Rethinking engineering education outcomes in the light of Artificial Intelligence

Anné H. Verhoef
AI Hub, North-West University, South Africa, Anne.Verhoef@nwu.ac.za

Willem van Niekerk
Faculty of Engineering, North-West University, South Africa, Willem.vanNiekerk@nwu.ac.za

Jean du Toit
School of Philosophy, South Africa, JduToit@ufh.ac.za

Liezl van Dyk
Faculty of Engineering, South Africa, Liezl.vanDyk@nwu.ac.za

Abstract:

The deployment of LLMs (large language models) in AI (artificial intelligence) has led to a wide-spread increase in the use of AI in contemporary society, which will impact how teaching and learning takes place in higher education in the future. Since constructive alignment – which suggests that in curriculum design there should be a close alignment of teaching and assessments with intended outcomes – plays a crucial role in higher education teaching and learning, this paper examines how burgeoning AI technology reshapes such alignment considering both human and AI capabilities. The current paper investigates an undergraduate engineering curriculum to determine which tasks specified in module outcomes, as presented in the yearbooks (program portfolio), can 1) be delegated to AI, 2) are uniquely human, and 3) require a combination of human and AI capabilities. This categorization of outcomes will, be compared to the ECSA prescribed graduate attributes of the South African engineering student. The aim will be to determine which module outcomes and graduate attributes remain relevant in an AI-dominated pedagogical environment, and which have been usurped by the increasing competence and accuracy of AI systems, to future proof students in a changing technological landscape. We recommend that the outcomes and graduate attributes should be reformulated to incorporate the potential and risks of AI from the beginning.

Keywords: Artificial Intelligence, Outcomes, Graduate Attributes, ECSA.

1 Introduction:

Artificial Intelligence (AI) can be described as the field of computer science that focuses on the simulation of human intelligence. AI includes mainly two categories. The first is machine learning (ML) where algorithms are used to train computers. This includes natural language processing (understanding and generating human language), deep learning (ML uses neural networks computer models as inspired by the human brain), and computer vision (ML that enables computers to see and act on visual information). The second category of AI is Generative AI (GenAI) which creates new text, images, audio and video. This category includes Large Language Models (LLMs) (trained to analyse prompts to generate human-like responses) which we see in AI apps like ChatGPT, Claude, CoPilot and others. GenAI includes productivity tools like design programmes and virtual assistants like Siri or Alexa. In an educational environment, GenAI can be defined as:

> The development and deployment of computer systems or sophisticated algorithms in teaching-learning or research with the capabilities to perform tasks that would typically require human intelligence. These systems can analyse large amounts of data, identify patterns, formulate predictions, learn from experience, and automate complex processes. Put differently: the development of computer systems that can copy human behaviour.

This definition was taken from the NWU Policy for Academic Integrity and it is expanded on in the NWU Guidelines on the Responsible and Ethical Use of Artificial Intelligence, where the following definition of AI as LLMs are given:

> AI, as Large Language Models (LLMs) or Generative AI, is primarily defined as "a type of artificial intelligence that can learn from and mimic large amounts of data to create content such as text, images, music, videos, code and more, based on inputs and prompts" (https://huit.harvard.edu/ai#block-boxes-1687273052). AI may also include other AI tools such as research summarising tools, automatic data analysis tools, and creation of synthetic data tools (https://sajs.co.za/article/view/17147). AI is not restricted to this definition and with new AI tools constantly being developed, the use of other or new forms of AI should not be excluded from this definition.

In this article we will work with the category of AI as GenAI, and then specifically how it is defined in the higher education context in the examples above. AI is understood as a tool students should learn to use effectively, and it is not seen as something that functions without human guidance and intervention. The relationship between AI and humans is thus crucial in any subject field. We argue therefore that GenAI will fundamentally reshape contemporary higher education landscapes, particularly in terms of (re)defining the desired graduate outcomes we pursue with our students. The impact of AI directly affects how constructive alignment between teaching and learning, but also assessments, takes place. Constructive alignment is an approach to curriculum design which places emphasis on closely aligning teaching and assessment to intended outcomes (Biggs & Tang, 2011).

