Journal of Engineering, Project, and Production Management
2024, 14(3), 0024

Integrating Industry 4.0 Concepts in Civil Engineering Education

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Project Management
Received May 23, 2023; received revision December 23, 2023; accepted November 8, 2023
Available online September 27, 2024

Abstract: Opportunities to improve students' civil engineering skills for Industry 4.0 and train them for potential challenges in their professional careers go beyond industry sponsorship of capstone design projects. Students and faculty can benefit from industry mentors' involvement who can use their expertise in addressing design problems and are enthusiastic about sharing their knowledge with students. Practicing engineers have a relevant, realistic, real-world viewpoint on their subject and reinforce their relevance to professional engineering practices. Students benefit tremendously from working on real-world problems of interest to industry, business, company-specific project management, product creation processes, and experience with financial, legal, and regulatory design constraints. This paper offers an overview of the multidisciplinary capstone design course in the civil engineering curriculum in Jordan and highlights relevant practices. It provides valuable guidance for incorporating Industry 4.0 skills into the teaching of capstone design courses to deal with challenges related to the context of digital transformation. The paper concludes that industry integration in engineering curriculum can generate multi-skilled and competent engineers with essential cognitive skills such as creativity, complex information processing, and lifelong learning.

Keywords: Capstone design projects, civil engineering curriculum, industry 4.0, professional engineering practices, university-industry collaboration.

DOI 10.32738/JEPPM-2024-0024

1. Introduction

Many higher education programs understand the value of partnering with industry in capstone design courses to prepare students for careers in engineering (Farr et al., 2001; Whitman and Malzahn, 2006; Goldberg, 2014; Pembridge and Paretti, 2019). The faculty should have specific expertise and engage collaborators from industry and other professional organizations to provide a practical and realistic real-world viewpoint on their subject (Rybnicek and Königsgruber, 2019). It is important to provide students with an open-ended theme topic that simulates real-world problems.

In Jordan, the capstone design project courses comprise two dependent courses of one and two credit hours that are required during the last year of study and should be completed during two semesters. The total number of credit hours in the Civil Engineering Bachelor's Program is 160 hours, which normally takes five years to complete. Students should finish an Engineering Practical Training course for eight weeks before they can start their capstone design project courses. These two courses are defined in the curriculum as a supervised project conducted by a group of three to five students aimed at providing practical experience in specified fields of civil engineering. Students are expected to complete a final report that comprises a literature survey, project specification, critical analysis, and necessary material needed to successfully accomplish the aim of the project. Finally, the students are required to present and defend their work.

The multidisciplinary concept in the capstone design course in Civil Engineering (CE) programs may involve collaborations from various sub-disciplines of CE, namely structural, geotechnical, environmental and sanitary, transportation, hydrology and water resources, surveying, construction and project management, and infrastructure engineering. The author's experience of previous examples of multidisciplinary projects involved constructing a dormitory complex on a parcel of land adjacent to the university campus. The design team completed the architectural drawings, infrastructure networks, geotechnical engineering, and the complex's structural components in this project. Alternatively, the multidisciplinary concept may involve representatives from other majors in the faculty of engineering and technology. For instance, a civil engineering student design team has finished working on cooled mass concrete applications for pavement design, including the injection of liquid nitrogen and the use of air chillers. This project is supervised by faculty members from civil engineering, mechanical engineering, and alternative energy technology programs (Alamayreh et al., 2021). In a typical semester, the capstone design teams are formed based on student choices subject to restrictions such as co-op schedules, required skills and experience, and team size. Usually, some of the projects are linked to the industry and other projects are introduced based on the needs of the local communities. The student design team submits a formal proposal to their supervisor to present the scope of engineering services, schedule, deliverables, and milestones. During the course, the supervisor conducts weekly progress meetings to review completed tasks and discuss plans. The supervisor may also request weekly peer reviews, progress reports, and keep a project design folder.

In higher education for civil engineering, Industry 4.0 applications are among the most challenging topics. In general, Industry 4.0 automation enables rapid measures and remedies for changes in the labor force, materials, equipment, cash flow, and unexpected changes in a project. This updating can be achieved using Cyber-Physical Systems (CPS) for vertical networking within the corporate's smart environment. Horizontal networking can take the form of integration via IT systems over the entire engineering process to permit communications across external stakeholders. It allows data flow between project parties, including clients, contractors, designers, vendors, subcontractors, and authorities. Additionally, in the context of civil engineering, Industry 4.0 requires specific features such as End-to-End (E-to-E) engineering over the whole value chain and acceleration of design and construction practices through exponential technologies.

