RESILIENCE IN ENGINEERING EDUCATION: EXPLORING INDUSTRIAL SKILLS TOWARDS SUSTAINABLE SYNERGIES

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ABSTRACT

Recent research firmly highlights the necessity of incorporating the perspectives of students and graduates to enhance educational strategies. This approach guarantees that education stays globally relevant and effectively addresses the specific needs of various stakeholders. As a direct outcome, resilience in engineering skills is gaining critical importance, focusing on the essential skills required to create sustainable synergies. Transformative changes in engineering education are driving this trend. This study analyses how resilience in engineering education can transform skills to foster sustainable synergies, focusing specifically on the perceptions of students and graduates in Sweden. Using a deductive approach, the research investigates these perceptions through a survey that includes qualitative questions, employing thematic analysis for the data. The study findings indicate that resilience skills are essential for creating sustainable synergies that benefit students, educators, higher education institutions (HEIs), and industry. However, academics face challenges in teaching engineering students' practical skills that are increasingly in demand rather than focusing on theoretical knowledge. Academics struggle to connect theoretical concepts with the problem-solving and engineering practices needed to enhance global competencies in the industry and maintain competitiveness, thereby providing sustainable outcomes. This issue was noted in a previous CDIO syllabus study in 2014, and surprisingly, a decade later, it continues to be a significant concern. This indicates that higher education institutions and educators still have a gap in pedagogical skills that must be addressed.

KEYWORDS

Industrial Skills, Resilience, Sustainable Synergies, Engineering Education; Students' Perceptions, CDIO Syllabus V3, CDIO Standards: 7-8.

INTRODUCTION

To prepare for future and successful engineers, the CDIO approach addresses the necessity for engineering education to provide the learning required by students developing desired attributes of engineers who can Conceive-Design-Implement-Operate complex value-added engineering products, processes and systems in a modern, team-based environment. CDIO Syllabus has added contemporary themes in Engineering in the previous Version 2, such as Sustainability, Innovation and Globalisation; then Digitalisation, Acceleration and Experiences in the last updated Version 3. The CDIO Syllabus lists knowledge, skills, and attitudes desired by graduating engineers. Personal and Professional Skills such as Analysis with Uncertainty and Attitudes to face Uncertainty are included; however, how can students, educators and Higher Institutions (HEIS) develop sustainable synergies and resilience skills in an accelerated world?

Recent research highlights the importance of considering the "perceptions of students and graduates" to improve educational strategies, ensuring that education is globally relevant and tailored to the specific needs of stakeholders (Rico-Cortez et al., 2024, p. 685). The concept of *resilience* in engineering is gaining traction as it focuses on transforming skills to create sustainable synergies, a trend driven by changes in the educational profile of engineering (Klaassen et al., 2023). This approach differs from traditional engineering education, primarily preparing graduates for lifelong employment (Hazrat et al., 2023). Engineers must develop flexible solutions to manage complex socio-technical systems, enhancing ***ecological synergies and resilience*** (Jain et al., 2019). Consequently, an updated curriculum must adopt a multi-disciplinary or transdisciplinary approach, incorporating the perspectives of both students and graduates (Klaassen et al., 2023).

By emphasising the perceptions of students and graduates, we aim to enhance resilience in engineering education and address ongoing trends within educational institutions (Rico-Cortez et al., 2024). However, there remains a gap in the literature regarding how engineering students articulate and understand their perceptions (Kafri, 2022; Coe-Nesbitt et al., 2021; Farley-Ripple et al., 2018; Fisher et al., 2015). With the growing interest in education that makes a difference, it is essential to consider students' perceptions of academic achievement. This requires interdisciplinary and cross-disciplinary approaches that foster resilience and skills, creating sustainable educational synergies, as defined in this article (Coe-Nesbitt et al., 2021; Henriksson et al., 2016). *Thus, our purpose is to analyse the resilience in engineering education by exploring skills to create sustainable synergies, specifically through the perceptions of students and graduates in Sweden*. To fulfil this purpose, we answer the following research question (RQ):

RQ: What skills are essential for enhancing the resilience in engineering education to reshape students' and graduates' views on sustainable synergies in Sweden?

The remainder of this paper is organised as follows. The introduction offers the background context and objectives of the study. In the second section, we outline the theoretical foundations that underpin this research, while section 3 details the research methodology employed. Section 4 presents the findings of the study. Finally, the concluding section includes a discussion that reflects the study's contributions to theory and practice, acknowledges its limitations, and suggests directions for future research.

THEORETICAL BACKGROUND

Resilience in Engineering Education

Resilience is fundamentally linked to the occurrence of disruptive and often extreme events. The capacity to adapt and learn is vital for developing resilience (Scharte, 2021). Significant inter- and transdisciplinary research has been undertaken regarding resilience, mainly focusing on strategies to enhance it (e.g., Gasser et al., 2021; Rockström et al., 2023; Walker, 2020). Rockström et al. (2023) synthesised pivotal studies on resilience. They identified five essential attributes for building and enhancing resilience across various disciplines and sectors: diversity, redundancy, connectivity, inclusivity and equity, and adaptive learning.

