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Curricula Assessment and Sustainability Key Competencies: A Case of MUET, Jamshoro, Pakistan

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ABSTRACT:

Education stands the pivotal process safeguarding the continuity of the human race. It serves as the propelling force for advancing both human society and technology. The persistence of human society, the well-being of its environment, and the evolution of its technology axis upon the education process. Engineering educators are urged to adopt a strategic mindset that aligns curricula with long-term sustainability objectives in their respective fields. The Chemical, Civil, Petroleum, and Textile disciplines of engineering universities play pivotal roles in shaping industries and addressing sustainability challenges. The assessment focused on five fundamental sustainability competencies. A score of 1 was assigned for each SKC identified, with a maximum potential score of five (5) per course, representing one for each SKC. In total, 170 courses were analyzed, and 316 signs of SKCs were found in the course content of 2015-2016 curricula of MUET, this accounts for an average of 1.85 signs each university course. The key competences (SKC) of four disciplines in Mehran University of Engineering and Technology (MUET) revealed that signs of SKC-1, Systems-thinking Competence was found in the highest in number of (102 signs), SKC-5, Interpersonal Competence (69 signs), SKC 4, Strategic Competence (64 signs), and SKC-2, Normative Competence (62 signs). Overall, the findings underscore the multifaceted nature of competency integration within MUET's departments, highlighting both strengths and opportunities for enhancement across the institution. Moving forward, targeted interventions and collaborative efforts among departments can further optimize curricular alignment with industry demands and societal needs, ultimately fostering the development of well-rounded graduates equipped to address the complexities of their respective fields.

Keywords: Curricula Assessment, Sustainability Key Competencies, Industries, Higher Education.

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Introduction

The world urgently needs skilled workers to move society toward sustainability (Gordon et al., 2019), and educational institutions should train students for these positions (Barth, 2016; Franco et al., 2023). As a result of this problem, sustainability science programs have proliferated (O'Byrne et al., 2015), and they are increasingly defining their students' learning objectives in terms of sustainability competencies (Salovaara et al., 2020). Competencies are "a complex combination[s] of knowledge, skills, understanding, values, attitudes, and desire which lead to effective, embodied human action in the world" (Crick 2008). The collection of essential skills for sustainability (Redman et al. 2020) is becoming more widely accepted. These include systems-thinking, futures-thinking, values-thinking, strategic-thinking, and interpersonal skills (Wiek et al. 2011). In a similar way, researchers, scholars, and educators have established an agreement on effective and efficient teaching methods to foster these skills (Brundiers et al. 2010; Frisk and Larson 2011; Barth and Michelsen 2013).

Sustainability in Higher Education (SHE) is an approach that aims to facilitate the acquisition and generation of knowledge whilst also developing graduates with the capabilities and competencies to improvise, adapt, innovate, and be creative. According to Barth et al. (2007), graduates need to possess skills such as interdisciplinary thinking, problem-solving, teamwork, and holistic thinking. Additionally, developing these skills is essential to prepare graduates for the challenges of the future. Moreover, to successfully implement ESD, it is important to shift from teaching to learning. This can be achieved by adopting a multidisciplinary approach that covers environmental, economic, and social aspects. It is essential to integrate key topics like climate change, disaster risk reduction, health, equity, and sustainable consumption into the curriculum. Teachers play a crucial role in this process, as their role must evolve from being just a knowledge provider to a facilitator who fosters sustainability competencies in students (Rieckmann, 2017).

For the selected study, the researcher has chosen MUET as the focal institution and chemical, textile, civil, and petroleum engineering disciplines as the cases for investigation. This strategic selection allows the researcher to examine sustainability competence within a diverse range of engineering fields, each with its unique challenges and opportunities regarding sustainability. MUET's commitment to sustainability and its multidisciplinary approach provide an ideal context for exploring how sustainability principles are integrated into engineering education and practice. By focusing on these specific disciplines, the study aims to provide insights into the effectiveness of sustainability education and identify areas for improvement in preparing future engineers to address sustainability challenges effectively. Additionally, studying these disciplines allows for a comprehensive assessment of sustainability competence across different sectors of the engineering profession, contributing valuable knowledge to both academia and industry.

The United Nations SDGs in Higher Education Institutions (HEIs)

Current studies in higher education reveal the ongoing progress in incorporating sustainable development into HEIs and their efforts to actively assume responsibility as advocates for sustainable development principles (Lozano et al., 2019; Lozano & Barreiro-Gen, 2021; Stough, 2018). The United Nations (UN) Sustainable Development Agenda presented 17 SDGs that articulate important development challenges essential to the well-being and survival of humanity (General, 2015). To achieve these goals, a fundamental shift in thinking and behavior is necessary for humanity. This transformation necessitates individuals possessing values, skills, and knowledge. Hence, education is deemed essential for the attainment of sustainable development (Bielefeldt and Canney, 2016).

However, it is important to note that not all forms of education align with the principles of sustainable development. The widely recognized and researched ESD approach empowers students to make informed decisions and take responsible actions to preserve environmental integrity, ensure economic viability, and promote a just society for present and forthcoming generations (Hüfner, 2000).