The Industry 4.0 revolution was sparked in 2011 when a high-tech strategy project in Germany to advance Cyber Physical Systems (CPS) into Cyber Physical Production Systems (CPPS) was completed (Vogel-Heuser and Hess, 2016). In 2021, the European Commission coined the term Industry 5.0 in response to societal and geopolitical changes to achieve a more sustainable, human-centric, and resilient industry (Breque et al., 2021; Xu et al., 2021). A recent study by Jaradat et al. (2021) showed that most of the current technological trends, including the concept of Industry 4.0, are still not popular in most Arab countries, and that the United Arab Emirates (UAE) is better at adopting current technologies than other Arab countries. However, another previous study by Ahmad et al. (2020) found that students studying in civil engineering programs are enthusiastic about modern technology in engineering and prefer education that combines traditional methods with innovative technological tools.

E-to-E engineering can be executed in CE projects through innovative improvements in the design process using advanced communication and virtualization methods. Virtualization presents an excellent tool to produce sound design and management decisions. The acceleration of design and construction practices may lead to the desired cut in costs and enhance flexibility. It can be done through Artificial Intelligence (AI), Internet of Things and Internet of Services (IoT/IoS), Cloud Computing, and Big Data (Gilchrist, 2016; Oesterreich and Teuteberg, 2016; Brettel et al., 2017; Zhou et al., 2015; Tjahjono et al., 2017).

Technically, civil engineers must possess advanced mathematical knowledge, computer programming, and knowledge of workforce-specific software tools and information processing. This knowledge will enhance their problem-solving, creativity, and design skills. Moreover, they should acquire experimental and investigative skills, a strong understanding of industry standards, and proficiency in designing and testing simulation models. Interpersonal skills, including analytical thinking, teamwork and leadership skills, and communication skills, are also needed for their profession, and the concept of digital skills is emerging in the academic and industrial worlds. Therefore, while digital literacy skills are essential for communicating and conducting basic Internet searches, workplace-specific digital skills are also essential for the application of specialized programs in engineering, digital technologies, and new products and services (Motyl et al., 2017).

Training and continuing professional development are vital components of realizing the Industry 4.0 intentions. It has become imperative to have a valuable partnership between industry and higher education to develop industry skills. There are few studies in CE related to the educational needs of students and the industrial workforce (Benešová and Tupa, 2017; Ersoz et al., 2018; Gorbunova et al., 2018).

This paper explores the necessary skills and competencies for future civil engineers to be equipped for the Industry 4.0 challenges. The researchers intend to present a teaching methodology for capstone design courses that incorporates Industry 4.0 skills. The paper investigates the concepts of Industry 4.0, how these concepts are linked to the construction industry, and how to provide students with skills that promote their success and adaptability to this transfer. The paper then presents the evaluation process for the students' performance, including their abilities for Industry 4.0. Finally, the recent University-Industry Collaboration (UIC) framework is discussed. A conceptual framework developed for integrating Industry 4.0 concepts in the civil engineering program is shown in Fig. 1 and will be discussed in the following sections.

