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# Aspects of sustainable training in engineering courses: a literature review

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**ABSTRACT**
In the pursuit of growth and development, human beings can end up threatening their own existence, making education focused on sustainability an urgent necessity. As construction industry is one of the largest in the world, responsible for the consumption of large quantities of raw materials and with a large workforce, a more careful look at professional training in this sector is necessary so that current and future demands of society can be met sustainably. This objective of this article is to present fundamental aspects of civil engineer training, taking into consideration sustainable development and the need to modernize the construction industry. The methodology consisted of a systematic literature review (SLR) using the Engineering Village, Scopus and Web of Science databases. This study is relevant in highlighting not only the technical training necessary to follow the technological transformations that have resulted from the current industrial revolution, but also the importance of professional-citizen training aimed at building a more just world. The results identified the skills and technologies that assist in civil engineer training, successful educational strategies used in engineering schools, ways to incorporate sustainability concepts into teaching, and a teacher profile for preparing this engineer. The information obtained is significant for Higher Education Institutions (HEIs), as the topic is current and necessary for a more equitable, socially inclusive, economically fair, and environmentally sustainable world.

**KEYWORDS:** Construction Industry. Civil Engineering. Sustainable Development.

## 1 INTRODUCTION

The construction industry is one of the largest in the world, representing 13% of the global Gross Domestic Product (GDP) (RIBEIRINHO *et al.*, 2020). Demands such as sustainability, costs, skill shortages, new materials, industrialization, and digitalization are being transformed in order to meet the needs of a new revolution in construction (LUND *et al.*, 2020; RIBEIRINHO *et al.*, 2020).

Industry 4.0 is the combination of automation with technologies that seek greater productivity and standardization of products and services, beginning with with the digitalization of processes (ALMADA-LOBO, 2016). In Industry 4.0, these processes include manufacturing, supply chain, and product life cycle management (CAVALCANTE; ALMEIDA, 2018).

In recent years, increased demand in different areas such as safety, energy, and cost management has led the construction industry to new tools and methods, including more efficient use of digital technologies (SIDANI *et al.*, 2021; WARNER; WÄGER, 2019).

Shared information is one of the principles of Industry 4.0, as it enables all stakeholders to participate in real time in a virtual universe, resulting in a broad and profound transformation of project management processes (DALLASEGA; RAUCH; LINDER 2018; HERMANN; PENTEK; OTTO, 2015; SURI *et al.*, 2017).

According to Lasi *et al.* (2014) and Pfohl, Yahsi, and Kurnaz (2017), connectivity, automation, decentralization, and digitalization are the principal characteristics of this industry. In civil construction, Building Information Modeling (BIM) is the technology that has stood out, because it is capable of building integrated projects, where it is possible to monitor all project stages (IBEC, 2021). With BIM, in addition to 3D modeling, it is possible to develop and monitor other construction activities.

The benefits of this new industry include: reduced costs and delivery times, higher quality work, predictive maintenance, lower risk of work accidents, and a better-trained

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workforce (Dos Santos Simão *et al.*, 2019). Other benefits of this new construction industry are revenue optimization, sustainability, production chain integration, greater competitiveness, and higher productivity (Pilloni, 2018; SENAI, 2018).

According to some scholars, the world is moving from the fourth to the fifth industrial revolution, in which Industry 5.0 emerges as an evolution of Industry 4.0 based on sustainability, circular economy, and redefinition of the role of human beings (XU *et al.*, 2021).

The literature consulted showed that, with the advent of the fourth industrial revolution, civil engineering will have to race against time to keep up, as Industry 4.0 is far from being used to its full potential in the construction sector. This is because progress is still occurring slowly with regard to the adoption and implementation of 4.0 technologies, due to high economic cost, acceptance of the technology, greater equipment requirements, and lack of knowledge (ANANYIN *et al.*, 2018; ARIPIN; ZAWAWI; ISMAIL, 2019; EGGERS; PARK, 2018).