The Sustainability Key Competencies

According to Barth et al. (2007), the primary objective of ESD, as advocated by the UN, is to cultivate competencies that empower individuals to critically assess their actions, taking into account the present and future societal, cultural, economic, and environmental impacts, both locally and globally. This entails equipping individuals to engage in sustainable practices in complex situations, transforming them into sustainable citizens. Achieving this goal may necessitate venturing into unexplored territories and actively participating in socio-political processes to steer societies toward sustainable development. Consequently, a re-evaluation of learning content, pedagogy, outcomes, and learning environment is crucial in universities. Hüfner (2000) enlightened that education for SD is more than just integrating topics. It requires a shift in the paradigm of traditional teaching towards a focus on learning, emphasizing the desired learning outcomes that students should achieve. To achieve this, a transformative pedagogy that supports self-directed learning, encourages participation and collaboration, emphasizes problem-solving, and embraces inter- and transdisciplinarity is required. Through these pedagogical approaches, the development of key competencies essential to drive SD can be fostered. Therefore, it is important to improve education and introduce innovative teaching and learning methods to develop sustainability-oriented competencies. (Sady et al., 2019). Globalization, urbanization, and industrialization resulted in harmful issues, such as poverty, conflict, desertification, and climate change (Wiek et al., 2011). Sustainability is a system theory-based strategy aimed at overcoming these complex and intimidating problems. Despite emphasizing the development of strong technical abilities, modern undergraduate engineering education lacks learning.

The SKCs model, proposed by Wiek, Withycombe, and Redman in 2011, offers a comprehensive framework for cultivating the essential skills and competencies required to address sustainability challenges effectively. Grounded in a holistic approach, the model identifies five core competencies that encompass cognitive, affective, and behavioral dimensions. Emphasizing the integration and application of these competencies in real-world contexts, the SKC model underscores the importance of experiential learning, interdisciplinary collaboration, and active engagement with sustainability issues. By providing a roadmap for designing education and training programs, assessing individual and collective competence, and fostering values-based decision-making, the model aims to empower individuals and organizations to contribute meaningfully to sustainability efforts and address the complex socio-ecological challenges facing society.

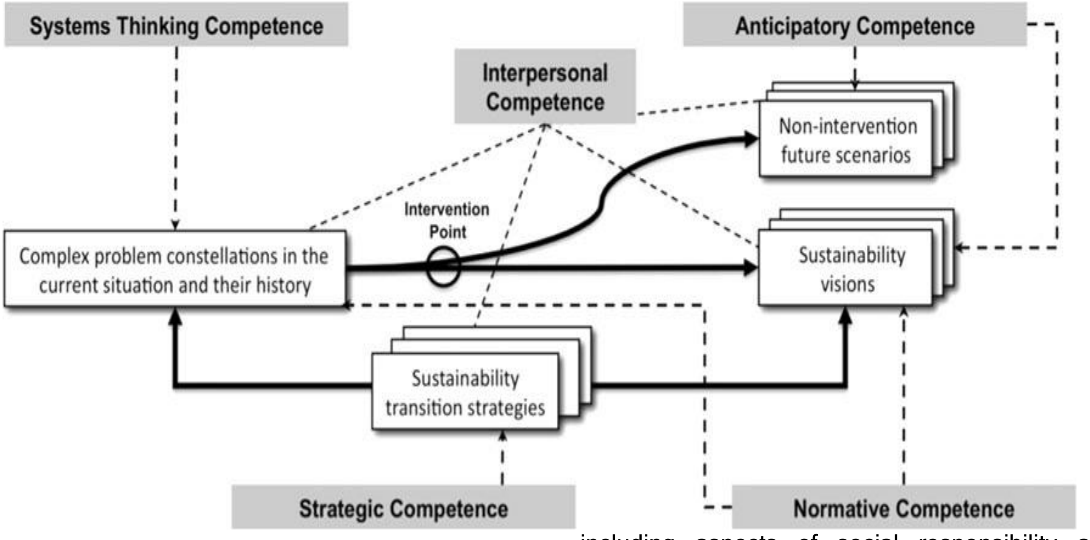

Figure 1. Sustainability Key Competence model (Wiek, et al. 2011)

Engineering education is crucial in influencing the future of industries and society on a large scale. With the growing urgency of global sustainability challenges, engineering universities face the imperative to reassess their curricula. The goal is to guarantee that graduates possess the essential competencies required to effectively tackle these pressing challenges. This abstract offers a summary of a curriculum assessment focused on the integration of sustainability competencies into engineering education. The assessment focuses on five core sustainability competencies:

1. Systematic Thinking Competency: The assessment of curricula aims to nurture systematic thinking skills among engineering students. This encourages the analysis of intricate sustainability issues from a systemic viewpoint, acknowledging interconnections and unintended consequences.

2. Normative Competency: The development of curricula places a strong emphasis on ethical and normative principles, ensuring that students possess a thorough understanding of the ethical considerations tied to sustainability, including aspects of social responsibility and environmental stewardship.

3. Anticipatory Competency: A primary objective is to equip engineers with the ability to foresee and adapt to upcoming sustainability challenges. This competency emphasizes forward-thinking approaches like scenario planning and risk assessment.

4. Strategic Competency: Engineering universities are urged to embrace a strategic outlook, aligning curricula with enduring sustainability objectives. This entails comprehending the broader context of sustainability and engineering's role in contributing to global solutions.

5. Interpersonal Competency: Collaboration is inherent to engineering. The assessment of curricula underscores the significance of interdisciplinary collaboration and effective communication skills, empowering students to collaborate efficiently in diverse teams to address sustainability challenges.

Sustainability in Engineering Education

Higher education's emphasis on sustainability extends beyond environmental stewardship. It encompasses equipping students with the expertise and abilities to contribute to SD (Filho et al., 2018). Many institutions acknowledge the paramount importance of sustainability and have integrated it into various aspects of their operations, curriculum, research endeavors, and community interactions (Menon & Suresh, 2022). This necessitates substantial transformations in how knowledge is both generated and disseminated. In disciplines like engineering, the incorporation of sustainability into the curriculum is imperative due to its profound impact on society and natural resources. Engineering holds a pivotal role in societal advancement and consequently carries responsibility for fostering sustainable growth (Bielefeldt and Canney, 2016). This entails not only imparting technical proficiencies but also fostering a holistic comprehension of the socio-economic and environmental ramifications of engineering practices (Azapagic et al., 2005).