Engaging engineering students in resilience thinking is essential; a critical aspect is learning from failures. Transforming educational skills within the broader framework of problem-based learning can be effective by analysing past academic failures and their implications for developing a capable workforce that meets changed industrial demands (Edmondson & Sherratt, 2022; Foley et al., 2022). This perspective is particularly valuable for acquiring skills that foster sustainable synergies and address complex problems in designing resilient educational systems thinking. Resilience educational systems thinking focuses on understanding and adapting to a changing world. By comprehending how and why systems are changing, we can better develop the capacity to engage with change rather than being victims of it (Walker & Salt, 2006, p. 14). Thus, resilience does not simply mean bouncing back after a disturbance; the concept is more accurately described as robustness or resistance to change, terms that are often mistakenly used interchangeably (Rockström et al., 2023; Winkens & Leicht-Scholten, 2021). Instead, resilience is characterised by adaptive capacity and a forward-looking approach that enables transformation to a different level (Folke, 2016; Folke et al., 2010). This understanding of resilience acknowledges the intertwined nature of ecosystems and humans, which together form conditions for sustainable synergies in complex integrated social-ecological systems (Folke, 2016; Folke et al., 2010; Rockström et al., 2023; Walker et al., 2004).

Skills for sustainable synergies

Our focus on resilience in engineering education emphasises the development of sustainable synergies defined as […] “competencies characterised by an anticipatory perspective and future orientation, the ability to think critically, creatively, and systemically, action competence, ethical sensitivity, and the capability to manage in conditions of change, uncertainty, and risk” (Sterling, 2014, p. 91). Developing skills like reflection, open-mindedness, knowledge integration, and critical thinking is crucial to balancing resilience with interdisciplinary collaboration (Barnett & Jackson, 2020). This suggests that engineering curricula should adopt inter- and multi-disciplinary approaches and consider the views of students and graduates (Klaassen et al., 2023). Today's engineering landscape requires graduates to not only meet rigorous technical standards but also to possess a range of soft skills that enhance their employability. Developing these soft skills is a crucial component of engineering education and training, as Campos et al. (2020) highlighted. This combination of technical knowledge and soft skills is vital for ensuring that engineering graduates are well-prepared to face the diverse challenges of their profession and gain a competitive advantage in the job market. Deep technical and collaboration skills are still valid in the industry. In addition, personal attributes, such as a propensity toward action, integrity, and self-reliance, are important skills that are valid for today's engineers (Crawley, 2014).

Engineering students must be able to effectively communicate their knowledge in different contexts, including academic environments, corporate settings, and research projects. They sometimes serve as skilled "translators," bridging the gap between complex technical concepts and their practical applications. The main objective is to balance engineering expertise and *professional skills* (Winberg et al., 2020).

Students` perspectives on engineering education

Engineering students' perspectives are increasingly seeking a broader standpoint. They have identified critical characteristics for developing learning environments and course activities that effectively support their competence in globally integrated learning (Richter & Kjellgren, 2023, p. 482). Kjellgren and Richter (2021) argued that teaching approaches that emphasise global competence should involve learning environments that are engaging, inclusive, and centred around students. Course activities must be designed to be relevant to real-world situations, incorporate collaborative elements, and be effectively supported and facilitated by instructors (Kerkhoff & Cloud, 2020). The integration of global competence in engineering education offers valuable insights into students' perspectives and experiences during their studies. Furthermore, it critically evaluates students' ideas and suggestions about opportunities for such learning within the field of educational science and proposes strategies for enhancing global competence in engineering education. Engineering curricula must integrate global competence learning to prepare graduates for success in globalised labour markets (Van den Beemt, 2020; Crawley, 2014). Focusing on students' skills (Wang et al., 2019), they are challenged to possess advanced knowledge of global competence is advantageous. However, it also highlights the challenge of representativeness within study populations (Wang et al., 2019). Reskilling students' knowledge is a notable trend, referring to acquiring new skills or updating existing ones to meet the changing demands of the job market (Richter & Kjellgren, 2023). This involves learning new competencies relevant to current or future job roles, while upskilling teaches employees additional skills. Jesiek et al. (2014) examined the "industry competencies" related to students' perceptions of their abilities, particularly in global engineering work. Their research revealed that global engineers frequently face challenges involving technical coordination, negotiation across diverse engineering cultures, and understanding ethics, standards, and regulations. Despite an increasing acknowledgement of the relevance of global competence in engineering professions, scholars have expressed frustration that educational institutions are progressing slowly in developing the global graduates that the industry requires (e.g., Richter and Kjellgren, 2023; Van den Beemt, 2020; Carter, 2020).

This study significantly advances existing literature by presenting a robust approach rooted in a logical framework developed from prior research (Rico-Cortez et al., 2024). It decisively analyses students' skills, academic abilities, and industry competencies, delivering a comprehensive perspective essential for enhancing educational strategies. This approach ensures that education is globally relevant and specifically tailored to the needs of stakeholders. The research suggests that by implementing a framework to assess the resilience of engineering education, we can effectively transform skills and promote sustainable synergies, including insights into student perceptions. **Table 1** presents three key focus areas influencing students' perceptions of enhanced educational strategies.

