Developing a Curriculum for the Fourth Industrial Revolution in Electrical Engineering Education

T. K. Magenuka[1] and M. Sibanda[2]

[1] Mangosuthu University of Technology, Durban, South Africa
magenuka@mut.ac.za

Abstract. The Fourth Industrial Revolution (4IR) is a global phenomenon that brings advancements in artificial intelligence, the Internet of Things (IoT), blockchain, and robotics. It has brought about radical changes in societal and economic structures, necessitating the re-evaluation of curricula across various disciplines, including electrical engineering. Electrical engineering education needs to adapt to the changing demands and opportunities of the 4IR era. By aligning the curriculum with the emerging needs of industry and society, educational institutions can effectively prepare future electrical engineering students to contribute to and lead the transformative changes brought by the 4IR. This paper explores the necessary adaptations and enhancements required in electrical engineering education to align with the transformative impact of the 4IR. It reviews/evaluates the implications of the 4IR on the field of electrical engineering and identifies the key knowledge areas, skills, and competencies that need to be incorporated into the curriculum. By analysing existing literature, the emerging technologies, trends, and challenges in electrical engineering that are driven by the 4IR are identified. The research also explores pedagogical approaches and instructional methods that can effectively equip electrical engineering students with the necessary skills and competencies to thrive in the 4IR era. This includes examining innovative teaching methodologies, such as project-based learning, hands-on experiences, and interdisciplinary collaboration, to foster critical thinking, problem-solving, and adaptability. The paper proposes a framework for designing a 4IR-oriented curriculum that incorporates interdisciplinary, project-based, problem-solving, and collaborative learning approaches. It also discusses the role of digital technology, industry partnerships, and social responsibility in enhancing the quality and relevance of electrical engineering education. The paper concludes with some recommendations for implementing and evaluating the proposed curriculum.

Keywords: Fourth Industrial Revolution (4IR), Electrical Engineering Education, Curriculum development.

M. Makua et al. (eds.), Proceedings of the 10th Focus Conference (TFC 2023), Advances in Social Science, Education and Humanities Research 788,
https://doi.org/10.2991/978-2-38476-134-0_19

1 Introduction

The Fourth Industrial Revolution (4IR) has ushered in a new era of technological advancements and societal transformations, presenting both opportunities and challenges across various industries. As we embrace the potential of this revolution, it becomes increasingly important to examine its implications for education, particularly in the context of electrical engineering education. In the field of electrical engineering education, it is imperative to develop a curriculum that adequately prepares students for the demands and complexities of this rapidly evolving revolution [1]. This paper aims to explore the impact of the 4IR on educational practices and curricula in the field of electrical engineering, seeking to identify the necessary adaptations to equip future engineering personnel with the skills and knowledge required to thrive in this dynamic landscape.

The 4IR is characterized by advancements in artificial intelligence, automation, the Internet of Things (IoT), big data analytics, and renewable energy technologies, among others. These technological breakthroughs have the potential to reshape industries and create new challenges and opportunities for professionals in various domains, including electrical engineering. Therefore, to ensure that graduates remain at the forefront of innovation and can address complex real-world problems, educational institutions must adapt their curricula to meet the demands of the 4IR.

In addition to the above, the electrical engineering curriculum is influenced by other factors that reflect the needs of industry, technological advancements, educational goals, and broader economic, environmental, and societal considerations. These needs must all be encompassed by the curriculum which needs to meet the accreditation standards set by its statutory professional body. The current curriculum fails in some areas to meet the requirements of the 4IR. Future graduates should not only possess electrical engineering skills but must be multidisciplinary as well as have entrepreneurial skills to meet the requirements of the 4IR, future jobs, and alleviate the current skills challenge experienced by the industry.

By addressing the specific challenges and demands posed by the 4IR, the curriculum for electrical engineering education can foster a multidisciplinary approach that integrates cutting-edge technologies, ethical considerations, and sustainable practices. This requires a comprehensive understanding of the evolving industry landscape, emerging trends, and the ethical implications associated with the use of advanced technologies in engineering.

