	15
ST A 431	Statistical Inference III	2	C	30	
MTH 427	Classical Mechanics I	3	C	45	
MTH 423	Mathematical Modeling II	3	C	45	
MTH 401	Theory and Applications of Ordinary Differential Equations	3	C	45	
MTH 402	Theory and Applications of Partial Differential Equations	3	C	45	
MTH 424	Control Theory and Optimization	3	C	30	15
MTH 417	Numerical Analysis II	3	C	45	
MTH 424	Mathematical Computing II	3	C	45	
MTH 428	Classical Mechanics II	3	C	45	
MTH 404	Project	6	C	90	
MTH 427	Optimization Theory	3	C	45	
MTH 406	Special Topics in Industrial Mathematics	2	C	30	15
	Total	**39**			
	Elective Courses				
MTH 408	Classical Mechanics	3	E	45	
MTH 413	Fluid Dynamics	3	E	45	
MTH 414	Elasticity	3	E	45	
MTH 415	Systems Theory	3	E	45	
MTH 426	Theory and Applications of Neural Networks	3	E	45	
	Total	**15**			

- Electives should be selected from Year IV courses in Mathematics, Physics, Computer Science, Economics and Accounting.

❖ Each of these courses runs for a minimum period of four (4) years for those students admitted into a four (4) year program and three (3) years for those admitted into a three (3) year program.

Appendix 1B. BSc. Industrial Mathematics: Kenya
Bachelor of Science in Industrial Mathematics in Kenya (tertiaryinstitutions.com)

Admission Requirement

KCSE mean grade of C+. In addition, an applicant must have. EITHER The following alternative combinations of cluster subjects, at the minimum grades shown: **Mathematics C+** Pass in any two of the following alternatives , **First alternative: Scoring Chemistry $C-$ and Physics $C-$ Second alternative: Scoring Physical Science $C-$ and Biological Science $C-$ OR** 2 principal passes in science subjects in IGCE/GCE or KACE. **OR**, Diploma in the relevant science subjects from an institution recognized by the University Senate, **OR**, Any other qualifications accepted by the University Senate as equivalent to any of the above.

Aim: The program aims

❖ Developing multidisciplinary scholars who have up-to date knowledge in the field and also appreciate linkage between Mathematics and business.
❖ Students will develop skills in abstracts reasoning, analysis and logical thinking.

The program puts emphasis on **mathematical modeling** and **computational techniques.**

Employment opportunities: include

- Systems Engineering
- Researchers
- Scientific computing
- Financial industry and
- Automotive companies

Course	Course Title	Credit

Number		Hours
SMA 2104	Mathematics For Science	3
HRD2101	Communication Skills	3
SZL 2111	HIV/Aids	3
SCH 2120	Chemistry I	3
HBC 2120	Business Law I	3
SPH 2130	Introduction To Physics	3
SMA 2111	Calculus For Industry-I	3
SMA 2113	Basic Industrial Mathematics I	3
ICS 2100	Introduction To Computer System	3
SMA 2215	Calculus For Industry-Iii	3
SMA 2214	Industrial Statistics I	3
SMA 2213	Calculus Of Vectors	3
SMA 2212	Differential Equations I	3
ICS 2104	Object Oriented Programming I	3
HBS 2211	Introduction To Industrial And Organizational Psychology	3
SMA 2210	Basic Industrial Mathematics Ii	3
HDR 2102	Developmental Studies And Social Ethics	3
ICS 2101	Introduction To Computer Programing	3
ICS 2102	Introduction To Computer System-Ii	3
SCH 2121	Chemistry Ii	3
SMA 2112	Calculus For Industry-Ii	3
SMA 2114	Applied Linear Algebra –I	3
SPH 2131	Advanced Physics	3
HBC2112	Business Law Ii	3
CILS 2101	Communication Skills On Line	3
SZL 2111	HIV/AIDS Online	3
ICS 2100	Introduction To Computer System	4
SCH 2120	Chemistry I	3
SMA 2104	Basic Industrial Mathematics I	3
SMA2111	Calculus For Industry-I	3
SMA2113	Basic Industrial Mathematics I	3
SPH21 30	Introduction To Physics	3
HRD2103	General Economics	3
ICS 2200	Electronics	3
SMA 2202	Algebraic Structure	3
SMA 2216	Applied Linear Algebra –II	3
SMA 2217	Differential Equations- II	3
SMA 2218	Industrial Statistics II	3
SMA 2219	Introduction To Financial Mathematics	3
HRD2114	Accounting And Finance	3
ICS 2105	Data Structure And Algorithm	3
SMA 2327	Fluid Dynamics II	3
SMA 2311	Numerical Technique I	3

SMA 2314	Introduction To Complex Variables	3
SMA 2318	Optimization II	3
SMA 2325	Mathematical Modeling	3
SMA 2319	Advanced Financial Mathematics	3

Appendix 1C. BSc in Mathematics and Statistics – Tanzania

University of Dar es Salaam - College Of Natural And Applied Sciences (udsm.ac.tz)

Program Type: Undergraduate Program

Duration: 3 Years

Academic Unit: College of Natural and Applied Sciences

Program Descriptions

The BSc. Mathematics and Statistics is a three year program (six semesters) and **produces a graduate with major in both mathematics and Statistics.** To graduate from the program, a candidate must earn a total of 352 credits from core courses and a minimum of 36 elective credits. In addition a candidate must complete a compulsory 8-week practical training is taken at the end of second year and carrying 8 credits. To graduate from the program, a candidate must therefore get a minimum of 388 credits.

Code	Course Title	Core/Elective	Credits
FIRST YEAR			
First Year: Semester I			
MT 100	Foundations of analysis	Core	12
MT 127	Linear algebra I	Core	12
ST 113	Basic Statistics	Core	12
FN 100	Principles of Microeconomics	Core	12
DS 112	Development Perspectives I	Core	12
MT 114	Computer programming	Core	12
Total Credit: Year I: Semester I			**72**

First Year: Semester II			
DS 113	Development Perspectives II	Core	12
MT 120	Analysis I: Functions of a Single Variable	Core	12
MT 135	Ordinary Differential Equations	Core	12
ST 114	Probability Theory I	Core	12
FN 101	Principles of Macroeconomics	Core	12
Total Credit: Year I: Semester II			**60**
SECOND YEAR			
Second Year: First Semester I			
MT 200	Analysis II: Functions of several variables	Core	12
MT 225	Partial Differential Equations I	Core	12
ST 212	Statistical Inference I	Core	12
ST 218	Applied Statistics I	Core	12
ST 210	Probability Distributions I	Core	12
Total Credit: Year II: Semester I			**60**
Second Year: Second Semester II			
MT 274	Numerical analysis I	Core	12
MT 278	Linear programming	Core	12
ST 211	Probability Distributions II	Core	12
ST 219	Applied Statistics II	Core	12
Total Credits: Year II, Semester II			**48**
THIRD YEAR			
Year III: Semester I			
MT 340	MT 340: Analysis 4-Real Analysis	Core	12
MT 357	MT 357: Abstract algebra	Core	12
ST 310	ST 310: Statistical Inference II	Core	12
ST 316	ST 316: Statistical Quality Control Management	Core	12
MT 398	MT 398: Practical Training	Core	8
Total Credits: Third Year: Semester I			**56**

Third Year: Semester II			
MT 310	Analysis 3: Complex Analysis	Core	12
MT 360	Functional Analysis	Core	12
ST 318	Sampling Theory and Methodology	Core	12
ST 321	Regression Analysis	Core	12
MT 389	Project	Core	8
Total Credits: Third Year, Semester II			**56**

Appendix 1D. BSc. in Industrial Mathematics **Malaysia**

https://science.utm.my/wp-content/uploads/2018/12/UG-HANDBOOK-2018_2019.pdf

Program Aim

The objectives of the BSc (Industrial Mathematics) program are to provide the knowledge, skills and attributes that should be achieved by the graduates for a successful career. It is therefore anticipated that, graduates of the program will

1. Be mathematically competent professionals capable of dealing with qualitative and quantitative problems in related industries.

2. be able to assume productive roles and positions in planning, decision making, analysis and supervision of work in the industrial and public sectors.

3. Exhibit team working and leadership skills with effective communication and desirable interpersonal skills.

4. Pursue life-long learning, enabling them to identify, adapt and seize business opportunities.

Year 1: Semester 1 (Course Code)	Course Title	Credit Hours
CSSCM1002	Introduction to Industrial Mathematics Program	2
SSCM1023	Mathematical Methods I	3

SSCM1103	Statistics	3
SSCM1303	Computer Literacy	3
SSCP1143/SSCC1003	Mechanics/Principles of Chemistry	3
UICI1012	**Islamic and Asian Civilization**	2
Total Credit Hours		**16**
Year 1: Semester 2	**Course Title**	**Credit Hours**
SSCM1033	Mathematical Methods II	3
SSCM1313	Computer Programming	3
SSCM1523	Linear Algebra	3
SSCM1703	Differential Equations I	3
ULAB1122	Academic English Skills	2
UHAS1172	**Malaysia Dynamics**	2
Total Credit Hours		**16**
Year 2: Semester 3	**Course Title**	**Credit Hours**
SSCM2103	Mathematical Statistics	3
SSCM2423	Numerical Methods I	3
SSCM2673	Discrete Mathematics	3
SSCM2773	Differential Equations II	3
SSCM2793	Vector Calculus	3
UICI2022	**Science Technology and Humanity**	2
Total Credit Hours		17
Year 2: Semester 4	**Course Title**	**Credit Hours**
SSCM2043	Mathematical Methods III	3
SSCM2613	Advanced Calculus	3
SSCM2803	Mathematical Modeling I	3
SSCM2833	Linear Programming	3
ULAB2122	Advanced English for Academic Skills	2
UHAS2122	Critical and Creative Thinking	2
UKQU2202	Innovation and Creativity	2
Total Credit Hours		**16**
Year 3: Semester 5	**Course Title**	Credit Hours
SSCM3133	Statistical Quality Control	3
SSCM3803	Mathematical Modeling- II	3
ULAB3162	English for Professional Purposes	2
Human Development Electives (Choose 2 credits)	**Course Title**	**Credit Hours**
UHAS2032	**Technocrat and Development**	2
UHAS2092	**Professional Ethics**	2
Electives (Choose 6 credits)		
	Decision Theory	3
SSCM3533	Set Theory and Logic	3
SSCM3703	Partial Differential Equations	3
SSCM3793	Calculus of Variations	3
SSCM3883	Multi-Objective Decision Making	3
SHAS1523	**Organizational Behavior**	3
Total Credit Hours		**16**
Year 3: Short Semester	**Course Title**	Credit Hours

SSCU3905	**Industrial Training (HW)**	5
Year 3: Semester 6	**Course Title**	**Credit Hours**
SSCM3103	Design of Experiments	3
SSCM3423	Numerical Methods II	3
UHAS3012	Entrepreneurship and Enterprise Development	2
UKQL3012	**Service Learning**	2
Electives (Choose 6 credits)		
SSCM3123	Multivariate Analysis	3
SSCM3153	Inferential Statistics	3
SSCM3353	C++ Programming	3
SSCM3753	Fluid Mechanics	3
SSCM3843	Optimization Methods	3
SHAS1113	Principles of Marketing	3
Total Credit Hours		**16**
Year 4: Semester 7	Course Title	Credit Hours
SSCU4902	Undergraduate Project I	2
Electives (Choose 12 credits)		
SSCM3503	Complex Variables	3
SSCM3523	Modern Algebra	3
SSCM4113	**Time Series**	3
SSCM4163	Stochastic Process	3
SSCM4763	Computational Fluid Dynamics	3
SSCM4823	**Scheduling**	3
SHAD1513	Principles of Management	3
Total Credit Hours		14
Year 4: Semester 8	Course title	Credit Hours
	Undergraduate Project II	4
SSCM4213	Generalized Linear Model	3
SSCM4243	Sampling Techniques	3
SSCM4813	Optimal Control	3
SSCM4833	Discrete Event Simulation	3
SSCM4863	Financial Mathematics	3
Total Credit Hours		**16**

Appendix 1E. BSc. in Industrial Mathematics and Computer Science

https://www.manchester.ac.uk/study/undergraduate/courses/2023/00490/bsc-computer-science-and-mathematics-with-industrial-experience/course-details/COMP10120#course-unit-details

Program Aims

The main aim of this course-unit is to develop various non-technical skills, within a context that students will find relevant and engaging: a project to create a web-based application. These skills will help students to succeed both during their time at University and, more importantly, in their future working life. Although there are lectures, they do not directly cover topics such as how to build a web-based application. Instead, students are encouraged to assess their own knowledge and decide what extra information they need and how they will obtain it (Inquiry Based Learning). The various events and deliverables within the project are chosen to widen the student's range of experiences and capabilities - for example, group working, self- and peer- learning, setting goals and managing progress towards them, innovation and design - whilst being carefully phased and managed so that students can cope with each new step. In particular, each group of 6 to 9 students has a tutor/facilitator who they meet each week, and who carefully guides them at the beginning, but gives them as much freedom and control as they need later on, tailoring the course-unit to individual needs.

Choosing the ***Computer Science and Mathematics program*** allows you to combine the study of these two disciplines, each occupying half of your studies, and explores the reliance of each on the other. This ***joint honors degree program*** enables you to acquire a useful combination of ***mathematical and computer science knowledge and skills***. It covers the knowledge needed to implement ***mathematical models in simulations*** that evaluate real world situations such as ***stress analysis in bridges and buildings, airflow over aircraft wings, or financial modeling.*** The topics studied include a number of important ideas of mathematics, including the concepts of rigorous argument, formal proof and the power of abstract formulation of problems. This is combined with the ***core computer science topics of programming and software engineering***, together with the study of mathematical principals underpinning the foundations of computing.

Carriers

Actuary, AI Engineer , Banker , Cloud Computing Engineer, Cyber Security Analyst , Data Analyst , Games Designer and/or Developer , Software Engineer, Web Designer and/or Developer

Title	Code	Credit hrs.	Mandatory/optional
First year team project	COMP10120	20	Mandatory
Introduction to programming 1	COMP16321	20	Mandatory
Introduction to programming 2	COMP16412	10	Mandatory
Linear Algebra	MATH11022	20	Mandatory
Mathematical Foundation & Analysis	MATH11121	20	Mandatory
Probability I	MATH11711	10	Mandatory
Fundamentals of computation	COMP11212	10	Optional
Data Science	COMP13212	10	Optional
Operating systems	COMP15212	10	Optional
Introduction to Differential Equations	MATH11412	10	Optional
Statistics I	MATH11712	10	Optional
Title	**Code**	**Credit rating**	**Mandatory/optional**
COMP – Careers Year 2	COMP2CARS	0	Mandatory
Real Analysis B	MATH20111	10	Mandatory
Algebraic Structures 1	MATH20201	10	Mandatory
Logic and Modeling	COMP21111	10	Optional
Database systems	COMP23111	10	Optional
Software Engineering 1	COMP23311	10	Optional
Software Engineering 1	COMP23412	10	Optional
Introduction to AI (Artificial intelligence)	COMP24011	10	Optional
Machine Learning	COMP24112	10	Optional
Knowledge Based AI	COMP24412	10	Optional
Programming Languages & Paradigms	COMP26020	20	Optional
Algorithms and Data Structures	COMP26120	20	Optional

Introduction to Visual Computing	COMP27112	10	Optional
Distributed Systems	COMP28112	10	Optional
Probability I	MATH11711	10	Optional
Metric Spaces	MATH20122	10	Optional
Calculus of Several Variables	MATH20132	10	Optional
Algebraic Structures 2	MATH20212	10	Optional
Introduction to Geometry	MATH20222	10	Optional
Introduction to Logic	MATH20302	10	Optional
Partial Differential Equations and Vector Calculus B	MATH20411	10	Optional
Fluid Mechanics	MATH20502	10	Optional
Numerical Analysis 1	MATH20602	10	Optional
Discrete Mathematics	MATH20902	10	Optional
Introduction to Financial Mathematics	MATH20912	10	Optional
Complex Analysis	MATH29142	10	Optional
Title	**Code**	**Credit rating**	**Mandatory/optional**
Third Year Project Laboratory	COMP30030	30	Mandatory
Giving Meaning of Programs	COMP31311	10	Optional
The internet of Things: Architectures and Applications	COMP32412	10	Optional
Agile Software pipelines	COMP33312	10	Optional
User Experience	COMP33511	10	Optional
AI and Games	COMP34111	10	Optional
Cognitive Robotics	COMP34212	10	Optional
Mathematical Topics in Machine Learning	COMP34312	10	Optional
Natural Language Processing	COMP34711	10	Optional

Natural Language Understanding	COMP34812	10	Optional
Algorithms and Complexity	COMP36111	10	Optional
Mathematical Systems and Computation	COMP36212	10	Optional
Graphics & Virtual Environments	COMP37111	10	Optional
Computer Vision	COMP37212	10	Optional
Advanced Distributed Systems	COMP38311	10	Optional
Quantum Computing	COMP39112	10	Optional
Mathematics Education	MATH30002	10	Optional
Fractal Geometry	MATH31042	10	Optional
Topology	MATH31051	10	Optional
Group Theory	MATH32001	10	Optional
Commutative Algebra	MATH32012	10	Optional
Coding Theory	MATH32031	10	Optional
Hyperbolic Geometry	MATH32052	10	Optional
Algebraic Geometry	MATH32062	10	Optional
Number Theory	MATH32072	10	Optional
Combinatorics and Graph Theory	MATH32091	10	Optional
Mathematical Logic	MATH33021	20	Optional
Complex Analysis Applications	MATH34001	20	Optional
Wave Motion	MATH35012	10	Optional
Mathematical Biology	MATH35032	10	Optional
Symmetry in Geometry and Nature	MATH35082	10	Optional
Matrix Analysis	MATH36001	10	Optional
Numerical Analysis 2	MATH36022	10	Optional
Problem solving by Computer	MATH36031	10	Optional

Convex Optimization	MATH36062	10	Optional
Mathematical Modeling in Finance	MATH39032	10	Optional

Appendix 1F. B.Sc. in Mathematics with Computer Applications -India 2018-2019

(https://ethirajcollege.edu.in/wp-content/uploads/2021/07/Ssmaths_with_ca.pd)

Program Aims

The B.Sc. degree program is designed in such a way to have a foundation in Mathematics and Computer Applications ; a Mathematical attitude towards problem formulation and solving analytical skills and desire for correctness; and appreciation of the approaching of mathematical techniques, the programming skills at higher level computer language and research aptitude in both Mathematics and Computer Applications . Part IV and Part V components will seek to build the capacity of the students and provide inputs for her social service and social analysis capabilities. Every academic year is divided into two semester sessions. Each semester will have minimum of 90 working days and each day will have five working hours, teaching is organized into a modular pattern of credits course. Credit is normally related to the number of hours a teacher teaches a particular subject. It is also related to the number of hours a student spends learning a subject or carrying out an activity.