Table 12. Areas influencing students' perceptions of enhanced educational strategies.

Students' perceptions	e.g., context	e.g., references
Students Skills	Advanced global competence is beneficial and highlights challenges in representativeness within study populations. Reskilling students is essential to meet the evolving job market demands.	(Wang et al., 2019)
Academic Abilities	Higher Education Institutions (HEIs) and teacher training programs should utilise insights into critical skills and their connections to various professional contexts.	(Peng & Kievit, 2020)
Industry Competencies	It is essential in the context of global engineering work.	(Jesiek et al. 2014)

METHODOLOGY

This deductive study uses a qualitative design to emphasise "contextual understanding". Researchers aim to understand behaviour, values, beliefs, and other factors within the context of Resilience (Scharte, 2021, p.17) in Engineering (Edmondson & Sherratt, 2022; Foley et al., 2022). The deductive approach is employed by analysing pre-existing theory, in this case, institutional theory (Bryman & Bell, 2011, p. 411). The study examines students' perspectives in the Swedish education context, focusing on the various skills (Wang et al., 2019), abilities (Peng & Kievit, 2020), and competencies (Jesiek et al., 2014) when the resilience of engineering education, is seen to transform skills and promote sustainable synergies effectively.

Data Collection

Surveying with "qualitative interview questions" can allow researchers to pose questions that respondents can reflect on and answer (Gephart, 2004, p.458). Survey questions addressed the students' perceptions of their education in Sweden, through Engineering Education at Jönköping University; see **Appendix 1**. We used a combination of theoretical sampling and snowball sampling to select our survey respondents. Some respondents were directly contacted based on their involvement at the engineering school, while others were identified through referrals (Bryman, 2011). A code of A1-A17 identifies participants to protect their anonymity **Table 2**.

Table 2. Participants information

Code	Level	Discipline	Time
A1	Master Student	Product design	20 min
A2	Master Student	Industrial engineering	10 min
A3	Master Student	Industrial engineering	24 min
A4	Master Student	Industrial engineering; Design; Chemical engineering;	25 min
A5	Master Student	Engineering management;	10 min
A6	Master Student	Industrial engineering;	09 min
A7	Bachelor Student	Mechanical engineering	07 min
A8	Master Student	Engineering management; Industrial engineering;	09 min
A9	Master Student	Engineering management; Industrial engineering;	40 min
A10	Master Student	Computer science and engineering, Graphic Design;	10 min
A11	Bachelor Student	Mechanical engineering;	10 min
A12	Master Student	Mechanical engineering; Engineering management	11 min
A13	Master Student	Mechanical engineering; Industrial engineering	15 min
A14	Master Student	Industrial engineering	12 min
A15	Bachelor Student	Mechanical engineering	13 min
A16	Master Student	Computer science and engineering	15 min
A17	Bachelor Student	Mechanical engineering	20 min

Data analysis

Data analysis was carried out through a thematic approach, which is common in the students' perceptions (Richter & Kjellgren, 2023, p. 482) and engineering education fields (Edmondson & Sherratt, 2022; Foley et al., 2022). ***Figure 1*** displays our theme analysis and research model. The gathered data was analysed by looking for common patterns, phrases, expressions, and words with relevance to the main themes of our study (Mäntylä et al., 2018). In the first level of coding (L1), data from the surveys were aggregated into superior categories, enabling the identification of patterns, structures, and relationships (Strauss & Corbin, 1990) in which related students' perceptions and contexts from the surveys were interpreted and transferred. In the second level of coding, thematic codes (L2) were extracted from both secondary materials (Teknikföretagen Kompetensunder-Söking, 2022; UNESCO Snapshots,2020) and surveys (Catelani et al., 2021). After gathering data through the survey, we looked at secondary data sources. Identifying thematic codes that align with our theoretical base affected our intended contribution. These themes aimed not simply to describe the context but rather to be more focused on explaining the internal constructs of our study: the third set of themes derived from Sterling (2014) and the various students' skills (Wang et al., 2019), academic abilities (Peng & Kievit, 2020), and industry competencies (Jesiek et al., 2014) built on the contextual facts presented in section 2.3, themes are abstract and subtle expressions, patterns, processes that explain a phenomenon (Saldana, 2013, p.14).

