Board 129: Preparing Engineering Students for Designing and Managing the Future of Work and Work Systems

Dr. Priyadarshini Pennathur, University of Texas at El Paso

Dr. Priyadarshini R. Pennathur is an associate professor of Industrial and Systems Engineering.

Dr. Arunkumar Pennathur, The University of Texas at El Paso

Dr. Arunkumar Pennathur is Associate Professor of Industrial Engineering at the University of Texas at El Paso. Dr. Pennathur is a Co-Editor in Chief of the International Journal of Industrial Engineering, and the Founding Editor-in-Chief of the Journal of Applications and Practices in Engineering Education. Dr. Pennathur's research interests are in human factors engineering and engineering education. In particular, he has conducted research on functional limitations in activities of daily living in older adults. The National Institutes of Health, and the Paso del Norte Health Foundation have funded his research on older adults. The US Army Research Laboratory has funded Dr. Pennathur's research on workload assessment. Dr. Pennathur has also been recently awarded two grants from the National Science Foundation in Engineering Education. In one of the grants, he is modeling how engineering faculty plan for their instruction. In a second grant, he is developing a model for institutional transformation in engineering which balances access and excellence. Dr. Pennathur is the author/co-author of over 100 publications in industrial engineering and human factors engineering. He is on the editorial board of the International Journal of Industrial Ergonomics, among other journals.

Dr. Amirmasoud Momenipour, Rose-Hulman Institute of Technology

Amir Momenipour is an Assistant Professor of Engineering Management at Rose-Hulman Institute of Technology with interests and expertise in teaching human factors, user experience, and work analysis and design. Dr. Momenipour is a member of the Institute of Industrial and Systems Engineers (IISE), and Human Factors and Ergonomics Society.

Preparing Engineering Students for Designing the Future of Work

Abstract

The next generation of engineering professionals require not only the engineering fundamentals we teach today, but future-ready skills such as critical thinking and argumentation skills, knowledge of innovation processes and an entrepreneurial mindset. In this paper, we discuss our efforts to better prepare undergraduate and graduate engineering students for the future of work through dedicated courses in the future of work, industrial innovation sciences, future work leadership and work systems management, and entrepreneurship. We present our observations of a shift in student thinking about future of work topics across these three courses, and discuss implications of such courses for our engineering students in future work systems.

1. Introduction

To design future work and work systems, and to succeed as workers in future work systems, the next generation of engineering professionals require not only the engineering fundamentals we teach today, but also an awareness and appreciation of future work systems. This includes an understanding of how future work and work systems will look like and function for workers, what knowledge and skills future workers will need, and how organizations can achieve differentiation and competitive advantages by embedding innovation and entrepreneurship into work systems. Research suggests that cultivating certain future-ready skills are crucial for both future engineering professionals and for organizations vying for global competitive success in the new work landscape. These future-ready skills include critical thinking and argumentation skills, convergent multidisciplinary problem-solving skills, individual and team creativity, knowledge of innovation processes, practices, tools and metrics, entrepreneurship practices, and an entrepreneurial mindset [1], [2], [3], [4]. Mainstream engineering curricula are beginning to include technical literacy and proficiency in topics such as AI, data mining, and even prompt engineering at the undergraduate and graduate levels. However a majority of the new-age engineering workforce and leadership skills, and the pedagogical principles and practices for teaching these new-age skills remain unintegrated in the engineering curriculum.

In this paper, we discuss our efforts to better prepare undergraduate and graduate engineering students for the future of work through dedicated courses in the future of work, industrial innovation sciences, future work leadership and work systems management, and entrepreneurship. These three courses are linked through a common goal of preparing the future generation of students for digital transformations in organizations and their emphasis on future-ready skills. These courses incorporate innovative pedagogical practices such as debates, pitch presentations, innovation tournaments, cultivating a curiosity and value creation mindset among students, discussions on risk management, decision-making, and strategic business planning. We discuss strategies for incorporating the appropriate blend of pedagogical practices into engineering courses to make learning and preparing for the future of work a fun, enjoyable, and effective engineering educational pursuit for students.