SEM	PART	COURSE CODE	COURSE TITLE	CREDITS	HRS
I	I	Part I	**Tamil/ Hindi / French/ Sanskrit**	3	5
	II	Part II	English	3	5
	III	MC18/1C/TLT// MA18/1C/TLT	Trigonometry & Laplace Transforms	4	5
		MC18/1C/PLC	Programming Language C (Theory)	3	3
		MC18/1C/PR1	Programming Language C (Practical)	1	2
		MC18/1A/FD1// MA18/1A/FD1	Calculus of Finite Differences-I	5	6
	IV	Part IV	1a/1b/NME	2	2
			Soft Skill(offered by English Department	3	2
II	I	Part I	Tamil/ Hindi / French/ Sanskrit	3	5
	II	Part II	English	3	5
	III	MC18/2C/CAL	Calculus	4	5
		MC18/2C/C++	Object Oriented Programming with C++(Theory)	3	3
		MC18/2C/PR2	Object Oriented Programming with C++(Practical)	1	2
		MC18/2A/FD2 // MA18/2A/FD2	Calculus of Finite Differences-II 5 6	5	6
	IV	Part IV	1a/1b/NME 2 2	2	2
			Soft Skill(offered by English Department)	3	2
	I	Part I	**Part I Tamil/ Hindi / French/ Sanskrit 3 5**	3	5
	II	Part II	English	3	5
		MC18/3C/CLA	Classical Algebra	4	5
		MC18/3C/DEF	Differential equations& Fourier series	4	5
		MC18/3A/MS1// MA18/3A/MS1	Mathematical Statistics& R Software –I	5	6
		Part IV	Soft Skill	3	2
			Environmental Studies	2	2
IV	I	Part I	**Tamil/ Hindi / French/ Sanskrit**	3	5
	II	Part II	English	3	5
		MC18/4C/DSA	Data Structures and Algorithms	4	5
		MC18/4C/VGF// MA18/4C/VGF	Vector Calculus, Geometry and Fourier Transforms	4	5
		MC18/4A/MS2// MA18/4A/MS2	Mathematical Statistics& R Software –II	5	6
		Part IV	Soft Skill 3 2 30 - 50 50	3	2
			Value Education	2	2
V	III	MC18/5C/ALS	Algebraic Structures	4	5
		MC18/5C/RAN	Real analysis	5	6
		MC18/5C/MEC	Mechanics	3	5
		MC18/5C/PYT	Python Programming(Theory)	1	3
		MC18/5C/PR3)	Python Programming (Practical)		
		MC18/5E/OR1	Operations Research-I	5	6
		MC18/5E/ENT	Elementary Number Theory	5	6
VI	IV	MC18/6C/LAL	Linear Algebra	4	5
		MC18/6C/CAN	Complex Analysis	4	5
		MC18/6C/JAV	Programming in Java(Theory))	3	6
		MC18/6C/PR4	Programming in Java(Practical)	1	3
		MC18/6E/DIM	Discrete Mathematics	4	5

		MC18/6E/OR2	Operations Research-II 5	5	6
		MC18/6E/FSA	Fuzzy set theory and its applications	5	6

Appendix- 1G. BSc Mathematics and Statistics-Manchester (UK)
https://www.manchester.ac.uk/study/undergraduate/courses/2024/07101/bsc-mathematics-and-statistics/course-details/#course-profile

Course Descriptions

This very flexible single honors degree program is particularly for you if you expect to use statistics in your future professional work. You will develop the capacity to formulate and analyze problems and to interpret scientific evidence using appropriate statistical methodology.

A core of basic mathematics, probability and statistics provides you with the fundamental knowledge and skills, and the basis for more advanced work later on. Core material is covered in the first year, developing the capacity to learn and apply mathematical and statistical ideas. In the second year, besides probability and statistics, you can choose to take on courses from pure or applied mathematics, along with other optional units such as Programming with R. You will understand the significance and power of mathematics, and to acquire a thorough knowledge and understanding of those topics that any employer would expect of a Mathematics and Statistics graduate.

After the first two years, you chose your lecture courses from a widening range of options in order that you can pursue those areas which most interest you. In the final year at least half of your module choices will be in probability and statistics. You can choose to do a final year project instead of a lecture course on an appropriate topic supervised by a member of the academic staff.

Course units for year 1

The course unit details given below are subject to change, and are the latest example of the curriculum available on this course of study

Title	Code	Credit rating	Mandatory/optional

Linear Algebra	MATH11022	20	Mandatory
Real Analysis	MATH11112	10	Mandatory
Mathematical Foundation & Analysis	MATH11121	20	Mandatory
Mathematical Problem Solving	MATH11221	20	Mandatory
Introduction to Vector Calculus	MATH11411	10	Mandatory
ODEs and Applications	MATH11422	20	Mandatory
Probability I	MATH11711	10	Mandatory
Statistics I	MATH11712	10	Mandatory

Course units for year 2

The course unit details given below are subject to change, and are the latest example of the curriculum available on this course of study.

Title	Code	Credit rating	Mandatory/optional
Managing my Future	MATH20040	0	Mandatory
Real Analysis	MATH20101	10	Mandatory
Algebraic Structures 1	MATH20201	10	Mandatory
Partial Differential Equations and Vectors Calculus A	MATH20401	20	Mandatory
Probability 2	MATH20701	10	Mandatory
Random Models	MATH20712	10	Mandatory
Statistical Methods	MATH20802	10	Mandatory
Practical Statistics	MATH20811	10	Mandatory
Metric Spaces	MATH20122	10	Optional
Calculus of Several Variables	MATH20132	10	Optional
Algebraic Structures 2	MATH20212	10	Optional
Introduction to Geometry	MATH20222	10	Optional

Fluid Mechanics	MATH20502	10	Optional
Principles of Mathematical Modeling	MATH20522	10	Optional
Numerical Analysis 1	MATH20602	10	Optional
Foundations of Modern Probability	MATH20722	10	Optional
Discrete Mathematics	MATH20902	10	Optional
Introduction to Financial Mathematics	MATH20912	10	Optional

Course units for year 3

The course unit details given below are subject to change, and are the latest example of the curriculum available on this course of study

Title	Code	Credit hrs.	Mandatory/optional
Foundations of Finance A	BMAN23000	20	Optional
Foundations of Finance A	BMAN23000A	20	Optional
Quantum Computing	COMP39112	10	Optional
Double Project	MATH30000	20	Optional
Mathematics education	MATH30002	10	Optional
Project (Semester One)	MATH30011	10	Optional
Project (Semester 2)	MATH30022	10	Optional
Linear Analysis	MATH31002	10	Optional
Fractal Geometry	MATH31042	10	Optional
Topology	MATH31051	10	Optional
Group Theory	MATH32001	10	Optional
Commutative Algebra	MATH32012	10	Optional
Hyperbolic Geometry	MATH32052	10	Optional
Algebraic Geometry	MATH32062	10	Optional
Number Theory	MATH32072	10	Optional

Combinatory and Graph Theory	MATH32091	10	Optional
Mathematical Logic	MATH33021	20	Optional
Complex Analysis &Applications	MATH34011	20	Optional
Green's Functions, Integral Equations and Applications	MATH34031	10	Optional
Viscous Fluid Flow	MATH35002	10	Optional
Wave Motion	MATH35012	10	Optional
Elasticity	MATH35021	10	Optional
Mathematical Biology	MATH35032	10	Optional
Mathematics of a Finite Planet	MATH35062	10	Optional
Symmetry in Geometry and Nature	MATH35082	10	Optional
Matrix Analysis	MATH36001	10	Optional
Numerical Analysis 2	MATH36022	10	Optional
Problem Solving by Computer	MATH36031	10	Optional
Convex Optimization	MATH36062	10	Optional
Martingales with Applications to Finance	MATH37001	10	Optional
Markov	MATH37012	10	Optional
Statistical Inference	MATH38001	10	Optional
Time Series Analysis	MATH38032	10	Optional
Medical Statistics	MATH38072	10	Optional
Regression Analysis	MATH38141	10	Optional
Multivariate Statistics and Machine Learning	MATH38161	10	Optional
Generalized Linear Models	MATH38172	10	Optional
Mathematical Modeling in Finance	MATH39032	10	Optional
Actuarial Models	MATH39511	10	Optional
Survival Analysis for Actuarial Science	MATH39512	10	Optional

Contingencies 2	MATH39522	10	Optional
Risk Theory	MATH39542	10	Optional
Advanced Technology Enterprise	MCEL30011	10	Optional
Advanced Technology Enterprise	MCEL30012	10	Optional
Interdisciplinary Sustainable Development	MCEL30022	10	Optional
Mathematical Fundamentals of Quantum Mechanics	PHYS30201	10	Optional
Leadership in Action Unit	UCIL20022	10	Optional

Appendix2A. M. Sc. (Industrial Mathematics with Computer Application)- India (https://nowrosjeewadia.mespune.org/course/m-sc-industrial-mathematics-with-computer-application/)

Introduction

M. Sc. (Industrial Mathematics with Computer Application) course is designed to prepare students to undertake careers involving problem solving in mathematics using computer science and technologies, or to pursue advanced studies and research in mathematics using computer science. The syllabus which comprises of Mathematics & Computer Science subjects covers the foundational aspects of mathematics & computing sciences and also develops the requisite professional skills and problem solving abilities using computing sciences. M. Sc. (Industrial Mathematics with Computer Application)) is a three years full time post-graduation course affiliated to Pune University. In order to match our scientific education system with that of global standards, Pune University has introduced Choice Based Credit System (CBCS) from the academic year 2019 onwards for all Post- Graduate programs under the faculty of Science. In CBCS, the minimum total no. of credits requirement is 120. These credits are distributed in 6 semesters. To obtain M. Sc. (Industrial Mathematics with Computer Application) degree, students have to obtain additional 8 Credits by participating in various activities along with these Compulsory 120 credits.

Eligibility

- B. Sc./ B. Sc. (Computer Science)/ B. A. students having Mathematics up to second year.

Course Structure

M. Sc. (Industrial Mathematics with Computer Application) is a three year Professional Post Graduate program under the faculty of Science and Technology affiliated to Pune University.

M. Sc. (Industrial Mathematics with Computer Application)

Semester I			
Sr. No	Subject Code	Subject Name	Credit Hrs.
1	MIM 101	Real Analysis	4
2	MIM 102	Linear Algebra	4
3	MIM 103	C- Programming	4
4	MIM 104	DBMS	4
5	MIM 105	Lab Work	4
Semester II	Subject Code	Subject Name	Credit Hrs.
1	MIM 201	Complex Analysis	4
2	MIM 202	Discrete Mathematical Structures	4
3	MIM 203	Data Structure	4
4	MIM 204	Software Engineering	4
5	MIM 205	JAVA	4
6	MIM 206	Lab Work	4
Semester III	Subject Code	Subject Name	Credit Hrs.
1	MIM 301	Operation Research	4
2	MIM 302	Algebra	4
3	MIM 303	Advance JAVA	4
4	MIM 304	Operating System	4
5	MIM 305	Lab Work	4
6	MIM 306 (E)	Computer Networks	4
7	MIM 307 (E)		4
Semester IV	Subject Code	Subject Name	Credit Hrs.
1	MIM 401	Differential Equations	4
2	MIM 402	Statistical Methods	4
3	MIM 403	Design and Analysis of Algorithms	4
4	MIM 404	Internet Programming	4
5	MIM 405	Mobile Technologies	4
6	MIM 406	Lab Work	4

Semester V			
Sr. No.	Subject Code	Subject Name	
1	MIM 501	Numerical Analysis	4
2	MIM 502	Computational Geometry	4
3	MIM 503	Data Analysis with Python	4
4	MIM 504	Digital Image Processing	4
5	MIM 505	Lab Work	4
6	MIM 506 (E)	Cryptography and Network Security	4
7	MIM 507 (E)	Internet of Things	4
Semester VI	Subject Code	Subject Name	Credit Hrs.
1	MIM 601	Industrial Training	4

Evaluation Process:

For each subject of 4 Credits, internal Assessment of 30 Marks and external Assessment of 70 Marks will be conducted separately for Semester I and Semester II.

Admission Procedure

- A Student has to obtain/ download the Admission Form in prescribed format from the College website.
- Students are requested to update themselves of the merit list (if any) on the College website and seek admission by payment of fees.
- The admission is confirmed only after the fees are paid in full and subject to submission of necessary documents.
-

Appendix2B. Master of Science (Industrial Mathematics) : Malaysia

<u>Centre for Mathematical Sciences - Master of Science (Industrial Mathematics) by Mixed-Mode (ump.edu.my)</u>

<u>Program Description</u>

Master of Science (Industrial Mathematics) is designed to provide in-depth coverage topics of the industrial and applied mathematics in two sub-specializations, namely

(i) Data Computing, and
(ii) Computational Mathematics.

The program caters two pillars of Industrial Revolution 4.0 (IR 4.0) including simulation and big data computing. The program emphasizes embedded case study in all courses that enables students to integrate theory and application as well as using mathematical software such as Python, R Language, VBA, EXCEL, Matlab, TORA, Minitab and KNIME as the vital computational tools. The program also requires every student to complete a project dissertation based on a chosen applied and industrial problems. The program caters to fresh graduates and professionals, especially the non-mathematics degrees holders, who aspire to enhance their knowledge and competency in one of the sub-specializations being offered. Applicants who possess a first degree in any of the following specializations; Statistics, Mathematics, Finance, Economy, Computing, Engineering and Sciences as well as good mastery in undergraduate mathematics courses are welcomed to apply.

	First Year Semester- One					
	Course Code	Course title	Credit Hours	Contact Hours	Pre-requisite	Assessment method
1.Core Courses	MSU4113	Research Methodology	3	Lecture-3 Hours	None	Project, , project presentation
	MSM4213	Industrial Statistics	3	Lecture-2 Hours Lab-2 Hours	None	Project, Test, Laboratory Report
	MSM4413	Computational Methods in industry	3	Lecture-2 Hours Lab-2 Hours	None	Project, Test, Laboratory Report
	MSM4424	Programming & Simulation	4	Lecture-3 Hours Lab-2 Hours	None	Project, Test, Laboratory Report
		Total Credit Hours	=13			
	First Year Semester- Two					
Specialization	Elective Courses (Choose two from either specialization 1 or 2)					
2.Data Computing	MSM4224	Statistical Quality Control	4	Lecture-3 Hours Lab-2 Hours	None	Project, Test, Laboratory Report
	MSM4234	Data Design Analysis	4	Lecture-3 Hours Lab-2 Hours	None	Project, Test, Laboratory Report
	MSM4244	Data mining	4	Lecture-3 Hours Lab-2 Hours	None	Project, Test, Laboratory Report
	MSM4254	Statistical modeling	4	Lecture-3 Hours Lab-2 Hours	None	Project, Test, Laboratory Report
	MSM4264	Time Series Analysis & Forecasting	4	Lecture-3 Hours Lab-2 Hours	None	Project, Test, Laboratory Report
	MSM4274	Multivariate Data	4	Lecture-3	None	Project, Test,

		Analysis		Hours Lab-2 Hours		Laboratory Report
	MSM4284	Applied machine Learning	4			
3.Computational Mathematics	MSM4434	Mathematical modeling	4	Lecture-3 Hours Lab-2 Hours	None	Project, Test, Laboratory Report
	MSM4444	Operational Research	4	Lecture-3 Hours Lab-2 Hours	None	Project, Test, Laboratory Report
	MSM4454	Partial differential Equations	4	Lecture-3 Hours Lab-2 Hours	None	Project, Test, Laboratory Report
	MSM4464	Computational Fluid Dynamics	4	Lecture-3 Hours Lab-2 Hours	None	Project, Test, Laboratory Report
	MSM4474	Advanced Numerical Methods	4	Lecture-3 Hours Lab-2 Hours	None	Project, Test, Laboratory Report
	MSM4484	Mathematical Image Processing	4	Lecture-3 Hours Lab-2 Hours	None	Project, Test, Laboratory Report
4.Dissertation	MSM4910	Dissertation I	8	Lecture-1 Hour Progress Monitoring	None	Progress report, Proposal report, Proposal Defense
	MSM5920	Dissertation II	13	Lecture-1 Hour Progress Monitoring	MSM4910	Progress report, Dissertation, VIVA-VOCE
	First Year Semester- Two					
5.Elective Courses	MSM4**4	Elective I	4			
	MSM4**4	Elective II	4			
	MSM4910	Dissertation I	8			
		Total Credit Hours	=16			
	Second Year Semester- One(III)					
	MSM5920	Dissertation II	13	Lecture-1 Hour Progress Monitoring	MSM4910	Progress report, Dissertation, VIVA-VOCE

Appendix2C. Master Of Business & Science In Industrial Mathematics

Master of Business & Science in Industrial Mathematics – Department of Mathematical Sciences (rutgers.edu)

The MBS degree is a combination of an MS and a MBA degree (see https://mbs.rutgers.edu/) Students in this program choose a particular science concentration, accompanied by a business curriculum. The science concentration consists of 24 credits and the curriculum is set by the unit offering the concentration. The business curriculum consists of 19 credits and is almost completely prescribed (see the business curriculum for details). Students do not write a thesis and are expected to do a Capstone project.

ADMISSION REQUIREMENTS

Bachelor degree in science or mathematics, with a GPA greater than 3.0

GRE scores

2 Letters of Recommendation

For applications whose native language is not English, the TOEFL.

Basic knowledge of programming language (C, C++, java, etc.)

If your degree is not in science/mathematics, then you need to take Calculus I, II, and III, and differential equations and/or linear algebra prior to starting the MBS. These courses could be taken anywhere where they are offered.

CURRICULUM

Industrial Mathematics

All students first take courses that provide a strong foundation in programming and algorithms relevant to current and emerging computational applications. Non-CS majors are required to take two background courses to acquire basic programming skills. In addition, students must take at least three of five core courses that relate to a wide range of science and engineering applications. In addition to these requirements, a total of eight courses (24 credits) must be taken.

Industrial Mathematics (24 credits)
Required (24 credits)
56:645:560 Industrial Mathematics (3)
56:645:562 Mathematical Modeling (3)
56:645:563 Statistical Reasoning (3)
56:645:571 Computational Mathematics I (3) 56:645: 572 Computational Mathematics II (3)
Electives (9 or 12 credits)
56:645:527 Methods of Applied Mathematics I (3) 56:645: 528 Methods of Applied Mathematics II (3)
56:645:533 Introduction to the Theory of Computation I (3) 56:645: 534 Introduction to the Theory of Computation II (3)
56:645:537 Computer Algorithms (3)
56:645:538 Combinatorial Optimization (3)
56:645:540 Computational Number Theory and Cryptography (3)
56:645:541 Introduction to Computational Geometry (3)
56:645:554 Applied Functional Analysis (3)
56:645:557 Signal Processing (3)
56:645:561 Optimization Theory (3)
56:645:574 Control Theory and Optimization (3)
56:645:575 Qualitative Theory of Ordinary Differential Equations (3)
56:645:578 Mathematical Methods of Systems Biology (3)
56:645:579 Celestial Mechanics (3)
56:645:580 Special Topics in Applied Mathematics (3)
56:645:699 Independent Study in Applied Mathematics (3)
56:645:701 Thesis in Applied Mathematics (3)
Business Courses (19 credits)
Finance & Accounting (3 credits)
Students select one from:
53:135:500 Managerial Economics (3 credits)
53:390:506 Financial Management (3 credits)
Marketing (3 credits)
Mandatory for all students:
53:630:508 Marketing Management (3 credits)
Communication & Leadership (3 credits)
Mandatory for all students:
53:135:501 Managerial Skills (3 credits)
Management of Science & Technology (3 credits)
Mandatory for all students
53:716:513 Operations Management (3 credits)
General Management (3 credits)
Students take one course. See the See Camden course listings for the MBS Business Curriculum
Ethnics and Professionalism (1 credit)

Mandatory for all students:
16:137:500* Ethics for Science & Technology Management (1 credit)
16:137:503Colloquium in Professionalism for Science & Technology Management (0 credits)
Capstone (3 credits)
Mandatory for all students:
16:137:600 Science & Technology Management Capstone (3 credits)

Appendix2D. Center for Industrial Mathematics and Statistics (CIMS)- WPI)
https://www.wpi.edu/academics/study/industrial-mathematics-ms

The Center for Industrial Mathematics and Statistics was established in 1997

- To foster partnerships between the university and industry, business and government in mathematics and statistics research
- The problems facing business and industry are growing ever more complex, and their solutions often involve sophisticated mathematics. The faculty members and students associated with CIMS have the expertise to address today's complex problems and provide solutions that use relevant mathematics and statistics.
- The Center offers undergraduates and graduate students the opportunity to gain real-world experience in the corporate world through projects and internships that make them more competitive in today's job market.
- In addition, it helps companies address their needs for mathematical solutions and enhances their technological competitiveness. The industrial projects in mathematics and statistics offered by CIMS provide a unique education for successful careers in industry, business and higher education.