In this paper we will investigate the effect of the burgeoning use of AI in higher education in terms of its impact on the relevance of module outcomes for an undergraduate engineering programme at a South African higher education institution. We argue that critical reflection is needed for ensuring the continuing validity and usefulness of module outcomes in an AI-integrated educational environment. A product of the paper is to suggest how we could integrate AI considerations into the module outcomes, graduate attributes, and engineering curriculum to future proof and prepare students.

We use AI, the free version of ChatGPT, to initially categorize the outcomes according to the framework, proposed by Cilliers (2024). He proposes six categories in which he categorizes module outcomes and engineering graduate attributes into the following domains: 1) those that can be delegated to AI, 2) those that remain uniquely human and cannot be delegated to AI, 3) those that require a combination of human and AI capabilities, 4) new outcomes that are now possible due to AI capabilities, 5) traditional outcomes that need to be approached differently in an AI-enabled world, and 6) outcomes that have become redundant in an AI enabled world. We only work with the first three, because the last three categories (especially category four and five) would require content knowledge and creative reformulation of the outcomes from a subject specialist. Furthermore, this is an initial exploratory study, and to limit the scope, the last three categories were not included. The categorization is then validated through double checking the results of AI. We argue that categorizing the modules and graduate outcomes within this framework will have distinct implications for engineering curricula of the future. It is clear that we need to rethink which outcomes should still be part of the intended outcomes, and which ones need to be reinterpreted and reformulated with the goal of optimal and efficient deployment of AI, while students are still learning the necessary skills to be an engineer. This is important for aligning the engineering curriculum with accreditation requirements, such as those set by the Engineering Council of South Africa (ECSA).

This paper therefore explores the continuing applicability of current module outcomes in terms of graduate attributes within the context of an AI-directed pedagogical space at an engineering faculty at a South African university. Using sources such as the ECSA graduate attributes, yearbooks (program portfolio), and ECSA exit-level outcome maps, we will critically evaluate how alignment may take place between AI and higher educational outcomes.

2 Research question, method, and outcomes:

Research question: We will indicate that AI in higher education radically impacts the module outcomes in an undergraduate engineering program. We will investigate this to focus on the question: How should we rethink, reimagine, and reformulate engineering education outcomes in the light of Artificial Intelligence? What criteria should be considered when rethinking engineering education outcomes in the light of Artificial Intelligence?

Methodological approach: We will examine how AI can potentially fulfil and even replace certain outcomes and graduate attributes as listed within an engineering curriculum in SA. We will analyse the outcomes and graduate attributes by first prompting AI, specifically ChatGPT, to answer which engineering module outcomes and graduate attributes can 1) be delegated to AI, 2) which remain uniquely human, and 3) which require a combination of human and AI capabilities. The AI output on these questions will then be compared to the initial data to identify shortcomings in this analysis and to ensure its correctness. Lastly, we will interpret the analysis and the framework to propose some ways in which we should rethink and redevelop engineering outcomes in the future, especially keeping in mind the potential and risks AI poses.

Outcomes: We aim to develop a framework and recommendation to ensure that AI-integrated engineering curricula remain relevant, future-proof, and effectively prepare students for industry demands.

3 Research on outcomes and graduate attributes

We analysed two documents for this study:

1. The first was the learning outcomes of all the modules which forms part of all the undergraduate engineering programmes at North-West University in 2025. These outcomes are listed in the NWU Engineering Yearbook (17_FENG-UG-2025.pdf) and are attached as Annexure 1.
2. The second document were the graduate attributes as listed in the Engineering Council of South Africa’s “Qualification Standard for Bachelor of Science in Engineering (BSc (Eng))/ Bachelors of Engineering (BEng): NQF Level 8, revision 7” (Annexure 2). Only the list of graduate attributes, as extracted from this ECSA document, is available in Annexure 3.

We uploaded Annexure 1 to ChatGPT (GPT-3.5 on OpenAI’s free plan) and asked the following questions: to provide us, based on the module outcomes in the document, an analysis of which outcomes can be comfortably delegated to AI, which cannot be delegated, and which require a combination of human and AI capabilities. We used the following prompt: Based on the module outcomes in the document, make an analysis of which outcomes can be comfortably delegated to AI, which cannot be delegated, and which require a combination of human and AI capabilities.

