

PERSPECTIVE

Sustainable development and digitization: A further discussion on the dual transformation of engineering education

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In today's ever-evolving world, human society finds itself at the crossroads of two profound transformations. The first is the digital transformation, reshaping the economy and society, driven by emerging productive forces represented by digital technology. The second transformation revolves about sustainable development, propelled by the imperative for humanity's enduring survival and prosperity. These two transformations are deeply intertwined, giving rise to a dual transformation characterized by both digitization and sustainability.

Education is an important component of the social system, inseparable from societal transformation. Moreover, education stands as a vital pillar of our social system, and plays a fundamental, global, and pioneering role in societal transformation. Education is not just a responsive component of societal change but a guiding force for the transformation, leading the way towards a sustainable and digitalized future.

While discussions regarding the dual transformation of engineering education have been held in previous forums, the urgency of this transformation has intensified and heightened as progress lags behind. Therefore, it is essential to revisit and further discuss the topic to reaffirm the necessity and significance of this transformation, sound stronger alarm about its pressing nature, and delve into the difficulties in the transformation and the pathways forward.

THE IMPERATIVE OF TRANSFORMATION

In November 2021, the Future of Education Committee

of the United Nations Educational, Scientific and Cultural Organization (UNESCO) released its report titled "Reimagining Our Future Together: A New Social Contract for Education".^[1] At the very beginning of the report, it emphasized the existential choice facing humanity: to persist on an unsustainable path or radically change the course. It highlighted the pivotal role of education in achieving a sustainable future. UNESCO's Director-General, in the preface of the report, summarized the inspiration behind the report: "We need to take urgent action to change course because the future of people depends on the future of the planet, and both are at risk." This underscores that the call for educational reform extends beyond academic circles; it is a societal imperative to achieve the dual transformation of green and digital education.

"Transforming our World: The 2030 Agenda for Sustainable Development", adopted at the 70th session of the United Nations General Assembly in 2015, comprises 17 sustainable development goals (SDGs).^[2] These 17 goals are not isolated goals but interconnected as an integrated system, focusing fostering a harmonious relationship between humanity and nature, encompassing economic growth, social development, and environmental protection. However, sustainable development is sometimes mistakenly associated solely with environmental protection. Environmental protection is undoubtedly a very important task in sustainable development, but it is not the whole idea of sustainable development. It needs to highlight that sustainable development encompasses all 17 goals and 169 specific targets, achieved through progress in

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economics, society, and environmental stewardship. As pointed out comprehensively by Chinese President Xi Jinping, “the United Nations’ 2030 Agenda for Sustainable Development focuses on coordinating the harmonious coexistence of humans and nature, considering the needs of current generation without compromising the needs of future generations. It coordinates the implementation of three major tasks: economic growth, social development, and environmental protection, and outlines a new vision for global development”,^[3] which embodies the essence of the agenda. To realize these goals, it is essential to coordinate economic growth, social development, and environmental protection. What are the implications of the Agenda and the SDGs for engineering education? This perspective has profound implications for engineering education, where the key to achieving SDGs lies in integrating these three dimensions into educational curricula and practices.

THE URGENCY OF TRANSFORMATION

In this year of 2023, we find ourselves at the midpoint of 2030 Agenda for Sustainable Development which spans 15 years from 2015 to 2030. Unfortunately, the progress toward achieving its goals is far from satisfactory. The Sustainable Development Summit was held in New York, from September 18–19, 2023, during the 78th session of the United Nations General Assembly. Leaders from member nations were shocked to see that only 15% of measurable indicators for SDGs are on track. Numerous goals related to hunger, health, biodiversity, strong institutions, pollution, and a peaceful society have all deviated from tracks. Figure 1 illustrates this situation, with green indicating the target in normal progress, and yellow, orange, and red colors representing varying degrees of deviation from the targets—“modified distance to target”, “far from target”, and “very far from target, even regressing”. It can be seen that the situation is very serious from the graph.