Career Outlook for WPI Mathematical Sciences Degrees

- Actuarial Mathematics
- Applied Statistics
- Applied Mathematics
- Financial Mathematics
- Mathematics for Educators
- Mathematical Sciences

Course Number	Course Title	Credit Hours
MA500	Basic Real Analysis	3
MA 501	Engineering Mathematics	3
MA 502	Linear Algebra	3
MA 503	Lebesgue Measure and Integration	3
MA 504	Functional Analysis	3
MA 505	Complex Analysis	3
MA508	Mathematical Modeling	3
MA 509	Stochastic Modeling	3
MA 510/CS 522	Numerical Methods	3
MA 511	Applied Statistics for Engineers and Scientists	3
MA 512	Numerical Differential Equations	3
MA 514	Numerical Linear Algebra	3
MA/DS 517	Mathematical Foundations for Data Science	3
MA 520.	Fourier Transforms and Distributions	3
MA 520.	Partial Differential Equations	3
MA 522	Hilbert Spaces and Applications to PDE	3
MA 524	Convex Analysis and Optimization	3
MA 525	Optimal Control and Design with Composite Materials I	3
MA 526	Optimal Control and Design with Composite Materials II	3
MA 529	Stochastic Processes	3
MA 530	Discrete Mathematics	3
MA 533	Discrete Mathematics II	3
MA 535	Algebra	3
MA 540/4631	Probability and Mathematical Statistics I	3

MA 541/4632	Probability and Mathematical Statistics II	3
MA 542	Regression Analysis	3
MA543/DS 502	Statistical Methods for Data Science	3
MA 546	Design and Analysis of Experiments	3
MA 547	Design and Analysis of Observational and Sampling Studies	3
MA 548	Quality Control	3
MA 549	Analysis of Lifetime Data	3
MA 550	Time Series Analysis	3
MA 552	Distribution-Free and Robust Statistical Methods	3
MA 554	Applied Multivariate Analysis	3
MA 556	Applied Bayesian Statistics	3
MA 557	Graduate Seminar in Analysis and Applied Mathematics (1 credit)	1
MA 559	Statistics Graduate Seminar (1 credit)	1
MA 560	Graduate Seminar (0 credits)	0
MA 562 A and B	Professional Master's Seminar (0 credits)	0
MA 571	Financial Mathematics I	3
MA 572	Financial Mathematics II	3
MA 573	Computational Methods of Financial Mathematics	3
MA 574	Portfolio Valuation and Risk Management	3
MA 575	Market and Credit Risk Models and Management	3
MA 579	Financial Programming Workshop (1 or 2 credits)	1 / 2
MA584/BCB 504	Statistical Methods in Genetics and Bioinformatics	3
MA 590	Special Topics	3

Appendix2E. Master's degree program in Mathematics and Statistics
https://www.manchester.ac.uk/study/undergraduate/courses/2023/07102/mmath-mathematics-and-statistics/#course-profile

This flexible single-honors undergraduate Master's degree program is for you if you expect to use statistics in your professional work. You will develop the capacity to formulate and analyze problems and to interpret scientific evidence using appropriate statistical methodology. You get good all-round mathematical knowledge together with the ability to experience more specialized results, methods and ideas; your education in these specialized areas is in sufficient depth to enable you to undertake postgraduate studies, conduct research or work as a specialist mathematician. A core of basic mathematics, probability and statistics provides you with the fundamental knowledge and skills, and the basis for more advanced work later on. Core material is covered in the first year, developing the capacity to learn and apply mathematical and statistical ideas. In the second year, besides probability and statistics, you can choose to take on courses from pure or applied mathematics, along with other optional units such as Programming with R. You will understand the significance and power of mathematics, and to acquire a thorough knowledge and understanding of those topics that any employer would expect of a Mathematics and Statistics graduate. After your first two years, you choose your lecture courses from a widening range of options in order that you can pursue whichever areas of mathematics most interest you. You also undertake a substantial final year project in probability and statistics.

Course units for year 1

The course unit details given below are subject to change, and are the latest example of the curriculum available on this course of study

Title	Code	Credit rating	Mandatory/optional
Linear Algebra	MATH11022	20	Mandatory
Real Analysis	MATH11112	10	Mandatory
Mathematical Foundation & Analysis	MATH11121	20	Mandatory

Mathematical Problem Solving	MATH11221	20	Mandatory
Introduction to Vector Calculus	MATH11411	10	Mandatory
ODEs and Applications	MATH11422	20	Mandatory
Probability I	MATH11711	10	Mandatory
Statistics I	MATH11712	10	Mandatory

Course units for year 2

The course unit details given below are subject to change, and are the latest example of the curriculum available on this course of study

Title	Code	Credit rating	Mandatory/optional
Managing my Future	MATH20040	0	Mandatory
Real Analysis	MATH20101	10	Mandatory
Algebraic Structures 1	MATH20201	10	Mandatory
Partial Differential Equations and Vectors Calculus A	MATH20401	20	Mandatory
Probability 2	MATH20701	10	Mandatory
Random Models	MATH20712	10	Mandatory
Statistical Methods	MATH20802	10	Mandatory
Practical Statistics	MATH20811	10	Mandatory
Metric Spaces	MATH20122	10	Optional
Calculus of Several Variables	MATH20132	10	Optional
Algebraic Structures 2	MATH20212	10	Optional
Introduction to Geometry	MATH20222	10	Optional
Fluid Mechanics	MATH20502	10	Optional
Principles of Mathematical Modeling	MATH20522	10	Optional
Numerical Analysis 1	MATH20602	10	Optional
Foundations of Modern Probability	MATH20722	10	Optional
Discrete Mathematics	MATH20902	10	Optional
Introduction to Financial Mathematics	MATH20912	10	Optional

Course units for year 3

The course unit details given below are subject to change, and are the latest example of the curriculum available on this course of study.

Title	Code	Credit hrs.	Mandatory/optional
Foundations of Finance A	BMAN23000	20	Optional
Foundations of Finance A	BMAN23000A	20	Optional
Quantum Computing	COMP39112	10	Optional
Double Project	MATH30000	20	Optional
Mathematics education	MATH30002	10	Optional
Project (Semester One)	MATH30011	10	Optional
Project (Semester 2)	MATH30022	10	Optional
Linear Analysis	MATH31002	10	Optional
Fractal Geometry	MATH31042	10	Optional
Topology	MATH31051	10	Optional
Group Theory	MATH32001	10	Optional
Commutative Algebra	MATH32012	10	Optional
Hyperbolic Geometry	MATH32052	10	Optional
Algebraic Geometry	MATH32062	10	Optional
Number Theory	MATH32072	10	Optional
Combinatory and Graph Theory	MATH32091	10	Optional
Mathematical Logic	MATH33021	20	Optional
Complex Analysis &Applications	MATH34011	20	Optional
Green's Functions, Integral Equations and Applications	MATH34031	10	Optional
Viscous Fluid Flow	MATH35002	10	Optional
Wave Motion	MATH35012	10	Optional
Elasticity	MATH35021	10	Optional
Mathematical Biology	MATH35032	10	Optional
Mathematics of a Finite Planet	MATH35062	10	Optional
Symmetry in Geometry and Nature	MATH35082	10	Optional
Matrix Analysis	MATH36001	10	Optional
Numerical Analysis 2	MATH36022	10	Optional
Problem Solving by Computer	MATH36031	10	Optional
Convex Optimization	MATH36062	10	Optional
Martingales with Applications to Finance	MATH37001	10	Optional
Markov	MATH37012	10	Optional
Statistical Inference	MATH38001	10	Optional
Time Series Analysis	MATH38032	10	Optional
Medical Statistics	MATH38072	10	Optional
Regression Analysis	MATH38141	10	Optional
Multivariate Statistics and Machine Learning	MATH38161	10	Optional
Generalized Linear Models	MATH38172	10	Optional
Mathematical Modeling in Finance	MATH39032	10	Optional
Actuarial Models	MATH39511	10	Optional
Survival Analysis for Actuarial Science	MATH39512	10	Optional
Contingencies 2	MATH39522	10	Optional
Risk Theory	MATH39542	10	Optional
Advanced Technology Enterprise	MCEL30011	10	Optional
Advanced Technology Enterprise	MCEL30012	10	Optional
Interdisciplinary Sustainable Development	MCEL30022	10	Optional
Mathematical Fundamentals of Quantum Mechanics	PHYS30201	10	Optional
Leadership in Action Unit	UCIL20022	10	Optional

Appendix- A: Consent Letters for industry professionals

COVER LETTER TO SURVEY QUESTIONS FOR INDUSRY PROFESSIONALS

DATE 15/11/2021

Dear Prospective respondent,

This questionnaire forms part of my research entitled: *Industrial Mathematics Curriculum Development for Ethiopian Science and Technology Universities* for the degree Doctor of Education (D.Ed.) at the University of South Africa. You have been selected by a *purposive sampling* strategy from the population of your industry/organization. Hence, I invite you to take part in this survey. The aim of this study is to investigate the need of the stakeholder on industrial mathematics to propose appropriate industrial mathematics curriculum to Ethiopian Science and Technology University (ESTU). The findings of the study may benefit you and your industry by providing an opportunity to conduct research in your area that arises from industrial problems through industrial mathematics. You are kindly requested to complete this survey questionnaire, as honestly and frankly as possible and according to your personal views and experience. No foreseeable risks are associated with the completion of the questionnaire which is for research purposes only. The questionnaire will take approximately 20 minutes to complete. You are not required to indicate your name and your anonymity will be ensured; however, indication of your service, gender, occupation position will contribute to a more comprehensive analysis.

Thank you for taking time to assist me in my educational endeavors. After the completion of the study, an electronic summary of the findings of the research will be made available to you on request. Permission to undertake this survey has been granted by the Addis Ababa science and Technology University and the Ethics Committee of the College of Education, UNISA. By completing the questionnaire, you imply that you have agreed to participate in this research. Please return the completed questionnaire to me before December___, 2021

Yours sincerely

Zewdie Woldeamanuel Habte

Lecturer, College of Natural and Social Science

Addis Ababa Science and Technology University, Addis Ababa, Ethiopia

64126846@mylife.unisa.ac.za / kenazewd@gmail.com / +251911392588/

Appendix-B: consent Letter for instructors

COVER LETTER TO SURVEY QUESTIONS FOR UNIVERSITY INSTRUCTORS

DATE 10/01/2022

Dear Prospective respondent,

This questionnaire forms part of my research entitled: *Industrial Mathematics Curriculum Development for Ethiopian Science and Technology Universities* for the degree of D.Ed. at the University of South Africa. You have been selected by a *purposive sampling* strategy from the population of your College/Faculty. Hence, I invite you to take part in this survey. The aim of this study is to investigate the need of the stakeholder on industrial mathematics to propose appropriate industrial mathematics curriculum to Ethiopian Science and Technology University (ESTU). The findings of the study may benefit you and your university by providing an opportunity to conduct research in your area that arises from industrial problems through industrial mathematics. You are kindly requested to complete this survey questionnaire, as honestly and frankly as possible and according to your personal views and experience. No foreseeable risks are associated with the completion of the questionnaire which is for research purposes only. The questionnaire will take approximately 20 minutes to complete. You are not required to indicate your name and your anonymity will be ensured; however, indication of your service, gender, occupation position will contribute to a more comprehensive analysis.

Thank you for taking time to assist me in my educational endeavors. After the completion of the study, an electronic summary of the findings of the research will be made available to you on request. Permission to undertake this survey has been granted by the Addis Ababa science and Technology University and the Ethics Committee of the College of Education, UNISA. By completing the questionnaire, you imply that you have agreed to participate in this research. Please return the completed questionnaire to me before January___, 2021.

Yours sincerely

Zewdie Woldeamanuel Habte

Addis Ababa Science and Technology University, Addis Ababa, Ethiopia

64126846@mylife.unisa.ac.za / kenazewd@gmail.com / +251911392588/

Appendix-C Questionnaire for Industry Expert

PART-I: BACKGROUND INFORMATION

INSTRUCTIONS: This part of the questionnaire is designed to collect the Personal information of industry experts regarding gender, Education, current position, and service years. The questions are contained closed-open -ended items, for the close-ended items put √ mark for the appropriate choice of your alternatives and for the open ended one write on the space provided.

1.1. Gender: 1.Male ☐ 2.Female ☐

1.2. Education: 1.Ph.D ☐ 2. Second degree ☐ 3.First Degree ☐ 4.If any__

1.3. Name of your industry /organization ________________________________

1.4. Your current position____

1.5. Service Years: 1. In Industry _____________2.Others institution_________

PART.2. INDUSTRIAL MATHEMATICS CURRICULUM DEVELOPMENT AND IMPLEMENTATIONS

2.1. Have you, in the past, participated in making suggestions on curriculum development and review program?

Yes ☐ No ☐

2.1.1. If your response for question 2.1 is "Yes "your level of participation___________________(Leader, Facilitator, Secretory, or , Member)

2.2. Do you have mathematical specialist in your company?

Yes ☐ No ☐

2.2.1. If your answer for 2.2 is "No", what are problems of industry in employing mathematician in industry? Please, indicate whether you agree or disagree with the following reason related to your industry or organization by putting (√)

		Yes	No
1	Lack of technical mathematical ability		
2	Bureaucratic procedure		
3	Officers is not often a judge of mathematics ability		
4	Lack of supervision knowledge of this type of personal		

5. If any specify here____

2.3. Industrial Mathematics

INSTRUCTIONS: This part of the questionnaire is designed to investigate your understanding about industrial mathematics. Please indicate how much you agree or disagree with each of the following statements by circling one of the numbers that stand for the following rating scales

Strongly Disagreed(1)	Disagree (2)	Undecided(3)	Agreed(4)	Strongly Agree (5)

	Industrial Mathematics					
1	It is basic for knowledge base industrial development of every country	1	2	3	4	5
2	It solves the industrial problems using different mathematical techniques	1	2	3	4	5
3	It is the mathematical analysis of problems that arise in an industrial setting	1	2	3	4	5
4	It is a mathematical work that is performed in an academic setting that is largely isolated from the demands, pressures, and constraints of industry	1	2	3	4	5
5	It designate all the research that is oriented at the solution of problems posed by industrial applications	1	2	3	4	5
6	It is an interdisciplinary course that integrates engineering courses, science and mathematics courses	1	2	3	4	5
7	It is a branch of mathematics that is concerned with developing mathematical methods and applying them to engineering, science, and industry	1	2	3	4	5

2.4. How important are the following mechanisms of working together between academics and industrial experts to implement industrial mathematics curriculum in Ethiopian science and technology universities and industries? Please indicate the degree of importance of the following statements by circling one of the numbers that stand for the following rating scales:

Unimportant [1]	Slightly Important [2]	Moderately Important [3]	Important [4]	Very important [5]

Mechanism to enhance working together

A.1	Initiates existing relationships between industry and universities	1	2	3	4	5
A.2	Trust and openness from both parties	1	2	3	4	5
A.3	Develop educational programs that educate personnel in a way that satisfies the missions of all parties involved	1	2	3	4	5

B.1	Establish interdisciplinary research center by teams of Universities and industries scholars	1	2	3	4	5
C.1	Assign Positions for Industrial Mathematics in university and industry	1	2	3	4	5
D.1	Supervise students together through a grant secured by university-industry collaboration	1	2	3	4	5
D.2	Embedding students in industries departments and government offices as Fellowships or as Industry Practicums	1	2	3	4	5
E.1	Establish industrial mathematics study groups enable Industries get their problems in short time by intensive work by independent experts	1	2	3	4	5
F.1	Technology translators identify industrial opportunities for mathematics, understand the detailed requirements of each company	1	2	3	4	5
G.1	Provide Consultancy service as an Intermediary organizations enable this mechanism of knowledge exchange in between university-industry links	1	2	3	4	5
G.3	Personnel exchange allows staff to work either specifically on a given project or freely between collaborators	1	2	3	4	5
G.4	Use of successful completed industrial mathematics project in the same framework in Ethiopian cases	1	2	3	4	5

2.5. Factors that influence the implementation of industrial mathematics Curriculum.

INSTRUCTIONS: This part of the questionnaire is designed to identify those factors that influence the implementation of industrial mathematics at Ethiopian Science and Technology University (ESTU). Please indicate how much you agree or disagree with each of the following statements by circling one of the numbers that stand for the following rating scales:

Strongly Disagree(1)	Disagreed (2)	Undecided (3)	Agreed (4)	Strongly agreed (5)

Factors that influences the implementations of industrial mathematics

1	An Industry expert has no the necessary mathematical background and knowledge	1	2	3	4	5
2	Poor university-industry link	1	2	3	4	5
3	Industry awareness in using research result of universities	1	2	3	4	5
4	Lack of knowledge in importing/using appropriate technology	1	2	3	4	5
5	Insufficient information about the graduate at the job market	1	2	3	4	5
6	Pedagogical practice that does not target the skill needed by the industry	1	2	3	4	5
7	Universities in Ethiopia do not have the opportunity to underpin quantitative understanding of industrial strategy and processes across all sectors of business	1	2	3	4	5
8	The necessary investment in mathematics are key challenges for Ethiopian industry	1	2	3	4	5
9	The industry experts often do not fully know the industrial context of the mathematics they used	1	2	3	4	5
10	Trained man power in the field of industrial mathematics	1	2	3	4	5

2.6. What benefits can be derived from deploying Industrial Mathematics in enriching careers in terms of professional development (research and industrial problem solving skills)?

	Benefits	Benefits gained by				
		Teachers	Students	Industry Expert	Industry	University
1	Academic Rank					
2	Publication					
3	Patent					
4	Financial gain					
5	Academic achievement					
6	Job opportunity					
7	Improve production and services					
8	Use innovation from the academia					
9	Job appraisal					
10	Global rank					
11	Increase export productions					

2.7. The limitations and strength of the existing University Mathematics Curriculum you were taking

2.7.1. To answer the following four questions, please use the nine –point scale (1=Poor, 5=Typical, and 9= Excellent).You may use any point on the scale for your answer.

1	How do you rate the quality of undergraduate mathematics courses in solving industrial problems?	
2	How do you rate the mathematics courses in solving industrial problems ability to meet the needs of your employees who took it?	
3	How relevant is the contents of mathematics courses to your employees' working conditions?	
4	All things considered, how do you rate the overall values of mathematics courses to your employees?	

2.7.2. What could be done to improve the courses?______________________________

2.7.3. Please provide additional information about the courses that you feel will contribute to its use and effectiveness.___________________________

2.8. Industrial Mathematics curriculum Model for Ethiopian industrial development.

2.8.1. Joint curriculum development and joint employment

2.8.1.1. Can you support to the *development of joint industrial mathematics curriculum* between science and technology universities and industries?

Yes ☐ No ☐

2.8.1.2. If your response for question number 2.8.1.1 is "No", can you mention your reason?

____

2.8.1.3. If your response for question number 2.8.1.1 is "yes", what are the advantages of having joint curriculum? ____________________________

2.8.2. Do you agree that on the *appointment of* professionals with high degree of relevant expertise from industry in Ethiopian science and technology universities?

Yes ☐ No ☐

2.8.2.1. If your response for question number 2.8.2 is "Yes", how can we use them in universities? (Indicate your response as many as possible by using tick mark √)

A. Guest Lecturer ☐ B. Counselor ☐C. Mentorship ☐. If any _______

2.8.3. What *major types of industrial issues or topics* your organizations/industry work with academic institutions? (Check all that apply). For the major issues of the industry which mathematical concepts you are used. (Match industrial topics that need mathematics from the lists of mathematical concept found in the right hand side. You can assign more than one)

	INDUSTRIAL ISSUE OR TOPICS	Assign a number for the Mathematical concepts		MATHEMATICAL CONCEPTS
1.	Investigative projects and research from industry		1.	Differential Equation
2.	Using various problem solving tools and techniques to solve problems of industry		2.	Numerical analysis
3.	Developing or designing models related to industrial Problems		3.	Statistical analysis
4.	Simulation activities, such as improving productivity		4.	Computational methods
5.	Initiating change /designing in industrial processes		5.	Discrete Mathematics
6.	Industry relevant software, technology and equipment		6.	Optimization

7. Other Industry issue____________________ 7. Other Math concept_________

2.8.4. How industry elective courses should be included in industrial mathematics courses? Please, indicate as many as possible which are appropriate for your industry or organization

	Mechanisms to include industry elective courses	
1	Industry will design the courses as per requirement	
2	Industry will select the candidate and organize special training	
3	Industry will develop their own courses and delivered through subject experts	
4	Industry will develop student project	

5. If you have any delivery mechanism suggest here___________________________

2.8.4. Which industrial mathematics curriculum is most recommended for Ethiopian industries and Ethiopian Science and Technology Universities? (Please √ as many responses as you think accurate)

№	Industrial Mathematics Curriculum	
1	BSc. Industrial Mathematics With Computer Applications	
2	MSc. Industrial Mathematics With Computer Applications	
3	BSc. Industrial Mathematics	
4	MSc. Industrial Mathematics	
5	BSc. Industrial Mathematics and Statistics	
6	MSc. Industrial Mathematics and Statistics	
7	BSc .Applied and Industrial Mathematics	
8	MSc .Applied and Industrial Mathematics	
9	BSc Industrial Mathematical Modeling	
10	MSc Industrial Mathematical Modeling	

2.8.5. Which of the following list of generic employability skills will you recommend for the students of industrial mathematics? Indicate by the degree of ***importance of the employability skills*** in your industry/organization/university to be included in industrial mathematics curriculum.