We did the same with Annexure 3 but just changed ‘modules outcomes’ to ‘graduate attributes’. The results of this question to ChatGPT about the outcomes, are available in Annexure 4, and the results about the graduate attributes are in Annexure 5. The prompts were: Provide me with a structured analysis of the graduate attributes based on their delegability to AI, human-only capabilities, and hybrid tasks. The further questions to ChatGPT in refining the analysis, and our answers, with the further analyses are all included in these annexures.

Our initial observations of the ChatGPT analysis were that the answers were vague, and we realised that not all modules were discussed. We did find that with the further prompts, the answers became more specific and clearer. The total number of modules listed in the yearbook is 174 and only 62 of those modules were discussed in the analysis. That is only one third of the modules. We repeated the exercise by providing a MS Word file (the first version was PDF) but the total modules analysed the second time were only 26. We decided to work with the initial analyses of 62 modules because that already provided enough data for our further analysis and discussion.

The analysis of the 11 graduate attributes were done much more efficiently and thoroughly by ChatGPT. The reason might be that this was a much shorter list (11 vs 174) with much less text to examine (only 3 pages). We only prompt once more on the answer of ChatGPT and then we had enough data to work with for the purpose of our research.

It is important to note that the descriptions of the module outcomes were the only data ChatGPT worked with and that more information and content of the modules were not provided. To verify the correctness of the analysis of ChatGPT, the lecturers for the specific modules need to be questioned. We did a control and verification of some of the modules’ analysis with the lecturers of Industrial Engineering modules (INGB). Our finding was that ChatGPT gave an overall fair analysis and that we could proceed to the next step, namely, to interpret and discuss the findings in the context of our research question, namely how we should rethink and redevelop engineering outcomes in the wake of AI’s increasing influence.

4 Discussion of analysis

We agreed with the key take-aways given by ChatGPT (page 11, Annexure 4) that regarding the role of AI and the lecture, we can think about outcomes in general:

- AI can automate repetitive, computational, and optimization-heavy tasks, such as simulations, numerical computations, and data analysis.
- AI cannot replace human intuition, ethical considerations, regulatory compliance, hands-on experimentation, and leadership roles.
- Best results come from AI-human collaboration in areas where AI can optimize performance, but final decisions require human expertise.

This is in line with the categorization of the module outcomes (page 8, Annexure 4):

Table 1: Expanded Categorization of Engineering Module Outcomes and AI Delegation

Module Name	AI Can Handle	Requires Human Expertise	Best Achieved Through AI-Human Collaboration
Statics and Mathematical Modelling (APPM121)	Solving force resultants, vector computations, dimensional analysis	Conceptualizing equilibrium, selecting appropriate models	Verifying AI-generated force systems for real-world accuracy
Dynamics I & II (APPM211, APPM221)	Computing displacement, velocity, acceleration, energy, and momentum	Understanding motion physics and interpreting unexpected results	Validating AI-assisted kinematics/kinetics predictions
Differential Equations (APPM212)	Solving ODEs/PDEs numerically, using Laplace transforms	Selecting the correct equation for specific engineering problems	Adjusting AI-driven solutions for real-world applications

The verbs used within the different categories are significant. The tasks AI can handle are described as "solving, computing" while human expertise is required to "conceptualise, understand, select" and for AI-human collaboration: "verifying, validating, adjusting". This gives a strong indication of the specific role of AI and the continuous needed role of humans, but also of the way they can strengthen each other.

The above description of the roles of AI and humans to reach the outcomes of the module should, in our view, be given to each lecturer, to rethink how the module outcome, the teaching and learning of it, and the assessment, could be rethought to keep the outcomes relevant. The question for the lecturer (subject specialist) should be what unique human skill should be focused on in this module to ensure that AI can be incorporated meaningfully and efficiently. In other words, the question is not which module outcomes should be dropped, but rather to take on the challenge to assess all outcomes in terms of what AI can do or not and reimagine and rethink them within this context.