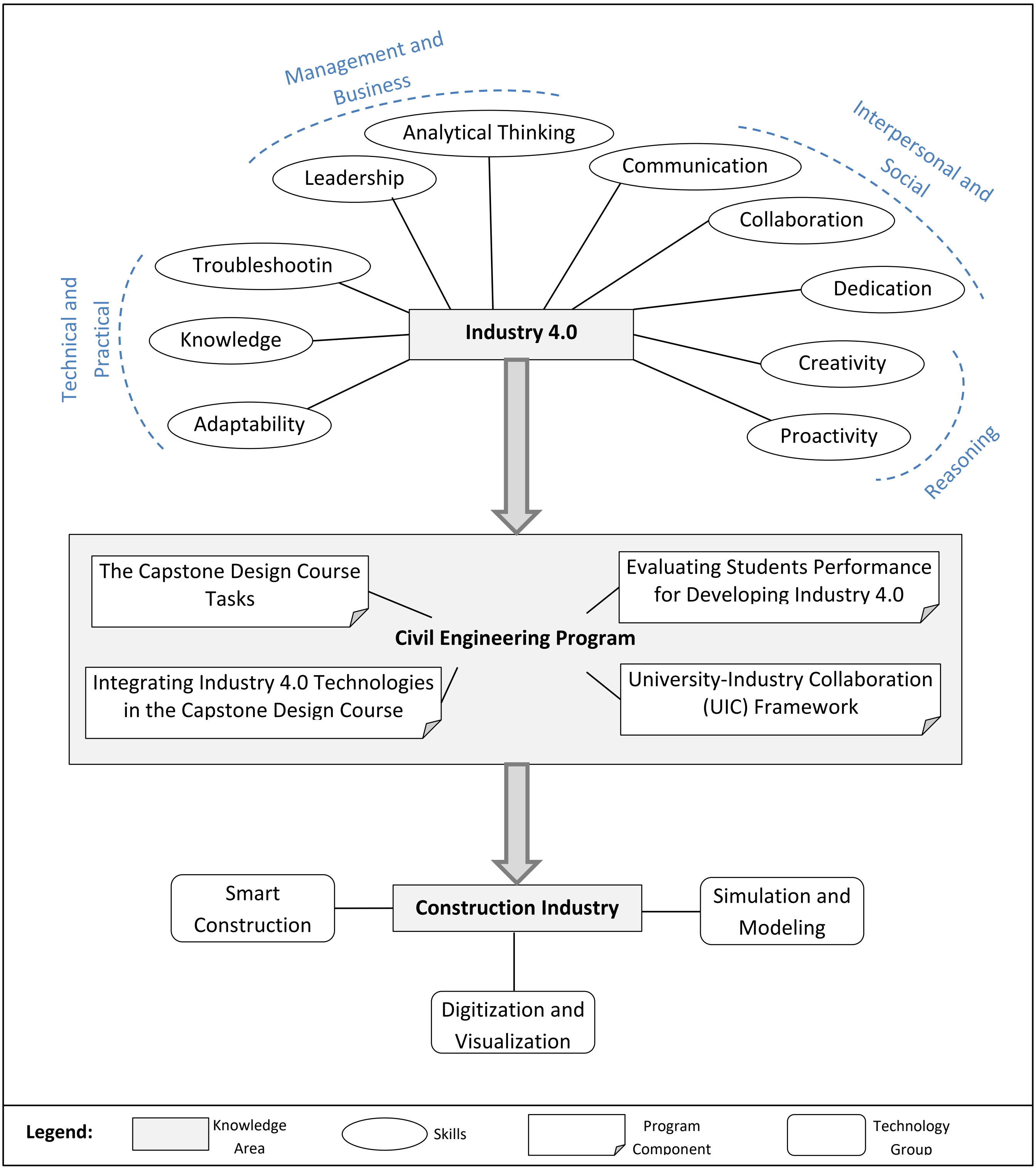

Fig. 1. Conceptual framework for integrating industry 4.0 concepts in the civil engineering program

2. Linking Concepts from Industry 4.0 to the Civil Engineering

The civil engineering industry's value chain is a management technique that considers all activities necessary to complete projects by enhancing consumer value. The construction sector is described as a complex value chain with critical elements of the Construction Value Chain (CVC) that links a life-cycle perspective to a supply chain approach and illustrates activities that traditionally occupy a significant position within the chain (Baker et al., 2017).

Industry 4.0 can offer greater consistency and robustness along with high-quality standards for engineering, planning, manufacturing, operational and logistics processes. This revolution in the industry will lead to dynamic, real-time optimized and self-regulating value chains based on several criteria, such as resource availability and consumption, cost, etc. (de Paula Ferreira et al., 2020). Practically, design updates, errors, and modifications within a project can cause delays and cost overruns. Usually, that can be due to ineffective real-time communication and a lack of good collaboration among participants. Furthermore, on-site project modifications cannot be easily incorporated within the Project Life-cycle Management (PLM) and are also susceptible to errors due to improper updating of records. Therefore, supply chain transparency and quality control are two significant logistics challenges in CE projects (Emblemsvåg, 2020; You and Feng, 2020).

The concept of the smart construction era is reforming the construction industry and bringing it into the Industry 4.0 context. The implementation of emerging technologies occurs in all phases of the development cycle of CE projects. The emerging technologies may include Building Information Modelling (BIM), Internet of Things and Internet of Services (IoT/IoS), Big Data, Cloud Computing, Artificial Intelligence, and others, as explained below (Onyegiri et al., 2011; Sardroud, 2012; Labonnote et al., 2016; Li and Yang, 2017; Ghaffar et al., 2018; Dalmarco et al., 2019; Hossain and Nadeem, 2019; Sawhney et al., 2020).

Industry 4.0 concepts and technologies in the civil engineering industry are classified into three groups (Oesterreich and Teuteberg, 2016):

- Smart Construction Site: The technologies associated with this cluster are tailored to end-to-end engineering feature of Industry 4.0. Generally, there are several approaches to create a "smart construction site," such as Cyber-physical system (CPS), Radio Frequency Identification (RFID), Robotics and drones, Modularization / Prefabricated Construction, Additive Manufacturing, Product Life Cycle Management (PLM), Human-Computer Interaction (HCI), and Internet of Things and Internet of Services (IoT/IoS).
- Modeling and Simulation: Civil engineering projects are unique and complex, affected by external variables and variations, unpredictable weather conditions, and work performance. Therefore, the implementation of modeling and simulation technologies can effectively manage construction and improve its design. This category comprises of Augmented Reality, Virtual Reality, Mixed Reality, Building Information Modeling, and other technologies.
- Digitization and Visualization: This group constitutes an extensive use of Information and Communication Technology (ICT) for establishing digital environment and value chain. Digitization and visualization technologies and concepts include Cloud and Mobile Computing, Big Data, Social Media, etc.