Furthermore, the curriculum development process must consider the evolving needs of industries and employers, ensuring that graduates possess technical expertise and critical thinking, problem-solving, communication, and collaboration skills. The curriculum should provide students with hands-on experiences, industry collaborations, and opportunities to apply their knowledge in real-world scenarios.

This paper will delve into the key aspects involved in developing a curriculum for the Fourth Industrial Revolution in electrical engineering education. We will explore the necessary adaptations and enhancements required, discuss pedagogical approaches that facilitate effective learning in this context, and address the ethical, social, and environmental considerations associated with engineering practices in the 4IR. By doing so, this research aims to contribute to the ongoing discussions and initiatives aimed at equipping electrical engineering students with the competencies required to succeed in the era of the Fourth Industrial Revolution.

2 Theoretical Background

The Fourth Industrial Revolution (4IR) is expected to bring significant transformations to numerous industries, with potential implications on the roles and skill sets required in the workplace. One domain that is particularly impacted is education, and more specifically, electrical engineering education. Given the nature of the 4IR, with its emphasis on technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Machine Learning, Big Data, Cloud, and Edge Computing, it is clear that the nature of electrical engineering education needs to and will inevitably evolve to equip students with the skills needed in this new industrial landscape [1], [2].

2.1 4IR Impact on Electrical Engineering

The 4IR brings about a confluence of technologies and trends that are dramatically impacting many fields, including electrical engineering [3]. A summary of some technologies, trends, and changes associated with the 4IR that impact the field of electrical engineering is provided in Table 1.

Table 1. Summary of specific technologies, trends, and changes associated with the 4IR that impact the field of electrical engineering.

Technology/Trend	Impact on Electrical Engineering
Internet of Things (IoT)	IoT involves the integration of numerous devices and sensors, all communicating with each other. Electrical engineers design and optimize these electronic systems for efficient communication and interoperability [4]–[6].
Robotics	The design, construction, and application of robots involve complex electrical systems. Robotics, as part of 4IR, provides electrical engineers with opportunities to design and optimize these systems [4], [5].
Virtual Reality (VR) and Artificial Intelligence (AI)	Both VR and AI offer new possibilities for electrical engineering, including the design of hardware and software systems to support these technologies [2], [4].
High-Speed Mobile Internet	This technology enables the fast transmission of vast amounts of data, necessitating robust and efficient networks. Electrical engineers play a crucial role in the design and optimization of these networks [5].
Big Data Analytics	Electrical engineers are instrumental in developing the hardware and software systems necessary for collecting, storing, and processing big data, which is essential in the era of 4IR [5].
Cloud Technology	This technology has transformed how data is stored and accessed, creating opportunities for electrical engineers to design and optimize the

	hardware and software systems that support cloud infrastructure [5].
Blockchain Technology	This decentralized and secure way of storing and sharing information requires robust and reliable electronic systems, which are designed and optimized by electrical engineers [5], [7].
Nanotechnology	Electrical engineers are needed for the development and application of nanotechnologies, which can involve creating microchips and other electronic components at a nanoscale [5].
Biotechnology	As biotechnology increasingly interfaces with electronics (e.g., in the development of medical devices or bio-sensors), electrical engineers are needed to design and optimize these hybrid systems [5].
Automated Production and 3D Printing	As production tasks are increasingly handled by new technologies like factory automation and 3D printing, electrical engineers are left to focus more on design work. This shift necessitates new skills in design-oriented engineering [5].
Quantum computing	This technology involves the use of quantum physics to perform computations that are beyond the capabilities of classical computers. For example, quantum computing can help electrical engineers to solve complex optimization problems, simulate quantum systems, enhance cryptography, and accelerate machine learning.