MUET stands as a pioneering institution in fostering sustainability within engineering education. Through its curriculum and initiatives, it emphasizes the integration of sustainability principles across various disciplines. Notably, the university's commitment to sustainability is evident in its deliberate selection of disciplines such as chemical, textile, civil, and petroleum engineering for assessing sustainability competence. These disciplines were chosen due to their significant impact on environmental, social, and economic aspects of sustainability. Chemical engineering plays a pivotal role in developing sustainable processes and products, while textile engineering addresses issues related to sustainable materials and production methods. Civil engineering focuses on sustainable infrastructure development and management, and petroleum engineering examines sustainable energy solutions and environmental stewardship in the oil and gas industry. By assessing sustainability competence in these disciplines, MUET aims to equip students with the knowledge, skills, and mindset necessary to address complex sustainability challenges in their respective fields.

CASE STUDY-1: Chemical engineering

Chemical engineering stands at the crossroads of technology, sustainability, and human development. It is not limited to designing industrial processes but extends to safeguarding the environment, supporting economies, and improving communities' quality of life. Chemical engineers design processes that use fewer resources, generate less waste, and minimize harmful emissions. They apply life cycle assessment to measure environmental impacts at every stage of production and use principles of green chemistry to replace hazardous materials with safer alternatives. For example, in wastewater treatment and renewable energy, chemical engineers innovate systems that clean pollutants while generating useful by-products. These efforts ensure that industries can meet production demands without causing long-term harm to the planet. By optimizing processes, chemical engineers reduce costs, conserve raw materials, and make industries more efficient. This optimization not only increases productivity but also creates new opportunities for businesses to grow and compete in the global market. From the energy sector to pharmaceuticals and agriculture, their contributions translate into job creation, innovative products, and sustainable industrial growth. Their expertise in project management and continuous improvement ensures that industries remain profitable while adhering to sustainability standards. Beyond technical solutions, chemical engineers address the social dimensions of engineering projects. They engage with stakeholders, evaluate community impacts, and integrate safety and health considerations into their designs. Access to clean water, clean air, affordable medicines, and sustainable food production are direct benefits of their work. By considering societal needs alongside industrial goals, chemical engineers help foster safer, healthier, and more equitable communities.

CASE STUDY-2: Petroleum engineering

Petroleum engineering, though often linked with fossil fuel extraction, also plays a crucial role in advancing sustainability when guided by the right competencies. Petroleum engineers adopt technologies that reduce air and water pollution, minimize greenhouse gas emissions, and prevent soil contamination. They also develop methods for cleaner refining and safer waste disposal. Through energy efficiency measures, they improve extraction processes, ensuring that resources are used wisely while lowering the industry's environmental footprint. The petroleum sector is the backbone of many economies. Petroleum engineers ensure that oil and gas reserves are managed responsibly, which sustains economic growth over the long term. Their innovations in refining and extraction boost efficiency, keeping production viable even as global demand shifts. The industry also generates jobs, supports infrastructure development, and attracts international investment, all facilitated by engineering expertise. Petroleum engineers contribute to communities by carrying out social impact assessments, engaging with local populations, and integrating community development projects alongside industrial activities. Their compliance with strict regulatory standards helps protect human health and safety, building trust between industry and society. When approached responsibly, petroleum engineering supports energy security and community development while reducing risks to people and the environment.

CASE STUDY-3: Civil engineering

Civil engineers play a transformative role in shaping sustainable societies, particularly through green building and infrastructure design, by designing eco-friendly infrastructure, energy-efficient buildings, water conservation systems, and sustainable transport networks. They integrate biodiversity into urban planning, ensuring that cities remain livable and environmentally balanced, and also emphasize recycling, waste reduction, and the principles of a circular economy in construction projects, and infrastructure development is directly tied to economic expansion. In addition, civil engineers support growth by creating long-lasting, cost-effective structures that reduce maintenance costs over time. Their projects—roads, bridges, dams, and housing—are essential for trade, mobility, and industrial growth. When built sustainably, these structures provide economic benefits without sacrificing environmental quality. Furthermore, civil engineers are responsible for the safety and resilience of the built environment. Their work ensures that communities have access to safe housing, reliable water supplies, transportation systems, and recreational spaces. By designing with sustainability in mind, they not only meet immediate human needs but also safeguard the welfare of future generations.

CASE STUDY- 4: Textile engineering

Textile engineering, often criticized for its environmental footprint, is undergoing a major shift toward sustainability. Textile engineers are developing eco-friendly materials, sustainable dyeing methods, and water-efficient manufacturing systems. The adoption of sustainable materials and recycling technologies also minimizes landfill waste. The textile industry is a major contributor to employment and exports worldwide. By integrating sustainable technologies, textile engineers help companies maintain competitiveness in global markets where demand for eco-friendly products is rising. This innovation secures the industry's profitability and ensures long-term economic resilience. Workers and surrounding communities benefit directly when textile engineers prioritize health and safety by reducing chemical exposure and toxic waste. By promoting ethical production practices and engaging stakeholders, they foster socially responsible supply chains. In this way, textile engineers contribute to both community well-being and consumer trust.