To continue in the same way would be to ignore the potential arising from technological and digital transformation. However, it is necessary to emphasize that, despite all the innovations and benefits brought about by this new industrial model, the rapid technological changes that are transforming the world do not always promote democratic participation, inclusion, and equity for all (UNESCO, 2021).

In this regard, the Brazilian National Curricular Guidelines for Undergraduate Engineering Courses. from the Brazilian National Education Council (DCN – CNE, Resolution 02 of April 24, 2019) corroborates this by recommending a graduate profile for engineers.

> [...] generalist, humanist, critical, reflective, creative, cooperative, ethical, able to research, develop, adapt, and use new technologies, with innovative and enterprising performance, capable of recognizing the needs of users, formulating problems based on these needs and opportunities for improvement to design creative engineering solutions, with a holistic approach in their practice, considering global, political, economic, social, environmental, and cultural aspects, and capable of acting and adapting to the new demands of society and the work environment with an attitude free from any type of discrimination and committed to social responsibility and sustainable development (CNE, 2018, p.5). (Own translation)

This document also recommends professors be mediators and students be active agents in the teaching-learning process, as well as the use of methodologies that adapt to the new global reality, as professors and students are the key players of the pedagogical act. According to Luckesi (2011), teaching must be structured based on the professional demands that students will face when entering the job market.

With regard to methodologies, UNESCO (2021) says that project-based and problem-based education is an authentic and relevant tool in the learning process, because it encourages initiative, as the activities require discovery and collaboration. As long as the goals and objectives are clear, it is inevitable that disciplinary boundaries will be transcended to find solutions. "Active learning recognizes the need to engage cognitively and emotionally" (UNESCO, 2021, p. 50).

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Evaluation of the knowledge construction process also deserves attention, because evaluation consists of information collection based on students' prior knowledge and their sociocultural context. In order to do this, it is necessary to know how to evaluate (GARCIA, 2013). Evaluative and emancipatory tools, such as field diaries, portfolios, rubrics, conceptual maps, and school performance tests, can greatly aid in the learning process, as advocated by Miranda Costa (2021).

In this same framework, the evaluation of learning is understood as a process of collective construction, where both teacher and student take the lead (COSTA; CERQUEIRA, 2013). "The nature of emancipatory assessment is defined as the process of analysis and criticism of a reality that is intended to transform" (MIRANDA COSTA, 2021, p. 121).

Innovation in teaching, on the other hand, can happen through the introduction of digital technologies into professional training, as it not only contributes to system modernization, but also brings the classroom closer to the labor market environment (DA SILVA; OLAVE, 2020). It should be noted that technological education also requires a set of critical skills and perspectives necessary to understand technology and harness it only for good (UNESCO, 2021).

In addition, it is worth highlighting the importance of the role of universities in propagating the Sustainable Development Goals (SDGs) (BAYUO; CHAMINADE; GÖRANSSON, 2020; CAEIRO *et al.*, 2020; IQBAL; PIWOWAR-SULEJ, 2022; MARTINS, 2019), as well as in raising the awareness of civil engineers towards their responsibilities due to interventions made in the environment (SILVA; SILVA; KOHLMAN RABBANI, 2017).

Subsequently, Ainger and Fenner (2014) propose a hierarchy of sustainability principles that can be incorporated throughout a project's life cycle: working within environmental limits; developing minimum socioeconomic standards for humanity; considering intergenerational equity, thinking about what they want to create for future generations in terms of benefits and avoiding harm; and designing integrated process solutions (AINGER; FENNER, 2014). Following this lien of thought, Martín-Garin *et al.* (2021) highlight the topics of circular economy, sustainable construction, and energy efficiency, aligned with the SDGs in engineering courses.

Furthermore, Carroll (2021) states that the world is increasingly approaching a circular economy model, which necessitates the inclusion of this subject in the engineering curriculum as a way of addressing sustainability, considering a teaching method that shows the condition of the industry and the planet, so that research with scholarships is supported. The author also says that it is necessary to give students a template to think differently, taking into consideration not only the immediate objective, but a project's entire life cycle and its interactions with the environment (CARROLL, 2021).