As these technologies and trends continue to evolve, the role of electrical engineers in driving innovation in these areas will also continue to grow. The need for continual learning and upskilling will be critical for engineers to adapt to these changes and remain relevant in the 4IR era [5].

2.2 Implications of the Fourth Industrial Revolution on Electrical Engineering

The implications of the 4IR for education, particularly in the field of electrical engineering, are vast and transformative. As the world becomes increasingly interconnected and digitized, the role of electrical engineering personnel becomes even more critical in the design, development, and maintenance of innovative solutions that drive technological progress. Thus, electrical engineering education must adapt its curriculum to include these cutting-edge technologies, to provide students with the skills needed to survive in the transforming industrial landscape. Some of the implications are:

- Integration of Emerging Technologies: The 4IR demands that electrical engineering education stays abreast of the latest developments in emerging technologies. Electrical engineering curricula need to integrate subjects like AI, machine learning, data science, and cybersecurity to equip students with the skills required to tackle real-world challenges [9].
- Interdisciplinary Approach: With the convergence of various technologies, electrical engineering education must adopt an interdisciplinary approach.

Collaborations between electrical engineers and professionals from other disciplines like computer science, biology, and materials science will become more common to address complex problems [9].
- Adaptive and Flexible Curricula: The rapidly evolving nature of technology necessitates adaptive and flexible curricula. Electrical engineering programs should be agile enough to incorporate new advancements while ensuring a strong foundation in core principles [8].
- Focus on Problem-Solving and Critical Thinking: In the Fourth Industrial Revolution, memorization of facts becomes less important than the ability to think critically and solve problems creatively. Electrical engineering education should emphasize hands-on projects and practical experiences to develop these essential skills [10].
- Lifelong Learning: Continuous learning will be essential for electrical engineers to keep up with technological advancements throughout their careers. Institutes of higher education should encourage and facilitate lifelong learning opportunities for professionals in the field [11].
- Ethical Considerations: As technology becomes more pervasive, ethical considerations become paramount. Electrical engineering education must incorporate ethics courses to address issues like data privacy, AI bias, and social implications of technological innovations.
- Industry Partnerships and Experiential Learning: Collaborations with industries and companies are crucial to provide students with real-world exposure and hands-on experiences. Experiential learning opportunities, such as internships and industry projects, will help bridge the gap between academia and practical applications [12], [13].
- Focus on Sustainability and Green Technologies: The Fourth Industrial Revolution also brings with it a greater awareness of sustainability and environmental impact. Electrical engineering programs should emphasize green technologies and sustainable practices to address global challenges like climate change.
- Global Perspective and Cultural Sensitivity: As technology connects the world, electrical engineers need to work in diverse and multicultural environments. Education should foster a global perspective and cultural sensitivity to enable graduates to collaborate effectively in an interconnected world.

The 4IR brings both significant challenges and opportunities to the field of electrical engineering. Adapting the curriculum to align with the demands of the 4IR, fostering interdisciplinary learning, integrating technology in teaching methods, and promoting lifelong learning are vital steps to ensure that electrical engineering graduates are well-prepared to meet the demands of the rapidly evolving technological landscape.

3 Curriculum Development Considerations

Designing a curriculum involves a thoughtful and systematic approach to creating an effective educational program. It needs to align with the goals and objectives of the educational institution, meets the needs of the learners, and facilitates successful learning outcomes. A curriculum Selamat *et al.* [14] propose a curriculum structured as shown in Fig. 1.