Research Methodology

This study is rooted in a meticulous investigation of course descriptions, usually encompassing 2-3 paragraphs detailing the content and learning outcomes for all courses enumerated in the MUETs course content for the academic year 2015-2016. Recognizing the diversity of courses offered, a comprehensive analysis was undertaken, focusing specifically on the entire curriculum of the Chemical, Petroleum, Civil, and Textile departments. Employing the content analysis method and interviews within the qualitative research framework, the course content from these four departments at MUET underwent thorough scrutiny. The findings are methodically presented using a descriptive approach, offering a nuanced understanding of the results.

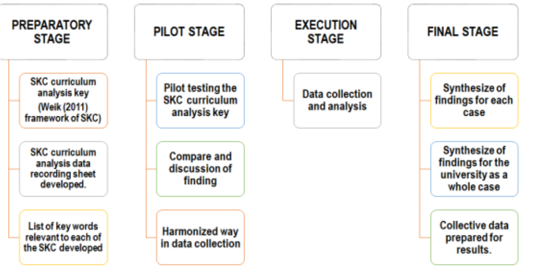

Figure 2: Curricula assessment process

The curriculum assessment progressed through four distinct phases, as depicted in Figure 2. In the initial phase, known as the preparation phase, as shown in Table 1 (concepts of SKC), the researcher, based on these Sustainability Key Competence concepts, developed (Table 2) a data recording sheet.

The value 1 was specified for each course in which the learning objectives or course descriptions contained a sign of each SKC. Therefore, each course could only score 1 once for each SKC, but each course could score for more than one SKC. This method was used to facilitate descriptive quantitative analysis of the results. The maximum number of signs per course could be five (5), i.e., one per SKC.

S#	Course Title	Course Code	Term	Year
	Name of SKCs	Concepts of competences	Concepts of competencies found in the course	Remarks
1	Systems-thinking Competence			
2	Anticipatory/Futures Competence			
3	Normative/Values Competence			
4	Strategic Competence			
5	Interpersonal Competence			

Table 1: Concepts of SKC

	SKC	**Concepts of SKC**
1	**"Systems Thinking Competence**: Ability to collectively analyze complex systems across different domains (society, environment, economy, etc.) and across different scales (local to global)"	Variables/indicators, subsystems, structures, and functions. People and social systems: values, preferences, needs, perceptions, (collective) actions, decisions, power, tactics, politics, laws, institutions, and cause and effect. Etc."
2	No**rmative Competence:** "Ability to collectively map, specify, apply, reconcile, and negotiate sustainability values, principles, goals, and targets"	"(Un-)sustainability of current or future states. Sustainability principles, goals, and targets. Concepts of justice, fairness, responsibility, safety, happiness, etc. Concept of risk, harm, and damage. Ethical concepts"
3	**Strategic Competence**: "Ability to collectively design and implement interventions, transitions, and transformative governance strategies toward sustainability"	"Transitions and transformation. Strategies, action programs, (systemic) intervention, and Transformative governance Success factors: viability, feasibility, effectiveness, and efficiency. Adaptation and mitigation Obstacles (resistance, reluctance, path dependency). Instrumentalization and alliances Social learning, Social movements"
4	**Anticipating Competence**: "Ability to collectively analyze, evaluate, and craft rich 'pictures'' of the future related to sustainability issues and sustainability problem-solving frameworks"	"Concepts of time: including temporal phases (past, present, future), terms (short, long), states, and continuity (dynamics, paths). The concept of uncertainty and epistemic status, including the possibility, probability, and desirability of future developments (predictions, scenarios, and visions). Concepts of risk, intergenerational equity, precaution"
5	**Interpersonal Competence**: "Ability to motivate, enable, and facilitate collaborative and participatory sustainability research and problem-solving"	"Functions, types, and dynamics of collaboration (within and beyond academia; interdisciplinarity, transdisciplinarity). Strengths, weaknesses, successes, and failures in teams. Concepts of leadership, limits of cooperation, and Empathy"

The researcher(s) generated a list of keywords associated with the SKC concept from previous literature (Weik, 2011). For instance, for the concept of "systems thinking competency" for SKC, the list included terms such as relationships, complex systems, systemic embedment, and uncertainty, accompanied by their respective explanations. These concepts and explanations formed the basis for the subsequent data analysis phase.

Table 3 (list of keywords relevant to each SKC concept):