Finally, the importance of this study is understood in its relevance to academic communities at Higher Education Institutions (HEIs), when proposing suggestions for improvement for the training of civil engineers. While keeping in mind that it is necessary to modernize the industry, humans and the environment need to be prioritized.

## 2 OBJECTIVE

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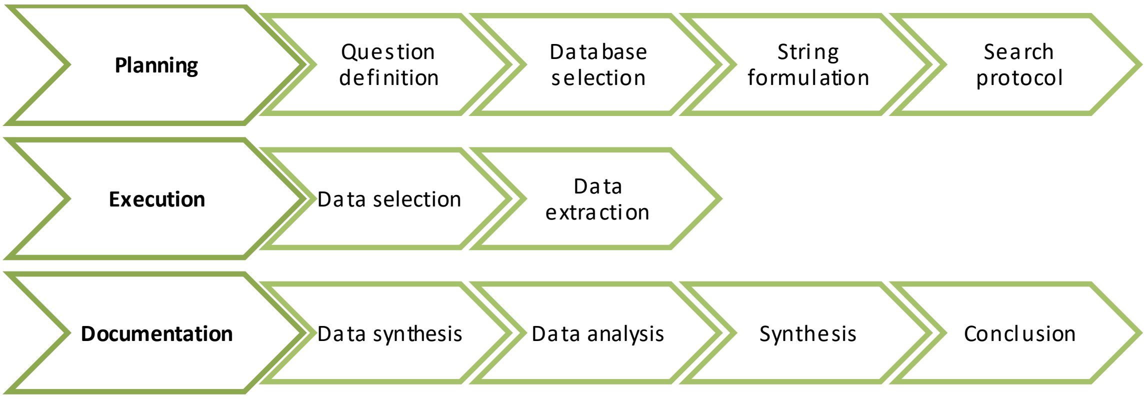
The objective of this study was to present fundamental aspects in civil engineer training, considering sustainable development and the need to modernize the construction industry to be able to meet the current demands of society and future generations.

## 3 METHODOLOGY

The methodology consisted of a systematic literature review (SLR), using the Coordination for the Improvement of Higher Education Personnel (CAPES - *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior*) Portal of Journals. The protocol tool adopted was the State of the Art through Systematic Review (StArt) software, made available free of charge by the *Universidade Federal de São Carlos* (UFSCar, 2022) Software Engineering Research Laboratory (LaPES).

The study was carried out in three stages: planning, execution, and documentation. In the planning stage, research questions were defined, databases were selected, and search strings and search protocol were formulated. In the execution stage, data was selected and extracted. Finally, documentation was formatted through synthesis and analysis of the data, summarizing, and concluding. Figure 1 shows the stages of this SLR.

Figure 1 - Systematic literature review stages




Source: Prepared by the authors.

**Planning** – In this stage, the research question was defined first. This question needed to be well-formulated and scientifically relevant so that it could be answered clearly, facilitating the development of subsequent steps. The selection of databases and formulation of search strings required numerous attempts before settling on the best results, as they determine the success or failure in number and relevance of studies obtained from the platforms. To formulate the strings, the acronym PICo was used, which corresponds to: population (P), interest (I), and context (Co). The terms defined as PICo criteria used keywords combined with Boolean descriptors (AND and OR). At the end of this step, the search protocol was completed, specifying all the information necessary to develop the study, such as title, objective, question, keywords,

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inclusion and exclusion criteria, and expected results. Chart 1 describes the research questions, the PICo criteria, the databases, and the search strings used.