Fig. 1. 21st-century curriculum for Higher Education 4.0 [14]

3.1 Curriculum Adaptations for 4IR

The following non-exhaustive list of competencies, knowledge areas, and skills will help electrical engineering graduates to thrive in the 4IR era and beyond:

- Soft Skills: Also known as 21st-century skills, these include communication, creativity, and problem-solving. These skills are essential for engineers to work effectively in teams, generate innovative solutions, and communicate their ideas clearly.
- Programming Skills: With the digital nature of the 4IR, programming skills have become increasingly important. These skills allow electrical engineers to write software, develop algorithms, and work with automated systems and digital technologies that are fundamental to the 4IR.
- Information Literacy: This is the ability to identify, locate, evaluate, and use information effectively. In the era of 4IR, electrical engineers need to deal with a vast amount of information from various sources, making information literacy crucial.
- Knowledge of Emerging Technologies: An understanding of technologies such as AI, IoT, robotics, and cloud computing, which are driving the 4IR.
- Systems Thinking: The ability to understand how different components of a system interact with each other, which is crucial for designing and optimizing complex electrical systems.
- Lifelong Learning: Given the rapid pace of technological advancement in the 4IR, engineers need to commit to continual learning and upskilling to

stay relevant.

The current electrical engineering curriculum has certain strengths and limitations in terms of preparing students for the Fourth Industrial Revolution (4IR) context. Some strengths are:

- Foundational Knowledge: The curriculum provides a solid foundation in fundamental concepts and principles of electrical engineering, such as circuit design and linear systems theory, which form the basis for understanding and applying 4IR technologies.
- Technical Skills: The curriculum emphasizes the development of technical skills, such as programming and hardware design, that are critical in the 4IR era. It exposes students to some of the software and programming tools that are widely used in electrical engineering practice, such as Proteus, Matlab, and Visual Studio. These tools enable electrical engineering students to design, simulate, test, and optimize electrical and electronic systems and products in the 4IR.
- Soft Skills: The curriculum provides opportunities for students to develop their problem-solving, critical thinking, communication, and collaboration skills. These are important soft skills for electrical engineering students to work effectively in multidisciplinary teams, communicate with clients and stakeholders, and tackle complex challenges.

Some of the limitations are [15], [16]:

- Limited Exposure to 4IR Technologies: The current curriculum does not provide sufficient exposure to emerging 4IR technologies such as AI, IoT, and cloud computing.
- Lack of Interdisciplinary Approach: The curriculum is typically focused on electrical engineering and does not offer enough interdisciplinary education to equip students with a broad understanding of how electrical engineering interacts with other disciplines, which is crucial in the 4IR context.
- Underemphasis on Soft Skills: Soft skills like communication, creativity, and problem-solving are essential for thriving in the 4IR, but they are underemphasized.
- Curriculum update: The curriculum is not updated frequently enough to keep pace with the rapid changes and innovations in electrical engineering technologies and applications in the 4IR. For example, some of the emerging topics that are not adequately covered in the current curriculum are blockchain, digital privacy, satellites, metaverse, and climate technologies.
- Curriculum Flexibility: The curriculum does not provide enough flexibility and choice for students to pursue their interests and passions in electrical engineering. For example, some students may want to specialize in a specific area of electrical engineering, such as micro- and nanoelectronics or systems engineering, or explore other disciplines that are related to electrical engineering.
- Lack of Emphasis on Ethics and Engineering Impact: The curriculum does not emphasize enough the ethical, social, environmental, and economic implications of electrical engineering technologies and solutions in the

4IR. For example, some of the issues that electrical engineers may need to consider are data privacy and security, energy efficiency and sustainability, digital inclusion and accessibility, and social responsibility and impact.

The necessary adaptations and enhancements required in the electrical engineering curriculum to align with the 4IR are:

- Incorporation of Emerging Technologies: The curriculum should include courses or modules on 4IR technologies, such as AI, IoT, and cloud computing.
- Promotion of Interdisciplinary Education: The curriculum should encourage students to explore courses in other disciplines, particularly those that intersect with electrical engineering in the 4IR context.
- Increased Emphasis on Soft Skills: The curriculum should emphasize the development of soft skills, potentially through project-based learning or team assignments.
- Integration of Industry-Relevant Skills: The curriculum should include hands-on experiences, internships, or capstone projects or Makerspaces [16] that allow students to apply what they have learnt in real-world settings.
- Promotion of Continual Learning: Given the rapid pace of technological change, the curriculum should instill in students the importance of lifelong learning.