SKC	CHEMICAL	PETROLEUM	CIVIL	TEXTILE
Systems Thinking Competence	Industrial hazards on the environment (Reniers et al., 2018)	Industrial hazards on the environment (Pathak and Mandalia, 2012)	Industrial hazards on the environment (Varma et al., 2021)	Industrial hazards on the environment (Uddin., 2021)
	Green chemistry (Zimmerman et al., 2020)	Understanding and knowledge of the system and its application	Understanding and knowledge of the system (principles, laws, structure, functions)	System, subsystem, structure, function, interdependent factors. (Taher et al., 2016)
	Green (Sustainable) Materials Selection. (Glassey and Haile, 2012), (Vatalis, 2013)	Green (Sustainable) Materials Selection. (Glassey and Haile, 2012), (Vatalis, 2013)	Green (Sustainable) Materials Selection. (Glassey and Haile, 2012), (Vatalis, 2013)	Eco-friendly Materials Selection (Jena et al., 2015)
	Technology (Glassey and Haile, 2012)	Technology (Glassey and Haile, 2012), (Al-Mulali, 2015)	Technology (Glassey and Haile, 2012), (Al-Mulali, 2015)	Sustainable Technologies (Al-Mulali, 2015)
	Green energy (Al-Mulali, 2015), (Zeb et al., 2014)	________	Green energy (Al-Mulali, 2015), (Zeb et al., 2014)	_____
	Green economy (Zeb et al., 2014)	Political sustainability Palmberg et al. (2017)	Cause and effect (Sandin et al., 2013)	Cause and effect (Sandin et al., 2013)
Anticipatory competence	Forecasting/prediction	Estimation	Forecasting/Estimation	prediction
	Estimation	Estimation/forecasting	Forecasting/estimation	Prediction/simulation
Normative Competence	Quality control (Kenett al., 2018)	Quality control (Kenett al., 2018)	Quality control (Kenett al., 2018)	Quality control (Taher et al., 2016)
	Regulatory Compliance (Franco et al., 2023), (Glassey and Haile, 2012)	Regulatory Compliance (Franco et al., 2023), (Glassey and Haile, 2012)	Regulatory Compliance (Franco et al., 2023), (Glassey and Haile, 2012)	Regulatory Compliance (Franco et al., 2023), (Glassey and Haile, 2012)
	Health, Safety, and Environmental (Ahmed et al., 2019)	Health, Safety, and Environmental (Ahmed et al., 2019)	Health, Safety, and Environmental (Ahmed et al., 2019)	Environmental, Health, and Safety (EHS). (Sandin et al., 2013)
	Concept of Ethics (Kibert, 2010)	Concept of Ethics (Kibert, 2010)	Concept of Ethics (Kibert, 2010)	Concept of Ethics (Kibert, 2010)
	______________	Risk assessment (Sadorsky, 2006)	Risk assessment (Sadorsky, 2006)	
	________	Environmental Impact Assessment (Glasson and Therivel, 2013)	Environmental Impact Assessment (Glasson and Therivel, 2013)	___________
Strategic Thinking Competence	______________	Sustainable gas transmission and distribution management (Carter, 2008)	Water supply and distribution method. (Chandrappa and Das, 2014)	Chemical Management and Toxicity Reduction
	Resource management (Efficiency) (Glassey and Haile, 2012)	Resource management (Efficiency) (Glassey and Haile, 2012)	Resource management (Efficiency) (Glassey and Haile, 2012)	Resource management (Efficiency) (Glassey and Haile, 2012)

	Waste Management (Bozkurt and Stowell, 2016)	Waste Management (Bozkurt and Stowell, 2016)	Waste Management (Bozkurt and Stowell, 2016)	Waste Management (Bozkurt and Stowell, 2016)
	Project management (Stanitsas et al., 2021)	Project management (Stanitsas et al., 2021)	Project management (Stanitsas et al., 2021)	________________
	Sustainable Product Design (Oehlberg et al., 2010)	________________	Infrastructure Design (Wolcott, 2011), (Kevern, 2011)	Sustainable Design method
	Environmental Impact Mitigation (Glassey and Haile, 2012), (Naeem & Ahmed, 2022)	Environmental Impact Mitigation (Glassey and Haile, 2012), (Naeem & Ahmed, 2022)	Environmental Impact Mitigation (Glassey and Haile, 2012), (Naeem & Ahmed, 2022)	Environmental Impact Mitigation (Glassey and Haile, 2012), (Naeem & Ahmed, 2022)
	Sustainable Production process/practices (Tabone et al., 2010)	Sustainable Production process/practices (Tabone et al., 2010)	Sustainable construction/building design Kanwar, et al. (2023)	Sustainable Production process/practices (Tabone et al., 2010)
	Continues learning (Lanz and Järvenpää, 2020)	Continues learning (Lanz and Järvenpää, 2020)	wastewater infrastructure (Delanka-Pedige et al., 2021)	Continues learning (Lanz and Järvenpää, 2020)
	Circular Economy (Naeem & Ahmed, 2022)	________________	Circular Economy (Naeem & Ahmed, 2022)	________________
	Water Management Nacheva (2011)	________________	Water Management (Vatalis, 2013)	Water Management Nacheva (2011)
	Innovation (Franco et al., 2023)	________________	Wastewater infrastructure. (Delanka-Pedige et al., 2021)	Innovation (Franco et al., 2023)
	________________	________________	Methods of testing	________________
	________________	________________	Transportation planning and design. Kanwar, et al. (2023)	________________
	________________	________________	Waste Reduction (Vatalis, 2013)	________________
Interpersonal Competence	Communication (Glassey and Haile, 2012)	Communication (Glassey and Haile, 2012)	Communication (Glassey and Haile, 2012)	Communication (Glassey and Haile, 2012)
	Collaboration, Teamwork (Wolcott, 2011)	Collaboration, Teamwork (Wolcott, 2011)	Collaboration (Wolcott, 2011)	Collaboration, Teamwork (Wolcott, 2011)
	Stakeholder Engagement Kanapathy et al., 2021	Stakeholder Engagement Kanapathy et al., 2021	Community Engagement Kanwar, et al. (2023)	Stakeholder Engagement Kanapathy et al., 2021
	Problem-solving (Tainter and Taylor, 2014)	Problem-solving (Tainter and Taylor, 2014)	Problem-solving (Tainter and Taylor, 2014)	Problem-solving (Tainter and Taylor, 2014)
	________________	Conflict management Brito et al., 2018)	________________	________________

In the pilot phase of the research project, the main goal was to ensure the accuracy and reliability of data collection. To achieve this objective, a collaborative working group meeting was held, which included faculty members of respective fields, as well as the supervisor/co-supervisors.