Regarding the graduate attributes the same pattern were noticed as with the module outcomes, namely that there are certain roles AI can play in fulfilling these attributes, but some of them will remain exclusively human tasks, with some to be hybrid. The summary ChatGPT gave after the analysis (Annexure 5, pp 5-6) is one we agree with:

5 Key AI Roles Across Graduate Attributes:

Examples of tasks according to the three categories we analysed, are as follows. The first category are tasks that can be fully delegated to AI. These include:

- Data analysis, pattern recognition, numerical simulations.
- Automating calculations, document formatting, report generation.
- Process optimization, scheduling, and workflow automation.

The second category are tasks that require a combination of human and AI capabilities:

- Design optimization (AI proposes solutions, engineers validate and refine).

- Experimentation and research (AI processes data, engineers conduct and interpret findings).
- Sustainability assessments (AI models impact, engineers integrate ethical and societal concerns).
- Teamwork and management (AI manages logistics, engineers lead and strategize).

Tasks that remain uniquely human:

- Ethical decision-making and professional judgment.
- Leadership, interpersonal collaboration, and conflict resolution.
- Innovation, creativity, and strategic planning.

The discussion of the first three graduate attributes by Chat GPT is a good example how the same verbs and actions are linked to humans, AI and humans with AI. From Annexure 5, pp4-5:

Table 2: AI Delegability Analysis of Graduate Attributes with AI's Role in Each Category

Graduate Attribute	AI's Role (Delegated Tasks)	AI Limitations (Why Humans Are Needed)	AI + Human Collaboration (Hybrid Approach)
1. Problem Solving	AI can analyze large datasets, detect patterns, optimize engineering solutions, and run simulations to test hypotheses.	AI struggles with ambiguous, ill-defined, or ethical problems requiring creativity and judgment.	AI generates possible solutions; engineers validate feasibility, ethics, and applicability.
2. Application of Scientific & Engineering Knowledge	AI can perform numerical analysis, simulations, and predictive modelling.	AI lacks real-world experience and cannot determine which principles best apply in novel situations.	AI speeds up calculations; engineers select, refine, and interpret models for application.
3. Engineering Design	AI can generate design alternatives, optimize layouts, and simulate performance under different conditions.	AI lacks human creativity, intuition, and the ability to balance trade-offs between conflicting constraints.	AI proposes optimized designs; engineers evaluate feasibility, compliance, and user needs.
4. Investigations, Experiments, and Data Analysis	AI can process large datasets, automate experimental data collection, and identify trends in research findings.	AI cannot design experiments requiring deep domain knowledge and physical intuition.	AI assists with data processing; engineers design experiments, interpret results, and refine hypotheses.
5. Engineering Methods, Tools, and IT Use	AI can assist with CAD modelling, predictive analytics, and process automation.	AI lacks adaptability when working with novel or unstructured data.	AI provides rapid calculations and design iterations; engineers oversee

Graduate Attribute	AI's Role (Delegated Tasks)	AI Limitations (Why Humans Are Needed)	AI + Human Collaboration (Hybrid Approach)
			tool selection, modifications, and integrations.
6. Professional and Technical Communication	AI can generate reports, summarize technical documents, and provide automated translations.	AI struggles with context, intent, and audience-specific communication nuances.	AI drafts initial reports; engineers refine them for accuracy, clarity, and professional tone.
7. Impact of Engineering on Society and the Environment	AI can model environmental impacts, optimize resource use, and assess regulatory compliance.	AI lacks ethical reasoning and cannot fully understand long-term societal implications.	AI provides data-driven insights; engineers ensure ethical, sustainable, and socially responsible decision-making.
8. Ethics, Responsibilities, and Professionalism	AI can flag potential ethical concerns in engineering designs or projects based on predefined rules.	AI cannot make value-based ethical decisions or exercise professional judgment.	AI highlights possible issues; engineers apply ethical reasoning and professional responsibility.
9. Independent and Lifelong Learning	AI can provide personalized learning paths, recommend relevant literature, and facilitate knowledge retrieval.	AI lacks curiosity, self-reflection, and the ability to critically assess new information.	AI helps engineers stay updated; engineers critically engage with content and apply knowledge contextually.
10. Engineering Management	AI can optimize project schedules, forecast risks, and assist in budgeting through data analysis.	AI lacks leadership, strategic vision, and human-centered decision-making skills.	AI provides analytical support; engineers make strategic, team-oriented, and financial decisions.
11. Project Management and Finance	AI can track budgets, predict cost overruns, and optimize resource allocation.	AI does not understand human factors, organizational culture, or negotiation dynamics.	AI enhances efficiency; engineers handle stakeholder interactions, compliance, and decision-making.