To effectively integrate emerging technologies, interdisciplinary knowledge, and industry-relevant skills into the curriculum, universities should collaborate with industry partners, update their resources and infrastructure, and provide faculty with professional development opportunities in 4IR-related technologies. They should also consider adopting innovative instructional strategies, such as project-based learning and flipped classrooms, that can foster the development of both technical and soft skills.

3.2 Pedagogical Approaches:

To address the 4IR challenges in electrical engineering education, innovative pedagogical approaches are critical for enhancing the teaching and learning process. Some of the approaches that may be considered are:

- Project-Based Learning (PBL): PBL offers a dynamic approach to teaching in which students can explore real-world problems and challenges. In the context of electrical engineering education, PBL can help students to apply their theoretical knowledge to practical problems, fostering a deeper understanding of 4IR technologies. Through PBL, students can work on projects involving AI, IoT, or machine learning, for example, which enhances their problem-solving skills and creativity.
- Hands-On Experiences [17]: These include laboratory work and internships. These experiences can provide students with a tangible understanding of electrical engineering concepts and 4IR technologies. This not only helps students to solidify their understanding but also equips them with

practical skills necessary for the industry.

- Technology Integration: This could include the use of digital tools and platforms for teaching and learning, as well as incorporating technologies like AI, and IoT into the curriculum. This allows students to learn about these technologies in a hands-on way and prepares them for their future roles in the industry.
- Blended Learning: This involves combining traditional face-to-face teaching methods with online learning. This approach can help to accommodate a wider range of learning styles and can also give students the flexibility to learn at their own pace. This could be particularly beneficial when teaching complex 4IR technologies.
- Adaptive Learning: Adaptive learning technologies can provide personalized learning experiences for students, adjusting the pace and level of difficulty based on each student's performance. This approach can help to ensure that all students are challenged and supported in their learning.

These innovative pedagogical approaches can offer a more interactive and engaging learning environment, which is crucial in preparing students for the 4IR. However, it's important to note that the successful implementation of these approaches requires institutional support, adequate resources, and professional development opportunities for faculty members. Also, these approaches must be complemented by a curriculum that is continuously and frequently updated to reflect the latest developments in the field of electrical engineering and the demands of the 4IR.

4 Curriculum Design and Evaluation

The development of the curriculum must be systematic and focused, and have a distinct vision and mission. It must be carried out in line with the broader institutional and thus national education direction [19]. A basic decision-making model [20] is presented in Fig. 2, which consists of seven questions that provide answers to the curriculum development and design as well as its implementation.

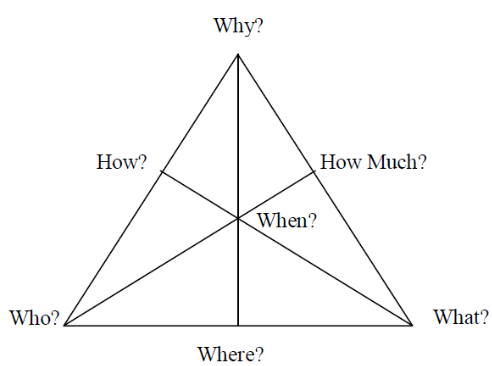

Fig. 2. Curriculum planning and design decision-making model [19]

The *Why?* question requires the specification of the aims and goals.

The *What?* question demands informed decision-making concerning the content of education/learning, that is expected to produce the desired knowledge, skills, and broader integrated competencies of the students.

The *Who?* question requires an analysis of the students and lecturers involved in the learning process.

The *How?* question requires specifying the potential methods of teaching and learning that can be used for the acquisition of the selected learning content.

The *How Much?* question requires specifying time as a resource allotted for learning in hours, courses, etc.

The *Where?* question requires the identification of the learning environments necessary for the acquisition of the selected content.