The meeting's purpose was to exchange information and conduct a pilot test for a developed study. Considerable standards for data collection and consistency were sought to maintain reliability, quality, and comparability. Creswell et al. (2006) validated the quality of work through researchers' participation in a minimum of two of the procedures in a given study, and these procedures were triangulation, peer review, and debriefing. These procedures were established through collaborative efforts among scholars and research leaders.

s#	Field of Study	Number of Courses Analyzed	Number of (SKC) Signs of Key Competencies per Course	Average of (SKC) Signs of Key Competencies per Course
01	Chemical	44 Courses	90	2.0
02	Petroleum	42 Courses	60	1.4
03	Civil	40 Courses	81	2.0
04	Textile	44 Courses	85	1.9
	Total	170 Courses	316	1.85

Analysis

Based on the course description consisting of 2-3 paragraphs, the learning outcomes for all courses featured in the MUET's course content during the academic year 2015-2016. As numerous courses are offered, a comprehensive analysis was conducted on the entire course of chemical, petroleum, civil, and textile. Using the content analysis method of the qualitative research method course, the content of four departments of MUET was analyzed, and the results are presented by the descriptive method. The purpose of this analysis was to evaluate the sustainability competencies included in MUET's curriculum. The results are divided into three sections: one for MUET Together, one for each school within MUET, and one for each SKC.

Overall Results for the MUET

The course descriptions and learning outcomes of 170 courses were analyzed. The course catalog for the year of 2015-2016 comprised 316 signs of SKC signs in the MUET, which describes an average of 1.85 signs per course in the university (Table 4).

Table 4. "Total number of courses analyzed and the number of signs of sustainability key competencies"

Table 4 shows the analysis of the total course and signs of SKC per course. The chemical and textile disciplines had the highest number of courses analyzed, with a total of 44 courses each, while the civil discipline had the fewest, with 40 courses analyzed. SKC signs were different across four disciplines. The lowest SKC signs was Petroleum (60 signs) and the highest was Chemical (90 signs). The average of SKC signs for institutions was different, ranging from 1.4 (Petroleum) to 2.0 (Chemical & Civil), and the maximum signs per course was five (One per SKC).

Table 5: Total signs of SKCs -Four case studies of the MUET

	"(SKC-1) Systems-thinking competence"	"(SKC-2) Anticipatory competence"	"(SKC-3) Normative competence"	(SKC-4) Strategic-thinking competence	(SKC-5) Interpersonal competence
Chemical	24	04	25	15	22
Petroleum	18	06	09	13	14
Civil	30	06	16	17	12
Textile	30	03	12	19	21
Total	102	19	62	64	69

Table 5 presents the number of SKC signs identified across the four MUET cases. The highest counts were observed for SKC-1 (102 signs), followed by SKC-5 (69 signs), SKC-4 (64 signs), and SKC-3 (62 signs). In contrast, SKC-2 exhibited by far the lowest number of signs, with only 19 recorded.

Figure 3. Overall percentage (Signs) of SKC in the MUET curriculum.

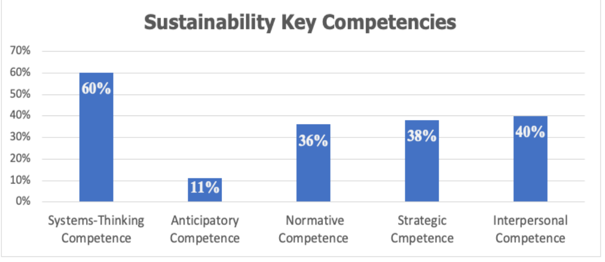

Figure 3 is the illustration of 170 courses and the percentage of SKC in four (4) cases of MUET. SKC-1 was identified in 60 % of the courses offered at the MUET, SKC-5 is 40 %, SKC-4 38 %, SKC-2 is 36 % and SKC-3 is 11 %.

Signs of SKCs for each case of the MUET

CASE STUDY - 1: SIGNS OF SKC-SUSTAINABILITY KEY COMPETENCIES IN CHEMICAL ENGINEERING OF THE MUET

Figure 4 illustrates the results for chemical engineering. A total of 90 signs were identified across 44 courses, yielding an average of 2.0 SKC signs per course. The SKC-3 has the highest proportion and percentage is 57 % of the course. SKC-1 was identified in 54% of courses, followed by SKC-5 in 50%, SKC-4 in 34%, and SKC-2, which was found in only 9% of the courses.

CASE STUDY-2: Signs of SKC-Sustainability Key Competencies in Petroleum Engineering of the MUET

Figure 5 illustrates the results of petroleum engineering. A total of 60 signs were found across the 42 courses, resulting in an average of 1.4 SKC signs per course. The largest number of signs was found in SKC-1, i.e., in 43% of the total courses. SKC-5 signs were found in 33% of the courses, followed by SKC-4 in 31%, SKC-3 in 21%, and SKC-2 in 14% of the courses.

CASE STUDY-3: SIGNS OF SKC-SUSTAINABILITY KEY COMPETENCIES IN CIVIL ENGINEERING OF THE MUET

Figure 6 shows the results for the civil engineering. A total of 81 signs were identified in 40 courses, with an average of 2 SKC signs per course. SKC-1 exhibited the highest number of signs, i.e., 75% of courses. The percentage of SKC-4 is 42 % of the total course offered. Similarly, the SKC-3 is 40%, SKC-5 is 30%, and SKC-2 is 15% of the total courses offered at MUET.