3. Integrating Industry 4.0 Concepts into Civil Engineering Programs

Transformation towards Industry 4.0 requires civil engineers to have the ability to successfully and effectively respond to new business environments and to integrate digital and automated business dynamics. This includes having competencies such as teamwork, problem-solving, lifelong learning, and digital and communication skills. Furthermore, they have to be designers with a multidisciplinary background, which requires new core management competencies. Based on an extensive literature review, the authors describe below four major categories of engineering competencies in Industry 4.0 (Kirschenman, 2011; Jäger et al., 2014; Osman et al., 2016; Cotet et al., 2017; Vila et al., 2017; Ab Rasid and Amin, 2019; Kamaruzaman et al., 2019; Marnewick and Marnewick, 2019; Rashidah et al., 2019; Dhinakaran et al. 2020; Kulkarni et al., 2020; Mitrović Veljković et al., 2020; Moghayedi et al., 2020; Papadopoulou, 2020; Rivera et al., 2020; Grzybowska and Łupicka, 2017). These competencies are identified and listed in Table 1.

Table 1. Categories of Industry 4.0 skills

Category	Skills	Engineering skills	Industry 4.0 skills
Technical and practical	Adaptability, knowledge, and troubleshooting	Problem solving, lifelong learning, ethics and professionalism, technology awareness	Critical thinking and analysis, complex problem solving, systems analysis/evaluation, active learning and learning strategies, technology design/programming,
Management and business	Leadership and analytical thinking	Management, thinking, leadership	Analytical thinking and innovation, leadership and social influence
Interpersonal and social	Communication, collaboration, and dedication	Communication, teamwork, decision making	Emotional intelligence
Reasoning	Creativity and proactivity		Creativity, originality and initiative, reasoning, problem solving and ideation

First, adaptability involves preparing graduates to analyze real-world problems in a living environment. The knowledge will allow professionals to apply principles of engineering, science, mathematics and industry requirements. Engineers must possess the skills to evaluate, select, and use resources, tools, and techniques from engineering and industry.

Second, business skills focus on making business decisions and leading subordinates within the organization. Typically, civil engineers need to manage projects, work in teams, and assign tasks according to the team's resources and expertise. Civil engineers are also required to initiate studies and research to analyze situations.

Third, communication skills will enable engineering graduates to articulate ideas clearly and adapt depending on the informative purpose. The practice of civil engineering requires individuals to participate in multidisciplinary work environments. To complete projects, civil engineers must have the ability to dedicate actions toward the commitments made.

Fourth, reasoning skills with engineers' creative and proactive potentials are particularly in demand in Industry 4.0. Civil engineers must design alternative solutions to model multidisciplinary civil engineering systems. They must also demonstrate initiatives in addressing environmental situations.

Hence, accrediting agencies are advised to set compatible criteria for future civil engineering programs with educational objectives that prepare civil engineers with innovative capabilities and creative, technical and professional competencies. To do this, civil engineering programs must aim to address innovative skills in the curriculum and develop robust educational methodologies for this purpose. Multidisciplinary engineering education requires changing the traditional way of teaching, launching new topics and modifying the conventional courses. CE curricula must adapt to industry requirements and teach students to design complex engineering systems in user-friendly, interactive environments (Kozák et al., 2018). It is not easy to present a single methodology for incorporating the implications of Industry 4.0 into the CE curriculum. Researchers suggest supplemental courses in civil engineering to prepare graduates to adapt quickly to emerging challenges in the future. Some have suggested undergraduate courses to include Modern Physics, and Introduction to Computer Science and Programming. Engineering courses such as Sensors and Actuators may be included in the CE postgraduate degree curriculum (Jeganathan et al., 2018; Coşkun et al., 2019; Hadgraft and Kolmos, 2020).

4. Structuring and Assessing a Capstone Project Course for Development of Industry 4.0 Skills

Civil engineering is a professional discipline concerned with the design, construction, and maintenance of the built environment. Civil engineers create solutions to real-world problems when working under a variety of realistic constraints, and they will be required to integrate real-time data processing, interoperability, virtualization, decentralization, agility, and service orientation in the context of Industry 4.0.

Traditional curricula in CE programs are designed to learn the required technical skills. When teaching a capstone design course in civil engineering programs, there are several opportunities to improve managerial and interpersonal skills.