Finally, the *When*? question forms the basis for an interdisciplinary approach that integrates the content, organises the learning experiences, and provides the sequence of activities for implementing the curriculum, educational reforms, or projects.

Developing the curriculum for the 4IR involves several key strategies, each requiring careful planning and execution. Here are some steps based on the general principles of curriculum development and implementation [21]–[27]:

1. Identifying Needs: Start by identifying the current gaps in the curriculum related to ethical implications, social responsibilities, and environmental sustainability considerations in electrical engineering for the 4IR. Consultation with faculty, students, and industry experts can help identify these gaps.
2. Form a Curriculum Development Team: This team could include faculty members, curriculum experts, industry professionals, and potentially even student representatives. The team will oversee the process of revising the curriculum and ensuring it aligns with the identified needs.
3. Define Learning Outcomes: Clearly articulate the learning outcomes you want to achieve with the new curriculum. For example, students should understand the ethical implications of their work, recognize their social responsibilities, and be able to create environmentally sustainable solutions.
4. Develop Content and Methods: Once learning outcomes are established, the next step is to develop the content and methods to achieve them. This could include new courses, adjustments to existing courses, new teaching methodologies, and hands-on experiences.
5. Implement the Changes: Implement the new curriculum, providing faculty with the necessary training and resources. It might be beneficial to implement changes gradually, starting with pilot classes or modules, and then scaling up based on feedback and results.
6. Evaluate and Report: Ongoing evaluation is crucial for assessing the effectiveness of the new curriculum. Collect feedback from students and faculty, assess student performance, and regularly review these findings with the curriculum development team.

Methods for evaluating the effectiveness of the proposed curriculum changes could include:

- Student Performance: Assess students' understanding of ethical implications, social responsibilities, and environmental sustainability through assignments, projects, and exams. These assessments should be specifically designed to measure the intended learning outcomes.

- Student Feedback: Regularly collect feedback from students about the new curriculum. This could be done through surveys or in-class discussions.
- Faculty Feedback: Faculty can provide valuable insights about how well the new curriculum is working. Regularly consult with faculty and adjust the curriculum based on their feedback.
- Post-Graduation Tracking: Track students' career trajectories after graduation to see how well the new curriculum is preparing them for the realities of the field. This could include surveys of graduates, feedback from employers, or tracking graduates' contributions to the field.

All these steps and methods should be continuously reviewed and adjusted as necessary to ensure the curriculum remains relevant and effective in the rapidly evolving context of the 4IR.

5 Curriculum Implementation Challenges and Solutions

Implementing the proposed curriculum changes for the 4IR in electrical engineering education may encounter challenges and barriers. Some of the challenges and possible solutions are as follows:

- Financial resources: The proposed curriculum changes may require additional financial resources, such as funding for new equipment, software, and faculty development. The University, government, and industry partners can be the source of funding for the implementation of the proposed curriculum changes.
- Faculty development: Faculty members may need to be trained on the new technologies and pedagogical approaches. This training can be costly and time-consuming. There is a need for universities to provide faculty development opportunities, such as workshops and conferences, to help faculty members learn about new technologies and pedagogical approaches.
- Industry partnerships: Industry partnerships can be helpful in providing students with hands-on experience and exposure to real-world problems. However, these partnerships can be difficult to establish and maintain. Universities can and should reach out to industry partners to establish partnerships that will provide students with hands-on experience and exposure to real-world problems.
- Resistance to change: There may be resistance to change from some students, faculty members, and stakeholders. This resistance can be overcome by providing clear and convincing arguments for the need for change. Universities should communicate the need for change to students, faculty members, and other stakeholders. They should also provide opportunities for feedback and discussion to address concerns about the proposed curriculum changes.
- Timeframe: It may take several years to fully implement the proposed cur-

riculum changes. This is due to the time it takes to develop new courses, train faculty members, and make other changes to the curriculum. Universities must develop a timeline for the implementation of the proposed curriculum changes to help to ensure that the changes are implemented in a timely and orderly manner.