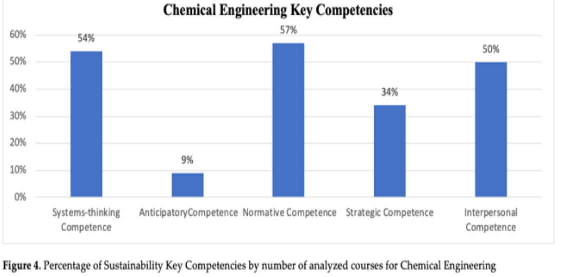

Figure 4. Percentage of Sustainability Key Competencies by number of analyzed courses for Chemical Engineering

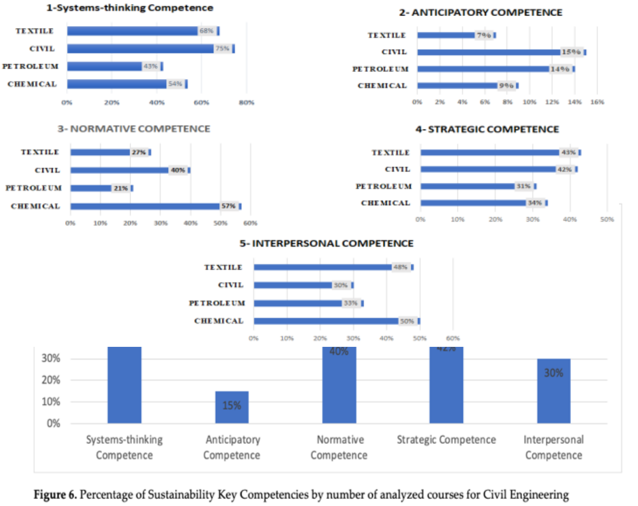

Figure 6. Percentage of Sustainability Key Competencies by number of analyzed courses for Civil Engineering

CASE STUDY -4: SIGNS OF SKC-SUSTAINABILITY KEY COMPETENCIES IN TEXTILE ENGINEERING OF THE MUET

Figure 7 presents the findings for textile engineering. Across 44 courses, a total of 85 signs of sustainability key competencies were identified, yielding an average of approximately 1.9 signs per course. SKC-1 was the most frequently observed, appearing in 68% of the courses. SKC-5 was identified in 48% of courses, while SKC-4 appeared in 43%. SKC-3 was present in 27% of courses, and SKC-2 was the least represented, found in only 7% of courses.

Overall, the highest proportion of SKC signs was observed for SKC-1. Additionally, SKC-4 and SKC-5 were identified in 30-50% of the courses analyzed at MUET, while SKC-2 is the least in number.

When examining individual disciplines within MUET, the greatest density of SKC signs was found in chemical and civil engineering courses, with an average of 2.0 signs per course, whereas

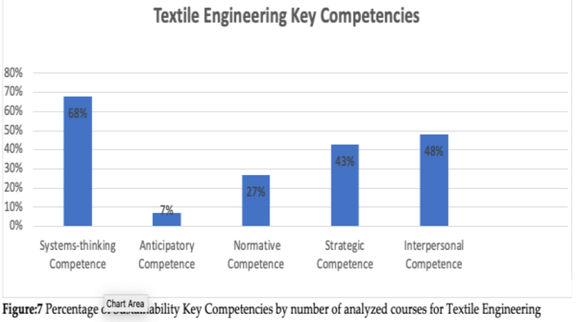

Figure:7 Percentage [illegible]ability Key Competencies by number of analyzed courses for Textile Engineering

petroleum engineering courses exhibited the Fewest, averaging 1.4 signs per course.

Signs of SKC-Sustainability Key Competencies–Comparison among the four cases of the MUET

Figures 8 and 9 below present the results of the identified sustainability key competences across the four departments included in the MUET case study. The figure 8 illustrates the proportion of signs for SKCs 1-5 relative to the total number of courses in each department.

• The SKC-1 was found within the four departments of the MUET, mostly within the civil department (in 75% of courses). For the other four departments, signs of SKC-1 ranged between 68% and 43%.

• The SKC-2, which was found for the most part within the civil department (15 %), and then petroleum 14 %) and chemical (9 %). The fewest signs of SKC-2 were identified for the textile (7 %).

SKC-3 was found in three departments: chemical engineering (57% of courses), civil engineering (40% of courses), and textile engineering (27% of courses). In petroleum engineering, SKC-3 was observed in comparatively fewer courses, appearing in 21% of them

SKC-4, representing strategic competence, was predominantly identified in the textile engineering department, where it appeared in 43% of courses, followed closely by the civil engineering department with 42% of courses.

Signs of SKC-4 were identified in 34% of courses within the chemical engineering department, while petroleum engineering showed the lowest proportion, with SKC-4 signs present in only 31% of courses.

• The SKC-5, representing interpersonal competence, was identified across all departments at MUET. It was most prevalent in chemical engineering (50% of courses), followed by textile engineering (48%). The lowest proportions were observed in petroleum engineering (33%) and civil engineering (30%)

In summary, the examination revealed that the courses within the chemical and civil departments demonstrated the highest prevalence of SKCs overall.

In contrast, the petroleum engineering department showed the lowest proportion of signs across all competencies, i.e., SKC-1, SKC-3, and SKC-4.