At this summit, UN Secretary General Antonio Guterres stated “the SDGs aren’t just a list of goals. They carry the hopes, dreams, rights and expectations of people everywhere”. “Yet today, only 15 percent of the targets are on track and many are going in reverse. Instead of leaving no one behind, we risk leaving the SDGs behind”. So, “the SDGs need a global rescue plan”. He called for global actions with multiplied efforts in six key areas, including addressing hunger, transitioning to renewable energy, leveraging digital transformation opportunities, improving the quality of education for children and adolescents, achieving gender equality, and fighting climate change.^[4]






















































The Global Sustainable Development Report titled “the time of crisis, the time of change: Accelerating the Transition of Science to Sustainable Development”^[5] had released officially by the United Nations in September 2023. In this new quadrennial report, the model of integrated approaches to achieve the SDGs with 4 levers acting on 6 entry points had been modified by adding a new lever of Capacity Building, as shown in Figure 2.

Engineering education plays a pivotal role, aligning with the levers of “science and technology” and “capacity building”. To expedite the transformation toward sustainable development, engineering education should focus on six critical areas: enhancing human well-being and capabilities, fostering a sustainable and equitable economy, securing food systems and nutrition models, advancing decarbonization and universal accessibility of energy, contributing to urbanization and peri-urban development, and addressing global environmental commons. The urgency of sustainable development transformation underscores the need for engineering education to accelerate its own transformation to meet these pressing needs.

Simultaneously, the rapid advancement of digital transformation, highlighted by the accelerated advancement of artificial intelligence (AI), is also presenting an urgent need for the digital transformation of engineering education situation. McKinsey released a report earlier this year titled “The State of AI in 2023: The Year of Generative AI Explosion”.^[6] The survey shows how individuals in different regions, industries, job positions and ages use generative AI tools in their work and daily life. From Figure 3, it can be seen that generative AI tools have become an integral part of work and life. Over 40% of interviewees people in North America and the Asia Pacific region regularly use generative AI tools in their work and/or life, with the highest usage rate of 50% among respondents working in the fields of technology, media and telecom. This indicates that AI has already entered into our work and life, and nobody could resist and stop the advance of this new productive force. With the empowerment of AI, digital transformation will accelerate on in both depth and breadth, leading to a pervasive adoption in the very near future.

In fact, Generative AI is a vital tool that assists in generating various forms of semi-finished products, including text, graphics, speech, music, scripts, and program code based on instructions from users, which are then processed and approved by the user, greatly reducing the intensity of lower-level human mental labor and improving its efficiency. And, this technological wave, driven by the big pretrained AI models, has ushered in a new work paradigm known as “Model as a

CURRENT STATE OF PROGRESS TOWARD THE SUSTAINABLE DEVELOPMENT GOALS BASED ON SELECT TARGETS

GOAL	INDICATOR	DISTANCE FROM TARGET (2023) ¹	TREND OF SDG PROGRESS (2023) ¹	CHANGE IN TREND OF SDG PROGRESS BETWEEN 2020 AND 2023 ²
	1.1.1 Eradicate extreme poverty		Limited or no progress	↩ Backward
	1.3.1 Implement social protection systems		Fair progress but acceleration needed	N/A
	2.1.2 Achieve food security		Deterioration	None
	2.2.1 End malnutrition (stunting)		Fair progress but acceleration needed	None
	3.1.2 Increase skilled birth attendance		Fair progress but acceleration needed	↩ Backward
	3.2.1 End preventable deaths under 5		Fair progress but acceleration needed	↩ Backward
	3.3.3 End malaria epidemic		Limited or no progress	None
	3.b.1 Increase vaccine coverage		Deterioration	↩ Backward
	4.1.2 Ensure primary education completion		Limited or no progress	↩ Backward
	5.3.1 Eliminate child marriage		Fair progress but acceleration needed	None
	5.5.1 Increase women in political positions		Fair progress but acceleration needed	None
	6.1.1 Universal safe drinking water		Limited or no progress	None
	6.2.1 Universal safe sanitation and hygiene		Fair progress but acceleration needed	None
	7.1.1 Universal access to electricity		Fair progress but acceleration needed	↩ Backward
	7.3.1 Improve energy efficiency		Fair progress but acceleration needed	None
	8.1.1 Sustainable economic growth		Deterioration	↩ Backward
	8.5.2 Achieve full employment		Limited or no progress	None
	9.2.1 Sustainable and inclusive industrialization		Limited or no progress	None
	9.5.1 Increase research and development spending		Fair progress but acceleration needed	➡ Forward
	9.c.1 Increase access to mobile networks		Substantial progress/on track	None
	10.4.2 Reduce inequality within countries		Fair progress but acceleration needed	N/A
	11.1.1 Ensure safe and affordable housing		Fair progress but acceleration needed	➡ Forward
	12.2.2 Reduce domestic material consumption		Limited or no progress	N/A
	12.c.1 Remove fossil fuel subsidies		Deterioration	↩ Backward
	13.2.2 Reduce global greenhouse gas emissions		Deterioration	None
	14.4.1 Ensure sustainable fish stocks		Deterioration	N/A
	14.5.1 Conserve marine key biodiversity areas		Limited or no progress	N/A
	15.1.2 Conserve terrestrial key biodiversity areas		Limited or no progress	None
	15.4.1 Conserve mountain key biodiversity areas		Limited or no progress	N/A
	15.5.1 Prevent extinction of species		Deterioration	None
	16.1.1 Reduce homicide rates		Limited or no progress	↩ Backward
	16.3.2 Reduce unsentenced detainees		Deterioration	None
	16.a.1 Increase national human rights institutions		Fair progress but acceleration needed	None
	17.2.1 Implement all development assistance commitments		Fair progress but acceleration needed	➡ Forward
	17.8.1 Increase internet use		Substantial progress/on track	None
	17.18.3 Enhance statistical capacity		Limited or no progress	None