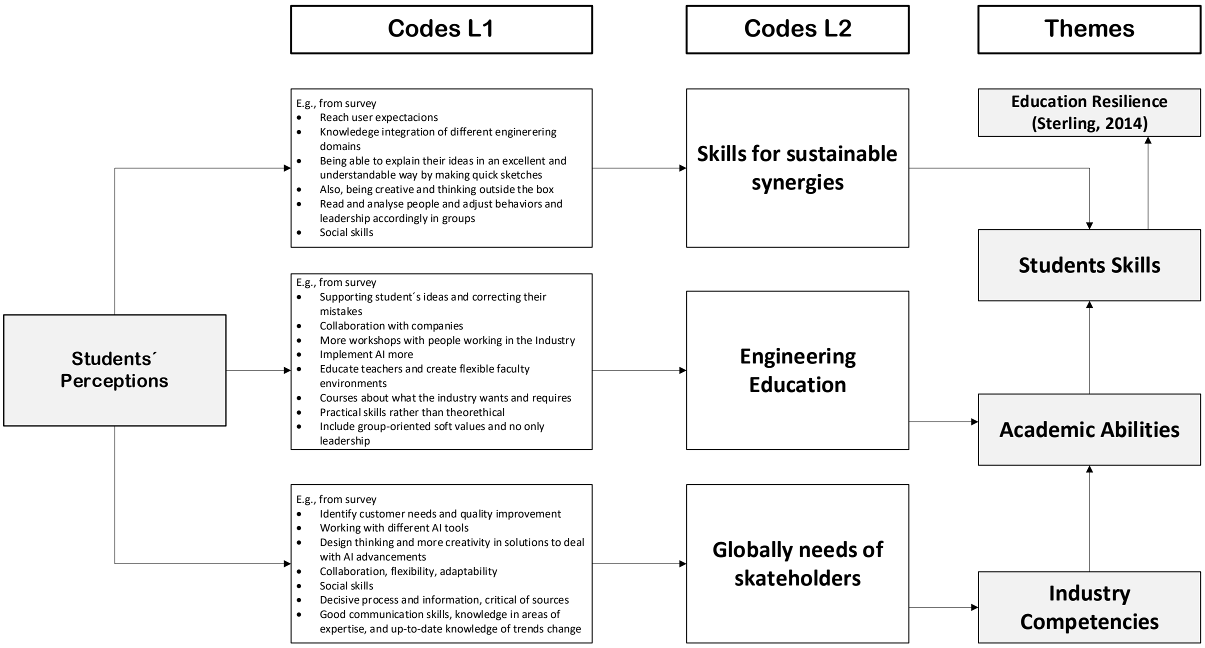

Figure 29. Themes analysis and research model

Thus, analysing our data with a deductive mind, we let the survey questions capture valuable insights. We avoid too much hanging on literature review constructs, blinding us from the subtle aspects of the engineering education resilience phenomenon. According to Mishra and Dey (2022), it is essential to maintain some distance from existing literature when framing research objectives, creating interview guides, and analysing data. Our study follows Guba and Lincoln (1994) to confirm the quality of this study for qualitative interpretative research, meaning credibility (internal validity), transferability (external validity), dependability (reliability) and confirmability (objectivity). Validity and reliability are critical considerations in paradigm findings from research design (Creswell, 2014). To prevent researcher bias, the first coding level was done independently by one team member, and the second was done separately by another team member. Any inconsistencies were thoroughly discussed within the team until a consensus was reached. This iterative approach ensured the reliability and high quality of the analysis (Catelani et al., 2021). Internal validity (Guba & Lincoln, 1994) was established by triangulating data from interviews and secondary documents.

FINDINGS

We provide a brief review of the resilience of Swedish engineering institutions by examining students' skills, academic abilities, and industry competencies. This assessment focuses on the strength of industrial engineering education, highlighting how these factors can effectively transform skills and foster sustainable synergies, including insights from students' perceptions. The review is grounded in a framework based on prior research that captures students' perceptions (Rico-Cortez et al., 2024).

Students 'skills

The findings indicate that many students wish to *develop or improve their problem-solving skills* (e.g., A1, A2, A3, A4, A5). Crawley (2014) argues that this desire is logical, as the skills of a genuine engineer primarily involve systematic problem-solving techniques in design. These techniques combine problem-solving and technological skills with personal creativity and judgment gained from experience. Students believe that *integrating knowledge across engineering domains would enhance their problem-solving skills* (e.g., A9, A10).

The second skill that students prioritised was *leadership and social skills*, which they found are closely related to communication skills (e.g., A4, A10, A11, A12). Several students desired *to feel more confident when sharing their ideas or presenting projects* (e.g., A10, A12, A4, A6). Students have identified *creativity, design thinking, and critical thinking as essential skills for professional development (e.g., A1, A2, A10, A12, A13)*. Furthermore, 50% of the students indicated that *management skills are associated with time management and the ability to make quick decisions*. Interestingly, artificial intelligence was not considered a high priority. It was noted as essential *to adapt to new systems and their changes, particularly in AI development* (e.g., A14, A15, A16). Only a student (A10) recognised "*resilience as essential for learning how to confront the world's challenges in both personal and professional life*." Students also noted that *being decisive involves processing much information and critically evaluating sources* (e.g., A1, A6, A17).