Chart 1 - Description of systematic literature reviews

| Systematic literature review | |
|---|---|
| **Research questions** | |
| P1 – What aspects are necessary to better train civil engineers to meet the demands of a sustainable society and help modernize construction industry? | |
| **PICo criteria** | |
| Population (P) | Civil engineering courses |
| Interest (I) | Sustainability |
| Context (Co) | Education and teaching |
| **Search string and databases** | |
| ("civil engineering") AND (Sustainability OR "sustainable development") AND (education OR "higher education institutions" OR teaching OR "hard skills" OR "soft skills" OR "construction education" OR "technological skills" OR teacher OR "innovative engineer") | |
| **Engineering Village** - https://www.engineeringvillage.com/home.url?redir=t | |
| **Scopus** - https://www.scopus.com/home.uri | |
| **Web of Science** - https://clarivate.com/webofsciencegroup/solutions/web-of-science/ | |

Source: Prepared by the authors.

The limitations of the SLR include the type of publication, object of investigation, time frame, language, and type of access, as described below. It should be noted that all filters were executed in the databases, so that, in StArt, search refinement only occurred in the data selection and extraction phase.

- Type of publication – articles published in journals or conferences.
- Object of investigation – higher education in engineering.
- Time frame – 2021, 2022, and 2023.
- Language of articles – Portuguese, English, and Spanish.
- Type of access – open or full text available.

**Execution** – In this stage, duplicate publications and those that did not include the search terms in the title, keywords, or abstracts were excluded. In the data extraction phase, the inclusion and exclusion criteria were considered, which were defined so that only articles relevant to the study were accepted for filtering. Chart 2 presents the SLR inclusion and exclusion criteria.

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Chart 2 - Inclusion and exclusion criteria for SLR articles

| SYSTEMATIC LITERATURE REVIEW | |
|---|---|
| **Criteria** | **Inclusion criteria description** |
| IC-1 | Present skills necessary for civil engineers |
| IC-2 | Point out successful strategies/practices |
| IC-3 | Show teaching methodologies that incorporate sustainability concepts |
| IC-4 | Identify teacher profiles |
| **Criteria** | **Exclusion criteria description** |
| EC-1 | Duplicates |
| EC-2 | Does not display the search terms from the strings in the title, keywords, or abstract |
| EC-3 | Does not adhere to the research topic |

Source: Prepared by the authors.

Article quality criteria were also adopted for publications that passed these first filters. Articles that were coherent and textually cohesive, studies that presented a clear and replicable methodological design, in addition to meeting the objectives of this SLR, were taken into consideration. Subsequently, data extraction went through the eligibility criteria regarding whether data had been extracted from the article, as well as being contextualized in civil engineering courses. It is worth remembering that all these filters were run on the StArt software. Chart 3 presents the sequence of filters performed in this study.

Chart 3 – SLR filter sequencing synthesis

| Filters | Exclusion criteria |
|---|---|
| 1st Filter | Duplicates |
| 2nd Filter | Did not display the search terms from the strings in the title, keywords, or abstract |
| 3rd Filter | Did not pass quality criteria |
| 4th Filter | Did not pass the eligibility criteria |

Source: Prepared by the authors.

**Documentation** – This step consisted of data summarization carried out using StArt, Excel, and Word. The analysis was carried out carefully based on the information obtained in the synthesis stage, by grouping the data. This was followed by a summarization process that created flowcharts and graphs as a way of better presenting mapping and bibliometric results. Finally, the descriptive analysis of the data is presented, which sought to answer the research question established in the SLR. Chart 4 summarizes the SLR methodological procedure.

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Chart 4 – Summary of the SLR methodological procedure

| **Planning** | **Search tools** | **Deliverables** |
|---|---|---|
| 1 | CAPES *Sucupira* Platform | Question definition |
| | | Database selection |
| | Engineering Village, Scopus and Web of Science | Search string formulation |
| | StArt | Search protocol |
| **Execution** | **Activities using StArt (identification and screening)** | **Deliverables** |
| 2 | Data selection | Content identification and separation |
| | Data extraction | Text formatting |
| **Documentation** | **Activities using StArt, Excel and Word (inclusion)** | **Deliverables** |
| 3 | Data synthesis | Meeting objectives, creating charts, graphs and flowcharts, and writing the article |
| | Data analysis | |
| | Synthesis | |
| | Conclusion | |

Source: Prepared by the authors.