4.1. Capstone Design Course Stages

It is mandatory to structure the capstone project to simulate a real-world design problem. The design team consists of senior students that share similar interests and the willingness to work together. At the initial stage, students are required to prepare their Statement of Qualifications (SOQ) to introduce themselves as a professional design team to potential clients. Faculty members oversee design projects as a whole and bring specialized expertise to project teams. Usually, industrial experience in a specific area is required to complete the project.

The academic department introduces design project problems in the project offering forms, which are simply the equivalent of Request for Proposals (RFP). The design team should gather information about the background of the project problem and the expected alternative solutions. At this stage, the design team may reach out to the customer through a Memorandum of Understanding (MoU). Then, the design team must be ready to formalize the project plan, including milestones, deliverables within the project schedule, and cost of engineering services. The supervisor will guide the design team through a time plan to accomplish these important milestones. It starts with generating viable alternative solutions and preparing a detailed design that meets the client's expectations and design requirements according to the project's technical proposal. The proposal serves as a contractual agreement that governs the project's milestones and deliverables.

The key skills that any good business development team must have are active learning and learning strategies. Table 2 shows the Industry 4.0 skills outline for the capstone design project assignments.

Table 2. Mapping of the capstone design course tasks to Industry 4.0 skills' categories

	Technical and practical category			Management and business category		Interpersonal and social category			Cognitive category	
The Capstone Design Course Tasks	Adaptability	Knowledge	Troubleshooting	Leadership	Analytical thinking	Communication	Collaboration	Dedication	Creativity	Proactivity
1. Introduce the design team to the engineering firm and client.		✓		✓		✓				
2. Define problem including the expected scope of services and a list of expected deliverables.	✓				✓		✓			✓
3. Gather pertinent information and field investigation reports.		✓					✓			
4. Prepare a request from the team to meet with their clients to form a memorandum of understanding.			✓		✓	✓		✓		
5. Prepare a formal engineering design proposal and the project plan: milestones and deliverables with a complete project schedule.		✓		✓		✓			✓	
6. Generate alternative solutions subject to realistic constraints.		✓					✓			✓
7. Select the feasible solution based on preset criteria.	✓				✓					
8. Complete, implement, document, verify, and modify.		✓	✓	✓			✓	✓	✓	
9. Submit a copy of final work to the company that contributed to the problem statement.						✓				
10. Meet representative of the contributing firm to discuss the project's final product.		✓			✓	✓				

4.2. Industry 4.0 Technologies and Capstone Design Course

Local engineering firms and government agencies may provide design statements. New projects' context data can be accessed using technologies like IoT/IoS, cloud storage, social media, and archives. Some digital information for infrastructure utilities is readily available via Geographic Information System (GIS) maps. Depending on the discipline and project requirements, the design team should be encouraged to use modeling and simulation methods. Building Information Modeling (BIM), for example, is a software platform for integrated design, modeling, planning, and collaboration in civil engineering. Other related Industry 4.0 technologies' applications may be dependent on the project design team's ingenuity in addressing problems outlined in their project problem statement. Alternative design technologies include modularization/prefabrication, on-site automation, additive manufacturing for buildings, and augmented and virtual reality.

4.3. Evaluating Students Performance for Developing Industry 4.0

The evaluation process adopted by the CE program should provide an individual and collective assessment of the design team. The assessment of team success is measured by the faculty using the project evaluation form based on the attainment of the project deliverables.

The teaching of CE capstone design courses for Industry 4.0 context should consider the use of CE industry resources, tools, and technologies to optimize engineering design sustainability. Student achievement is assessed based on their ability to create a virtual analysis model, considering automation requirements for the continuous improvement of the physical and hypothetical processes of the civil engineering system to promote sustainable development. The project offerings must include realistic constraints to present a comprehensive potential design experience to student teams in future semesters. The capstone design course requires students to understand the global, economic, environmental and societal constraints of engineering solutions. Incorporating these design constraints is assessed based on their identification and analysis, as detailed in the project documentation. Besides, some CE design projects require laboratory assignments to achieve the final design. The laboratory tasks may allow students to practice engineering judgment to complete real design projects using advanced technologies.

Furthermore, faculty members should incorporate contemporary issues and new technologies into CE capstone design courses as design requirements. Civil engineering students are required to know new issues that have influenced civil engineering design and construction methods. Examples of contemporary and new civil engineering issues may include computer design software, advanced construction technologies, green building implementation, and the recycling of waste into innovative building materials. Knowledge of contemporary civil engineering issues aims to develop students' creative and proactive skills.