Academic abilities

Academic abilities are highly sought after in reorienting teacher training programs. These programs should incorporate insights into critical skills, which, according to Peng and Kievit (2020), are related to the resilience of Higher Education Institutions (HEIs) in various professional contexts. HEIs should improve their feedback systems, as students perceive that *feedback is essential for supporting their ideas and correcting mistakes* (e.g., A1, A2, A6, A7). Students noted that "*enhancing collaboration with companies is essential*" (A10). Holding *more workshops with industry professionals could be beneficial* (e.g., A3, A4, A11, A12). Some students suggested that *HEIs collaborate more closely with industry* (e.g., A10, A14, A17). In their view, *academic ability refers to additional courses focusing on industry demands and requirements* (e.g., A2, A5, A6, A6). Several students expressed the importance of *learning to network and present themselves to future employers* (e.g., A13, A14, A7). They emphasised the need for *environments and facilities that boost their confidence* (e.g., A1, A2). It is crucial to integrate *more "AI into education to keep pace with the new digital era"* (A10). Students emphasised the *importance of training teachers and creating flexible faculty environments to support this transition* (e.g., A11, A7, A8, A9). Students also highlighted that *feedback is essential for supporting their ideas and addressing mistakes* (e.g., A9, A10, A11). When addressing academic resilience, students emphasised the importance of *increasing collaboration with companies and suggested that hosting more workshops with industry professionals could be beneficial* (e.g., A5, A10, A11, A6, A17). Some students also recommend *establishing closer partnerships with industry when necessary* (e.g., A15, A16, 17). HEIs should offer more courses that align with industry demands and requirements (e.g., A16, A17).

Industry competencies

Industry competencies are emphasised by Jesiek et al. (2014) as essential in the context of global engineering work. In students' perceptions, the growing demand for *AI skills that adapt to various industries* (A1-A17) has emphasised the importance of *utilising multiple AI tools* *tailored to meet industry needs* (e.g., A2, A3, A4, A5). Additionally, students noted that *design thinking and enhanced creativity are essential for addressing advancements in AI* (e.g., A6, A7, A8, A9). They also highlighted the significance of *understanding customer needs and improving product quality* (A1-A17). Additionally, students acknowledged that the industry values *collaboration, flexibility, and adaptability*, which are essential for academic resilience and should be *incorporated into the academic competency portfolio* (e.g., A5, A7, A8, A9, A10, A12). Students pointed out the necessity of *strong communication skills and the ability to make quick decisions* (A13, A14, A15, A16). Students emphasised the importance of *gaining in-depth knowledge and staying current with evolving work trends* (A1-A17). Students recommended *integrating research with the goal of solving industrial challenges and meeting resilience and sustainable outcomes* (A1-A17). **Table 3** summarises the perceptions of students found in the study.

DISCUSSION AND CONCUSSIONS

This study analysed *the resilience of industrial engineering education in exploring skills to create sustainable synergies, specifically through the perceptions of students and graduates in Sweden*. The study found that essential skills for enhancing the resilience of engineering education and reshaping students' and graduates' views on sustainable synergies in Sweden are lacking. Key skills to improve or develop include design thinking, creativity, management, leadership, problem-solving, AI, and resilience. These are recommended for higher education institutions to adopt and enhance in this new digital era. According to Sharte (2021), adapting and learning are essential for building resilience.

RQ. What skills are essential for enhancing the resilience in engineering education to reshape students' and graduates' views on sustainable synergies in Sweden?

The study revealed that students’ perceptions are linked to their ability to quickly adapt to new systems and the changes that come with them, particularly concerning adopting AI development. This finding aligns with version 3 of the CDIO Syllabus, which includes significant updates regarding sustainability skills, innovation, globalisation, acceleration, and digitalisation experiences. Additionally, the importance of confronting uncertainty has been emphasised. However, there is still a gap in understanding the concept of resilience and how to properly prepare engineering students, educators, and institutions for it. Developing anticipatory perspectives and a forward-thinking mindset is essential for tackling global challenges and adapting to the rapid changes brought about by digital trends.

Table 3. Summary of findings, building on students’ perceptions

Students’ perceptions		
Industry competencies	**Students’ skills**	**Academic ability**
Skills Required to Meet Future Demands and Remain Competitive	Design thinking, Creativity, Management, Leadership, Problem-solving, AI, Resilience	Systematic problem-solving techniques in design combine scientific and technological skills with personal creativity and judgment gained from experience.
Higher education institutions (HEI´s) need to enhance their ability to meet the needs of the industry.	Feedback, Collaboration with Industry, AI, educating teachers, practical skills, working with others, and the faculty environment.	Higher education institutions (HEIs) must improve their understanding of industry needs.

Students must develop skills that will keep them an attractive part of the workforce.	User experience, Knowledge integrations in different engineering domains, Communication skills, Creative thinking, Project management, and social skills	Academic capability must incorporate more AI in education to adapt to the new digital era. Teachers should create flexible and confident learning environments.
Skills Relevant to Aligning with Global Industry Demand for Engineers	User experience, AI (8), Design Thinking, *Resilience*, Collaboration, and making decisions fast.	The ability to strengthen partnerships with industry for academic purposes.
Unnecessary skills result in inefficient use of resources and capabilities.	Material calculations and stress analysis by hand. Learning many formulas that feel inapplicable, Entrepreneurship	Students asserted the critical necessity of integrating AI into education to navigate the digital era effectively. Students underscored the urgent need for comprehensive teacher training and the establishment of flexible faculty environments to facilitate this essential transition.
Recommendations for the Education of the Future	Focus on creativity and Problem-solving. Integrate Industry and research, collaboration with industry, AI,	The academic emphasis on understanding customer needs is crucial for improving product quality.
Desired skills that companies will need in 5-10 years	User needs, quality improvement, AI, design thinking, creativity, good communication, and decisiveness.	Academies must integrate research to solve industrial challenges and achieve resilience and sustainable outcomes.