## 4 RESULTS

A total of 283 articles were considered suitable for the study, of which 213 (75.27%) were from Engineering Village, 19 (6.71%) were from Scopus, and 51 (18.02%) were from Web of Science. The first filter excluded 253 articles for not complying with the study. Another nine articles were rejected for being duplicates, leaving only 21 at the end of the selection phase. In the extraction phase, the articles were read in full to ensure that the eligibility and quality criteria were met.

The eligibility questions included: Do the articles present skills needed for civil engineers? Do they point out successful strategies/practices? Do they show teaching methodologies that incorporate sustainability concepts? Do they identify teacher profiles?

The quality criteria included: Do the articles present coherence and textual cohesion? Are strategies and methodologies reported objectively? Do they present a clear and replicable methodological design? Do they adhere to research?

Of the 21 articles that remained, 17 were accepted and four were rejected. Of the 17 articles accepted into the study, ten (58.82%) were from Engineering Village and seven (41.18%) were from Web of Science. The identification, screening, and inclusion steps were carried out through StArt and are shown in Figure 1.

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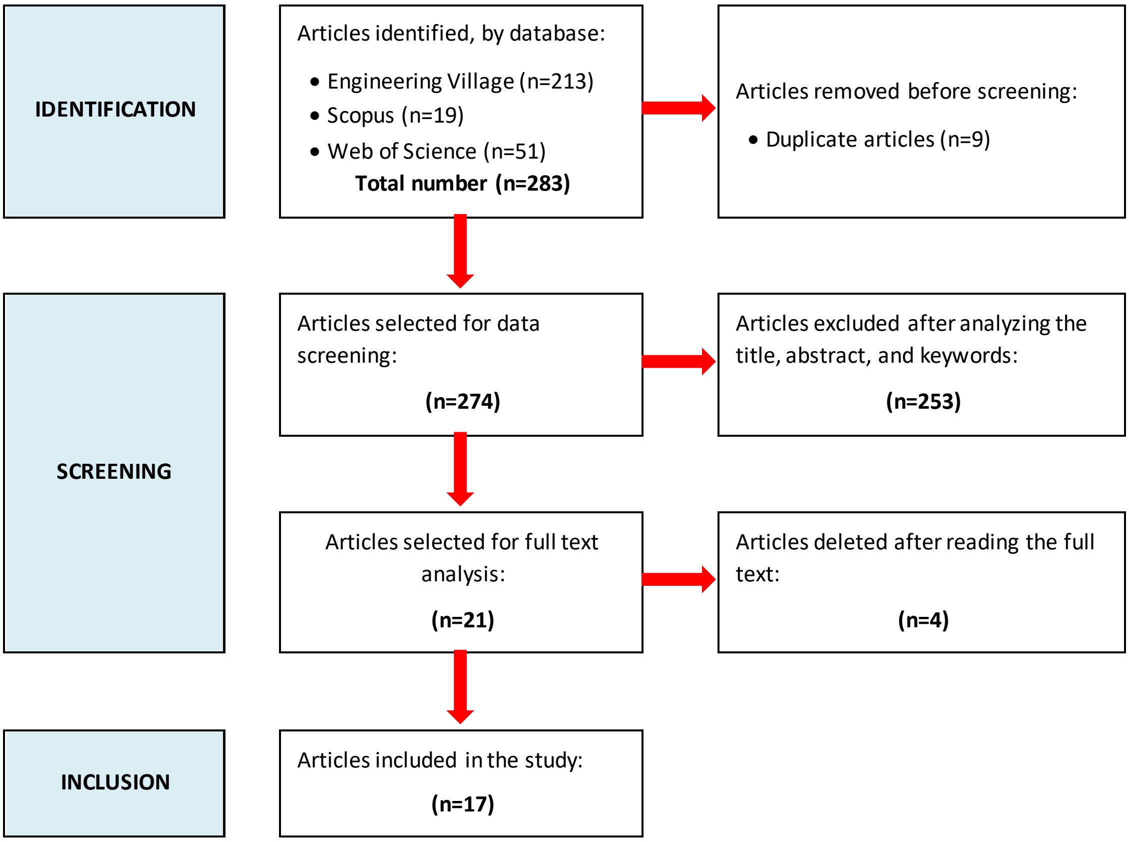
Figure 1 - Flowchart for identification, screening, and inclusion of articles