The verbs used within the different categories are similar to those in the analysis of the module outcomes. The tasks AI can handle are describe as "analyse, identify patterns, optimise, mathematical modelling, simulations, statistical analysis, simulate performance” while human expertise is required to “handle ambiguous, ethical, or novel problems; apply domain knowledge; ensure applicability; ensure feasibility and practicality” and for AI-human collaboration these two come together in various ways.

The interesting thing about the modules outcomes and the graduate attributes are that they are normally only thought of as human abilities and characteristics. With AI this mindset needs to change to incorporate, from the beginning, the combined abilities and characteristics to be developed within curricula and programs. It will always be a question of how AI and humans will together be able to fulfil certain tasks.

6 Findings and recommendations

This study has its limitations in the sense that it only analysed the modules outcomes of 62 of the 174 of the engineering curricula. It only used one AI tool, and that was the free version of ChatGPT because that is available to all lecturers. The stronger ChatGPT-4 version is however recommended for analysis of longer texts.

Another limitation was that the outcomes – as described in the Yearbook – do not include the unarticulated outcomes of the modules and programmes. The outcomes are just short descriptions of the main objects to achieve within the module, but there are always more that are achieved in the classroom, in discussions, in assessments, and in the curriculum, that is described by theses outcomes. To assess all these unarticulated outcomes is important but is beyond the scope of this study. We furthermore found that many outcomes are not well defined and that is it critical to evaluate and reformulate outcomes continuously, even if AI did not exist. As the rule is with most AI apps, ‘garbage in, garbage out’, we concur that the better the outcomes were formulated, the better analysis was given by ChatGPT.

Furthermore, we did not focus in our analysis on the powerful AI Bots that are available for engineers to use. One example is Leo AI: Revolutionary AI-Powered Engineering Design Copilot for Mechanical Engineers. This bot is trusted (see their website) by mechanical engineers in mega companies like Scania, HP, Phillips, Zutacore and by MIT. How these bots will play a role in rethinking outcomes and graduate attributes should be part of further research about AI and development of engineering curricula.

The data gathered in our module outcomes analysis by ChatGPT, with the analysis of the graduate attributes, were limited as mentioned above, but is still indicative of certain patterns. We can therefore list the following findings and make some recommendations based on the interpretation of the data from our analysis.

How should we rethink engineering education outcomes in the light of Artificial Intelligence? We found that:

1. It is important to critically evaluate and reformulate outcomes in the light of AI. An analysis of the outcomes should be done, not to phase them out, but to reinterpret and reformulate them within the possibilities AI poses.
2. Outcomes and graduate attributes remain crucial for developing curricula, but they should be reimagined and reformulated to think AI and humans as a team, and not only think about humans in isolation.
3. By rethinking outcomes and graduate attributes, it will become possible to rethink assessment in creative and alternative ways.

4. There are always opportunities and risks associated with AI, and it will become increasingly important to highlight these in rethinking module outcomes.
5. Proven educative principles in designing curricula and assessments, like those found in Bloom's taxonomy for example, should not be ignored or dropped in the face of AI, but they should also be rethought and redeveloped. We see some examples of this already in the work of the Vanderbilt University Centre for Teaching (see online article of Morgan (2024), and by Gonsalves (2024).

Our recommendations aim to ensure that an AI-integrated engineering curricula remain relevant, future-proof, and effectively prepare students for industry and society's demands. The following framework can be used in this regard:

1. Analyse all modules' outcomes of all programmes. This can initially be done through different AI tools, but it is crucial to get subject specialist and lecturers involved to analyse it further, in more detail, and in the context of the module's content and assessments
2. Further analysis of the module outcomes can be done by following the last three categories as proposed by Cilliers (2024), namely:
    a. Identifying and formulating new outcomes that are now possible due to AI capabilities.
    b. Reimagining traditional outcomes that need to be approached differently in an AI-enabled world.
    c. Identifying outcomes that have become obsolete or unnecessary in an AI enabled world.
3. Rethink and reformulate outcomes, and do not just change assessments. The problem is that many lecturers just change assessments because AI can do the assessments and students use AI then to complete the tasks, sometimes unethically.
4. The ethical and responsible use of AI is of course crucial and should be promoted in all possible ways (e.g. by forming a Community of Practice for academic integrity as indicated by Verhoef et al, 2022). We should however not get stuck at only changing assessments but rather rethink the outcomes. The new assessments should then be linked to the reimagined module outcomes that incorporate AI. Various AI Assessment Scales have been developed with AI incorporation, e.g. Furze, Perkins et al 2024, and provides excellent guidance in this regard.
5. Regarding the graduate attributes that are prescribed by ECSA to be part of the outcomes of the engineering curriculum, we would encourage a rethink of these to make them more specific and aligned with the capabilities of AI.
6. Some new skills will need to be developed in our students for our future that will be increasingly one influenced by AI. Some of the critical skills young people in the workplace (ECSA competencies) need in the era of AI are according to Verhoef (as quoted in Carew 2024:43), are the ability to:
    a. Always be willing to learn. Students must experiment, test, and play using different forms of AI. This is the fun part of AI. There is so much to explore, but it needs to be discovered, and this skill should be encouraged.
    b. Acknowledge and embrace their unique contributions. AI can do so much. In response, young people need to understand how they can complement AI's answers with their own creativity.
    c. Prioritise critical thinking. This is crucial in a world of AI everything. We should not just trust what AI presents as a true or good answer but question it.
    d. Not be too dependent on AI. We still need basic subject knowledge to judge whether AI gives a good answer.

e. Learn to work ethically and responsibly with AI, by being transparent in our use of it and by being honest if we have used it so that we can keep the integrity of our work intact.
f. Be mindful of issues regarding privacy, security and safety when using AI. The safeguarding of personal information and respect for user privacy will become an increasingly important skill.

To conclude, AI poses new challenges and opportunities for higher education. To constructively engage with these, we propose that we should start to rethink, reimagine, and reformulate the outcomes of modules, programs, graduate attributes and degrees. We examined how this might look in terms of engineering education at a South African university. We realised that outcomes should be carefully rethought and formulated. During the analysis of the outcomes by AI, some outcomes were identified as something AI can do, others were however outcomes that remain something only humans can achieve, or in AI-human combination. In general, we would recommend that all outcomes should be rethought and reformulated with the integration of AI part of it. The outcomes will then include what skills students will need to use AI as a tool to co-achieve higher levels of outcomes.

References

Biggs, J. & Tang, C. 2011. *Teaching For Quality Learning at University.* McGraw-Hill Education: London.

Carew, J. 2024. With great tech must come great responsibility. Varsity Skills. Public Sector ICT Forum. *The Public Technologist*. December, 41-43. https://brainstorm.itweb.co.za/archive/the-public-technologist

Cilliers, F. 2024. *AI's curveball: Is the problem with assessment or with our learning outcomes?* Paper presented at the Stellenbosch University AI in Assessment Symposium 9/10/2024.

Furze, L., Perkins, M., Roe, J., & MacVaugh, J. 2024. *The AI Assessment Scale (AIAS) in action: A pilot implementation of GenAI supported assessment.* https://doi.org/10.48550/arXiv.2403.14692

Gonsalves, C. 2024. Generative AI's Impact on Critical Thinking: Revisiting Bloom's Taxonomy. *Journal of Marketing Education*, 1-16. https://doi.org/10.1177/02734753241305980

Morgan, D. 2024. *Bloom's Generative Taxonomy*. 24 June. Future of Education Blog. https://www.mindjoy.com/blog/blooms-generative-taxonomy

Verhoef, A.H., Fourie, M., Janse van Rensburg, Z., Louw, H & Erasmus, M. 2022. The enhancement of academic integrity through a community of practice at the North-West University, South Africa. *International Journal for Educational Integrity*, 18:1-19. https://doi.org/10.1007/s40979-022-00115-y

Annexures

The annexures referred to in this research paper can be found in the following folder:

https://drive.google.com/drive/folders/1qa36Dbf-n2iZkTeNaA3SSuJsgqJXoI-e?usp=sharing