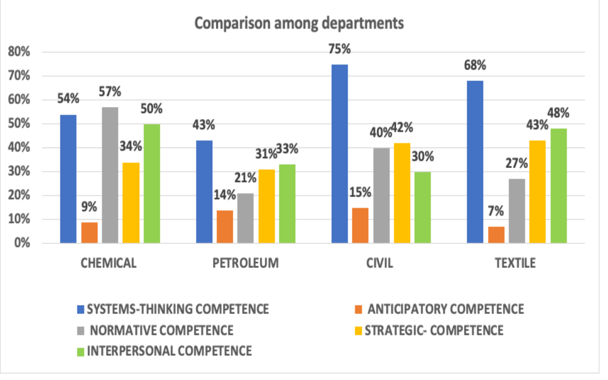

Figure 9: Comparison among disciplines

Validation of results

In order to ascertain the validity and comprehensiveness of the findings, researchers rigorously interacted with the pertinent academic departments. Through in-depth interviews conducted with faculty members directly or indirectly involved in shaping the curricula, the researchers sought nuanced perspectives regarding the incorporation of SKCs within the academic framework. The investigation uncovered that while sustainability key competencies are interwoven within the curricular structure, their integration predominantly occurs informally. This suggests that although sustainability principles are inherent within the educational fabric, there lack explicit delineation of each sustainability key competency. Further exploration within the academic milieu unveiled a breadth of topics addressed during lectures facilitated by faculty members and educators. These discussions span a diverse spectrum, encompassing discourse on energy optimization, thermodynamic laws, operational dynamics of power plants, eco-friendly materials, green buildings, and other critical subjects. Notably, discussions about energy utilization patterns emerge as particularly salient. Faculty members delve into the complexities surrounding energy consumption, highlighting issues of overutilization and resultant wastage, while also delving into the profound environmental, economic, and societal implications of energy mismanagement. Situating these discussions within the broader context, it becomes apparent that they serve as foundational elements toward the attainment of SDGs. The interdisciplinary nature of these dialogues underscores their pivotal role in fostering a holistic understanding of sustainability, transcending conventional academic confines. As students engage with these multifaceted dialogues, they are not only equipped with technical acumen but also develop a nuanced appreciation for the interconnectedness of environmental, economic, and social dimensions inherent within the realm of sustainability.

Discussion

The importance of engineering disciplines, including chemical, civil, petroleum, and textile, in forming industries and solving sustainability issues makes it imperative that engineering schools review their curricula. Given the urgent global concerns around resource depletion, social responsibility, and environmental effects, engineering programs must make sure that their graduates have the skills required for sustainability, as Winter and Cotton (2012) emphasize the importance of undergraduates acquiring the skills necessary for navigating the complexities of postmodern society, which encompass issues such as resource depletion, social inequality, economic challenges, and climate change. They stress the significance of competencies in ESD, highlighting that merely understanding sustainability concepts and principles is inadequate for fostering the mindsets and inclinations necessary for making sustainable decisions.

The findings of the study shed light on the distribution and prevalence of five key competencies across various departments within the MUET. Notably, the Civil Department emerges as a frontrunner in integrating SKC-1, indicating a strong emphasis on holistic problem-solving approaches within its curriculum. Conversely, the Textile Department demonstrates a significant presence of SKC-4, suggesting a strategic focus in its educational framework. These variations among departments highlight the nuanced approaches to competency development within specialized fields and underscore the importance of tailored pedagogical strategies to meet department-specific needs.

Moreover, the study identifies areas of potential improvement, particularly in departments where certain competencies show lower prevalence rates. For instance, the relatively limited presence of SKC-2 in the Textile Department signals an opportunity for curriculum enhancement to foster forward-thinking skills among students. According to Huhtala and Lindfors (2021), in daily practice, skills enable the professional competencies that are required for successful work. The qualitative anticipation of professional competencies gives information about the knowledge and skills that will be required for the future. Anticipation is challenging in the technical field since it is easy to consider technological and engineering developments alone. Similarly, the lower integration of SKC-5 in the Civil Department underscores the need for targeted interventions to promote effective communication and collaboration within the departmental context. By addressing these discrepancies and aligning curriculum objectives with industry demands and societal challenges, educational institutions can better equip graduates with the diverse skill sets required for success in today's dynamic workforce.

Conclusion

In conclusion, the analysis of curricula assessment across four departments—Civil, Textile, Chemical, and Petroleum—within MUET reveals distinct patterns in the integration of key competencies. Firstly, SKC-1 demonstrates significant prevalence within the Civil Department, indicating a robust emphasis on holistic problem-solving approaches. However, the other departments also exhibit substantial signs of SKC-1, albeit with varying degrees, highlighting a collective recognition of systems-oriented thinking across the institution. SKC-2 predominantly surfaces within the Civil Department, followed by the Petroleum and Chemical departments, suggesting a proactive approach to future-oriented skill development. Nevertheless, the Textile Department shows the least incorporation of SKC-2, suggesting room for improvement. Moreover, SKC-3 is evident across the chemical, civil, and textile departments, underscoring a widespread acknowledgment of normative aspects in curriculum design and implementation. SKC-4 primarily manifests within the Textile and Civil Departments, while Petroleum displays the lowest proportion of SKC-4 signs, indicating potential areas for strategic enhancement. SKC-5 emerges uniformly across all departments, with varying degrees of prevalence, emphasizing the universal recognition of interpersonal skills as essential in professional contexts. By emphasizing hands-on experiences, soft skills, and continuous improvement, these assessments ensure graduates possess the strategic competencies essential for success in dynamic professional environments. Industries, in turn, play a vital role in sustainable development by adopting environmentally friendly practices, promoting social responsibility, and contributing to economic stability through eco-friendly technologies, ethical supply chain management, and community engagement. Key sustainable competencies empower engineers to integrate eco-friendly practices, ethical considerations, and societal impact into their work, fostering innovation and responsible solutions within their workplaces. Wiek's sustainability competency framework, encompassing environmental literacy, systems thinking, collaboration, anticipatory skills, and normative competency, guides individuals to comprehensively analyze and address sustainability challenges, promoting interdisciplinary collaboration, ethical decision-making, and resilient solutions. This proposal advocates for enhancing sustainability education in the MUET engineering curriculum and aligning industry practices with sustainable development principles to bridge the knowledge gap between graduates and industry actions, ultimately informing future policies and guidelines for sustainable curriculum design and best practices. The study underscores the need to align university curricula with sustainability competencies, considering disciplinary differences, and addressing observed discrepancies between university rankings and sustainability emphasis. These findings seek to improve the relevance and impact of sustainability education, ensuring that graduates are well-prepared to address current sustainability challenges faced by industry and society.

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