Source: Prepared by the authors.

Graph 1 shows the number of articles accepted and the total in each database. Engineering Village presented the best results: 213 articles, of which ten were used. Scopus only retrieved 19, none of which were used. Finally, Web of Science retrieved 51 articles, with seven of these included in the study.

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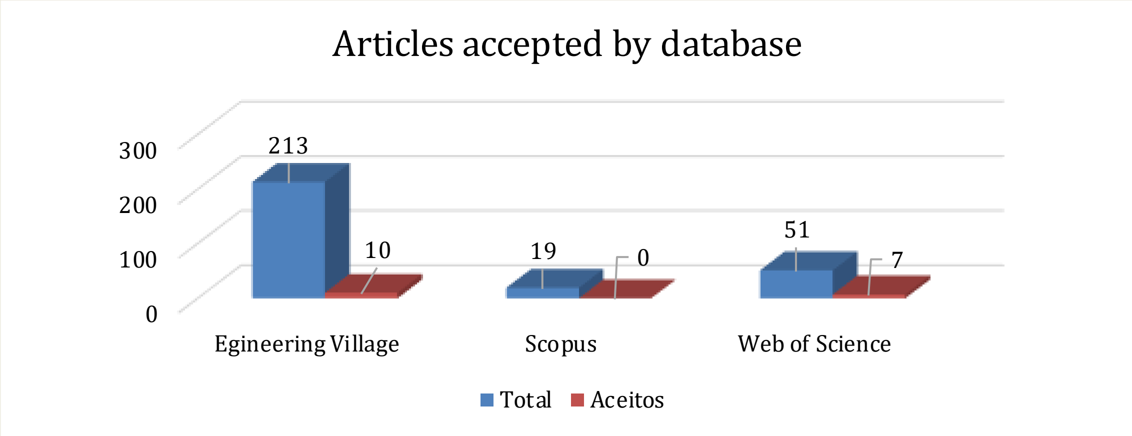
Graph 1 - Total articles from the databases and the number included in the study




Source: Prepared by the authors.

The 17 articles retrieved in the SLR are shown in Chart 5. Only the years 2021 and 2022 were included, with 12 Journal Articles (JA) and 5 Conference Articles (CA). Countries included Mexico, Norway, Ireland, Chile, Spain, Russia, Portugal, China, Ukraine, Poland, India, Hungary, Malaysia, and the United Kingdom.