Unimportant [1]	Slightly Important [2]	Moderately Important [3]	Important [4]	Very important [5]

	Employability Skills					
1	Communication that contributes to productive and harmonious relations between employees and customers;	1	2	3	4	5
2	Teamwork that contributes to productive working relationships and outcomes;	1	2	3	4	5
3	Problem-solving that contributes to productive outcomes;	1	2	3	4	5
4	Initiative and enterprise that contribute to innovative outcomes;	1	2	3	4	5
5	Planning and organizing that contribute to long term and short-term	1	2	3	4	5
6	Self-management that contributes to employee satisfaction and growth	1	2	3	4	5
7	Learning that contributes to on-going improvement and expansion in employee and company operations and outcomes;	1	2	3	4	5
8	Technology that contributes to effective execution of tasks;	1	2	3	4	5
9	Personal attributes that contribute to overall employability (e.g. loyalty, honesty & integrity, adaptability) (our emphasis added).	1	2	3	4	5

10. If any specify ____

2.8.6. Job opportunity for industrial mathematics graduate in your organization (Please put √ as many responses as you think accurate)

	Job opportunity	
1	Operations Research Analysts	
2	Scientific programmer	
3	Data analyst	
4	Financial Analysts	
5	Production line optimization	
6	Risk management	
7	Software testing and verification	

8. If any specify ____

2.8.7. General comment ____________________________________

Appendix- D Questionnaire for Instructors

PART-I: BACKGROUND INFORMATION

INSTRUCTIONS: This part of the questionnaire is designed to collect the Personal information of instructors regarding gender, Education, current position, and service years. The questions are contained closed-open -ended items, for the close-ended items put √ mark for the appropriate choice of your alternatives and for the open ended one write on the space provided

1.1. Gender: 1.Male ☐ 2.Female ☐

1.2. Education: 1.Ph.D ☐ 2. Second degree ☐ 3.First Degree ☐ 4.If any__

1.3. Name of your department ________________________________

1.4. Your current Position	1. President		2. Vice-president		3.Directoriate		4. College Dean
	5.Associate Dean		6.Department Head		7. Teacher		8.Other ________________

1.5. Service Years: 1. In Industry _____________2.Others institution_________

PART.2. INDUSTRIAL MATHEMATICS CURRICULUM DEVELOPMENT AND IMPLEMENTATIONS

1.1. Have you, in the past, participated in making suggestions on curriculum development and review program? Yes ☐ No ☐

1.1.1. If your response for question 2.1 is "Yes "your level of participation ________________________(Leader, Facilitator, Secretory, member)

1.2. Which of the following are the barriers you have come across in your work with curriculum development and review of new programs in university and how

Very Significant [4]	Significant [3]	A little Significant[2]	Not Significant [1]

	Barriers				
1	Lack time to fully participate in the program	1	2	3	4
2	Lack of interest to fully participate in the program	1	2	3	4
3	Inadequate background knowledge in curriculum development and review	1	2	3	4
4	Inadequate understanding of new technology	1	2	3	4
5	Lack of support within my organizations	1	2	3	4
6	The Curriculum is prepared by scholars selected from different institutions, but not from diversified groups.	1	2	3	4

7. Other-Specify here____

2.9. Industrial Mathematics

INSTRUCTIONS: This part of the questionnaire is designed to investigate your understanding about industrial mathematics. Please indicate how much you agree or disagree with each of the following statements by circling one of the numbers that stand for the following rating scales:

Strongly Disagreed(1)	Disagree (2)	Undecided(3)	Agreed(4)	Strongly Agree (5)

Industrial Mathematics

1	It is basic for knowledge base industrial development of every country	1	2	3	4	5
2	It solves the industrial problems using different mathematical techniques	1	2	3	4	5
3	It is the mathematical analysis of problems that arise in an industrial setting	1	2	3	4	5
4	It is a mathematical work that is performed in an academic setting that is largely isolated from the demands, pressures, and constraints of industry and industry-university collaborations.	1	2	3	4	5
5	It designate all the research that is oriented at the solution of problems posed by industrial applications	1	2	3	4	5
6	It is an interdisciplinary course that integrates engineering courses, science and mathematics courses	1	2	3	4	5
7	It is a branch of mathematics that is concerned with developing mathematical methods and applying them to engineering, science, and industry	1	2	3	4	5

2.10. How important are the following mechanisms of working together between academics and industrial experts to implement industrial mathematics curriculum in Ethiopian science and technology universities and industries? Please indicate the degree of importance of the following statements by circling one of the numbers that stand for the following rating scales:

Unimportant [1]	Slightly Important [2]	Moderately Important [3]	Important [4]	Very important [5]

Mechanism to enhance working together

A.1	Initiates existing relationships between industry and universities	1	2	3	4
A.2	Trust and openness from both parties	1	2	3	4
A.3	Develop educational programs that educate personnel in a way that satisfies the missions of all parties involved	1	2	3	4
B.1	Establish interdisciplinary research center by teams' universities and industries scholars.	1	2	3	4
C.1	Assign Faculty Positions for Industrial Mathematics in University and industry.	1	2	3	4
D.1	Supervise students together through a grant secured by university-industry collaboration	1	2	3	4
D.2	Assign students in industries departments and government offices as Fellowships	1	2	3	4

	or as Industry Practicums				
E.1	Establish industrial mathematics study groups that enable Industries get their problems in short time by intensive work by independent experts.	1	2	3	4
F.1	Technology translators identify industrial opportunities for mathematics, understand the detailed requirements of each company	1	2	3	4
G.1	Provide Consultancy service as an intermediary organizations enable this mechanism of knowledge exchange in between university-industry collaboration	1	2	3	4
G.2	Personnel exchange allows staff to work either specifically on a given project or freely between collaborators	1	2	3	4
G.3	Use of successful completed industrial mathematics project in the same framework in Ethiopian cases.	1	2	3	4

2.11. Factors that influence the implementation of industrial mathematics Curriculum.

INSTRUCTIONS: This part of the questionnaire is designed to identify those factors that influence the implementation of industrial mathematics at Ethiopian Science and Technology University (ESTU). Please indicate how much you agree or disagree with each of the following statements by circling one of the numbers that stand for the following rating scales:

Strongly Disagree(1)	Disagreed (2)	Undecided (3)	Agreed (4)	Strongly agreed (5)

	Factors that influences the implementations of industrial mathematics					
1	An Industry expert has no the necessary mathematical background and knowledge	1	2	3	4	5
2	Poor university-industry link	1	2	3	4	5
3	Industry awareness in using research result of universities	1	2	3	4	5
4	Lack of knowledge in importing/using appropriate technology	1	2	3	4	5
5	Insufficient information about the graduate at the job market	1	2	3	4	5
6	Pedagogical practice that does not target the skill needed by the industry	1	2	3	4	5
7	Universities in Ethiopia do not have the opportunity to underpin quantitative understanding of industrial strategy and processes across all sectors of business	1	2	3	4	5
8	The necessary investment in mathematics are key challenges for Ethiopian industry	1	2	3	4	5
9	The industry experts often do not fully know the industrial context of the mathematics they used	1	2	3	4	5
10	Trained man power in the field of industrial mathematics	1	2	3	4	5

2.12. What benefits can be derived from deploying Industrial Mathematics in enriching careers in terms of professional development (research and teaching learning)?

	Benefits	Benefits gained by				
		Teachers	Students	Industry Expert	Industry	University

1	Academic Rank					
2	Publication					
3	Patent					
4	Financial gain					
5	Academic achievement					
6	Job opportunity					
7	Improve production and services					
8	Use innovation from the academia					
9	Job appraisal					
10	Global rank					
11	Increase export productions					

2.13. The limitations and strength of the existing University Mathematics Curriculum you were taking

2.13.1. To answer the following questions, please use the nine –point scale (1=Poor, 5=Typical, and 9= Excellent).You may use any point on the scale for your answer.

1	How do you rate the quality of undergraduate mathematics courses in solving industrial problems?	
2	How do you rate the mathematics courses in solving industrial problems ability to meet the needs of your employees who took it?	
3	How relevant is the contents of mathematics courses to your employees' working conditions?	
4	All things considered, how do you rate the overall values of mathematics courses to your employees?	

2.13.2. What could be done to improve the courses?_________________________

2.13.3. Please provide additional information about the courses that you feel will contribute to its use and effectiveness.__________________________

2.14. Industrial Mathematics curriculum Model for Ethiopian industrial development.

2.14.1. Joint curriculum development and joint employment

2.14.1.1. Can you support to the *development of joint industrial mathematics curriculum* between science and technology universities and industries?

Yes ☐ No ☐

2.14.1.2. If your response for question number 2.8.1.1 is "No", can you mention your reason? ______________________________________

2.14.1.3. If your response for question number 2.8.1.1 is "Yes", what are the advantages of having joint curriculum? _______________

2.14.2. Do you agree that on the *appointment of* professionals with high degree of relevant expertise from industry in Ethiopian science and technology universities?

Yes ☐ No ☐

2.14.3. If your response for question number 2.8.2 is "Yes", how can we use them in universities? (Indicate your response as many as possible by using tick mark

A. Guest Lecturer ___ B. Counselor__ C. Mentorship___ D. If any______

2.14.4. What *major industrial issues or topics* your department working with industries? (Check all that apply). For the major issues of the industry which mathematical concepts you used. (Match industrial topics that need mathematics from the lists of mathematical concept found in the right hand side. You can assign more than one

	INDUSTRIAL ISSUE OR TOPICS	Assign a number for the Mathematical concepts		MATHEMATICAL CONCEPTS
1.	Investigative projects and research from industry		1.	Differential Equation
2.	Using various problem solving tools and techniques to solve problems of industry		2.	Numerical analysis
3.	Developing or designing models related to industrial Problems		3.	Statistical analysis
4.	Simulation activities, such as improving productivity-		4.	Computational methods
5.	Initiating change /designing in industrial processes-		5.	Discrete Mathematics
6.	Industry relevant software, technology and equipment		6.	Optimization

7. Other Industry issue_________________7. Other Math concept____________

2.14.5. How <u>industry elective courses</u> should be included in industrial mathematics courses? Please, indicate as many as possible which are appropriate for industry or organization.

	Mechanisms to include industry elective courses	
1	Industry will design the courses as per requirement	
2	Industry will select the candidate and organize special training	
3	Industry will develop their own courses and delivered through subject experts	

4	Industry will develop student project	

5. If you have any delivery mechanism suggest here________________________

2.14.6. Which industrial mathematics curriculum is most recommended for Ethiopian industries and Ethiopian Science and Technology Universities? (Please √ as many responses as you think accurate)

№	Industrial Mathematics Curriculum	
1	BSc. Industrial Mathematics With Computer Applications	
2	MSc. Industrial Mathematics With Computer Applications	
3	BSc. Industrial Mathematics	
4	MSc. Industrial Mathematics	
5	BSc. Industrial Mathematics and Statistics	
6	MSc. Industrial Mathematics and Statistics	
7	BSc .Applied and Industrial Mathematics	
8	MSc .Applied and Industrial Mathematics	
9	BSc Industrial Mathematical Modeling	
10	MSc Industrial Mathematical Modeling	

2.14.7. Job opportunity for industrial mathematics graduate in university and organization (Please put √ as many responses as you think accurate)

	Job opportunity	
1	Operations Research Analysts	
2	Scientific programmer	
3	Data analyst	
4	Financial Analysts	
5	Production line optimization	

6	Risk management	
7	Software testing and verification	
8	University Instructor	
9	High School Teacher	

10. If there are other job opportunities specify here ________________________

2.14.8. General ______________________________________

Appendix- E: Focus group Discussions Questions

1.Do you think that Mathematics course you took at the university level sufficient to solve problems of industry? Engineering? Applied Science? Yes/No

2.If the response is Yes/No, can you mention some of the strength/limitation of Mathematics curriculum related to problems in industry? Engineering? Applied Science?

3.What are the roles of academician (mathematician, engineers and applied science scholars)/Industry expert implementing industrial mathematics curriculum in Ethiopian Science and Technology Universities/ In Ethiopian industries?

4.What are those factors that influence the implementation of industrial mathematics in Ethiopian university? Industries? Regarding: Teaching learning? University industry link?

5.What are the values of implementing industrial mathematics in enriching careers in terms of, research? Teaching &training? Mentorship/advisor? Job opportunity?

6.Which industrial mathematics curriculum you recommend for Ethiopian science and Technology University?

Participants' discussion Report

Participant1. In practice, in Ethiopia curriculum is develop form upper level to lower level this is the first experience curriculum development initiative arise from a teacher , I admire this Initiation. Therefore, I support such curriculum development method from the lower level or from stakeholder to upper level management. However, my fear is by how much the higher level management supports such initiations.

Participant2. Ethiopian curriculum development is politically motivated. Thus, it is better to cross the line and shows the importance of the new curriculum to promote industrial development in Ethiopia.

Participant3. It is better to conduct need assessment of the stakeholder and conduct gap analysis of the need of the new industrial mathematics curriculum.

Participant4. He strongly comments to publish on APOS theory of curriculum development and research on mathematics education.

Participant5. To integrate disciplines from different field of study think of the mechanism to organize these group in the same framework.

Participant6. Think of the quality assurance of the Curriculum you suggest to Ethiopian and Science and Technology Universities. Explain briefly the profile of graduate to employ in industries.

Participant7. To implement this program in Ethiopian Industries the universities should have to facilitate students field visit, the curriculum should have to select industrial based project, internship program, student placement in the industries, and embedded students in fellowship and industrial practicum program.

> *Participant 1. "In practise, in Ethiopia, curriculum is developed from upper level to lower level. This is the first time I have experienced a curriculum development initiative arise from a teacher, and I admire this initiative." Therefore, I support such a curriculum development method from the lower level or from stakeholder to upper-level management. However, my fear is how much higher-level management supports such initiations."*

Participant 2: "Ethiopian curriculum development is politically motivated. Thus, it is better to cross the line and show the importance of the new curriculum to promote industrial development in Ethiopia".

The third participant said, "It is better to conduct a stakeholder need assessment and a gap analysis of the need for the new industrial mathematics curriculum."

Participant 4. "He strongly comments to publish on APOS theory of curriculum development and research on mathematics education."

Participant 5. "To integrate disciplines from different fields of study, think of the mechanism to organise these groups in the same framework."

Participant 6.. " Consider the quality monitoring of the curriculum you recommend to the universities of science and technology in Ethiopia. Briefly describe the profile of graduates who will work in industries."

Participant 7. "The curriculum should choose an industrial-based project, an internship programme, place students in the industries, and embed students in a fellowship and an industrial practicum programme in order to implement this programme in Ethiopian industries.."

In the discussions, the instructors mentioned many advantages of the development of an industrial mathematics curriculum for Ethiopian Science and technology universities, which are included that industrial mathematics:

- is helpful to industry and Research universities.
- contributes to filling the gaps that were observed between industry and universities.
- is used as input for the development of the nation by providing graduates in this discipline.
- demands for an assessment tool that is being used to determine programme development, so the curriculum is applicable.
- it helps to work together for professional development.
- encourages students to learn mathematics.

- is very important for problem solving and increased productivity in industries.
- links people's knowledge with technology

<u>Participant Questions</u>

1. What are the result of gap for choosing Industrial Mathematics Curriculum for Ethiopian Science and Technology Universities?

Answer: I will analysis the “Gap analysis of the current undergraduate and graduate mathematics curriculum in solving industrial problems in Ethiopia industries”

2. Why you choose APOS theory of curriculum development? What makes APOS theory different from the others theories?

Answer:

- The theory explains specific success and failures of individuals groups of students in trying to learn mathematical topics.
- A theory should help us to predicate that if certain phenomena, call them antecedents, are observed, then other phenomena, are likely to occur as consequences. Antecedents can be possible to foster its occurrence in students through instructional treatments.
- It can be applicable in wide range of phenomena (Research and Curriculum Development)
- Help organize thinking about learning phenomena (Pedagogical)
- Serve as a tool for analyzing data (Research method of mathematics education)
- Provide a language for communication about learning.

Comments from Applied Science and engineering Instructors

7. If any specify here/ Barriers in curriculum development and review programs / applied Science and Engineering Instructors responses

- *Top down* approach to be followed
- Most of the time curriculum development *not based on theory* simply it was prepared by selection of contents and *copying curriculum* of others

- Curriculum development is based on the *teachers need* especially on *PhD programs* mostly *focus on the teachers not on the need of the stakeholders*
- *No need assessment* done at all. If it has done, it was not properly done to dig out information up to *course content and teaching methodology selection*. This leads have copy-paste curriculum.
- *Curriculums* are directly *copied* from other *abroad institutions*
- VERY LITTLE COMMITMENT FROM THE *TOP OFFICIALS* OF THE INSTITUTIONS DUE TO THIER *PERSONAL INTERST* AND TEST
- *lack of understanding the competency* required by Ethiopian *industry*

2.7.2. What could be done to improve the courses?

- Include *applicable mathematics contents* that help to *solve industrial problems*
- Revise the course contents
- Incorporate *industrial problems* in curriculum
- Apply Mathematics to *real life*
- Connection to real life problems should be taking into accounts
- Update applied mathematics courses by taking examples from different field of study
- Revision
- Include applicable exercises and term papers at higher level mathematics courses.
- Work on the behavior of teachers and students.
- curriculum revision
- timely revision
- Giving Awareness and teaching the course
- Better to deliver with its practical application and meaning
- Curriculum Revision
- more linked with the recent demands (industry)and findings (institutions)
- Make it up to the internationally accredits standard
- To give focus on *contents* related to optimization.
- All the expert should have to *participate* and organized in that way
- *adding the solutions* of some of the question which are most difficult

- The *need assessment* should be collected from industry or the curriculum should be developed including experts from industry.
- they should be *designed based* on the *industry needs*
- better if it *designed based* on industry needs
- master *latest skills* from industry *experts* from companies, using *online courses*
- *Workshops* should be organized in *collaboration* with *stakeholders* such as industries
- should be *need based*
- develop *new curriculum* as you *proposed*
- High *quality* *teaching material* and tools, and *student teacher ratios* should be improved.
- focus on its *application*
- begin from the *graduate profile* and *assess the courses needed*
- better if *same courses are delivered* by professionals(teachers)from same department in *state (USA)*
- need to be tailored to the *need of industry*
- *integrate approach* with better interaction
- needs *content modification* but it should be answered by *employer*
- All required *recourses* on *priority basis*
- design courses as per the *need of modern technology*
- make it *practical using software* and *link the course with industry*
- *revising the existing curriculum* periodically for necessary updates
- Should improve based on *industry needs*
- *General courses* should be broken and geared to the *needs industries*

2.7.3. Please provide additional information about the courses that you feel will contribute to its use and effectiveness

- *Modeling* and simulations
- *Modeling* and *PDE* courses should be included in the program
- *update*
- *Optimization with software* on practical exercises from different industries
- Modeling
- *participatory* in nature
- *Application* of Mathematics in Industry sector
- It is necessary
- *Optimization*, and *advanced numerical analysis*
- *Physics and mathematics* course should be included like *mathematical physics*
- the problems which are given as an *activity question*
- It is *different* (selection of courses and course contents)based on the industry type
- *feedback* collection from *graduate* students and *stakeholder*
- the *importance or practical* (rationale , Aims , general objectives and specific objectives) aspect of the courses need to be clearly stated

- the courses like *applied mathematics* must be related to their possible application are to increase their effectiveness

n/a

- *business mathematics ,quantitative analysis (operational research) and econometrics*
- mathematics should be used in a way it can solve problems like *computational mathematics* e.t.c. in or towards the *counties developmental goal*
- *effectiveness* depends on its *demand and use ability*
- mathematical *modeling* and mathematics in *programming*
- Both the *applied mathematics and statistics* courses are useful, but the *way of delivery* as a *general course* is the main problem. Think of developing *modular curriculum* that take into account the *industrial application*