The study revealed that innovation and systems are faster than ten years ago. However, we still face challenges in educating engineering students with practical skills instead of just theoretical knowledge, which is increasingly demanded. The study revealed that students find engineering theory often requires memorisation of formulas for exams, making it difficult for them to connect this theory to practical problem-solving and real-world engineering practice. This disconnect was highlighted in students' perspectives on teaching and learning by Crawley et al. (2014), and surprisingly, it remains an issue even after a decade. Students perceive a disconnect between practical skills and theoretical knowledge, expressing concerns that they must "learn so many formulas that feel inapplicable" and that "material calculations and stress analysis by hand are unnecessary skills" (A3-14). This suggests that engineering educators may neglect critical pedagogical needs, placing significant pressure on academics to provide education that effectively meets industrial competencies. For instance, students indicate that even digital learners face this gap, highlighting the need for institutions and educators to rethink their teaching approaches. In this context, resilience can be more accurately described as resistance to change.

The study highlighted a crucial aspect of AI and digitalisation: the need for education on effectively managing Artificial Intelligence (AI). Students stressed the importance of teaching proactive strategies for using AI instead of merely making its use "illegal" (A11). Engaging industrial engineering students with resilience thinking is vital to help them adapt quickly to new systems and understand how they change (A10).

The study revealed that students desire the ability to understand past and future trends. As noted by A10, “With the willingness to learn both old and new work trends, it is clear how digitalised the world is becoming over time.” This perspective aligns with the CDIO syllabus V3 (4.1.4), emphasising that students should be aware of historical and cultural contexts. Additionally, students continue to face challenges with leadership and social skills, particularly in communication within international environments. This is especially true for those who struggle to adapt to new educational systems that feature multicultural settings.

Implications
Collaboration with Industry: Students emphasise that collaboration with industry is crucial for their education. Understanding the needs of both industry and society is essential for becoming a successful engineer. In addition to technical skills, management and business skills are also necessary. Students mentioned that efficiently organising work materials is critical, and the ability to do so using AI is increasingly valuable (A8, A11, and A16).

Academic ability: Feedback plays a vital role in educational development. Higher Education Institutions (HEIs) should support students by guiding them and creating an environment where they can express their ideas without fear of criticism. It is essential for students to feel safe to explore and innovate.

Future research must incorporate students' perceptions of the resilience of Higher Education Institutions (HEIs) strategies in the present study, with research demonstrating that building competence and reliability for future employers is required—comparative studies that demonstrate the integration of the different perspectives from relevant stakeholders: students, academics and industry managers. The sample size of 17 responses limited the study. Future research should aim to increase the number of responses to enable more in-depth analysis.

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REFERENCES

Bäckstrand J, Johansen K, Löfving M. (2022). Mutual Benefits-Linking SMEs in the Wood Industry and HEIs Using a Translator. Swedish Production Symposium, Sweden 2022

Barak, M. (2017). “Science Teacher Education in the Twenty-First Century: A Pedagogical Framework for Technology-Integrated Social Constructivism.” Research in Science Education 47 (2): 283–303

Barnett, R., & Jackson, N. (2020). Ecologies for learning and practice. London: Routledge.

Bryman, A. & Bell, E. (2011). Business Research Methods, Oxford University Press, Oxford.

Campos DB, Resende LM, Fagundes AB. (2020). Soft Skills by Engineering Employers. Creative. Education,11:2133-2152

Carter, A. (2020). “In Search of the Ideal Tool for International School Teachers to Increase Their Global Competency: An Action Research Analysis of the Global Competency Learning Continuum. Journal of Research in International Education 19 (1): 23–37.

Catelani, M., Ciani, L., Guidi, G., & Patrizi, G. (2021). Reliability Allocation: an iterative approach for complex systems. In 2021 IEEE International Symposium on Systems Engineering (ISSE) (pp. 1-6). IEEE.

Catelani, M., Ciani, L., Guidi, G., & Patrizi, G. (2021). Reliability Allocation: an iterative approach for complex systems. In 2021 IEEE International Symposium on Systems Engineering (ISSE) (pp. 1-6). IEEE.

Ciolacu, M., Alves, G., Terkowsky, C., Zoubi, A., Boettcher, K., Pozzo, M., & Kist, A. (2023). Developing future skills in engineering education for industry 5.0: enabling technologies in the age of digital transformation and green transition. In International Conference on Remote Engineering and Virtual Instrumentation (pp. 1019-1031). Cham: Springer Nature Switzerland.

Coe-Nesbitt, H. A., Soleas, E. K., Moucessian, A. M., Arghash, N., & Kutsyuruba, B. (2021). Conceptualizing thriving: An exploration of students' perceptions of positive functioning within graduate education. In Frontiers in Education (Vol. 6, p. 704135). Frontiers Media SA.