Leadership and analytical thinking abilities are mostly assessed by observing the student's deep understanding of the project problem and design requirements. An integrated engineering approach is necessary to produce a value engineering project. The faculty should pay further attention to observing the weekly tasks of the project team as specified in a time plan that students should prepare at the beginning of the capstone design course. The final grade correlates strongly to the observed collaboration of the team members measured through quantitative metrics. Confidence in answering and quality of answers to committee questions is also included in the student assessment. The design team must communicate the project's documentation effectively with various audiences, both written and orally.

5. University-Industry Collaboration (UIC) Framework

The University-Industry Collaboration (UIC) framework has been implemented in the CE program since the end of the 2021/2022 academic year. The UIC implementation engages ongoing-multidisciplinary teams of undergraduates in faculty research, design, and other initiatives. Every semester, each UIC team involves second through final year undergraduates. New students will be added to a team when seniors graduate.

Benefits of the UIC Implementation

The following list shows examples of the expected benefits of the UIC implementation:

- Because of their consistency, scope, long-term character, disciplinary depth, and multidisciplinary depth, UIC teams can make major contributions to professors' research and other projects.
- People from the industry value the teamwork and leadership skills – both organizational and disciplinary leadership skills – that UIC team members will develop over the semesters in which they earn academic credit through the UIC implementation.
- Members of UIC teams will be regularly pursued by corporations for internships and permanent jobs due to the skills and experience they will obtain while at UIC.
- The UIC implementation will also encourage corporations to participate in the UIC teams and receive benefits such as new ideas and development of work.

Challenges to the UIC Implementation

The following list shows examples of the challenges that may affect the UIC implementation:

- Lack of industry awareness of university capabilities and lack of university awareness of industry needs.
- Lack of mutual trust, commitment, and common interests.
- Nature of construction projects with high financial and time pressure.
- Lack of adequate funding and human resources.
- Complexity and long process of policies related to patents and intellectual property.

6. Conclusions

This paper provides valuable guidance for incorporating Industry 4.0 skills into the teaching of CE capstone design courses. Integrating the concepts and techniques of Industry 4.0 in the CE capstone design courses will be beneficial in preparing CE graduates to adapt to future challenges quickly. Civil engineering education should enhance the cognitive skills of graduates to acquire higher abilities in problem-solving, complex information processing, creativity, critical thinking, and lifelong learning. The paper concludes that the industry can generate multi-skilled and competent engineers who can deal with challenges related to the context of digital transformation through this development.

Although the methods presented in this paper have continuously improved over the last few years, there is still a need for more refinement. Furthermore, the case study can be extended to be applied to other programs, or to use courses other than the capstone design course. Future research may consider analyzing the challenges of integrating Industry 4.0 concepts in engineering education. Feedback from academics, practitioners, and engineering graduates can be useful for this purpose. This study is still in its early stages and will need more opinions from users and deeper planning and details.

Author Contributions

Rana Alhorani contributes to methodology, analysis, investigation, data collection, draft preparation, and manuscript editing. Subhi Bazlamit contributes to validation, analysis, investigation, and manuscript editing. Wejdan Abu Elhaija contributes to conceptualization, methodology, validation, manuscript editing, supervision, and project administration. Hesham Rabayah contributes to analysis, investigation, manuscript editing, and visualization. All authors have read and agreed with the manuscript before its submission and publication.

Funding

This research received no specific financial support from any funding agency.

References

Ab Rasid, N., and Amin, N. F. (2019). Industry 4.0 Civil Engineer Job Skills Required By Employers In Malaysia. *Journal Kemanusiaan*.

Ahmad, H. S., Abu-Elhaija, W., and Qandoos, Y. (2020). New Strategy for Enhancing Engineering Practical Teaching through the Development of Infrastructure Learning Hub (ILH). In *MATEC Web of Conferences* (Vol. 312, p. 02001). EDP Sciences.

Alamayreh, M. I., Alahmer, A., Bazlamit, S. M., and Younes, M. B. (2021). Energy Analysis and Refrigerant Replacement in Pre-Cooling Concrete System in Massive Concrete Structures. *EPPM 2021*, 11.

Baker, P., Giustozzi, L., Gloser, J., Hanzl-Weiss, D., Merkus, E., Molemaker, R. J., and Stehrer, R. (2017). *The European construction value chain: performance, challenges and role in the GVC* (No. 418). wiiw Research Report.

Benešová, A., and Tupa, J. (2017). Requirements for education and qualification of people in Industry 4.0. *Procedia manufacturing*, *11*, 2195-2202.

Breque, M., De Nul, L., and Petridis, A. (2021). Industry 5.0: towards a sustainable, human-centric and resilient European industry. *Luxembourg, LU: European Commission, Directorate-General for Research and Innovation*.

Brettel, M., Friederichsen, N., Keller, M., and Rosenberg, M. (2017). How virtualization, decentralization and network building change the manufacturing landscape: an industry 4.0 perspective. *FormaMente*, *12*.