In the following sections, we provide a brief description of the three courses, pedagogies, and activities used in these courses, and then discuss the implications of courses such as these to prepare students to flourish in future work systems.

2. Future of Work Courses and Learning Methods

2.1 Future of Work Course Teaching Method and Pedagogies:

This graduate course examines the future of work systems. Future work systems will integrate significant technology and automation including Artificial Intelligence, Robotic Process Automation, and both soft and physical bots [5]. Additionally, the nature and structure of the work itself is changing as remote work becomes mainstream [6]. The first iteration of the course included research readings and in-class discussions on the future of work systems and implications for workers, case studies from industry discussing the implementation of AI and other technology, and the impacts on workers, guest speakers from industry who are engaged in digital transformation, two in-class debates on the future of work topics, and a pitch presentation where students propose innovative ideas on how future work systems should be designed.

Research Readings and In-Class Discussions

The in-class discussion was structured by providing students with discussion questions prior to the class session. Students discussed the highlights of a research paper in their team before presenting a brief summary, questions, and additional thoughts for the class to discuss. The topics covered in these discussions spanned a wide range of topics including: (1) the impact of advanced technology and AI on work (AI, Robotic Process Automation, Chatbots) [7], [8], [9]; (2) organizational design and its impacts on how people will work (Crowd Work, Care Work, Telework, Smart Working, Remote Work, Four Day Workweek) [10], [11], [12]; (3) demographics of workers, (4) communication and coordination (Human-machine interaction and human-human interaction), (5) collaboration and social interactions, including human-autonomy and teaming; (6) physical and cognitive implications and ergonomics (fatigue, cognition, work design, knowledge work and cobots); (7) health and well-being (well-being, burnout, job satisfaction, boredom) and (8) a broad discussion of different industry sectors such as banking, dentistry, healthcare, tourism, farming and manufacturing that are being impacted by AI.

Industry Case Studies

The instructor selected relevant AI-related case studies from the Harvard Business Review [13] and assigned them to student teams, along with case discussion questions. The student teams presented their analyses and the entire class discussed the case.

Guest Speakers on Digital Transformation

Guest speakers from industries were invited to speak about the digital transformation they are leading, and how they envision the future of work to be in their industry sector.

Debates on the Future of Work

In this activity, student teams were assigned a topic relevant to the future of work and a side (for or against) to debate. Debate instructions available online [14] were adapted and modified to suit this course. Students were provided with instructions about how to prepare for the debate as a structured argument supported by evidence. In particular, they were provided with a detailed

primer on what an argument is (in the form of claim, reasons and evidence), and how to support it with evidence[15], [16]. There were three phases in the debate: (1) in round one, both for and against teams presented their initial arguments; round 1 was timed for 10 minutes; (2) following round one, there was a discussion period when student teams prepared responses based on the opposing teams' arguments in the first round; students were provided 20 minutes for the discussion period; and (3) in round 2, the teams presented their counter arguments based on round 1 in 10 minutes. When one team was presenting in round 1, the other team took copious notes on the arguments made so that they could prepare for it in the discussion period and refute the opposing teams' arguments in round 2.

Students were instructed to provide evidence to support their claims to ensure a strong rebuttal to the opposing team. Given the limited time for the discussion period, the emphasis was on solid reasons and a reasonable amount of evidence for their claims. In Round 2, the teams used the same argument structure, but responded to the other team's arguments. A classroom debate rubric was used to assess the debates [17].

Pitch Presentation

In this final project (paper and presentation), student teams were asked to assume the role of a work system designer and pitch an idea to perform work differently or improve current work system activities in any industry of their choice. This project did not just focus on advanced technology such as robotics or AI and how it would change work, but also on new work practices and policies that AI might entail in future work systems. The project intended to make students critically think and reflect about the technology/product/process innovations that could revolutionize work, reduce costs, increase benefits, create value from the innovations, positively impact the worker, and integrate ethics, well-being, and the economics of work.