Commission E, Employment, Social Affairs & Inclusion (2023). European Commission. 13 10 Available https://ec.europa.eu/social/main.jsp?catId=1607&langId=en.

Cooper, M. M., & Sandi-Urena, S. (2009). Design and validation of an instrument to assess metacognitive skillfulness in chemistry problem-solving. Journal of Chemical Education,86(2), 240

Crawford, E. O., H. J. Higgins, & J. Hilburn. (2020). "Using a Global Competence Model in an Instructional Design Course Before Social Studies Methods: A Developmental Approach to Global Teacher Education." Journal of Social Studies

Crawley, F., Malmqvist, J., Sören, Ö., Brodeur, D., Edström, K. (2014) Rethinking Engineering Education. The CDIO approaches second edition. Springer Cham Heidelberg New York Dordrecht London.

Creswell, J. W., & Poth, C. N. (2016). Qualitative inquiry and research design: Choosing among five approaches. Sage publications

Edmondson, V., & Sherratt, F. (2022). Engineering judgement in undergraduate structural design education: enhancing learning with failure case studies. European Journal of Engineering Education, 47(4), 577–590.

Farley-Ripple, E., May, H., Karpyn, A., Tilley, K., & McDonough, K. (2018). Rethinking connections between research and practice in education: A conceptual framework. Educational Researcher, 47(4), 235-245.

Fisher, P. B., & McAdams, E. (2015). Gaps in sustainability education: The impact of higher education coursework on perceptions of sustainability. International Journal of Sustainability in Higher Education, 16(4), 407–423.

Foley, M., Foley, J. T., & Kyas, M. (2022). Embracing failure is an integral aspect of engineering education. 18th International CDIO Conference, Reykjavik, Iceland: Reykjavik University.

Folke, C. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. Global Environmental Change, 16(3), 253–267.

Folke, C., Carpenter, S., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience Thinking: Integrating Resilience, Adaptability and Transformability. Ecology and Society, 15(4).

Gasser, P., Lustenberger, P., Cinelli, M., Kim, W., Spada, M., Burgherr, P., . . . Sun, T. Y. (2021). A review on resilience assessment of energy systems. Sustainable and Resilient Infrastructure, 6(5), 273-299.

Gephart, R.P. (2004), "Qualitative research and the academy of management journal", Academy of Management Journal, Vol. 47 No. 4, pp. 454-462

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. Handbook of qualitative research, 2(163-194), p. 105.

Hazrat, M. A., Hassan, N. M. S., Chowdhury, A. A., Rasul, M. G., & Taylor, B. A. (2023). Developing a skilled workforce for future industry demand: The potential of digital twin-based teaching and learning practices in engineering education. Sustainability, 15(23), 16433.

Henriksson, F., Johansen, K., Wever, R., & Berry, P. (2016). Student-developed laboratory exercises- An approach to cross-disciplinary peer education. DS 85-2: Proceedings of NordDesign 2016, Volume 2, Trondheim, Norway, 10th-12th August 2016, 226-235.

Huet, I. (2018). “Research-based Education as a Model to Change the Teaching and Learning Environment in STEM Disciplines.” European Journal of Engineering Education 43 (5): 725–740.

Jain, Prerna, Efstratios N. Pistikopoulos, and M. Sam Mannan. (2019) "Process resilience analysis-based data-driven maintenance optimization: Application to cooling tower operations." Computers & Chemical Engineering 121, 27-45.

Jesiek, B. K., Q. Zhu, S. E. Woo, J. Thompon, and A. Mazzurco (2014). “Global Engineering Competency in Context: Situations and Behaviors.” Online Journal of Global Engineering Education 8 (1): 1.

Kafri, B. A. (2022). Critical thinking (CT) in sustainable higher education: Ensuring consistent CT perception-practice and identifying gaps between college instructors' and students' perceptions in advanced academic writing courses in the UAE. Thinking Skills and Creativity, 46, 101182.

Kerkhoff, S. N., and M. E. Cloud. (2020). “Equipping Teachers with Globally Competent Practices: A Mixed Methods Study on Integrating Global Competence and Teacher Education.” International Journal of Educational Research 103:101629.

Kirn, A., & Benson, L. (2018). Engineering students' perceptions of problem-solving and their future. Journal of Engineering Education, 107(1), 87-112.

Kirn, A., Faber, C. J., & Benson, L. C. (2014). Engineering students’ perceptions of the future. Proceedings of the American Society for Engineering Education 2014 Annual Conference, Indianapolis

Kjellgren, B., and T. Richter. (2021). “Education for a Sustainable Future: Strategies for Holistic Global Competence Development at Engineering Institutions.” Sustainability 13 (20): 11184

Klaassen, R. G., Hellendoorn, H., & Bossen, L. (2023). Transforming Engineering Education in Learning Ecosystems for Resilient Engineers. IEEE Transactions on Education.