Coşkun, S., Kayıkcı, Y., and Gençay, E. (2019). Adapting engineering education to industry 4.0 vision. *Technologies*, *7*(1), 10.

Cotet, G. B., Balgiu, B. A., and Zaleschi, V. C. (2017). Assessment procedure for the soft skills requested by Industry 4.0. In *MATEC web of conferences* (Vol. 121, p. 07005). EDP Sciences.

Dalmarco, G., Ramalho, F. R., Barros, A. C., and Soares, A. L. (2019). Providing industry 4.0 technologies: The case of a production technology cluster. *The journal of high technology management research*, *30*(2), 100355.

de Paula Ferreira, W., Armellini, F., and De Santa-Eulalia, L. A. (2020). Simulation in industry 4.0: A state-of-the-art review. *Computers and Industrial Engineering*, 106868.

Dhinakaran, V., Partheeban, P., Ramesh, R., Balamurali, R., and Dhanagopal, R. (2020). Behavior and Characteristic Changes of Generation Z Engineering Students. In *2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS)* (pp. 1434-1437). IEEE.

Emblemsvåg, J. (2020). On Quality 4.0 in project-based industries. *The TQM Journal*.

Ersoz, F., Merdin, D., and Ersoz, T. (2018). Research of Industry 4.0 Awareness: A Case Study of Turkey. *Economics and Business*, *32*(1), 247-263.

Farr, J. V., Lee, M. A., Metro, R. A., and Sutton, J. P. (2001). Using a systematic engineering design process to conduct undergraduate engineering management capstone projects. *Journal of Engineering Education*, *90*(2), 193-197.

Ghaffar, S. H., Corker, J., and Fan, M. (2018). Additive manufacturing technology and its implementation in construction as an eco-innovative solution. *Automation in Construction*, *93*, 1-11.

Gilchrist, A. (2016). *Industry 4.0: the industrial internet of things*. Apress.

Goldberg, J. R., Cariapa, V., Corliss, G., and Kaiser, K. (2014). Benefits of industry involvement in multidisciplinary capstone design courses. *International Journal of Engineering Education*.

Gorbunova, T. N., Papchenko, E. V., Bazhenov, R. I., and Putkina, L. V. (2018). Professional standards in engineering education and industry 4.0. In *2018 IEEE International Conference" Quality Management, Transport and Information Security, Information Technologies" (IT, QM and IS)*, 638-642. IEEE.

Grzybowska, K., and Łupicka, A. (2017). Key competencies for Industry 4.0. *Economics and Management Innovations*, *1*(1), 250-253.

Hadgraft, R. G., and Kolmos, A. (2020). Emerging learning environments in engineering education. *Australasian Journal of Engineering Education*, *25*(1), 3-16.

Hossain, M. A., and Nadeem, A. (2019). Towards digitizing the construction industry: State of the art of construction 4.0. In *Proceedings of the ISEC*, 10.

Jaradat, Y., Masoud, M., Jannoud, I., Manasrah, A., and Zerek, A. (2021). Popularity of Current Technology Trends in Arab Countries. *2021 IEEE 1st International Maghreb Meeting of the Conference on Sciences and Techniques of Automatic Control and Computer Engineering MI-STA,* 924-928. IEEE.

Jäger, A., Ranz, F., Sihn, W., and Hummel, V. (2014). Implications for Learning Factories from Industry 4.0. In *Proceedings of the 4th Conference on Learning Factories. Stockholm, 28.05,* 1-35.

Jeganathan, L., Khan, A. N., Raju, J. K., and Narayanasamy, S. (2018). On a Frame Work of Curriculum for Engineering Education 4.0. In 2018 World Engineering Education Forum-Global Engineering Deans Council (WEEF-GEDC). *Albuquerque, NM, USA*, 12-16.

Kamaruzaman, M., Hamid, R., Mutalib, A., and Rasul, M. (2019). Comparison of engineering skills with IR 4.0 skills.

Kirschenman, M. D. (2011). Improvements to the culture and attitudes in civil engineering education. *Leadership and Management in Engineering*, *11*(2), 223-225.

Kozák, Š., Ružický, E., Štefanovič, J., and Schindler, F. (2018). Research and education for industry 4.0: Present development. In *2018 Cybernetics and Informatics (K and I)*, 1-8. IEEE.

Kulkarni, P. M., Deshpande, A. S., Arunkumar, P., and Tiwary, V. (2020). Personality traits and Industry 4.0-a new dimension for engineering education. *International Journal of Continuing Engineering Education and Life Long Learning*, *30*(1), 35-51.