2.2 Work Analysis and Design Course Teaching Method and Pedagogies:

The primary objective of this second course is to provide a comprehensive understanding of the basics of work systems and measurements within human-production systems. Traditionally, Work Analysis and Design courses have focused on work measurement and methods related to manual work. Given how technological advancements have transformed manual work to technology supported or automated work, there is a need to revisit work measurement and methods for assessing the new workplaces of today. For example, technological advancements such as robots, and exoskeleton suits are changing how manual work is performed. Extensive efforts have been made to update and develop advanced work measurement instruments to monitor tasks and measure work outcomes. For example, productivity can no longer be defined solely by the duration or movements involved in a task. Instead, it requires a more nuanced integration of technological, human centered,system safety, and managerial considerations. Additionally, automated means of work measurement with devices such as wearable sensors have enabled rapid, real-time and large volume data gathering of human performance. These significant changes in today's workplaces necessitate us to train students, especially those in engineering management roles, with the skills to successfully navigate work in systems integrating automation, artificial intelligence, data and people.

To better prepare engineering management students to navigate contemporary work systems, new modules and projects that focus on emerging trends in the future of work were introduced

into the work analysis and design course offered to engineering management graduate students. The goal of this course was to apply engineering methods to improve work systems while also identifying opportunities to modernize them through the adoption of emerging technologies such as AI, computer vision, sensors, exoskeleton suits, and virtual and augmented reality. Towards this end, course materials were developed using the entrepreneurial minded learning framework to train students on innovative thinking, enhance their curiosity about emerging technologies, and improve their abilities to connect engineering and managerial topics to address future work systems issues with a value creation mindset.

The learning objectives of this course are to:

1. Apply appropriate industrial engineering tools or methodologies to solve work systems problems that may affect productivity or safety.
2. Analyze work processes using work assessment tools and guidelines that help technical managers quantify or interpret the risks of unsafe operations.
3. Discuss and analyze organizations' work systems and propose strategies to improve the work system and modernize work measurement methods.

In the following sections, we discuss the entrepreneurial minded learning framework (EML) used for the development of materials related to future of work and the creation of a research project on the future of work.

Entrepreneurial Minded Learning (EML):

The course incorporated a range of pedagogical approaches including subject-based learning, case-based learning, active and collaboration learning, and problem-based learning. However, the primary teaching method used in the future of work systems modules was Entrepreneurial-Minded Learning (EML). EML is based on three mindset components: curiosity (discovery), connection (identifying unexpected opportunities), and creating value (for stakeholders). Developing this mindset enables students to think broadly and deeply about how their ideas correspond to their environments through 1) demonstrating constant curiosity about our changing world 2) exploring contrarian views of accepted solutions 3) integrating information from many sources to gain insight 4) assessing and managing identified risks 5) identifying opportunities to create value. The EML provided a suitable path towards learning how future engineer managers in the rapidly technologically advancing era need to analyze and address challenges in future work systems by applying research and strategy development integrating their skills in risk assessment, communication, teamwork, cost-benefits, and ROI analysis with value creation mindset.
More details about EM outcomes, including complementary skills, are provided in the KEEN Framework [18].

Five course modules were developed using EML. The details of the module topics, learning objectives, methods, and outcomes for each module are presented in the Appendix. In the first few modules, the focus was more on problem-solving and risk assessment methods at the micro-level in work systems, and towards the end of the term, the topics shifted more to problem-solving methods at the macro-level. The course's first two learning objectives (linked to learning materials in Modules A and B) directed students toward the third learning objective (learning materials in Modules C, D, and E). The first two learning objectives prepare students to

develop the necessary skills for analyzing micro-level issues in work systems. Activities are based on ***curiosity*** and ***connection*** outcomes. The third learning objective requires students to evaluate which technologies ***create value*** in an organization and propose recommendations to improve the work system and modernize work measurement.

Future of Work Research Project:

A new course module with a research project titled, "Future of Work" was introduced in the course to encourage students to cultivate curiosity, foster connections and practice value creation by engaging in business decision-making and by generating a value-added strategy proposal for an organization. The goal of this activity was to allow students to:

1. Discuss the future of work and its impact on occupational safety and productivity.
2. Analyze and discuss organizations' needs to adopt new technologies to improve their workforce safety, productivity, and technical skills while considering economics of business.
3. Investigate Political, Economic, Social, Technical, Environmental, or Legal (PESTEL) issues and investigate the consequences on workforce well-being and productivity if organizations do not adapt to future work requirements and changes.