2.8.1.2. If your response for question number 2.8.1.1 is No can you mention your reason?

- Give *Priority* for other *supportive course*
- *Interdisciplinary* expansion
- *limited* information of *relevance*
- Might be a *better expert* is there to do that, otherwise*, I can*.
- I am basically *Biotechnology(This respondent is not aware of " Biology Is a new challenge as Physics to mathematics ")*
- I am not an expert in the area of industrial mathematics

2.8.1.3. If your response for question number 2.8.1.1 is Yes what are the advantages of having joint curriculum?

- It enable to get good teachers
- The *curriculum development* starts from the *real problem*
- To d*evelop the curriculum* based on *common interest*
- It would insight *real industrial problems solving skill*
- *Allow students* to be exposed to *real case studies* and *latest industry* insight and
- Quality enhancement
- *Mutual benefits* i.e. *exchanging reputable or experienced professionals* from both sides (University and Industry)
- Provide an opportunities to use resources
- It's a *win-win approach* for both the university and the industry as well
- It will help to address the *real problem* of the industry and the *focus areas* that need to be given attention.
- improve *university-industry linkage*
- *Experience* sharing

- It might be helpful to deal with *problems of the industry* with *mathematical applications*, Which *enhances the productivity* of the industries that is the core for the *development of the country*
- because it is a *multidisciplinary* course and thus act as a *bridge*
- target *full teaching* to meet *timing problem* in industry
- It will improve existing *problem solving method*
- Checking the curricula in line with *international standards* i.e. *ABET standards*
- Helps for the *development* of *both parties* and the *economy*.
- the *university and industry* will do based on need
- It is good to prepare *more* *productive curriculum*
- *multidisciplinary* knowledge
- it is important to solve the *industry problems*
- *important section* could be included in the course if *jointly developed*
- they can identify the *real problems (gap)* on both sides
- helps to identify and *solve real world problems*
- more capabilities for all types of digital communications
- the *industries* can *benefits* from the *trainees*
- *staff exchange* and *knowledge transfer*
- practically *applicable curriculum* can be designed
- to develop *mutual understanding* and *benefits* as well as *to create job opportunity*
- it *strengths* the curriculum and its *acceptance*
- because it is one and *important discipline for science*
- help to see *different perspective*
- to focus on their *area of application*
- graduates will be directly involved in the *industry matters*
- *uniformity*, *easy credit transfer* and *consistency*
- will generate *competent graduates* who will support the *industry*
- It can create *shared values*
- may solve the *core problem*
- it is possible to *fill the gap* between trainers and employers
- anything *useful* for industry
- to *understand* the *need* of the industry
- its application in *modeling the spatial distribution of life* *multidisciplinary* approaches that solves problems *different discipline*
- it is very important to *solve problem* using *mathematical modeling*
- the *instructors* will have practical understanding of problems
- It will help to address *real problems of industries*
- *courses* will be *geared to the competencies* required by *industry*

7. If you have others Industry issue /topics write here with the mathematics you used in solving it

- *BIM (Building Information Modeling)* also used some *Mathematical software.* So including it in this curriculum might be important.
- *Profitability, asset management, production chain control, effective labor and resources utilization*
- Physical lab --- *Numerical analysis, Statistical analysis , Computational methods and Differential Equation*

5 If you have any delivery mechanism suggest here

- *Delivering data* for *practical exercises*
- Industry will *invite the university staff* to select an elective course

10. If there are other job opportunities specify here

- Research assistant

2.8.7. General comment

- I kindly and respectfully suggest giving *priority* to the course, which is more aligned/ supportive to *the Industry and Research Universities*. Thank you
- This *proposed curriculum* is very important as it contributes to *fill the gaps* that were observed between the Industry and Universities as well as used as an input for the *development of the nation* by providing graduates in this discipline.
- Better to say "*MSc Applied Industrial Mathematics and Statistics*
- to get *different ideas* from *different intellectuals*, such questionnaires are very important
- Good luck for the candidate
- Try to share what I feel about *enhancing mathematics curriculum* for in *ESTU*, as an out-side observer; hope it's useful!
- If this program is launch it is very important for both the university and industry. Such important inter *-related* field is crucial for our country. *Without mathematics* there is no industry. So, it needs math related work should be applied.
- the questionnaire fine and I will express you to conduct an *interesting research*
- very useful and *applicable field of study* for universities , industries and for the country as a whole
- I think it is crucial to consider developing /relating / the *mathematics people* with the industry problems, helps to *solve real life problems* from the industry. Hope industrial mathematics *will be parts of our curriculum*
- It is good if there is *appropriate industrial mathematics to ESTU*

- the *effort of the researcher* is appreciated as the demand assessment tool is being used to determine *program development*
- All in all, *industrial mathematics* can be very applicable in a way a good curriculum at *post graduate level* can be developed where *problem solving graduates can be produced*

Comments from Mathematics Instructors

7. If any specify here

- curriculum development is highly influenced by *politecal system*
- The University *top management* understanding about the *relevance of the program* is the main discouraging factor, and *takes long time* for assessing the *need and demand* of the program.

2.7.2. What could be done to improve the courses?

- Revising the course to be fittest with *engineering curriculum*
- *No need* of improvement.
- The curriculum must and need to be *revised and add courses*, course contents which are related to *existing industries*.
- *Include contents* that are arise from the *practical problems*
- *revised curriculum*
- It should be *Industries demand* based rather than *curriculum developers interest*
- It need a detailed research on the *main limitation*, *prioritizing the problem for improvement*, and mainly develop the curriculum which is *more relevant* and *share experience* from *other country*
- Mathematical development because education is *global context* and competent.
- At least students must work in industry like in developed counties eg*, Germany*
- *linking university with industries* for practical problems solution
- *Industry based curriculum* shall be developed for Ethiopia.
- Revise *syllabus* as per *need*
- Continues training
- Integrate the *objective* of the course with *real application problems*
- Mathematics curriculum should be *revised* according to the *market needs*.
- Develop to Curriculum together with the *potential employers.*
- The courses should be more *applicable to associate with industries*.
- strong *university and industry linkage*
- It should be relevant to the *lives of our learners and industry,* Hence the courses should contain *indigenous mathematics knowledge*
- It needs significant *revision* , mathematics should be a tool for *problem solving*
- making it *more practical than theoretical* and industry oriented
- curriculum *review and lab* implementation

- revise based on *new concepts* and *industry based contents*
- first investigate the *need for the industry*, and to develop the course needed for that industry
- there should be *interdisciplinary* cooperation and from *linkage with industry*
- we have to focus on the *practical* are rather than it's *theory*
- more of *practical mathematical* contents should be included
- *industrial problems and solution* must be included in the textbook and curriculum
- more work /read on *application areas for applied mathematics* course
- it is important to include *industrial problem-solving* contents in the curriculum
- *more application problems* are included in the curriculum
- contracting the industrial and developing a relevant curriculum
- Support with *practical examples*

2.7.3. Please provide additional information about the courses that you feel will contribute to its use and effectiveness

- Course should be prepared in *consultation* with *course instructors.* However, there was no such trend
- All courses regarding *industrial environment* must add. *Financial mathematics, mathematical biology courses*
- *Numerical simulations and Modeling problems* based on real problems
- *optimization, and modeling*
- I feel that the curriculum should have much strength and have some limitation. The problem may solve using a *detailed research* and *professional discussion* with *other discipline* as well.
- Mathematics must be more supplemented with *computer software*. *Matlab, Python, Numerical analysis, fluid dynamics, Crptograpgy, Optimaization and modeling* must be in focus
- *financial mathematics and actuarial mathematics*
- *cryptography, computer algebra*, ...
- Require *practical approach*
- Mathematics curriculum is *designed based* on *Model-eliciting activities*
- Try to *make courses computer based* and with more applied courses.
- Applied mathematics courses, Modeling courses, Control theory
- Some industrial courses should be included such as mathematical problem solving, *financial mathematics, industrial mathematical modeling*, and so on.
- mathematics should not be thought without coding and algorithm development
- the teachers and the students can model every world real problem using mathematics
- computational mathematics, industrial mathematics (with industry visits)
- mathematical modeling, optimization, differential ,computational courses are effective to alleviate the problems we face in real life application

- many courses are good in mathematics but still incorporating the contents on business, industry sector is mandatory
- optimization numerical mathematics
- I think most of our country curriculum has to be revised and must include the idea of industries
- applied courses with industrial problems should be included
- combinatorial design which is applicable in medicine synthesis, actuarial mathematics , etc
- given enough time for both students and instructors to understand the concepts

2.8.1.2. If your response for question number 2.8.1.1 is No•, can you mention your reason?

- For better work performance

2.8.1.3. If your response for question number 2.8.1.1 Is Yes•, what are the advantages of having joint curriculum?

- It has advantages for both employee , employer, and researcher
- For collaborative research and to solve practical industrial problem
- To transfer knowledge between science and engineering students. If science and engineering students can work together, they can invent a big technology and will improve economy of Ethiopia through industry development.
- We can use potential candidate of both institutions
- to get real data from industry and model problems
- It will be problem based curriculum
- The industry expertise mainly identifies the industry problem and lack Mathematical tools to overcome the problem. The Mathematician has detail knowledge on general Mathematical Concept and lack the specific industrial problem. So jointly develop the curriculum to address and improve the industrial productivity challenge.
- Share experience, build graduates with practical activities, job opportunity, lay a foundation for the development of the country
- Efficient utilization of human and material resources, accelerate capacity building in the institutions, strengthen knowledge and technology transfer
- better understanding and trust b/n two parties
- Because the curriculum is developed by inter disciplinary professionals.
- able to solve real time problems
- To analyze the gap that have to be covered in the education systems
- It simply industries curriculum best fit to the market
- To show application of mathematics in technology.
- For improving the productivity of the companies.
- A joint Curriculum may address the interest of all the parties involved

- Students after completing their study, they will apply their knowledge in the industries and the industry will also beneficial by increasing its quality.
- It helps to graduate professionals that can solve problems in industry
- for cooperative work among universities that leads to industry
- It will strengthen the university- industry linkage and solve problems of industry
- the universities can produce industrial mathematics skillful led graduate
- solving real problem-- productivity & profit
- it will fit the purpose because stakeholders are clearly knows the problems out there
- We will be able to force on the courses based on the real problem of the industry
- it paves the way to design the curriculum to best extent
- it helps to the development of the country
- cooperative work b/n science and technology university and industry are important
- the graduate will gain knowledge of industrial problems
- The gap should be resolved
- creates job opportunity , enhance industry- university linkage
- helps to connect graduate with industries

7. If you have others Industry issue /topics write here with the mathematics you used in solving it

- Mathematical modeling, Biomathematics, Fractional calculus (variable order and constant order differential and integral equations), Analysis
- mathematical modeling
- Programming course related to Matlab and other computing software (Of course it is included in Computational Methods)
- Mathematical modeling, Numerical biology, financial mathematics and some other courses are crucial based on the type of Industries. .
- Modeling industrial processing way --- mathematical modeling
- product advertisement and sell --- Modeling and simulation
- combinatorial design

5 If you have any delivery mechanism suggest here

- Industry will buy or fund invented projects by any experts.
- industry provides information and university design the course
- The industrial expertise participating in curriculum review workshop frequently suggested a course of Industrial Mathematics in both undergraduate and postgraduate curriculum as either in elective or supportive course
- through interaction
- Course can be included in the Curriculum by both parties
- joint development of the course and the project
- university and industry will jointly develop the course

- university will assess the industry to identify relevant course

10. If there are other job opportunities specify here

- Work in research center
- computational consultancy
- Researcher in Industry.

2.8.7. General comment

- I am so interested on the issue and I need to work together for professional development.
- There is no patent for mathematics by World intellectual property right!
- I hope that this research be a good asset if the Ethiopian Ministry of education is looking at it
- Academic, research and industry interaction important
- Go ahead and try completing your research.
- It is good to see such a Curriculum in Ethiopia
- The importance of mathematics is unarguable, so that we need to apply to solve real life problem in industries. I will be very happy to see it happened.
- MSc in industrial mathematics and data science
- Industrial mathematics is a ground tool to make dynamic change in the industry sectors of one country , so, it need to look in depth to form industrial mathematics as university curriculum
- Every mathematics curriculum has to be designed in such a way that it can solve the problem of the country. Moreover, it must be designed involving the participation of industrial top managers , man powers who are skilled in industry sectors in addition to mathematics and some academician
- I really appreciate the research and it helps to strengthen the relation between industry and university and it is also helps to solve industrial problem help
- it is very interested idea
- It is appreciated to do such like *life changing research* for the academic society especially and the country as a whole by identifying the back pain of most of mathematics professionals and cups up with those flouts making us back . i.e most of the mathematics curriculum are designed industrial unfriendly. Keep up dear!! we are with you whenever you need something information that we have and know. Thank you very much!
- The questionnaire has tried to include all the gap and mechanisms. I found it nice but bulky
- This research work has to be supported. I think , it will come up with new findings which can enhance university -industry linkage , collaboration between the two parties in developing mathematics curriculum which is the best one

- industrial Mathematics curriculum is very important and also applicable for our country as well as it encourages students to learn mathematics

Comments from Industry Professionals

6. If any reason specify here

- not have knowledge about the relation of university and industry
- No need of Mathematician In our Institution
- there is no related position for him/her currently
- When I was working for the company, I did not see a need for mathematician personnel may be their role would be better suited to other areas.
- The role of mathematician in industry like Belayab (Car assembling company)is not clear
- The profession is unknown
- i think mathematics is not important in this industry
- I do not think it is necessary
- The requirement set for job positions does not include Mathematics
- no place for mathematics specialty
- not as such very important in the factory
- lack of awareness for the field of study whether it has benefits to the industry sector
- THE INDUSTRY DOES NOT REQUIRE COMPREHENSIVE MATHEMATICAL KNOWLEGDE. RATHER REQUIRES ENGINEERING SKILL AND WOULD BE BETTER TO DEVELOP COMPREHENSIVE SKILLS ON ENGINEERING PARTS

2.7.2. What could be done to improve the courses?

- It would focus on application of mathematics to enhance industrial development , not theory
- courses given are more of academicals, emphasis should be given on the application(practical problem solving)
- It must be related with practical application in the industry
- It has to include practical examples in the classrooms
- To educate on practical relevance of the courses besides numbers and calculations
- Extensive promotion of the course, especially in industrial organization.
- I have no exposure to take industrial mathematics courses
- simulation , numerical analysis should be coordinated
- read every day and try to know practical skills
- learn with other courses for solving industrial problems
- Notify any mathematical and statistical data from the document exists in the library.
- INCREASE INDUSTRY UNIVERSITY LINKAGE
- THE COURSE SHOULD TARGET TO SOLVE THE REAL PROBLEM OF INDUSTRY

- Develop good quality of curriculum and training materials related to courses
- The course should focus on problem solving area
- link courses with industry related problem solving
- add practical activity in the curriculum (add practical learning way to curriculum)
- continuous awareness on industrial mathematics
- needs real problems of the industry
- focus on practical application
- first of all implement the concept of mathematics in industry
- good relationship between industry and university
- mathematics curriculum shall be designed based on industrial problems
- TEACHING THE PRACTICALITY OF ALL THE MATHEMATICS FORMULAS AND CALCULATION
- MAKING IT MORE PRACTICAL
- USE STRATEGIC LEARNING
- INCLUDE IN OTHER APPILICABLE COURSES

2.7.3. Please provide additional information about the courses that you feel will contribute to its use and effectiveness

- In industry, especially those who focus on productivity, engineering course is enough because engineering integrates all application of mathematics and other useful courses.
- Most of the courses given at educational institutions and those to be applied in the real world (industry) are relatively less; thus simulations or practical training and internships should be encouraged.
- It uses to do problem solving steps in short and precise.
- Analyze and syntheses any products in scientific method and redesign
- DATA SCIENCE / DATA MINING /FORECASTING
- It should consider different industry case studies
- statistics for engineers, for aviation management
- It is better to do research before preparing curriculum
- any courses with application
- briefly put its application area in industry
- I feel the course if appropriately designed will make students and all the beneficiaries fruitful or effective in their professional disciplines as well.
- CACULUS ,GEOMETRY APPARTUS DESIGN AND REACTION ENGINEERING
- BETTER PLANNING TO SUPPLEMENT OTHER APPLICABLE COUSES LIKE ENGINEERING SKILLS

2.8.1.2. If your response for question number 2.8.1.1 is No•, can you mention your reason?

- I do not think industrial mathematics bring any change the problems of industries in Ethiopia.
- the technical personnel already know the curriculum
- MOST OF THE INDUSTRY (PRODUCT) DESIGNS ARE NOT DEVELOPED HERE IN ETHIOPIA

2.8.1.3. If your response for question number 2.8.1.1 is Yes •, what are the advantages of having joint curriculum?

- Sometimes providing chance to instructors from industry lets the students to focus and get the right way of understanding the course.
- To develop mathematics knowledge in industry
- application of mathematics focuses to improve industrial problems
- for the development of both parties (fruitfully outcomes)
- It create related knowledge for the industry
- knowledge transfer and sharing
- It will be possible to implement easily
- It ensures that what is developed in academia is applicable to the industry
- To improve industrial development and to provide advanced services.
- I think there is interrelated
- to increase the capital of industries
- To be specific
- used to solve problems in short
- to conduct the industrial work
- It is advantageous practically known in case of theoretical
- To improve industry production rate and quality of products
- It can solve the gap between theory and practice
- To support or adjust industries need with curriculum
- Because the industry expert have known the gap of the industries cause in
- HAVING APPLICABLE CURRICULUM IN BOTH SIDES
- IT GIVE THE CHANCE FOR CUSTOMIZING WHAT THE INDUSTRY NEEDS
- To make (Develop) curriculum in good quality
- It will be task oriented training
- it helps to design applied mathematics courses
- Taking industry scenarios into the course
- The curriculum development will focus both on the industry situation and academic area
- to address specific problem of industries
- pass for implementation of industrial mathematics
- they may have easily identify and calculate the problem related to mathematical behavior to have good output
- helps in identifying the mathematical requirement of the industries

- information sharing know how to facilitate problem solving mechanisms
- used for industrial research
- technical problem-solving method developed
- course contents can be enriched by real problem-solving case studies
- PROBLEMS WILL BE SOLVED EASILY THROUGH DIGITALIZATION
- CREATING EASY PROBLEM-SOLVING OPPORTUNITIES
- PROVIDE BETTER OPPORTUNIES IN PROBLEM SOLVING

7. If you have others Industry issue /topics write here with the mathematics you used in solving it

- selecting a technology ---- Attp
- programing
- work process flow, matrix, probability

5 If you have any delivery mechanism suggest here

- Optimization courses should be design by industry, special training should be given on statistical analysis, industry will develop courses on statistics and computational method and the courses should be delivered through subject experts , industry will develop student project on " statistic courses"
- Is it the industry that should design the courses or academia?
- consulting services
- research center will develop projects

2.8.8. General comment

- Industry needs knowledge of Engineering. Engineering integrates all mathematics knowledge and engineering courses. Implementing industrial mathematics (curriculum) cannot fully help without knowledge of engineering.
- In my opinion, industrial mathematics is very important for problem solving and increased productivity of industries, therefore we need exercise hiring experts.
- Industrial mathematics may solve the problems exists in many organization if properly designed and applied
- It is beneficial to integrate industrial mathematics with software application to control after -sales services and inventory transient
- good evaluation
- This is jejune questionnaire , be clear and precise
- make it real as it is good proposal
- I appreciate the effort made to fill the actual problem that mathematics courses are not as such utilized in industries
- IT IS ALWAYS A GREAT IDEA LINKING PEOPLES KNOWLEDGE WITH TECHNOLOGY

Appendix- F: Ethical Clearance Form

UNISA

UNISA COLLEGE OF EDUCATION ETHICS REVIEW COMMITTEE

Date: 2021/02/10

Ref: 2021/02/10/ 64126846/25/AM
Name: Mr H W ZEWDIE
Student No.: 64126846

Dear Mr H W ZEWDIE

Decision: Ethics Approval from 2021/02/10 to 2026/02/10

Researcher(s): Name: Mr H W ZEWDIE
E-mail address: 64126846@mylife.unisa.ac.za/
Telephone: +251116953966

Supervisor(s): Name: Prof Mosha Moses Phoshoko
E-mail address: phoshmm@unisa.ac.za
Telephone: +27124296893

Title of research:

Industrial Mathematics Curriculum Development for Ethiopian Science and Technology Universities.