Despite these challenges, it is the authors' belief that the proposed curriculum changes are necessary to prepare electrical engineering graduates for the 4IR. The 4IR is a rapidly changing environment, and electrical engineering graduates need to be equipped with the skills and knowledge to adapt to these changes. The proposed curriculum changes will help to ensure that electrical engineering graduates have the skills and knowledge they need to succeed in the 4IR. By working together, the various stakeholders can overcome the challenges of implementing the proposed curriculum changes and prepare electrical engineering graduates for the 4IR.

6 Conclusion

This paper has explored the necessary adaptations and enhancements required in electrical engineering education to align with the transformative impact of the 4IR. It has reviewed/evaluated the implications of the 4IR on the field of electrical engineering and identified the key knowledge areas, skills, and competencies that need to be incorporated into the curriculum. By analysing existing literature, the emerging technologies, trends, and challenges in electrical engineering that are driven by the 4IR have been identified. The research has also explored pedagogical approaches and instructional methods that can effectively equip electrical engineering students with the necessary skills and competencies to thrive in the 4IR era. This includes examining innovative teaching methodologies, such as project-based learning, hands-on experiences, and interdisciplinary collaboration, to foster critical thinking, problem-solving, and adaptability.

The paper has proposed a framework for designing a 4IR-oriented curriculum that incorporates interdisciplinary, project-based, problem-solving, and collaborative learning approaches. It has also discussed the role of digital technology, industry partnerships, and social responsibility in enhancing the quality and relevance of electrical engineering education. The paper concludes with some recommendations for implementing and evaluating the proposed curriculum.

The ethical implications, social responsibilities, and environmental sustainability aspects related to electrical engineering practice in the 4IR require investigation and also have to be integrated into the curriculum.

In conclusion, the 4IR is a major challenge and opportunity for electrical engineering education. By adapting the curriculum to the changing demands of the 4IR, educational institutions can prepare future electrical engineering students to be successful in this new era.

References

1. K. Menon and G. Castrillón, "Reimagining curricula for the Fourth Industrial Revolution," *The Independent Journal of Teaching and Learning*, vol. 14, no. 2, pp. 6–19, 2019.
2. Lupanda, "The Impact of 4IR Technology Advancement on the Engineering Sector," 2020. https://www.polity.org.za/article/the-impact-of-4ir-technology-advancement-on-the-engineering-sector-2018-11-28 (accessed Jul. 30, 2023).
3. ECSA, "Impact of the Fourth Industrial Revolution on Engineering Technology Education Programmes," Apr. 2022. [Online]. Available: www.ecsa.co.za
4. B. Alsulaimani and A. Islam, "Impact of 4IR Technology and its Impact on the Current Deployment," International Journal of Computer Science and Information Technology, vol. 14, no. 4, pp. 53–67, Aug. 2022, doi: 10.5121/ijcsit.2022.14405.
5. A. Patel, "How the 4IR will impact the engineering profession?," 2019. https://chro.co.za/articles/how-the-4ir-will-impact-the-engineering-profession/ (accessed Jul. 30, 2023).
6. McKinsey, "What is industry 4.0 and the Fourth Industrial Revolution?," 2022.https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-are-industry-4-0-the-fourth-industrial-revolution-and-4ir (accessed Jul. 30, 2023).
7. N. Ndung'u, "The Fourth Industrial Revolution and digitization will transform Africa into a global powerhouse | Brookings," 2020. https://www.brookings.edu/articles/the-fourth-industrial-revolution-and-digitization-will-transform-africa-into-a-global-powerhouse/ (accessed Jul. 30, 2023).
8. T. Marwala, "Education in the fourth industrial revolution - University of Johannesburg," 2020. https://www.uj.ac.za/news/education-in-the-fourth-industrial-revolution/ (accessed Jul. 30, 2023).
9. W. S. Bainbridge and M. C. Roco, "Science and technology convergence: with emphasis for nanotechnology-inspired convergence," J. Nanoparti-cle Res., vol. 18, no. 7, 2016.https://doi.org/10.1007/s11051-016-3520-0
10. N. W. Gleason, "Higher Education in the Era of the Fourth Industrial Revolution," High. Educ. Era Fourth Ind. Revolut., pp. 1–229, 2018.
11. W. Naudé, "Entrepreneurship, Education and the Fourth Industrial Revolution in Africa," IZA Discuss. Pap. No. 10855, no. 10855, pp. 1–25, 2017.
12. S. Ward, "The Impact of Shared Leadership on a Career and Technical Education Campus," vol. 13, no. 1, 2017.
13. M. A. Gottfried and J. S. Plasman, "Linking the Timing of Career and Technical Education Coursetaking With High School Dropout and Col-lege-Going Behavior," Am. Educ. Res. J., vol. 55, no. 2, pp. 325–361, 2018.
14. A. Selamat, R. A. Alias, S. N. Hikmi, M. Puteh, and S. H. Tapsir, "Higher Education 4.0: Current Status and Readiness in Meeting the Fourth Industrial Revolution Challenges," in Redesigning Higher Education Towards Industry 4.0, Kuala Lumpur, 2017.