Students were required to select one of the following topics and prepare a presentation discussing the intricacies of technology integration, new work practices and well being considerations in future work sytems.

Table 1. Future of Work Topics for Research Project

Future of Work Topic	Description
Wearable sensors/suits	Wearable sensors/suits that monitor workforce posture, movement, location/proximity, or measure unsafe operations risk factors.
Exoskeleton and assistive technologies	Exoskeleton and assistive technologies that support, amplify, or reinforce the performance of workforce body components.
Computer vision technology	Computer vision technology to monitor workforce posture, movement, location/proximity, or measure unsafe operations risk factors.
Virtual Reality / Augmented Reality	Virtual Reality / Augmented Reality technology to monitor workforce posture, movement, location/proximity, or measure unsafe operations risk factors.
Working from home	Working from home and employees' safety/productivity and impacts on organizations
Simulation Software	Simulation Software and tools to evaluate workplace environment, and/or physical ergonomic
Use of Drones for Occupational Safety Inspections	Explore the role of drones in conducting safety inspections in hazardous or hard-to-reach areas. This could include research on drone technology for structural inspections, environmental monitoring, and accident scene investigations.

Telemedicine and Digital Health Tools for Occupational Health	Focus on the use of telemedicine and digital health tools in monitoring and improving the physical and mental health of employees. This could cover topics like remote health monitoring, digital wellness programs, and ergonomic assessment via telehealth.
Inclusive Design for Diverse Workforce	Examine the importance of designing workplaces and work tools that are accessible and beneficial for a diverse range of workers including those with disabilities. Research how inclusive design principles can improve safety, comfort, and productivity.
Mental Health and Well-being Apps, platforms, and programs	With the rise of remote work and increasingly stressful work environments, investigate the role of technology in supporting mental health and well-being. This could include apps for mindfulness and stress management, platforms for virtual mental health services, and tools for monitoring and improving mental well-being.
Intelligent Personal Protective Equipment (PPE)	Explore the future of PPE which incorporates smart technologies such as sensors, connectivity, and data analysis to improve worker safety. Investigate how these technologies can predict potential hazards, provide real-time monitoring, and enhance the wearers' capabilities. Research on the role of algorithmic management and management programs in adopting intelligent PPE.
Blockchain for Worker Safety and Compliance	Research how Blockchain technology can be used to improve safety compliance and worker rights. This might involve secure, transparent systems for tracking safety training, incidents, and compliance with regulations, or platforms for workers to report issues anonymously.
Generative AI	Research on integrating Generative AI like ChatGPT into the workplace, focusing on opportunities, challenges, risks (socio-technical), and impacts on productivity, safety, and health.

The materials and methods used in this course can be tailored for use in courses such as work measurement, work analysis and design, or operations management. These topics may also be helpful for other engineering majors and for engineering capstone design projects.

2.3. Industrial Innovation Sciences Course Teaching Method and Pedagogies:

Industrial Innovation Science was a survey and analysis course that aimed to develop an understanding of the basic elements of innovation, processes, and models for innovating, managing innovation, and how organizations innovate, all important considerations for designing future organizations and how work might be embodied in future organizations while still retaining innovation goals. In particular, artificial intelligence is already upending the creativity skill requirements in workplaces further emphasizing the need for students to strengthen their innovation skills and perhaps co-innovate with technologies of the future, and co-create value. The emphasis was not on any specific innovation, but rather on the *process elements and requisites* for innovation from classical readings published on this topic. The goal was to have students understand to how these might relate to designing future work, and how the people aspects when innovating including leadership, cultural factors, and teamwork would be impacted

by technological innovations, and how organizations could respond to the changes so they become more competitive. Course topics included:

- Tools and Processes for Innovating
- Organizational Factors including leadership, culture, and people and teams in Innovation
- Collaboration, Networks and Innovation
- Technology/Data and Innovation
- Measurement of Innovation including innovation portfolio management, revenues, and costs
- Lessons from innovation in industry

The format of the class included discussion of readings on innovation, case studies on various aspects of innovation, and a review of innovations. At the end of the course, the student was expected to:

a. develop an understanding of factors, good and bad, that impact innovation;
b. develop an appreciation for how real businesses and organizations innovate;
c. be able to develop a structure/framework for innovating, and
d. identify factors to include in studies of innovation; and
e. critically evaluate and analyze innovation efforts and present data about innovation efforts.