¹ Distance from target (2023) and trend of Sustainable Development Goals progress (2023) refer to current level and trend information for the latest available data utilizing the calculation methodology from the Sustainable Development Goals 2022 Progress Chart Technical Note. Latest available data as of May 2023 from the SDG global indicator database. Please note that information for indicators 1.1.1, 10.4.2, 13.2.2, 17.2.1 and 17.18.3 are from the Sustainable Development Goals Progress Chart 2022.

² To capture the impacts of the COVID-19 pandemic on progress of the Sustainable Development Goals, a comparison of the trend assessment from the Sustainable Development Goals 2020 Progress Chart and the trend of progress of the Goals (2023) was made, with some indicators showing reversal or slowed progress.

N/A: trend comparisons unavailable due to: i) lack of trend analysis from insufficient data; ii) indicator not included in the 2020 Progress Chart; or iii) indicator has changed between progress charts. Source: Calculations based on United Nations Department of Economic and Social Affairs, 2023b.

Figure 1. Current state of progress toward the sustainable development goals (SDGs) based on select targets

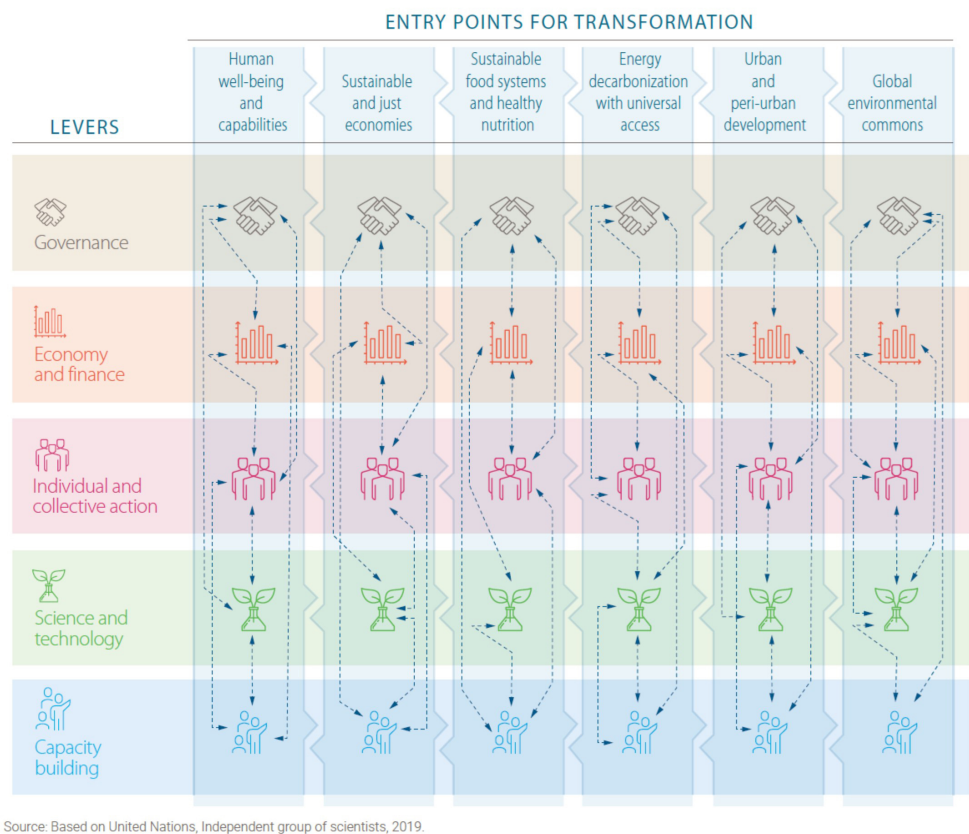


Figure 2. Model of transformation to sustainable development goals (SDGs) given by Global Report of Sustainable Development 2023