Chart 5 - Articles found in the search of Web of Science and Engineering Village

| **Engineering Village** | | | | | |
|---|---|---|---|---|---|
| | **Type** | **Title** | **Authors** | **Year** | **Country** |
| 1 | JA | A collaborative approach for urban underground space development toward sustainable development goals: Critical dimensions and future directions | PENG, F. L.; QIAO, Y. K.; SABRI, S.; ATAZADEH, B.; RAJABIFARD, A. | 2021 | China |
| 2 | CA | A Comprehensive Program of activities to develop sustainable core skills in novice scientists | VLASENKO, K. V.; ROVENSKA, O. G.; CHUMAK, O. O.; LOVIANOVA, I. V.; ACHKAN, V. | 2021 | Ukraine |
| 3 | JA | Analysis of Employees Competencies in the Context of Industry 5.0 | KOWAL, B.; WŁODARZ, D.; BRZYCHCZY, E.; KLEPKA, A | 2022 | Poland |
| 4 | JA | Circular economy approach in solid waste management system to achieve UN-SDGs: Solutions for post-COVID recovery | SHARMA, H. B.; VANAPALLI, K. R.; SAMAL, B.; CHEELA, V. S.; DUBEY, B.; BHATTACHARYA, J. | 2021 | India |
| 5 | JA | Earth observation and geospatial big data management and engagement of stakeholders in Hungary to support the SDGs | MIHÁLY, S.; REMETEY-FÜLÖPP, G.; KRISTÓF, D.; CZINKÓCZKY, A.; PALYA, T.; PÁSZTOR, L.; ... ZENTAI, L. | 2021 | Hungary |
| 6 | CA | Prevention through Design: Architecture Student Cognizance | SAMSUDIN, N. S.; ABIDIN, M. N. Z.; MOHAMMAD, M. Z.; YUSOF, A.; SALEHAN, M. H. M. | 2021 | Malaysia |
| 7 | CA | Project-Based Learning as an Important Element of Training Students Majoring in Environmental Engineering | SEMENOVA, N. | 2021 | Russia |
| 8 | CA | The effect of classroom environment on satisfaction and performance: towards iot-sustainable spaces | HAO, X.; FLOREZ-PEREZ, L. | 2021 | United Kingdom |
| 9 | JA | The Role of Machine Learning and Artificial Intelligence for making a Digital Classroom and its sustainable Impact on Education during Covid-19 | SHAIKH, A. A.; KUMAR, A.; JANI, K.; MITRA, S.; GARCÍA-TADEO, D. A.; DEVARAJAN, A. | 2022 | India |
| 10 | JA | The role of universities in sustainable development and circular economy strategies | SUKIENNIK, M.; ZYBAŁA, K.; FUKSA, D.; KĘSEK, M. | 2021 | Poland |

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| Web of Science | | | | | |
|---|---|---|---|---|---|
| | Type | Title | Authors | Year | Country |
| 11 | JA | Assessment of Multiple Intelligences in First-Year Engineering Students in Northeast Mexico | CHAVARRIA-GARZA, W. X.; SANTOS-GUEVARA, A.; MORONES-IBARRA, J. R.; AQUINES-GUTIERREZ, O. | 2022 | Mexico |
| 12 | JA | Infrastructure Asset Management: Historic and Future Perspective for Tools, Risk Assessment, and Digitalization for Competence Building | UGARELLI, R.; SAEGROV, S. | 2022 | Norway |
| 13 | JA | Opportunities and barriers faced by early-career civil engineers enacting global responsibility | CHANCE, S.; DIREITO, I.; MITCHELL, J. | 2022 | Ireland |
| 14 | JA | Strategy for the Evaluation and Monitoring of Competencies in Engineering Programs to Improve Students' Learning and Quality of Education | HERMOSILLA, P.; RIVERA, M. L.; ATEAGA, N.; GALLARDO, E. | 2021 | Chile |
| 15 | JA | Student Long-Term Perception of Project-Based Learning in Civil Engineering Education: An 18-Year Ex-Post Assessment | CORONADO, J. M.; MOYANO, A.; ROMERO, V.; RUIZ, R.; RODRÍGUEZ, J. | 2021 | Spain |
| 16 | JA | Sustainable Urban Development Strategic Initiatives | PANTELEEVA, M.; BOROZDINA, S. | 2022 | Russia |
| 17 | CA | Teaching Ethics to Engineering Students: Case Studies | SOEIRO, A.; OLIVEIRA, L. A. | 2021 | Portugal |

Source: Prepared by the authors.

The inclusion criteria for the articles allowed us to identify the skills and technologies that help engineers modernize the construction industry, successful educational strategies, how sustainability concepts can be addressed in civil engineering courses, and the characteristics of teachers who contribute to technical-citizen training.