The course was designed to not use formal textbooks. Instead, it used research readings, book chapters and published case studies on innovation. The course was a dual level offering, so both senior undergraduate students and graduate students enrolled in the course. A unique characteristic of the student body enrolled in the course was their industry background: the graduate students in the class were full-time practicing engineers, some in the local industry in El Paso, Texas, and some in Juarez, Mexico. Their unique perspective shaped by their insights and experiences on how their industry sector innovated validated much of the course content on innovation tools, methods metrics, and measures. Each component of the course is discussed further in the following sections.

<u>Case analysis and discussions</u>
Case studies for the class discussions were picked based on how organizations in various business and industrial sectors innovate, and how their innovation processes would be impacted based on technology changes in future work systems and the work design landscapes in organizations. Each team was assigned two cases to analyze and discuss. The following ten case studies were assigned:

1. Best Buy: Merging lean six sigma with innovation, BAB Case No. 697.
2. Herman Miller (A): Innovation by design, HBS Case No. 9-602-023.
3. Innovation at Timberland: Thinking outside of the shoe box, HBS Case No. 9-306-064.
4. Open innovation at Siemens, HBS Case No. 9-613-100.
5. Innovation at 3M Corporation (A), HBS Case No. 9-699-012.
6. Business teams at Rubbermaid, HBS Case No. 9-897-165.
7. Eli Lily & Co: Innovation in diabetes care, HBS Case No. 9-696-077.
8. CVS Health: Prescription for Transformation, HBS Case Product #322091-PDF-ENG.

9. The strategic transformation of Royal Phillips, London Business School, Case Product #LBS338-PDF-ENG.
10. Responsible AI: Tackling tech's largest corporate governance challenges, Haas Berkeley Case Product #B6021-PDF-ENG.

Guiding questions were posted well in advance of the case analysis and discussion sessions. Student teams prepared a brief presentation outlining the case with relevant background information for case discussions. Student teams discussed the main case guiding questions, summarized the key questions and topics addressed in the cases, and generated key insights and takeaways from the case. Student contributions to the case discussions were evaluated based on their preparation, facilitation of the discussions, clarification and emphasis of central ideas, and identification of key takeaways and new insights on innovation.

In-class reading discussions

A major component of this course was discussion of research readings from leading thinkers on innovation. Class discussions helped bring out varied perspectives on the elements of innovation and provided a forum for critical and thoughtful thinking about innovation, particularly about how organizational innovation might be impacted by changes in work organization, worker roles, and workplace dynamics precipitated by technological change due to AI. Class discussions included both team-based activities, and individual components.

There were 2 components to the discussion:

1. Leading and participating in discussions for the research readings.
2. Each student completing individual written reflections for any five readings of their choice. They were provided the option to pick other articles on innovation not prescribed by the instructor.

Discussion questions were posted for every article at least a week prior to the assigned date for discussion. During the discussion sessions, student teams summarized the articles and discussed key questions. Teams were instructed to provide well thought-out responses for the discussion questions and bring additional sources about the topic to facilitate their peers during discussion. Written responses to the questions were not required. Their contributions to the discussions were evaluated based on a format similar to that of case studies. In addition to participation in class discussions, each student completed a written individual reading reflection for up to five readings in the semester. Students were asked to reflect on their their understanding of the key issues in the reading, and their considered analysis and thoughts, rather than presenting a condensed summary of the research reading.