Kohlbeck E, et al. (2021). Engineering skills: Systematic Review in the Field of Professional Ethics,” Scientific Research Publishing, 2021 Aug;(12):2335-2355,

Leandro M, Gillian N, Saunders S, Pim G. (2020). Evaluation of competency methods in engineering education systematic review, European Journal of engineering education. 45(5):729-757.

Mäntylä, M. V., Graziotin, D., & Kuutila, M. (2018). The evolution of sentiment analysis—A review of research topics, venues, and top cited papers. Computer Science Review, 27, 16-32.

McCracken, W. M., & Newstetter, W. C. (2001). Text to diagram to symbol: Representational transformations in problem-solving session F2G. American Society of Engineering Education and Frontiers in Education Conference (pp. 13–17)

Mishra, S., & Dey, A. K. (2022). Understanding and identifying ‘themes’ in qualitative case study research. South Asian Journal of Business and Management Cases, 11(3), 187-192

Pawar, B., Park, S., Hu, P., & Wang, Q. (2021). Applications of resilience engineering principles in different fields focusing on industrial systems: A literature review. Journal of Loss Prevention in the Process Industries, 69, 104366.

Peng, P., & Kievit, R. A. (2020). The development of academic achievement and cognitive abilities: A bidirectional perspective. Child Development Perspectives, 14(1), 15-20.

Report, Teknikföretagen Kompetensunder-Söking, (2022) Sweden. Research 44 (4): 367–381.

Richter, T., & Kjellgren, B. (2023). Engineers of the future: student perspectives on integrating global competence in their education. European Journal of Engineering Education, 49(3), 474–491.

Rico-Cortez, M., Andersson, N. E., & Johansen, K. (2024). Exploring the Industrial Engineering Competences in the Changing Landscape of the New Industrial Revolution. In Sustainable Production through Advanced Manufacturing, Intelligent Automation and Work Integrated Learning (pp. 672-686). IOS Press.

Rockström, J., Norström, A. V., Matthews, N., Biggs, R., Folke, C., Harikishun, A., Nel, D. (2023). Shaping a resilient future in response to COVID-19. Nature Sustainability, 6(8), 897-907

Saldana, J. (2013). The coding manual for qualitative researchers. SAGE Publications

Scharte, B. (2021). Resilience Engineering: Oder von der Kunst, in der zivilen Sicherheitsforschung mit Komplexität umzugehen (Vol. 4). Nomos Verlagsgesellschaft mbH & Co. KG

Sterling, S. (2014). Separate tracks or real synergy? Achieving a closer relationship between education and SD, post-2015. Journal of Education for Sustainable Development, 8(2), 89–112.

Strauss, A., & Corbin, J. (1990). Basics of qualitative research (Vol. 15). Newbury Park, CA: sage

UNESCO Snapshots, (2021). https://unesdoc.unesco. org/ark:/48223/pf0000381065

Van den Beemt, A., et al. (2020). “Interdisciplinary Engineering Education: A Review of Vision, Teaching, and Support.” Journal of Engineering Education 109 (3): 508–555.

Walker, B. (2020). Resilience: what is and is not. Ecology and Society, 25(2).

Walker, B., & Salt, D. (2006). Resilience thinking. Sustaining Ecosystems and People in a Changing World. Island Press.

Walker, B., Holling, C. S., Carpenter, S., & Kinzig, A. (2004). Resilience, Adaptability and Transformability in Social-ecological Systems. Ecology and Society, 9(2).

Wang, J., G. H.-L. Cheng, T. Chen, and K. Leung. (2019). “Team Creativity/Innovation in Culturally Diverse Teams: A Meta-Analysis.” Journal of Organizational Behavior 40 (6): 693–708

Winberg C, Bramhall M, Greenfield P, Johnson P, Rowlett O, Waldock J, Wolff K. (2020). Developing employability in engineering education: a systematic review of the literature. European Journal of Engineering Education, 165-180.

Winberg C., Branhall M, Greenfield P, Johnson P, Rowlett O, Waldock J, Wolff K. (2020). Developing employability in engineering education: a systematic review of the literature. European Journal of Engineering Education, 165-180

Winkens, A., & Leicht-Scholten, C. (2021). Resilience as a key competence in engineering education – conceptual framework development. SEFI 49th Annual Conference 2021: Blended Learning in Engineering Education: challenging, enlightening – and lasting? (pp. 628–636). Berlin, Germany: TU Berlin (online).

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APPENDIX 1: SURVEY QUESTIONS

Skills to Improve	**Higher Education Institutions (HEIS) should work on improving their programs and practices.**	**Skills the Industry Seeks or Desires**
What other (like “soft”) or engineering skills should students have to increase their competitiveness in the industry?	How could the Higher Education Institutions (HEIs) improve the preparation of tomorrow´s engineers?	What skills does the industry or (research project) currently look for in engineers?
Which skills, categorised as soft or hard, are considered unnecessary in engineering education?	From your perspective, what are the anticipated skills or competencies, such as digital skills, sustainability, AI expertise, and circularity, that companies will require in the next 5 to 10 years?	What skills do you want to develop or improve for your daily work?
		Desired skills that companies will need in 5-10 years