Qualification: PhD Mathematics Education

Thank you for the application for research ethics clearance by the UNISA College of Education Ethics Review Committee for the above mentioned research. Ethics approval is granted for the period 2021/02/10 to 2026/02/10.

*The **low risk** application was reviewed by the Ethics Review Committee on 2021/02/10 in compliance with the UNISA Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher will ensure that the research project adheres to the relevant guidelines set out in the Unisa Covid-19 position statement on research ethics attached.
2. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.

3. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the UNISA College of Education Ethics Review Committee.
4. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
5. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing.
6. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
7. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data requires additional ethics clearance.
8. No field work activities may continue after the expiry date **2026/02/10**. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:

The reference number **2021/02/10/ 64126846/25/AM** *should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Kind regards,

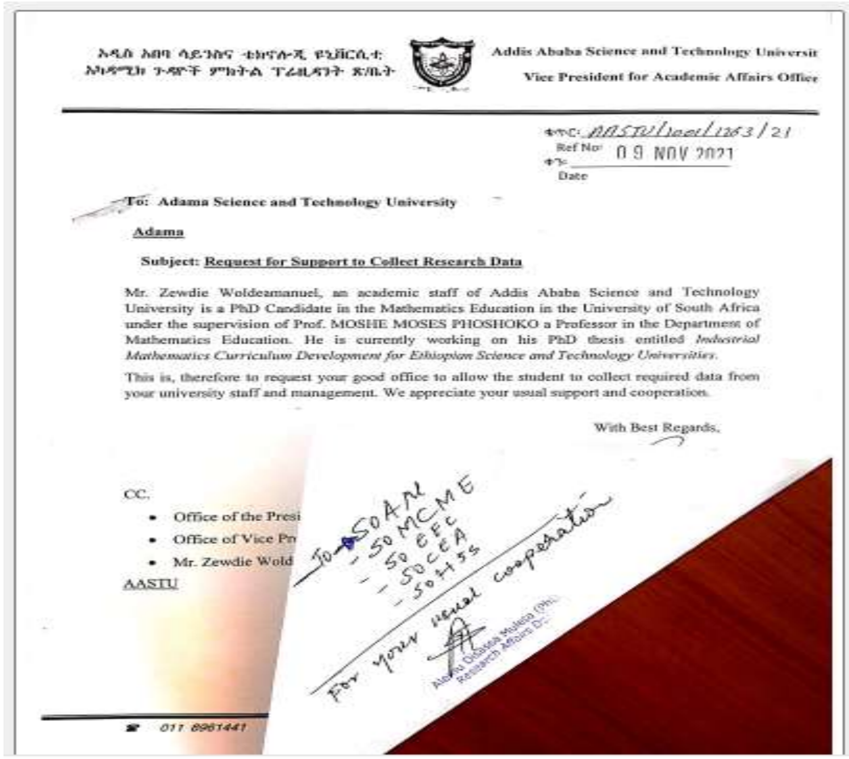
Prof AT Motlhabane
CHAIRPERSON: CEDU RERC
motlhat@unisa.ac.za

Prof PM Sebate
EXECUTIVE DEAN
Sebatpm@unisa.ac.za

Approved - decision template – updated 16 Feb 2017

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

Appendix- G: Permission Letters for Academic Institutions



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Addis Ababa Science and Technology Universit
Vice President for Academic Affairs Office

ቁጥር: AASTU/1263/21
Ref No:
ቀን: 09 NOV 2021
Date

To: Adama Science and Technology University

Adama

Subject: Request for Support to Collect Research Data

Mr. Zewdie Woldeamanuel, an academic staff of Addis Ababa Science and Technology University is a PhD Candidate in the Mathematics Education in the University of South Africa under the supervision of Prof. MOSHE MOSES PHOSHOKO a Professor in the Department of Mathematics Education. He is currently working on his PhD thesis entitled *Industrial Mathematics Curriculum Development for Ethiopian Science and Technology Universities*.

This is, therefore to request your good office to allow the student to collect required data from your university staff and management. We appreciate your usual support and cooperation.

With Best Regards,

CC.

- Office of the Presi
- Office of Vice Pr
- Mr. Zewdie Wold

AASTU

To SOAN
- SOMCME
- SOEFC
- SOCEA
- SOH55

For your usual cooperation

☎ 011 8961441

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Addis Ababa Science and Technology Univ
Vice President for Academic Affairs Of

ቁጥር:
Ref No:
ቀን: 09 NOV 2021
Date

To: Adama Science and Technology University

Adama

Subject: Request for Support to Collect Research Data

Mr. Zewdie Woldeamanuel, an academic staff of Addis Ababa Science and T… University is a PhD Candidate in the Mathematics Education i… under the supervision of Prof. MOSHE MOSE… Mathematics Education … Math…

To: SOANM
- SOMCME
- SOEEC
- SOCCEA
- SOHSS
For your usual cooperation

Alemu Disassa Mulata (PhD)
Research Affairs D…

To: All HODs
ADAA
ADRTT
For your cooperation

አዲስ አበባ ሳይንስና ቴክኖሎጂ ዩኒቨርሲቲ
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Addis Ababa Science and Technology Universit
Vice President for Academic Affairs Office

ቁጥር: AASTU/1001/1263/21
Ref No:
ቀን: 09 NOV 2021
Date

To: Adama Science and Technology University

Adama

Subject: Request for Support to Collect Research Data

Mr. Zewdie Woldeamanuel, an academic staff of Addis Ababa Science and Technology University is a PhD Candidate in the Mathematics Education in the University of South Africa under the supervision of Prof. MOSHE MOSES PHOSHOKO a Professor in the Department of Mathematics Education. He is currently working on his PhD thesis entitled *Industrial Mathematics Curriculum Development for Ethiopian Science and Technology Universities.*

This is, therefore to request your good office to allow the student to collect required data from your university staff and management. We appreciate your usual support and cooperation.

To: SOAM
- SOMCME
- SOEEC
- SOCEA
- SOASS
For your usual cooperation

Alemu ... Muleta (PhD)
Research Affairs Dean

CC.

- Office of the
- Office of Vic
- Mr. Zewdie W

AASTU

☎ 011 8961441

Appendix- H Permission Letters for Industries

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Addis Ababa Science and Technology University

Office of University-Industry Linkage Directorate

ቁጥር Ref. No AASTU/UIL/001/1092/21

ቀን Date 03 NOV 2021

To: Ethiopian Airlines

Addis Ababa

Subject: Request Support to Collect Research Data

Mr. Zewdie Woldeamanuel, an academic staff of Addis Ababa Science and Technology University is a Ph.D candidate in Mathematics Education in UNISA under the supervision of Prof. MOSHE MOSES Phoshoko. Currently he is collecting research data from relivant stakeholders for conducting his PhD research. Accordingly, we request your good office to provide him the necessary support in this regard.

Thanks in advance for your usual cooperation.

Befekadu Sirahbizu Yigezu (PhD)
University-Industry Linkage
Directorate Director

CC:
- Office of R/T/T/V/President
- UIL Directorate Office
- Mr. Zewdie Woldeamanuel
  AASTU

RECEIVED
29 Nov 2021
VICE PRESIDENT CORPORATE
HUMAN RESOURCE MANAGEMENT

(Abebe)
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When replying please indicate our reference No. Web site : www.aastu.edu.et Addis Ababa Ethiopia

የኢትዮጵያ ኤሌክትሪክ ኃይል
Ethiopian Electric Power
To
From

To Dr. LEFP/... Caders.
For your
Support

Wondwossen Kassa (Ph.D)
Human Resource Development Management Director

Addis Ababa Science and Technology University

Office of University-Industry Linkage Directorate

ቁጥር AASTU/1001/1095/21
Ref. No
ቀን 0 3 NOV 2021
Date

To: Ethiopian Electric Power
Addis Ababa

Subject: Request Support to Collect Research Data

Mr. Zewdie Woldeamanuel, an academic staff of Addis Ababa Science and Technology University is a Ph.D candidate in Mathematics Education in UNISA under Prof. MOSHE MOSES Phoshoko. Currently he is collecting research stakeholders for conducting his PhD research. Accordingly, we request y provide him the necessary support in this regard.

Thanks in advance for your usual cooperation.

09/3/2019
Helen

Belet Sirahbizu Yigezu (PhD)
University-Industry Linkage
Directorate Director

CC.

- Office of R/T/T/V/President
- UIL Directorate Office
- Mr. Zewdie Woldeamanuel

AASTU

251-118-120-509 Web site : www.aastu.edu.et
16417 አዲስ አበባ ኢትዮጵያ Addis Ababa Ethiopia

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Addis Ababa Science and Technology University
Office of University-Industry Linkage Directorate

ቁጥር AASTU/UIL/1028/21
Ref. No
ቀን 03 NOV 2021
Date

To: Ethiopian Road Authority 19/11/21
Addis Ababa

Subject: Request Support to Collect Research Data

Mr. Zewdie Woldeamanuel, an academic staff of Addis Ababa Science and Technology University is a Ph.D candidate in Mathematics Education in UNISA under the supervision of Prof. MOSHE MOSES Phoshoko. Currently he is collecting research data from relivant stal eholders for conducting his PhD research. Accordingly, we request your good office to provide him the necessary support in this regard.

Thanks in advance for your usual cooperation.

Kind regards!!

Belet Sirahbizu Yigezu (PhD)
University-Industry Linkage
Directorate Director

CC.
- Office of R/T/T/V/President
- UIL Directorate Office
- Mr. Zewdie Woldeamanuel

AASTU

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When replying please indicate our reference No. Web site : [illegible] Addis Ababa Ethiopia

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Addis Ababa Science and Technology University
Office of University-Industry Linkage Directorate

ቁጥር: AASTU/U001/U086/21
Ref. No 03 NOV 2021
ቀን ______
Date

To: Ethiopian Sugar Corporation
<u>Addis Ababa</u>

Semal
29/11/21

Subject: <u>Request Support to Collect Research Data</u>

Mr. Zewdie Woldeamanuel, an academic staff of Addis Ababa Science and Technology University is a Ph.D candidate in Mathematics Education in UNISA under the supervision of Prof. MOSHE MOSES Phoshoko. Currently he is collecting research data from relivant stakeholders for conducting his PhD research. Accordingly, we request your good office to provide him the necessary support in this regard.

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<u>CC.</u>

- Office of R/T/T/V/President
- UIL Directorate Office
- Mr. Zewdie Woldeamanuel
  <u>AASTU</u>

Appendix- I Samples of completed questionnaires

QUESTIONNAIRE FOR INDUSTRY EXPERT

PART-I: BACKGROUND INFORMATION

INSTRUCTIONS: This part of the questionnaire is designed to collect the Personal information of industry experts regarding gender, Education, current position, and service years. The questions are contained closed-open -ended items, for the close-ended items put √ mark for the appropriate choice of your alternatives and for the open ended one write on the space provided.

1.1. Gender: 1.Male [✓] 2.Female [ ]

1.2. Education: 1.Ph.D [ ] 2. Second degree [✓] 3.First Degree [ ] 4.If any__

1.3. Name of your industry /organization Belayab Motors P.L.C

1.4. Your current position Supervisor

1.5. Service Years: 1. In Industry 1 2.Others institution 7

PART.2. INDUSTRIAL MATHEMATICS CURRICULUM DEVELOPMENT AND IMPLEMENTATIONS

2.1. Have you, in the past, participated in making suggestions on curriculum development and review program?

Yes [ ] No [✓]

2.1.1. If your response for question 2.1 is "Yes "your level of participation________(Leader,Facilitator,Secretory,or , Member)

2.2. Do you have mathematical specialist in your company?

Yes [ ] No [✓]

2.2.1. If your answer for question №2. 2 is "yes" indicate the following

1.1. His employment position ________

1.2. Job description ________

2.2.2. If your answer for 2.2 is "No", what are problems of industry in employing mathematician in industry? Please, indicate whether you agree or disagree with the following reason related to your industry or organization by putting (√)

		Yes	No
1	Lack of technical mathematical ability		✓
2	Salary policy based on birr return		✓
3	Bureaucratic procedure		✓
4	Officers is not often a judge of mathematics ability		✓
5	Lack of supervision knowledge of this type of personal		✓

6. If any specify here When I was working for the company I worked for, I didn't see a need for mathematicia personnel may be their role would be better suited to other areas

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CamScanner

2.3. Industrial Mathematics

INSTRUCTIONS: This part of the questionnaire is designed to investigate your understandin about industrial mathematics. Please indicate how much you agree or disagree with each of th following statements by circling one of the numbers that stand for the following rating scales:

Strongly Disagreed(1)	Disagree (2)	Undecided(3)	Agreed(4)	Strongly Agree (5)

	Industrial Mathematics					
1	It is basic for knowledge base industrial development of every country	1	2	3	4	5
2	It solves the industrial problems using different mathematical techniques	1	2	3	4	5
3	It is the mathematical analysis of problems that arise in an industrial setting	1	2	3	4	5
4	It is a mathematical work that is performed in an academic setting that is largely isolated from the demands, pressures, and constraints of industry	1	2	3	4	5
5	It designate all the research that is oriented at the solution of problems posed by industrial applications	1	2	3	4	5
6	It is an interdisciplinary course that integrates engineering courses, science and mathematics courses	1	2	3	4	5
7	It is a branch of mathematics that is concerned with developing mathematical methods and applying them to engineering, science, and industry	1	2	3	4	5

2.4. How important are the following mechanisms of working together between academics and industrial experts to implement industrial mathematics curriculum in Ethiopian science and technology universities and industries? Please indicate the degree of importance of the following statements by circling one of the numbers that stand for the following rating scales:

Unimportant [1]	Slightly Important [2]	Moderately Important [3]	Important [4]	Very important [5]

	Mechanism to enhance working together				
A.1	Initiates existing relationships between industry and universities	1	2	3	4
A.2	Trust and openness from both parties	1	2	3	4
A.3	Develop educational programs that educate personnel in a way that satisfies the missions of all parties involved	1	2	3	4
B.1	Establish interdisciplinary research center by teams of Universities and industries scholars	1	2	3	4

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C.1	Assign Positions for Industrial Mathematics in university and industry	1 2 3 (4) 5
D.1	Supervise students together through a grant secured by university-industry collaboration	1 2 3 (4) 5
D.2	Embedding students in industries departments and government offices as Fellowships or as Industry Practicams	1 2 3 (4) 5
E.1	Establish industrial mathematics study groups enable Industries get their problems in short time by intensive work by independent experts	1 (2) 3 4 5
F.1	Technology translators identify industrial opportunities for mathematics, understand the detailed requirements of each company	1 2 3 (4) 5
G.1	Provide Consultancy service as an Intermediary organizations enable this mechanism of knowledge exchange in between university-industry links	1 2 3 (4) 5
G.3	Personnel exchange allows staff to work either specifically on a given project or freely between collaborators	1 2 3 (4) 5
G.4	Use of successful completed industrial mathematics project in the same framework in Ethiopian cases	1 2 3 4 (5)

2.5. Factors that influence the implementation of industrial mathematics Curriculum.

INSTRUCTIONS: This part of the questionnaire is designed to identify those factors that influence the implementation of industrial mathematics at Ethiopian Science and Technology University (ESTU). Please indicate how much you agree or disagree with each of the following statements by circling one of the numbers that stand for the following rating scales:

Strongly Disagree(1)	Disagreed (2)	Undecided (3)	Agreed (4)	Strongly agreed (5)

	Factors that influences the implementations of industrial mathematics	
1	An Industry expert has no the necessary mathematical background and knowledge	1 (2) 3 4 5
2	Poor university-industry link	1 2 (3) 4 5
3	Industry awareness in using research result of universities	1 2 3 (4) 5
4	Lack of knowledge in importing/using appropriate technology	1 2 3 (4) 5
5	Insufficient information about the graduate at the job market	1 2 3 (4) 5
6	Pedagogical practice that does not target the skill needed by the industry	1 (2) 3 4 5
7	Universities in Ethiopia do not have the opportunity to underpin quantitative understanding of industrial strategy and processes across all sectors of business	1 2 (3) 4 5
8	The necessary investment in mathematics are key challenges for Ethiopian industry	1 (2) 3 4 5
9	The industry experts often do not fully know the industrial context of the mathematics they used	1 2 3 (4) 5
10	Trained man power in the field of industrial mathematics	1 2 3 (4) 5

2.6. What benefits can be derived from deploying Industrial Mathematics in enriching careers in terms of professional development (research and industrial problem solving skills)?

	Benefits	Benefits gained by				
		Teachers	Students	Industry Expert	Industry	University
1	Academic Rank		✓			
2	Publication	✓				
3	Patent			✓		
4	Financial gain			✓		
5	Academic achievement	✓				
5	Job opportunity		✓			
7	Improve production and services				✓	
1	Use innovation from the academia				✓	
'	Job appraisal			✓		
0	Global rank					✓
1	Increase export productions				✓	

7. The limitations and strength of the existing University Mathematics Curriculum you were taking

7.1. To answer the following four questions, please use the nine –point scale (1=Poor, 5=Typical, and 9= Excellent).You may use any point on the scale for your answer.

How do you rate the quality of undergraduate mathematics courses in solving industrial problems?	5
How do you rate the mathematics courses in solving industrial problems ability to meet the needs of your employees who took it?	9
How relevant is the contents of mathematics courses to your employees' working conditions?	1
All things considered, how do you rate the overall values of mathematics courses to your employees?	1

2. What could be done to improve the courses? Extensive Promotion of the Course, especially in Industrial Organization

3. Please provide additional information about the courses that you feel will contribute to its use and effectiveness.__________

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2.8. Industrial Mathematics curriculum Model for Ethiopian industrial development.

2.8.1. Joint curriculum development and joint employment

2.8.1.1. Can you support to the *development of joint industrial mathematics curriculum* between science and technology universities and industries?

Yes [✓] No [ ]

2.8.1.2. If your response for question number 2.8.1.1 is "No", can you mention your reason?

2.8.1.3. If your response for question number 2.8.1.1 is "yes", what are the advantages of having joint curriculum? [illegible]

2.8.2. Do you agree that on the *appointment of professionals* with high degree of relevant expertise from industry in Ethiopian science and technology universities?

Yes [✓] No [ ]

2.8.2.1. If your response for question number 2.8.2 is "Yes", how can we use them in universities? (Indicate your response as many as possible by using tick mark √)

A. Guest Lecturer [ ] B. Counselor [✓] C. Mentorship [ ] D. If any ____________

2.8.3. What *major types of industrial issues or topics* your organizations/industry work with academic institutions? (Check all that apply). For the major issues of the industry which mathematical concepts you are used. (Match industrial topics that need mathematics from the lists of mathematical concept found in the right hand side. You can assign more than one)

	INDUSTRIAL ISSUE OR TOPICS	Assign a number for the Mathematical concepts		MATHEMATICAL CONCEPTS
1.	Investigative projects and research from industry	1	1.	Differential Equation
2.	Using various problem solving tools and techniques to solve problems of industry	3	2.	Numerical analysis
3.	Developing or designing models related to industrial Problems	2	3.	Statistical analysis
4.	Simulation activities, such as improving productivity	6	4.	Computational methods
5.	Initiating change /designing in industrial processes	5	5.	Discrete Mathematics
6.	Industry relevant software, technology and equipment	4	6.	Optimization

8. Other Industry issue____________ 8. Other Math concept____________

2.8.4. How industry elective courses should be included in industrial mathematics courses? Please, indicate as many as possible which are appropriate for your industry or organization.