Innovation identification presentations

The final component of the course was for each student to identify and present one innovation in any domain that interested them. The innovation could be a unique process innovation, or a product innovation in any application setting. Domains such as manufacturing, materials, energy, health, medicine, service industry and science were also suggested for students to consider. Students were asked to provide a presentation with specifics of the innovation, their reasoning on

why it is an innovation, the story behind the innovation, and the impact of the innovation on society.

3. Implications and Discussion

Understanding how to design work in light of rapidly developing technologies such as ChatGPT, and new work systems and work models such as the four-day workweek, and remote or hybrid work are important for engineering management and industrial engineering students so they are able to adapt to, and and are able to innovate in the workforce of the future. In particular, learning about these newer manifestations of work and work systems is not only important for their professional development, but being able to critically think and delineate any benefits, harms, and costs from these future work systems will also place them at a competitive advantage for decision-making, managerial, and leadership positions in the future workplace. For example, the goal of the Innovation Sciences course was to impress upon students that industries innovate constantly to stay competitive and innovation need not occur as a chance event, and that there was a formal science-based approach to industrial innovation, to the tools and techniques to innovate, and to the measures and metrics for innovation, which will become important when balancing innovation goals with goals for designing how people work in the future. A persistent concern in the discussions in the innovation course that students from industry voiced were how industries would be able to innovate and stay on the cutting-edge without first clearly defining the role of the worker in the future as a result of new technology. Discussions also centered on whether we were revisiting themes on lights-out-factories of the future that many debated in the 1980s – deskilling due to automation and computerization, and the resulting fear among workers of job losses, retraining and cross-training, and how completely automated factories were only a concept on paper that never materialized fully.

Similarly, pitch presentations in the future of work course were conducted to make students conceptualize innovative work system models or innovate current work system practices to make them safe, healthy, efficient, and effective. Students became familiar with robotics, AI, and other technologies, as well as areas and application domains such as healthcare, through research discussions and case studies in this course. This helped them think about the use of such technologies to meet the demands of the most vulnerable workers and challenging work environments, such as care work and emergency room environments. The problems students chose to work on in the course highlighted the importance and benefits of emphasizing the beneficial use of AI and other advanced technologies and to always have a focus on human-centered design. We believe that providing students with knowledge of advanced technologies, innovation models, and metrics and training them to develop and employ best practices in human-centered managerial decision-making are key requirements for a healthy, competitive, and sustainable work system.

We observed that across all these courses, it was important to engage students in conversations, problem-solving and strategizing activities and to help them practice critical thinking skills about the future of work and innovation. This helped students become better prepared to discuss the requirements to adopt technologies, work methods, and productivity (performance, well-being, and safety) measurement tools in organizations. For example, through the research project in the Work Design course, students learned that in the evolving era of work systems, they must be able to adapt

and respond rapidly to changes by gaining knowledge and skills in risk assessment, communication, teamwork, cost-benefits, and ROI analysis with an entrepreneurial mindset. Moreover, students learned that future engineers need to engage in research and develop relevant research questions for their proposals, and be able to consider and manage intra- and inter-organizational factors to remain competitive.

Similarly, debates in the Future of Work course were structured to help students engage in evidence-based critical thinking to take a position on a topic. Training students to link evidence to their arguments to think and reason about future of work problems is key given the emerging evidence available about future of work models and technologies such as AI. In the Future of Work course, students were able to assemble evidence from literature sources to present and refute their arguments. They used statistics, highlighted interesting and surprising evidence to convey their arguments, and engaged in succinct and respectful communication when participating in the debate.

One noteworthy observation in our courses was the change in sophistication of student "language and discourse" indicative of an increase in "awareness" among students of these different future of work and innovation terminologies, models, practices, and technologies. In the beginning of the semester, for example in the future of work course, many students were not aware of technologies such as ChatGPT and work models such as a four-day work week. However, by the midpoint in the semester, the students could not only fluently speak the language of future of work, but also started experimenting with these technologies and practices. For instance, a student began using ChatGPT for tourism and another student began experimenting with the four-day workweek in their own work to boost well-being and productivity. These changes were significant and were indicative of their learning. We think, as observed in this course, two important skills gained from offering courses on topics related to future of work and innovation is the ability to have knowledgeable conversations about the future of work, advanced technologies and innovation, and the ability to identify and recognize use cases where these tools and practices would be most beneficial. We believe that these skills will not only prepare our students to adapt to and work in future work systems but will also make them competitive and enable them to make decisions, lead, and innovate.