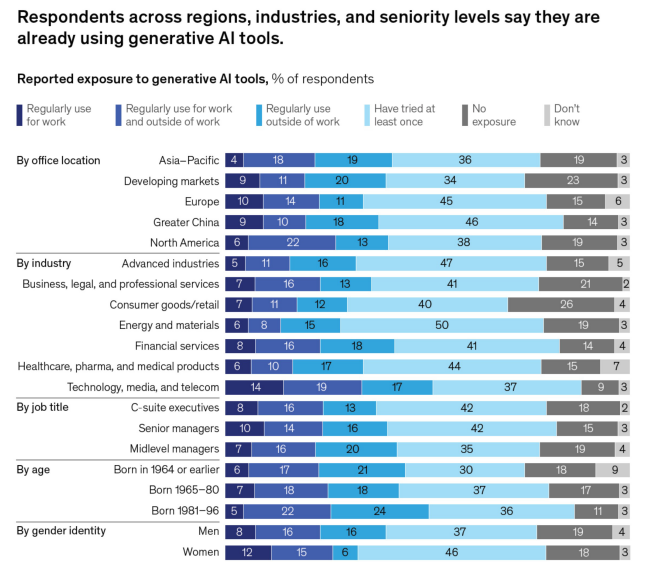


Figure 3. Reported exposure of generative artificial intelligence (AI) tools, by McKinsey

Service (MaaS)”, which allows large number of enterprises establishing their own AI models based on the pre-trained large models, to streamline a wide range

of tasks by fine-tuning the pretrained model with their professional knowledge and data. As the pre trained basic models are becoming new digital “infrastructure”, this engineering model of “universal pre training + downstream task fine-tuning” for AI deployment greatly reduces the threshold for AI applications, promotes the rapid popularization of AI applications, and changes traditional working mode. This new way of working will enter into the work environment of most people, reducing many cognitive workloads and enhancing efficiency. It is poised to become the norm in the near future, rendering AI proficiency an indispensable skill in the workforce.

Aldert Kamp, in his keynote speech, at the 7th World Conference of Engineers (WEC) in 2023, classified labor into three types in his keynote speech: physical labor, cognitive labor, and emotional labor.^[7] He had also underscored the impending transformation in labor dynamics (Figure 4). While emotional labor (labor related to ethics, relationships, and emotions) will not be replaced by machines, most physical labor (excluding precision work) and cognitive labor (excluding labor related to psychological flexibility and critical thinking) will be replaced by machines in the later stages of

Industry 4.0. Considering that for big part of the skills in the current programs will be replaced by machines in the near future, engineering education has to be transformed urgently to adapt itself to the change of working environment, in order to cultivate the young engineers to be qualified to work in the era of 4th industrial revolution. Figure 5 shows the top required skills in the coming years reported by World Economic Forum in “The Future of Jobs Report 2023”.^[8]

Shift in the division of labour

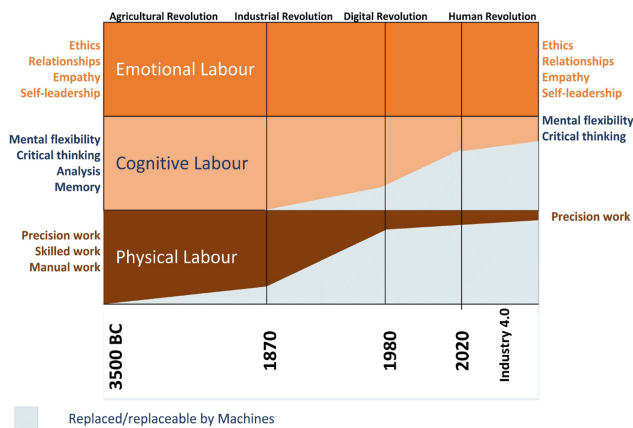


Figure 4. From Aldert Kamp, presentation at WEC2023

Top-10 of Reskilling Ranking 2027

- | | |
|--|------------------------------------|
| 1. Analytical thinking | 6. Curiosity and lifelong learning |
| 2. Creative thinking | 7. Technological literacy |
| 3. AI and big data | 8. Design and user experience |
| 4. Leadership and social influence | 9. Motivation and self-awareness |
| 5. Resilience, flexibility and agility | 10. Empathy and active listening |
- Cognitive skills
 ■ Technology skills
 ■ Self-efficacy
 ■ Working with others