	Mechanisms to include industry elective courses	
1	Industry will design the courses as per requirement	✓
2	Industry will select the candidate and organize special training	
3	Industry will develop their own courses and delivered through subject experts	
4	Industry will develop student project	

5. If you have any delivery mechanism suggest here__________

2.8.5. Which industrial mathematics curriculum is most recommended for Ethiopian industries and Ethiopian Science and Technology Universities? (Please √ as many responses as you think accurate)

№	Industrial Mathematics Curriculum	
1	BSc. Industrial Mathematics With Computer Applications	✓
2	MSc. Industrial Mathematics With Computer Applications	✓
3	BSc. Industrial Mathematics	
4	MSc. Industrial Mathematics	
5	BSc. Industrial Mathematics and Statistics	
6	MSc. Industrial Mathematics and Statistics	
7	BSc .Applied and Industrial Mathematics	
8	MSc .Applied and Industrial Mathematics	
9	BSc Industrial Mathematical Modeling	
10	MSc Industrial Mathematical Modeling	

2.8.6. Which of the following list of generic employability skills will you recommend for the students of industrial mathematics? Indicate by the degree of ***importance of the employability skills*** in your industry/organization/university to be included in industrial mathematics curriculum.

mportant	Slightly Important [2]	Moderately Important [3]	Important [4]	Very important [5]

	Employability Skills					
1	Communication that contributes to productive and harmonious relations between employees and customers;	1	2	3	4	(5)
2	Teamwork that contributes to productive working relationships and outcomes;	1	2	3	4	(5)
3	Problem-solving that contributes to productive outcomes;	1	2	3	4	(5)
4	Initiative and enterprise that contribute to innovative outcomes;	1	2	3	(4)	5
5	Planning and organizing that contribute to long term and short-term	1	2	3	4	(5)
6	Self-management that contributes to employee satisfaction and growth	1	2	3	4	(5)
7	Learning that contributes to on-going improvement and expansion in employee and company operations and outcomes;	1	2	3	4	(5)
	Technology that contributes to effective execution of tasks;	1	2	3	4	(5)
	Personal attributes that contribute to overall employability (e.g. loyalty, honesty & integrity, adaptability) (our emphasis added).	1	2	3	4	(5)

10. other – specify ____________

2.8.7. Job opportunity for industrial mathematics graduate in your organization (Please put √ as many responses as you think accurate)

	Job opportunity	
1	Operations Research Analysts	
2	Scientific programmer	✓
3	Data analyst	
4	Financial Analysts	
5	Production line optimization	
6	Risk management	✓
7	Software testing and verification	✓

8. Other – Specify ____________

2.8.8. General comment

It is beneficial to integrate industrial mathematics with software applications to control after-sales services & inventory management

Mathematics Instructors

COVER LETTER TO SURVEY QUESTIONS FOR UNIVERSITY INSTRUCTORS

DATE 15/12/2021

Dear Prospective respondent,

This questionnaire forms part of my research entitled: *Industrial Mathematics Curriculum Development for Ethiopian Science and Technology Universities* for the degree of D.Ed. at the University of South Africa. You have been selected by a *purposive sampling* strategy from the population of your College/Faculty. Hence, I invite you to take part in this survey.

The aim of this study is to investigate the need of the stakeholder on industrial mathematics to propose appropriate industrial mathematics curriculum to Ethiopian Science and Technology University (ESTU). The findings of the study may benefit you and your industry by providing an opportunity to conduct research in your area that arises from industrial problems through industrial mathematics. You are kindly requested to complete this survey questionnaire, as honestly and frankly as possible and according to your personal views and experience. No foreseeable risks are associated with the completion of the questionnaire which is for research purposes only. The questionnaire will take approximately 20 minutes to complete. You are not required to indicate your name and your anonymity will be ensured; however, indication of your service, gender, occupation position will contribute to a more comprehensive analysis.

Thank you for taking time to assist me in my educational endeavors. After the completion of the study, an electronic summary of the findings of the research will be made available to you on request. Permission to undertake this survey has been granted by the Addis Ababa science and Technology University and the Ethics Committee of the College of Education, UNISA. By completing the questionnaire, you imply that you have agreed to participate in this research. Please return the completed questionnaire to me before December___, 2021.

Yours sincerely

Zewdie Woldeamanuel Habte
Addis Ababa Science and Technology University, Addis Ababa, Ethiopia
64126846@mylife.unisa.ac.za / kenazewd@gmail.com / +251911392588/

QUESTIONNAIRE FOR INSTRUCTORS

PART-I: BACKGROUND INFORMATION

INSTRUCTIONS: This part of the questionnaire is designed to collect the Personal information of instructors regarding gender, Education, current position, and service years. The questions are contained closed-open -ended items, for the close-ended items put √ mark for the appropriate choice of your alternatives and for the open ended one write on the space provided.

1.1. Gender: 1.Male ☑ 2.Female ☐

1.2. Education: 1.Ph.D ☐ 2. Second degree ☑ 3.First Degree ☐ 4.If any__

1.3. Name of your department physics & Statistics

1.4. Your current Position	1. President		2. Vice-president		3.Directoriate		4. College Dean
	5.Associate Dean		6.Department Head		7. Teacher		8.Other ____

1.5. Service Years: 1. In Industry ____ 2.Others institution ____ 3. University 15

PART 2. INDUSTRIAL MATHEMATICS CURRICULUM DEVELOPMENT AND IMPLEMENTATIONS

2.1. Have you, in the past, participated in making suggestions on curriculum development and review program? Yes ☐ No ☑

2.1.1. If your response for question 2.1 is "Yes "your level of participation ____ (Leader, Facilitator, Secretory, member)

2.2. Which of the following are the barriers you have come across in your work with curriculum development and review of new programs in university and how significant they are? (Please circle the degree of significance for each barrier)

Very Significant [4]	Significant [3]	A little Significant[2]	Not Significant [1]

	Barriers				
1	Lack time to fully participate in the program	1	2	3	4
2	Lack of interest to fully participate in the program	1	2	3	4
3	Inadequate background knowledge in curriculum development and review	1	2	3	4
4	Inadequate understanding of new technology	1	2	3	4
5	Lack of support within my organizations	1	2	3	4
6	The Curriculum is prepared by scholars selected from different institutions, but not from diversified groups.	1	2	3	4

7. Other-Specify here ____

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2.3. Industrial Mathematics

INSTRUCTIONS: This part of the questionnaire is designed to investigate your understanding about industrial mathematics. Please indicate how much you agree or disagree with each of the following statements by circling one of the numbers that stand for the following rating scales:

Strongly Disagreed(1)	Disagree (2)	Undecided(3)	Agreed(4)	Strongly Agree (5)

	Industrial Mathematics					
1	It is basic for knowledge base industrial development of every country	1	2	3	4	5
2	It solves the industrial problems using different mathematical techniques	1	2	3	4	5
3	It is the mathematical analysis of problems that arise in an industrial setting	1	2	3	4	5
4	It is a mathematical work that is performed in an academic setting that is largely isolated from the demands, pressures, and constraints of industry and industry-university collaborations.	1	2	3	4	5
5	It designate all the research that is oriented at the solution of problems posed by industrial applications	1	2	3	4	5
6	It is an interdisciplinary course that integrates engineering courses, science and mathematics courses	1	2	3	4	5
7	It is a branch of mathematics that is concerned with developing mathematical methods and applying them to engineering, science, and industry	1	2	3	4	5

2.4. How important are the following mechanisms of working together between academics and industrial experts to implement industrial mathematics curriculum in Ethiopian science and technology universities and industries? Please indicate the degree of importance of the following statements by circling one of the numbers that stand for the following rating scales:

Unimportant [1]	Slightly Important [2]	Moderately Important [3]	Important [4]	Very important [5]

Mechanism to enhance working together

A.1	Initiates existing relationships between industry and universities	1	2	3	4	5
A.2	Trust and openness from both parties	1	2	3	4	5
A.3	Develop educational programs that educate personnel in a way that satisfies the missions of all parties involved	1	2	3	4	5
B.1	Establish interdisciplinary research center by teams' universities and industries scholars.	1	2	3	4	5
C.1	Assign Faculty Positions for Industrial Mathematics in University and industry.	1	2	3	4	5
D.1	Supervise students together through a grant secured by university-industry collaboration	1	2	3	4	5
D.2	Assign students in industries departments and government offices as Fellowships or as Industry Practicums	1	2	3	4	5
E.1	Establish industrial mathematics study groups that enable Industries get their problems in short time by intensive work by independent experts.	1	2	3	4	5
F.1	Technology translators identify industrial opportunities for mathematics, understand the detailed requirements of each company	1	2	3	4	5
G.1	Provide Consultancy service as an intermediary organizations enable this mechanism of knowledge exchange in between university-industry collaboration	1	2	3	4	5
G.2	Personnel exchange allows staff to work either specifically on a given project or freely between collaborators	1	2	3	4	5
G.3	Use of successful completed industrial mathematics project in the same framework in Ethiopian cases.	1	2	3	4	5

2.5. Factors that influence the implementation of industrial mathematics Curriculum.

INSTRUCTIONS: This part of the questionnaire is designed to identify those factors that influence the implementation of industrial mathematics at Ethiopian Science and Technology University (ESTU). Please indicate how much you agree or disagree with each of the following statements by circling one of the numbers that stand for the following rating scales:

Strongly Disagree(1)	Disagreed (2)	Undecided (3)	Agreed (4)	Strongly agreed (5)

Factors that influences the implementations of industrial mathematics

1	An Industry expert has no the necessary mathematical background and knowledge	1	2	3	4	5
2	Poor university-industry link	1	2	3	4	5
3	Industry awareness in using research result of universities	1	2	3	4	5
4	Lack of knowledge in importing/using appropriate technology	1	2	3	4	5
5	Insufficient information about the graduate at the job market	1	2	3	4	5
6	Pedagogical practice that does not target the skill needed by the industry	1	2	3	4	5
7	Universities in Ethiopia do not have the opportunity to underpin quantitative understanding of industrial strategy and processes across all sectors of business	1	2	3	4	5
8	The necessary investment in mathematics are key challenges for Ethiopian industry	1	2	3	4	5
9	The industry experts often do not fully know the industrial context of the mathematics they used	1	2	3	4	5
10	Trained man power in the field of industrial mathematics	1	2	3	4	5

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2.6. What benefits can be derived from deploying Industrial Mathematics in enriching careers in terms of professional development (research and teaching learning)?

	Benefits	Benefits gained by: Teachers	Students	Industry Expert	Industry	University
1	Academic Rank	✓		✓		
2	Publication	✓	✓	✓		
3	Patent	✓	✓	✓	✓	✓
4	Financial gain	✓				
5	Academic achievement	✓	✓	✓		
6	Job opportunity	✓	✓		✓	✓
7	Improve production and services	✓			✓	✓
8	Use innovation from the academia	✓			✓	✓
9	Job appraisal	✓	✓	✓		
10	Global rank	✓	✓			✓
11	Increase export productions				✓	

2.7. The limitations and strength of the existing University Mathematics Curriculum you were taking

2.7.1. To answer the following questions, please use the nine –point scale (1=Poor, 5=Typical, and 9= Excellent).You may use any point on the scale for your answer.

1	How do you rate the quality of undergraduate mathematics courses in solving industrial problems?	5
2	How do you rate the mathematics courses in solving industrial problems ability to meet the needs of your employees who took it?	6
3	How relevant is the contents of mathematics courses to your employees' working conditions?	6
4	All things considered, how do you rate the overall values of mathematics courses to your employees?	5

2.7.2. What could be done to improve the courses? Better if it designed based on industry needs.

2.7.3. Please provide additional information about the courses that you feel will contribute to its use and effectiveness

2.8. Industrial Mathematics curriculum Model for Ethiopian industrial development

2.8.1. Joint curriculum development and joint employment

2.8.1.1. Can you support to the development of joint industrial mathematics curriculum between science and technology universities and industries?

Yes [✓] No [ ]

2.8.1.2. If your response for question number 2.8.1.1 is "No", can you mention your reason?

2.8.1.3. If your response for question number 2.8.1.1 is "Yes", what are the advantages of having joint curriculum? Helps to identify and Solve Real world problem

2.8.2. Do you agree that on the appointment of professionals with high degree of relevant expertise from industry in Ethiopian science and technology universities?

Yes [✓] No [ ]

2.8.2.1. If your response for question number 2.8.2 is "Yes", how can we use them in universities? (Indicate your response as many as possible by using tick mark √)

A. Guest Lecturer [✓] B. Counselor [ ] C. Mentorship [ ] D. If any ______

2.8.3. What major industrial issues or topics your department working with industries? (Check all that apply). For the major issues of the industry which mathematical concepts you used. (Match industrial topics that need mathematics from the lists of mathematical concept found in the right hand side. You can assign more than one

	INDUSTRIAL ISSUE OR TOPICS	Assign a number for the Mathematical concepts		MATHEMATICAL CONCEPTS
1.	Investigative projects and research from industry	3	1.	Differential Equation
2.	Using various problem solving tools and techniques to solve problems of industry	1	2.	Numerical analysis
3.	Developing or designing models related to industrial Problems	5	3.	Statistical analysis
4.	Simulation activities, such as improving productivity	6	4.	Computational methods
5.	Initiating change /designing in industrial processes	2	5.	Discrete Mathematics
6.	Industry relevant software, technology and equipment	4	6.	Optimization

7. Other Industry issue______ 7. Other Math concept______

2.8.4. How industry elective courses should be included in industrial mathematics courses? Please, indicate as many as possible which are appropriate for industry or organization.

	Mechanisms to include industry elective courses	
1	Industry will design the courses as per requirement	✓
2	Industry will select the candidate and organize special training	✓
3	Industry will develop their own courses and delivered through subject experts	✓
4	Industry will develop student project	✓

5. If you have any delivery mechanism suggest here____________________________

2.8.5. Which industrial mathematics curriculum is most recommended for Ethiopian industries and Ethiopian Science and Technology Universities? (Please √ as many responses as you think accurate)

№	Industrial Mathematics Curriculum	✓
1	BSc. Industrial Mathematics With Computer Applications	✓
2	MSc. Industrial Mathematics With Computer Applications	✓
3	BSc. Industrial Mathematics	✓
4	MSc. Industrial Mathematics	✓
5	BSc. Industrial Mathematics and Statistics	✓
6	MSc. Industrial Mathematics and Statistics	✓
7	BSc .Applied and Industrial Mathematics	✓
8	MSc .Applied and Industrial Mathematics	✓
9	BSc Industrial Mathematical Modeling	✓
10	MSc Industrial Mathematical Modeling	✓

2.8.6. Job opportunity for industrial mathematics graduate in university and organization (Please put √ as many responses as you think accurate)

	Job opportunity	
1	Operations Research Analysts	✓
2	Scientific programmer	✓
3	Data analyst	✓
4	Financial Analysts	✓
5	Production line optimization	✓
6	Risk management	✓
7	Software testing and verification	✓
8	University Instructor	✓
9	High School Teacher	✓

10. If there are other job opportunities specify here

2.8.7. General comment

I think it's crucial to consider developing relating the mathematics people with the industry problems, helps to solve real life problems from the industry.
Hope industrial mathematics will be [illegible] part of our curriculums.

COVER LETTER TO SURVEY QUESTIONS FOR UNIVERSITY INSTRUCTORS

DATE 15/12/2021

Dear Prospective respondent,

This questionnaire forms part of my research entitled: *Industrial Mathematics Curriculum Development for Ethiopian Science and Technology Universities* for the degree of D.Ed. at the University of South Africa. You have been selected by a *purposive sampling* strategy from the population of your College/Faculty. Hence, I invite you to take part in this survey.

The aim of this study is to investigate the need of the stakeholder on industrial mathematics to propose appropriate industrial mathematics curriculum to Ethiopian Science and Technology University (ESTU). The findings of the study may benefit you and your industry by providing an opportunity to conduct research in your area that arises from industrial problems through industrial mathematics. You are kindly requested to complete this survey questionnaire, as honestly and frankly as possible and according to your personal views and experience. No foreseeable risks are associated with the completion of the questionnaire which is for research purposes only. The questionnaire will take approximately 20 minutes to complete. You are not required to indicate your name and your anonymity will be ensured; however, indication of your service, gender, occupation position will contribute to a more comprehensive analysis.

Thank you for taking time to assist me in my educational endeavors. After the completion of the study, an electronic summary of the findings of the research will be made available to you on request. Permission to undertake this survey has been granted by the Addis Ababa science and Technology University and the Ethics Committee of the College of Education, UNISA. By completing the questionnaire, you imply that you have agreed to participate in this research. Please return the completed questionnaire to me before December___, 2021.

Yours sincerely

Zewdie Woldeamanuel Habte
Addis Ababa Science and Technology University, Addis Ababa, Ethiopia
64126846@mylife.unisa.ac.za / kenazewd@gmail.com / +251911392588/

QUESTIONNAIRE FOR MATHEMATICS INSTRUCTORS

PART-I: BACKGROUND INFORMATION

INSTRUCTIONS: This part of the questionnaire is designed to collect the Personal information of instructors regarding gender, Education, current position, and service years. The questions are contained closed-open -ended items, for the close-ended items put √ mark for the appropriate choice of your alternatives and for the open ended one write on the space provided.

1.1. Gender: 1.Male [√] 2.Female [ ]

1.2. Education: 1.Ph.D [ ] 2. Second degree [√] 3.First Degree [ ] 4.If any__

1.3. Name of your department *mathematics*

1.4. Your current Position	1. President		2. Vice-president		3.Directoriate		4. College Dean
	5.Associate Dean		6.Department Head		7. Teacher		8.Other *PhD student*

1.5. Service Years: 1. In Industry *0* 2.Others institution *> 10 yrs*

PART.2. INDUSTRIAL MATHEMATICS CURRICULUM DEVELOPMENT AND IMPLEMENTATIONS

2.1. Have you, in the past, participated in making suggestions on curriculum development and review program? Yes [√] No [ ]

2.1.1. If your response for question 2.1 is "Yes "your level of participation *member* (Leader, Facilitator, Secretory, member)

2.2. Which of the following are the barriers you have come across in your work with curriculum development and review of new programs in university and how significant they are? (Please circle the degree of significance for each barrier)

Very Significant [4]	Significant [3]	A little Significant[2]	Not Significant [1]

	Barriers				
1	Lack time to fully participate in the program	1	2	(3)	4
2	Lack of interest to fully participate in the program	1	(2)	3	4
3	Inadequate background knowledge in curriculum development and review	1	2	(3)	4
4	Inadequate understanding of new technology	1	2	(3)	4
5	Lack of support within my organizations	1	2	(3)	4
6	The Curriculum is prepared by scholars selected from different institutions, but not from diversified groups.	1	2	3	(4)

7. Other-Specify here____________________

1 | Page

2.3. Industrial Mathematics

INSTRUCTIONS: This part of the questionnaire is designed to investigate your understanding about industrial mathematics. Please indicate how much you agree or disagree with each of the following statements by circling one of the numbers that stand for the following rating scales:

Strongly Disagreed(1)	Disagree (2)	Undecided(3)	Agreed(4)	Strongly Agree (5)

	Industrial Mathematics					
1	It is basic for knowledge base industrial development of every country	1	2	3	4	5
2	It solves the industrial problems using different mathematical techniques	1	2	3	4	5
3	It is the mathematical analysis of problems that arise in an industrial setting	1	2	3	4	5
4	It is a mathematical work that is performed in an academic setting that is largely isolated from the demands, pressures, and constraints of industry and industry-university collaborations.	1	2	3	4	5
5	It designate all the research that is oriented at the solution of problems posed by industrial applications	1	2	3	4	5
6	It is an interdisciplinary course that integrates engineering courses, science and mathematics courses	1	2	3	4	5
7	It is a branch of mathematics that is concerned with developing mathematical methods and applying them to engineering, science, and industry	1	2	3	4	5

2.4. How important are the following mechanisms of working together between academics and industrial experts to implement industrial mathematics curriculum in Ethiopian science and technology universities and industries? Please indicate the degree of importance of the following statements by circling one of the numbers that stand for the following rating scales:

Unimportant [1]	Slightly Important [2]	Moderately Important [3]	Important [4]	Very important [5]

Mechanism to enhance working together

A.1	Initiates existing relationships between Industry and universities					
A.2	Trust and openness from both parties	1	2	3	4	5
A.3	Develop educational programs that educate personnel in a way that satisfies the missions of all parties involved	1	2	3	4	5
B.1	Establish interdisciplinary research center by teams' universities and industries scholars.	1	2	3	4	5
C.1	Assign Faculty Positions for Industrial Mathematics in University and industry.	1	2	3	4	5
D.1	Supervise students together through a grant secured by university-industry collaboration	1	2	3	4	5
D.2	Assign students in industries departments and government offices as Fellowships or as Industry Practicums	1	2	3	4	5
E.1	Establish industrial mathematics study groups that enable Industries get their problems in short time by intensive work by independent experts.	1	2	3	4	5
F.1	Technology translators identify industrial opportunities for mathematics, understand the detailed requirements of each company	1	2	3	4	5
G.1	Provide Consultancy service as an intermediary organizations enable this mechanism of knowledge exchange in between university-industry collaboration	1	2	3	4	5
G.2	Personnel exchange allows staff to work either specifically on a given project or freely between collaborators	1	2	3	4	5
G.3	Use of successful completed industrial mathematics project in the same framework in Ethiopian cases.	1	2	3	4	5

2.5. Factors that influence the implementation of industrial mathematics Curriculum.

INSTRUCTIONS: This part of the questionnaire is designed to identify those factors that influence the implementation of industrial mathematics at Ethiopian Science and Technology University (ESTU). Please indicate how much you agree or disagree with each of the following statements by circling one of the numbers that stand for the following rating scales:

Strongly Disagree(1) Disagreed (2) Undecided (3) Agreed (4) Strongly agreed (5)

Factors that influences the implementations of industrial mathematics

An Industry expert has no the necessary mathematical background and knowledge	1	2	3	4	5
Poor university-industry link	1	2	3	4	5
Industry awareness in using research result of universities	1	2	3	4	5
Lack of knowledge in importing/using appropriate technology	1	2	3	4	5
Insufficient information about the graduate at the job market	1	2	3	4	5
Pedagogical practice that does not target the skill needed by the industry	1	2	3	4	5
Universities in Ethiopia do not have the opportunity to underpin quantitative understanding of industrial strategy and processes across all sectors of business	1	2	3	4	5
The necessary investment in mathematics are key challenges for Ethiopian industry	1	2	3	4	5
The industry experts often do not fully know the industrial context of the mathematics they used	1	2	3	4	5
Trained man power in the field of industrial mathematics	1	2	3	4	5

2.6. What benefits can be derived from deploying Industrial Mathematics in enriching careers in terms of professional development (research and teaching learning)?