In the Work Analysis and Design course, specifically throughout the 'Future of Work' presentation week, the audience's engagement was evident through the volume and depth of questions asked. The sophistication and depth of these questions were signs of what is perceived as a shift from an elementary engineering problem-solving mindset to a more advanced, and value-driven perspective in addressing work systems' challenges. Most of the questions not only reflected students' curiosity but also their interest in understanding the implications, challenges, risks, requirements, impacts, and strategic roadmaps for integrating emerging technologies into future work systems. This shift to the mindset of value-added inquiry and high-level impact analysis of solutions was one of the noteworthy observations among engineering students.

Finally, a major theme that emerged was the role of the worker in the new innovation economy and how people's work could be designed in practice, while still reaping the benefits of industrial innovation. One particular concern that emerged from the practicing engineers in the Innovation Sciences course was how new AI-driven technology, while being innovative and a

boon to industrial productivity, could displace workers in many sectors of the economy, and how workers who had spent many years in that job could cope and adapt to the new economy driven by AI technologies. Although students understood that they needed to adapt and equip themselves for future work systems, there was considerable concern among the engineers in the class that it would be difficult, if not impossible, for them to retool, reskill, and reequip themselves quickly to adapt to the changes to continue to play roles in the new economy. These emerging questions point to the need for further research and evaluation so that technology and automation in the new innovative economy fueled by AI do not leave behind a whole generation of workers and students who will be part of the next generation of working professionals.

The consensus from these courses was that the design of future work should carefully consider and balance the benefits of rapid and large-scale innovations that can be realized from emerging technologies such as AI, with the role of people and their future work and livelihoods when innovating future work and workplaces.

4. Conclusions

Integrating future-ready skills and the pedagogical principles and practices for teaching these skills in the engineering curriculum can better prepare students to adapt to and flourish in future work systems. Such skills are essential to have a competitive edge as a future engineering professional, innovate and co-create value with technology, in a work landscape driven by AI and automation. We discuss how three courses in the future of work, industrial innovation sciences, future work leadership and work systems management, and entrepreneurship cultivate such skills. Given the pace and scope of technology development, there is a need for future research to explore how curricula and pedagogy development could be made agile in response to changing work needs.

References

[1] K. Dery, S. Woerner, and C. Beath, “Equipping and empowering the future-ready workforce,” MIT Center for Information Systems Research, Cambridge, MA, 2020. [Online]. Available: https://cisr.mit.edu/publication/2020_1201_FutureReadyWorkforce_DeryWoernerBeath

[2] K. Ellingrud, R. Gupta, and J. Salguero, “Building the vital skills for the future of work in operations,” McKinsey & Company, 2020. [Online]. Available: https://www.mckinsey.com/capabilities/operations/our-insights/building-the-vital-skills-for-the-future-of-work-in-operations#/

[3] M. Dondi, J. Klier, F. Panier, and J. Schubert, “Defining the skills citizens will need in the future world of work,” McKinsey & Company, 2022. [Online]. Available: https://hrday.nl/wp-content/uploads/2022/10/JTB.pdf

[4] National Science Board, “Science and Engineering Indicators 2024: The State of Scinece of U.S. Science and Engineering,” National Science Foundation, Alexandria, VA, NSB-2024-3, 2024. [Online]. Available: Available at https://ncses.nsf.gov/pubs/nsb20243

[5] W. Wang and K. Siau, “Artificial Intelligence, Machine Learning, Automation, Robotics, Future of Work and Future of Humanity: A Review and Research Agenda,” *J. Database Manag.*, vol. 30, no. 1, pp. 61–79, Jan. 2019, doi: 10.4018/JDM.2019010104.