Labonnote, N., Rønnquist, A., Manum, B., and Rüther, P. (2016). Additive construction: State-of-the-art, challenges and opportunities. *Automation in construction*, *72*, 347-366.

Li, J., and Yang, H. (2017). A research on development of construction industrialization based on BIM technology under the background of Industry 4.0. In *MATEC Web of Conferences* (Vol. 100, p. 02046). EDP Sciences.

Marnewick, A. L., and Marnewick, C. (2019). The ability of project managers to implement industry 4.0-related projects. *IEEE Access*, *8*, 314-324.

Mitrović Veljković, S., Nešić, A., Dudić, B., Gregus, M., Delić, M., and Meško, M. (2020). Emotional Intelligence of Engineering Students as Basis for More Successful Learning Process for Industry 4.0. *Mathematics*, *8*(8), 1321.

Moghayedi, A., Le Jeune, K., Massyn, M., and Ekpo, C. (2020). Establishing The Key Elements of Incorporation and Outcomes of 4th Industrial Revolution in Built Environment Education: A Mixed Bibliographic and Bibliometric Analysis. *Journal of Construction Project Management and Innovation*, *10*(1), 1-19.

Motyl, B., Baronio, G., Uberti, S., Speranza, D., and Filippi, S. (2017). How will change the future engineers' skills in the Industry 4.0 framework? A questionnaire survey. *Procedia manufacturing*, *11*, 1501-1509.

Oesterreich, T. D., and Teuteberg, F. (2016). Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. *Computers in industry*, *83*, 121-139.

Onyegiri, I., Nwachukwu, C., and Jamike, O. (2011). Information and communication technology in the construction industry. *American journal of scientific and industrial research*, *2*(3), 461-468.

Osman, S. A., Khoiry, M. A., Rahman, N. A., Rahni, A. A. A., Mansor, M. R. A., Nordin, D., and Johar, S. (2016). The effectiveness of industrial training from the perspective of students of the civil and structure engineering department. *Journal of engineering Science and Technology*, *11*, 1-12.

Papadopoulou, T. (2020). Developing construction graduates fit for the 4th industrial revolution through fieldwork application of active learning. *Higher Education Pedagogies*, *5*(1), 182-199.

Pembridge, J. J., and Paretti, M. C. (2019). Characterizing capstone design teaching: A functional taxonomy. *Journal of Engineering Education*, *108*(2), 197-219.

Rashidah, M. S., Humphrey, J. V., and Anizahyati, A. (2019). Essential Skills for Civil Engineering Graduates Towards Industry Revolution 4.0. In *2019 IEEE 11th International Conference on Engineering Education (ICEED)* 137-140. IEEE.

Rivera, M. L., Hermosilla, P., Delgadillo, J., and Echeverría, D. (2020). The sustainable development goals (SDGs) as a basis for innovation skills for engineers in the industry 4.0 context. *Sustainability*, *12*(16), 6622.

Rybnicek, R., and Königsgruber, R. (2019). What makes industry–university collaboration succeed? A systematic review of the literature. *Journal of business economics*, *89*(2), 221-250.

Sardroud, J. M. (2012). Influence of RFID technology on automated management of construction materials and components. *Scientia Iranica*, *19*(3), 381-392.

Sawhney, A., Riley, M., Irizarry, J., and Pérez, C. T. (2020). A proposed framework for Construction 4.0 based on a review of literature. *EPiC Series in Built Environment*, *1*, 301-309.

Tjahjono, B., Esplugues, C., Ares, E., and Pelaez, G. (2017). What does industry 4.0 mean to supply chain? *Procedia manufacturing*, *13*, 1175-1182.

Vila, C., Ugarte, D., Ríos, J., and Abellán, J. V. (2017). Project-based collaborative engineering learning to develop Industry 4.0 skills within a PLM framework. *Procedia manufacturing*, *13*, 1269-1276.

Vogel-Heuser, B., and Hess, D. (2016). Guest editorial Industry 4.0–prerequisites and visions. *IEEE Transactions on automation Science and Engineering*, *13*(2), 411-413.

Whitman, L., and Malzahn, D. Industry/University Partnership in a Capstone Course.

Xu, X., Lu, Y., Vogel-Heuser, B., and Wang, L. (2021). Industry 4.0 and Industry 5.0—Inception, conception and perception. *Journal of Manufacturing Systems*, *61*, 530-535.

You, Z., and Feng, L. (2020). Integration of industry 4.0 related technologies in construction industry: a framework of cyber-physical system. *IEEE Access*, *8*, 122908-122922.

Zhou, K., Liu, T., and Zhou, L. (2015). Industry 4.0: Towards future industrial opportunities and challenges. In *2015 12th International conference on fuzzy systems and knowledge discovery (FSKD)*, 2147-2152. IEEE.

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