	Benefits	Benefits gained by				
		Teachers	Students	Industry Expert	Industry	University
1	Academic Rank	✓		✓		
2	Publication	✓	✓	✓	✓	✓
3	Patent	✓		✓		
4	Financial gain	✓	✓	✓	✓	✓
5	Academic achievement	✓	✓	✓		
6	Job opportunity	✓	✓	✓	✓	✓
7	Improve production and services	✓	✓	✓	✓	✓
8	Use innovation from the academia	✓	✓	✓	✓	✓
9	Job appraisal	✓	✓	✓		
10	Global rank				✓	✓
11	Increase export productions				✓	✓

2.7. The limitations and strength of the existing University Mathematics Curriculum you were taking

2.7.1. <u>The current universities Mathematics curriculum</u>

INSTRUCTIONS: The following questionnaires are conducted to investigate your opinion on the existing mathematics undergraduate and graduate mathematics curriculum in the university. Please indicate how much you agree or disagree with each of the following statements which describe the limitations and strength of the existing Mathematics Curriculum in promoting research for both the academic community and industry experts by circling one of the numbers that stands for the following rating scales:

agly Disagreed(1)	Disagree (2)	Undecided(3)	Agreed(4)	Strongly Agree (5)

Limitations	Undergraduate	Graduates
Curriculum are more general than being specific	1 2 3 4 5	1 2 3 4 5
Less emphasis on methodology	1 2 3 4 5	1 2 3 4 5
focus on knowledge than practical problems	1 2 3 4 5	1 2 3 4 5
graduate has demand for high school teachers	1 2 3 4 5	1 2 3 4 5
The curriculum concentrates in a specific area	1 2 3 4 5	1 2 3 4 5
transfer their skills into business and industry	1 2 3 4 5	1 2 3 4 5
develop methods for previously formulated problems rather than on the more realistic case	1 2 3 4 5	1 2 3 4 5
Strength	**Undergraduate**	**Graduate**
have vertical relation to other mathematics courses	1 2 3 4 5	1 2 3 4 5
Advance courses are included	1 2 3 4 5	1 2 3 4 5
will contribute to the scientific and technological development of Ethiopia	1 2 3 4 5	1 2 3 4 5
Provide an in-depth understanding of the fundamental principles and techniques	1 2 3 4 5	1 2 3 4 5
Develop the mathematical skills needed in modeling and solving practical problems	1 2 3 4 5	1 2 3 4 5
It is sufficient to teach in secondary schools	1 2 3 4 5	1 2 3 4 5
It is sufficient to teach in colleges, and universities	1 2 3 4 5	1 2 3 4 5
It is adaptable to work in industries and research institutes	1 2 3 4 5	1 2 3 4 5

2.7.2. To answer the following questions, please use the nine -point scale (1=Poor, 5=Typical, and 9=Excellent).You may use any point on the scale for your answer.

1	How do you rate the quality of undergraduate mathematics courses in solving industrial problems?	5
2	How do you rate the mathematics courses in solving industrial problems ability to meet the needs of your employees who took it?	9
3	How relevant is the contents of mathematics courses to your employees' working conditions?	9
4	All things considered, how do you rate the overall values of mathematics courses to your employees?	9

2.7.3. What could be done to improve the courses? connecting the industries and developing a relevant curriculum.

2.7.4. Please provide additional information about the courses that you feel will contribute to its use and effectiveness. Combinatorics design which is applicable in medicine synthesis, Actuarial mathematics, etc

2.8. Industrial Mathematics curriculum Model for Ethiopian industrial development

2.8.1. Joint curriculum development and joint employment

2.8.1.1. Can you support to the *development of joint industrial mathematics curriculum* between science and technology universities and industries?

Yes ☑ No ☐

2.8.1.2. If your response for question number 2.8.1.1 is "No", can you mention your reason?

____

2.8.1.3. If your response for question number 2.8.1.1 is "Yes", what are the advantages of having joint curriculum? Creates Job opportunity, enhance industry-university [illegible]

.8.2. Do you agree that on the *appointment of* professionals with high degree of relevant expertise from industry in Ethiopian science and technology universities?

Yes ☑ No ☐

2.8.2.1. If your response for question number 2.8.2 is "Yes", how can we use them in universities? (Indicate your response as many as possible by using tick mark √)

. Guest Lecturer ☑ B. Counselor ☑ C. Mentorship ☑ D. If any ______________

8.3. What *major industrial issues or topics* your department working with industries? (Check all that apply). For the major issues of the industry which mathematical concepts you used. (Match industrial topics that need mathematics from the lists of mathematical concept found in the right hand side. You can assign more than one

	INDUSTRIAL ISSUE OR TOPICS	Assign a number for the Mathematical concepts		MATHEMATICAL CONCEPTS
1.	**Investigative projects and research from industry**	2,3, 6, 5,1	1.	Differential Equation
2.	**Using various problem solving tools and techniques to solve problems of industry**	1,2,3,4,5,6	2.	Numerical analysis
3.	**Developing or designing models related to industrial Problems**	1,2,3,4,6	3.	Statistical analysis
4.	**Simulation activities, such as improving productivity-**	1,2,3,4,5,6	4.	Computational methods
5.	**Initiating change /designing in industrial processes-**	1,2,3,4,5,6	5.	Discrete Mathematics
6.	**Industry relevant software, technology and equipment**	1,2,3,4,5,6	6.	Optimization

7. Other Industry issue__________ 7. Other Math concept Combinatorial design.

2.8.4. How industry elective courses should be included in industrial mathematics courses? Please, indicate as many as possible which are appropriate for industry or organization.

	Mechanisms to include industry elective courses	
1	Industry will design the courses as per requirement	✓
2	Industry will select the candidate and organize special training	✓
3	Industry will develop their own courses and delivered through subject experts	✓
4	Industry will develop student project	✓

5. If you have any delivery mechanism suggest here University will allow the industry to (develop) relevant course/courses.

2.8.5. Which industrial mathematics curriculum is most recommended for Ethiopian industries and Ethiopian Science and Technology Universities? (Please √ as many responses as you think accurate)

№	Industrial Mathematics Curriculum	
1	BSc. Industrial Mathematics With Computer Applications	✓
2	MSc. Industrial Mathematics With Computer Applications	✓
3	BSc. Industrial Mathematics	
4	MSc. Industrial Mathematics	
5	BSc. Industrial Mathematics and Statistics	✓

6	MSc. Industrial Mathematics and Statistics	✓
7	BSc Applied and Industrial Mathematics	✓
8	MSc Applied and Industrial Mathematics	✓
9	BSc Industrial Mathematical Modeling	✓
10	MSc Industrial Mathematical Modeling	✓

2.8.6. Job opportunity for industrial mathematics graduate in university and organization (Please put √ as many responses as you think accurate)

	Job opportunity	
1	Operations Research Analysts	✓
2	Scientific programmer	✓
3	Data analyst	✓
4	Financial Analysts	✓
5	Production line optimization	✓
6	Risk management	✓
7	Software testing and verification	✓
8	University Instructor	✓
9	High School Teacher	✓

10. If there are other job opportunities specify here

Data Security official/analyst

2.8.7. General comment

This research work has to be supported. I think it will come up with new findings which can enhance university-industry linkage, collaboration between the two parties in developing mathematics curriculum which is the best one.

Engineering

QUESTIONNAIRE FOR INSTRUCTORS

PART-I: BACKGROUND INFORMATION

INSTRUCTIONS: This part of the questionnaire is designed to collect the Personal information of instructors regarding gender, Education, current position, and service years. The questions are contained closed-open -ended items, for the close-ended items put √ mark for the appropriate choice of your alternatives and for the open ended one write on the space provided.

1.1. Gender: 1.Male [✓] 2.Female [ ]

1.2. Education: 1.Ph.D [✓] 2. Second degree [ ] 3.First Degree [ ] 4.If any__

1.3. Name of your department Civil Engineering

1.4. Your current Position	1. President		2. Vice-president		3.Directoriate		4. College Dean
	5.Associate Dean		6.Department Head		(7. Teacher)		8.Other ____

1.5. Service Years: 1. In Industry ________ 2.Others institution ________ 3. Industry 10

PART.2. INDUSTRIAL MATHEMATICS CURRICULUM DEVELOPMENT AND IMPLEMENTATIONS

2.1. Have you, in the past, participated in making suggestions on curriculum development and review program? Yes [✓] No [ ]

2.1.1. If your response for question 2.1 is "Yes "your level of participation member (Leader, Facilitator, Secretory, member)

2.2. Which of the following are the barriers you have come across in your work with curriculum development and review of new programs in university and how significant they are? (Please circle the degree of significance for each barrier)

Very Significant [4]	Significant [3]	A little Significant[2]	Not Significant [1]

2.3. Industrial Mathematics

INSTRUCTIONS: This part of the questionnaire is designed to investigate your understanding about industrial mathematics. Please indicate how much you agree or disagree with each of the following statements by circling one of the numbers that stand for the following rating scales:

Strongly Disagreed(1)	Disagree (2)	Undecided(3)	Agreed(4)	Strongly Agree (5)

Industrial Mathematics

1	It is basic for knowledge base industrial development of every country	1	2	3	(4)	5
2	It solves the industrial problems using different mathematical techniques	1	2	3	(4)	5
3	It is the mathematical analysis of problems that arise in an industrial setting	1	2	3	(4)	5
4	It is a mathematical work that is performed in an academic setting that is largely isolated from the demands, pressures, and constraints of industry and industry-university collaborations.	1	2	(3)	4	5
5	It designate all the research that is oriented at the solution of problems posed by industrial applications	1	2	3	(4)	5
6	It is an interdisciplinary course that integrates engineering courses, science and mathematics courses	1	2	3	(4)	5
7	It is a branch of mathematics that is concerned with developing mathematical methods and applying them to engineering, science, and industry	1	2	3	(4)	5

2.4. How important are the following mechanisms of working together between academics and industrial experts to implement industrial mathematics curriculum in Ethiopian science and technology universities and industries? Please indicate the degree of importance of the following statements by circling one of the numbers that stand for the following rating scales:

Unimportant [1]	Slightly Important [2]	Moderately Important [3]	Important [4]	Very important [5]

Mechanism to enhance working together

.1	Initiates existing relationships between industry and universities	1	2	3	4	5
.2	Trust and openness from both parties	1	2	3	4	5
3	Develop educational programs that educate personnel in a way that satisfies the missions of all parties involved	1	2	3	4	5
.1	Establish interdisciplinary research center by teams' universities and industries scholars.	1	2	3	4	5
.1	Assign Faculty Positions for Industrial Mathematics in University and industry.	1	2	3	4	5
.1	Supervise students together through a grant secured by university-industry collaboration	1	2	3	4	5
.2	Assign students in industries departments and government offices as Fellowships or as Industry Practicums	1	2	3	4	5
.1	Establish industrial mathematics study groups that enable Industries get their problems in short time by intensive work by independent experts.	1	2	3	4	5
.1	Technology translators identify industrial opportunities for mathematics, understand the detailed requirements of each company	1	2	3	4	5
i.1	Provide Consultancy service as an intermediary organizations enable this mechanism of knowledge exchange in between university-industry collaboration	1	2	3	4	5
i.2	Personnel exchange allows staff to work either specifically on a given project or freely between collaborators	1	2	3	4	5
i.3	Use of successful completed industrial mathematics project in the same framework in Ethiopian cases.	1	2	3	4	5

.5. Factors that influence the implementation of industrial mathematics Curriculum.

INSTRUCTIONS: This part of the questionnaire is designed to identify those factors that influence the implementation of industrial mathematics at Ethiopian Science and Technology University (ESTU). Please indicate how much you agree or disagree with each of the following statements by circling one of the numbers that stand for the following rating scales:

Strongly Disagree(1)	Disagreed (2)	Undecided (3)	Agreed (4)	Strongly agreed (5)

Factors that influences the implementations of industrial mathematics

1	An Industry expert has no the necessary mathematical background and knowledge	1	2	3	4	5
2	Poor university-industry link	1	2	3	4	5
3	Industry awareness in using research result of universities	1	2	3	4	5
4	Lack of knowledge in importing/using appropriate technology	1	2	3	4	5
5	Insufficient information about the graduate at the job market	1	2	3	4	5
6	Pedagogical practice that does not target the skill needed by the industry	1	2	3	4	5
7	Universities in Ethiopia do not have the opportunity to underpin quantitative understanding of industrial strategy and processes across all sectors of business	1	2	3	4	5
8	The necessary investment in mathematics are key challenges for Ethiopian industry	1	2	3	4	5
9	The industry experts often do not fully know the industrial context of the mathematics they used	1	2	3	4	5
10	Trained man power in the field of industrial mathematics	1	2	3	4	5

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2.6. What benefits can be derived from deploying Industrial Mathematics in enriching careers in terms of professional development (research and teaching learning)?

	Benefits	Benefits gained by				
		Teachers	Students	Industry Expert	Industry	University
1	Academic Rank	✓				
2	Publication	✓				
3	Patent	✓				
4	Financial gain	✓		✓	✓	✓
5	Academic achievement	✓	✓	✓	✓	✓
6	Job opportunity	✓	✓	✓	✓	✓
7	Improve production and services		✓			
8	Use innovation from the academia			✓	✓	
9	Job appraisal	✓	✓			
10	Global rank					✓
11	Increase export productions			✓	✓	
		✓				✓
				✓	✓	

2.7. The limitations and strength of the existing University Mathematics Curriculum you were taking

2.7.1. To answer the following questions, please use the nine –point scale (1=Poor, 5=Typical, and 9= Excellent). You may use any point on the scale for your answer.

1	How do you rate the quality of undergraduate mathematics courses in solving industrial problems?	5
2	How do you rate the mathematics courses in solving industrial problems ability to meet the needs of your employees who took it?	5
3	How relevant is the contents of mathematics courses to your employees' working conditions?	5
4	All things considered, how do you rate the overall values of mathematics courses to your employees?	5

2.7.2. What could be done to improve the courses? better if some courses are delivered by professionals (teachers) from same department as in States (USA)

2.7.3. Please provide additional information about the courses that you feel will contribute to its use and effectiveness

n/a

2.8. Industrial Mathematics curriculum Model for Ethiopian industrial development.

2.8.1. Joint curriculum development and joint employment

2.8.1.1. Can you support to the *development of joint industrial mathematics curriculum* between science and technology universities and industries?

Yes [✓] No [ ]

2.8.1.2. If your response for question number 2.8.1.1 is "No", can you mention your reason?

N/A

2.8.1.3. If your response for question number 2.8.1.1 is "Yes", what are the advantages of having joint curriculum? [illegible]

2.8.2. Do you agree that on the *appointment of professionals* with high degree of relevant expertise from industry in Ethiopian science and technology universities?

Yes [✓] No [ ]

2.8.2.1. If your response for question number 2.8.2 is "Yes", how can we use them in universities? (Indicate your response as many as possible by using tick mark √)

A. Guest Lecturer [✓] B. Counselor [✓] C. Mentorship [ ] D. If any ____________

2.8.3. What *major industrial issues or topics* your department working with industries? (Check all that apply). For the major issues of the industry which mathematical concepts you used. (Match industrial topics that need mathematics from the lists of mathematical concept found in the right hand side. You can assign more than one

	INDUSTRIAL ISSUE OR TOPICS	Assign a number for the Mathematical concepts		MATHEMATICAL CONCEPTS
			1.	Differential Equation
1.	Investigative projects and research from industry	4	2.	Numerical analysis
2.	Using various problem solving tools and techniques to solve problems of industry	4	3.	Statistical analysis
3.	Developing or designing models related to industrial Problems	4	4.	Computational methods
4.	Simulation activities, such as improving productivity-	4	5.	Discrete Mathematics
5.	Initiating change /designing in industrial processes-	4	6.	Optimization
6.	Industry relevant software, technology and equipment	4		

7. Other Industry issue N/A 7. Other Math concept N/A

2.8.4. How industry elective courses should be included in industrial mathematics courses? Please, indicate as many as possible which are appropriate for industry or organization.

	Mechanisms to include industry elective courses	
1	Industry will design the courses as per requirement	✓
2	Industry will select the candidate and organize special training	✓
3	Industry will develop their own courses and delivered through subject experts	✓
4	Industry will develop student project	✓

5. If you have any delivery mechanism suggest here Ma

2.8.5. Which industrial mathematics curriculum is most recommended for Ethiopian industries and Ethiopian Science and Technology Universities? (Please √ as many responses as you think accurate)

№	Industrial Mathematics Curriculum	
1	BSc. Industrial Mathematics With Computer Applications	✓
2	MSc. Industrial Mathematics With Computer Applications	✓
3	BSc. Industrial Mathematics	✓
4	MSc. Industrial Mathematics	✓
5	BSc. Industrial Mathematics and Statistics	✓
6	MSc. Industrial Mathematics and Statistics	✓
7	BSc .Applied and Industrial Mathematics	✓
8	MSc .Applied and Industrial Mathematics	✓
9	BSc Industrial Mathematical Modeling	✓
10	MSc Industrial Mathematical Modeling	✓

2.8.6. Job opportunity for industrial mathematics graduate in university and organization (Please put √ as many responses as you think accurate)

	Job opportunity	
1	Operations Research Analysts	✓
2	Scientific programmer	✓
3	Data analyst	✓
4	Financial Analysts	✓
5	Production line optimization	✓
6	Risk management	✓
7	Software testing and verification	✓
8	University Instructor	
9	High School Teacher	

10. If there are other job opportunities specify here n/a

2.8.7. General comment The effort of the researcher is appreciate and so the demand assessment tool will be used to determine program development.

Appendix-J : Certificate of language editing

ADDIS ABABA SCINCE AND TCHNOLOGY UNIVERSITY

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Certificate of Language Editing

Dear Mr. Zewdie Woldeamanuel Habte,

This letter is to certify that the thesis document titled "Industrial Mathematics Curriculum Development for Ethiopian Science and Technology Universities" has been edited by a professional English language editor. The editing process included proofreading and correcting grammar, spelling, punctuation, style, and technical vocabulary in the document.

The editor has ensured that the document is free of language errors and is ready for submission to your institution. We have attached a certificate of editing to this letter as proof of the editing process.

If you have any questions or concerns, please do not hesitate to contact us.

Sincerely,

Dr. Belihu Bekena

Department of English Language studies
Email: belihu.bekena@aastu.edu.et
Phone: +251911976051

Appendix-K Similarty Report