15. A. Al-Maskari, T. Al Riyami, and S. Ghnimi, “Factors affecting students’ preparedness for the fourth industrial revolution in higher education institutions,” Journal of Applied Research in Higher Education, 2022, doi: 10.1108/JARHE-05-2022-0169.
16. B. E. Penprase, “The fourth industrial revolution and higher education,” in Higher Education in the Era of the Fourth Industrial Revolution, Springer Singapore, 2018, pp. 207–228. doi: 10.1007/978-981-13-0194-0_9.
17. M. I. Carnasciali, S. M. Gillespie, and A. M. Hossain, “Integrating Makerspaces into the Curriculum - Faculty Development Efforts,” in Proceedings - Frontiers in Education Conference, FIE, Institute of Electrical and Electronics Engineers Inc., 2021. doi: 10.1109/FIE49875.2021.9637230.
18. E. J. Lavernia et al., “The Bridge: Linking Engineering and Society,” 2013. [Online]. Available: www.nae.edu/TheBridge.
19. A. Kosasih, H. Muljono, and S. Arifin, “Curriculum Development in the Industrial Revolution Era 4.0,” 2021.
20. U. Läänemets and T. Rüütmann, “Educational Decision-Making About Curriculum Development, Environments and Economics of Education,” in Proceedings of 2015 IEEE Global Engineering Education Conference (EDUCON) , 2015, pp. 764–767.
21. G. J. Mullen, “History and Analysis of Curriculum Thought, 1940-1975.,” in Annual Meeting of theAmerican Educational Research Association, 1975.
22. U. Wolz, G. Carmichael Shopify Ottawa, and A. Marie Webber, A Framework for Designing Contextualized Computing Curriculum.
23. R. Duarte, Â. L. Nobre, F. Pimentel, and M. Jacquinet, “Rethinking curriculum development through design thinking,” in 2021 4th International Conference of the Portuguese Society for Engineering Education, CISPEE 2021, Institute of Electrical and Electronics Engineers Inc., 2021. doi: 10.1109/CISPEE47794.2021.9507246.
24. J. W. Wiles and J. C. Bondi, Curriculum Development: A Guide to Practice. Pearson, 2015.
25. A. S. Adagale, “Curriculum Development in Higher Education,” International Journal of Applied Research , vol. 1, no. 11, pp. 602–605, 2015, [Online]. Available: www.allresearchjournal.com
26. H. Taba, Curriculum Development: Theory and Practice. Harcourt Brace Jovanovich, Inc, 1962.
27. A. Lucietto, M. Taleyarkhan, and E. Schott, “Engineering Technology Curriculum Development When Similar Programs are Limited,” in FIE Cincinnati 2019, 2019.