[6] "What's next for remote work: An analysis of 2,000 tasks, 800 jobs, and nine countries".
[7] FORE School of Management, New Delhi, India, S. Madakam, R. M. Holmukhe, Bharati Vidyapeeth University, Pune, India, D. Kumar Jaiswal, and National Institute of Industrial Engineering (NITIE), Mumbai, India, "The Future Digital Work Force: Robotic Process Automation (RPA)," *J. Inf. Syst. Technol. Manag.*, vol. 16, pp. 1–17, Jan. 2019, doi: 10.4301/S1807-1775201916001.
[8] M. H. Jarrahi, "Artificial intelligence and the future of work: Human-AI symbiosis in organizational decision making," *Bus. Horiz.*, vol. 61, no. 4, pp. 577–586, Jul. 2018, doi: 10.1016/j.bushor.2018.03.007.
[9] E. H. Almansor and F. K. Hussain, "Survey on Intelligent Chatbots: State-of-the-Art and Future Research Directions," in *Complex, Intelligent, and Software Intensive Systems*, vol. 993, L. Barolli, F. K. Hussain, and M. Ikeda, Eds., in Advances in Intelligent Systems and Computing, vol. 993. , Cham: Springer International Publishing, 2020, pp. 534–543. doi: 10.1007/978-3-030-22354-0_47.
[10] A. Kittur *et al.*, "The future of crowd work," in *Proceedings of the 2013 conference on Computer supported cooperative work*, San Antonio Texas USA: ACM, Feb. 2013, pp. 1301–1318. doi: 10.1145/2441776.2441923.
[11] M. Sng, W. J. Khor, T. Oide, S. C. Suchar, and B. C. K. Tan, "Effectiveness of a Four-days/Eight Hour Work Week".
[12] L. Addati, U. Cattaneo, V. Esquivel, and I. Valarino, *Care work and care jobs for the future of decent work*. Geneva: International Labour Office, 2018.
[13] "Harvard Business Review Journal." Accessed: Aug. 28, 2023. [Online]. Available: https://hbsp.harvard.edu/cases/
[14] "Debate Instructions." Accessed: Aug. 28, 2023. [Online]. Available: https://www.niu.edu/citl/resources/guides/instructional-guide/classroom-debates.shtml
[15] K. L. Turabian, *A manual for writers of research papers, theses, and dissertations: Chicago style for students and researchers*. University of Chicago Press, 2018.
[16] W. C. Booth, G. G. Colomb, and J. M. Williams, *The craft of research*. University of Chicago press, 2003.
[17] "Debate Rubric." Accessed: Aug. 28, 2023. [Online]. Available: https://web.stanford.edu/class/cs326/classroom_debate_rubric.pdf
[18] Kern Family Foundation, "The Framework | Engineering Unleashed." Accessed: Feb. 15, 2023. [Online]. Available: https://engineeringunleashed.com/framework

Module	Title	Learning Objectives	EML outcomes	Method	Assessment
A	Risk Assessment and Analysis	• Apply assessment methods to measure the risk of work-related injuries in modern work systems.	Curiosity, Connection	Problem-solving Collaboration Think, pair, share	Case reports
B	Ergonomics Intervention Strategies	• Discuss the benefits of an ergonomic work system.	Curiosity, Connection	Collaboration Think, pair, share	Case reports Questions list
C	The Business of Occupational Ergonomics in Work Systems.	• Identify the costs of ergonomics issues in work systems. • Apply Return On Investment (ROI) and Cost-Benefit Analysis (CBA) for intervention cost justification.	Connection, Creating Value	Problem-solving Collaboration	Report1
D	Modernizing Work Systems-Future of Work Technologies	• Discuss the future of work technologies and systems and their impact on occupational safety and productivity	Connection	Critical Thinking Collaboration	Presentation
E	Business of Future of Work, technology management, Decision Making (AHP)	• Analyze and discuss organizations' needs to adopt new technologies to improve their work system safety, productivity, and technical skills while considering economic options. • Investigate political, economic, social, technical, environmental, or legal (PESTEL)to investigate the consequences on workforce wellbeing and productivity, if organizations do not adapt to future work requirements, and changes.	Curiosity, Connection, Creating Value	PBL Critical Thinking Communication Stakeholder analysis	Report 2