Figure 5. Top-10 skills in Reskilling Ranking for 2027, World Economic Forum

It is important to be aware that AI has potential negative impact on safety, security, privacy, equity and inclusion, *etc.* Engineering education should shoulder the responsibility of training young engineers to conduct AI in a responsibly and ethical way. In the era of AI, there is a very important technology in the interaction between humans and AI tools, which is Human Feedback Reinforcement Learning (RLHF). Models can utilize human feedback for model updates and optimization, gradually improving the quality and responsiveness of the model, thereby better meeting the needs of users. Correspondingly, a new engineering profession has emerged, namely prompt engineer. Promoting engineering could introduce human values, ethical norms, social responsibility, scientific knowledge, legal discipline, and good customs into AI tools to make AI with human values for sustainable development.

THE DIFFICULTIES OF TRANSFORMATION AND THE WAY FORWARD

In view of the urgency of the global transformation and the magnitude of educational transformation required to play the leading role for accelerating the social transformation, although many efforts had been made and progresses had been achieved, the transformation of engineering education itself is still insufficient and relative slow. To advance the transformation of engineering education, we must first identify the major difficulties and then find the way forward.

Among many others, the major difficulties in transformation of engineering education are:

(1) the lack of profound understanding of transformation. More attention is paid to setting new courses or updating the contents of courses, while not realized that the transformative change is about the entire education mode including to greening and digitalizing all curriculum of all disciplinary programs and the manner of teaching and learning;

(2) the lack of given model to follow up. The transformation is a new challenge for the entire engineering profession and for every high learning institution in all countries, and there is no ready-made model to follow. We must take the path of innovation;

(3) the lack of capacity to carry out the transformation, especially among the educators, who need the capability to integrate sustainable development conscious, values and skills into their curriculum and leveraging digital techniques in their professional field effectively, and find the way to inspire students to be proactive in learning and practicing.

These three are intertwined and could be called “triple deficiency”. To surmount the “triple deficiency”, we propose three approaches:

(1) Deepen Understanding. We must embrace paradigm shifts and deepen understanding of educational change in the context of new industrial revolution. Recognizing the historical interplay between industrial revolutions and engineering education, we should view the dual transformation through the lens of paradigm change.

(2) Innovate modes. Breaking down disciplinary barriers and championing paradigm innovation with “New Engineering Education” as the focal point is essential. This involves reimagining knowledge and skill structures, teaching and (or) Learning methods, curricular frameworks, and the roles of teachers and students, Higher education institutes and society to foster the

multifaceted abilities needed for the future.

(3) Develop capacity. Addressing the deficiency in capabilities, particularly among educators, is paramount. Teachers should be equipped with social responsibility, sustainable development awareness, problem-solving skills, digital literacy and capability, interdisciplinary mindset, ethical awareness, and a broad knowledge base. Teachers should also be good at heuristic teaching to inspiring students to actively learn in order to achieve mutual empowerment between teachers and students.

In conclusion, the dual transformation of digitization and sustainable development present profound challenges and opportunities for engineering education. The imperative to adapt, innovate, and equip future engineers with the comprehensive skills and ethical frameworks required in this evolving landscape cannot be overstated. While AI continues to advance, it is not a force to be halted but a transformative tool that amplifies human potential. The real question is whether our education system can nurture adaptable, AI-savvy citizens capable of mastering the AI tools and use the AI tools and other digital tools to promote sustainable development—an inquiry that engineering education must confront and answer.

DECLARATION

Author contributions

Gong K developed the concept for the manuscript, reviewed the literature, formulated research questions, collected the data, conducted analyses and interpreted the data. The author read and approved the final

manuscript.

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Conflict of interest

The authors declare no competing interest.

Data availability statement

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