## 4.1 Skills and technologies that help engineers modernize the construction industry

One study shows that this new industrial revolution requires technical, digital, social, and personal skills, especially soft skills, such as multidisciplinary teamwork (KOWAL *et al.*, 2022). The authors cite the following skills in the study: working with information technology systems, data analysis and modeling, systems network monitoring, innovation, good communication, teamwork, knowledge sharing, and linguistic competence (KOWAL *et al.*, 2022).

The authors also state that the career development of young scientists contributes to the sustainable development of society and has become an essential attribute in the construction of knowledge that accompanies globalized world dynamics. This idea supports Cameron *et al.* (2020), who point out that scientific communication is essential.

Vlasenko *et al.* (2021) draw attention to scientific literacy, stating that even graduate students face difficulties in interpreting results and critically analyzing data, making courses aimed at producing journal articles necessary.

Another issue is widespread digitalization and the Internet of Things, as this requires engineers to be able to to operate information technology systems as well as deal with large volumes of data (VLASENKO *et al.*, 2021). This information reinforces the need to include BIM in the first year of undergraduate school. A study carried out by Mihály *et al.* (2021) points to geoinformation and big data technologies as a way of supporting the SDGs.

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Panteleeva and Borozdina (2021) present a study on strategic initiatives for sustainable urban development, using digital hubs[1] based on artificial intelligence. Hao and Florez-Perez (2021) present a smart classroom based on the Internet of Things in the United Kingdom, where devices incorporated with sensors and other technologies exchange data in real time. The study aimed to show that the physical environment of the classroom impacts student performance. Therefore, lighting, acoustics, temperature, environment, and schedules are intelligently controlled at the institution. With this system, even students can find out which study rooms are available (HAO; FLOREZ-PEREZ, 2021).

In the classroom presented by these authors, it can be seen that, although it is very far from the Brazilian reality, the tendency towards this type of installation will be common in the future, as it is the reality of Industry 5.0. In this context, students who are accustomed to this reality are already ahead of those who have no contact with this universe of technologies.

Finally, Shaikh *et al.* (2021) discuss the use of artificial intelligence and machine learning in education. This shows how much technology is already present in classrooms and how much progress still needs to be made to be able to keep up with this Society 5.0.

### 4.2 Successful educational strategies

Reflecting on the most appropriate training for civil engineers, cooperative work between students, the development of research projects, problem solving, seminars, field studies, action research, and community projects are presented as pedagogical practices that need to be expand in higher education.

Semenova (2021) presents project-based learning as an excellent tool for developing teamwork skills and states that collective tasks require a different way of thinking and seeking innovative solutions. The author also highlights the importance of this methodology in the use of BIM, as this technology enables teamwork.

Coronado *et al.* (2021) also present the use of project-based learning in a civil engineering course in Spain. At the time (1998), the course was considered innovative, as it had a reduced number of students and a project-based learning methodology. 15 years after the graduation of this class, students were assessed, with the intention of identifying the effectiveness of the methodology.

Ultimately, the results showed that the methodology contributed greatly to the development of student skills, especially group work, communication, and leadership. Students assessed that the methodology demands a lot, but the integration of theory with practice made learning more effective. The graduates stated they were very satisfied with their theoretical and practical training. It is important to emphasize that the methodology was used for all of the subjects of the curriculum, and the quality of this training was recognized not only by students, but through a survey on employability by the Ministry of Education, Culture, and Sport of Spain.

[1] Digital hubs are interdisciplinary teams that work in cells, but share information and are guided by the same objective, vision, and analysis (VALTECH, 2020).

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### 4.3 Sustainability concepts covered in civil engineering courses

Regarding sustainability concepts, solid waste management based on the circular economy can generate jobs and contribute to sustainability (SHARMA *et al.*, 2021). Therefore, discussing the circular economy in the classroom can be a great opportunity to introduce sustainability concepts into civil engineering courses.

Ugarelli and Sægrov (2022) recall that infrastructure asset management was not part of civil engineering education; however, today there is a need to introduce questions regarding risks, the circular economy, sustainability, and digitalization into the university curriculum.

The study by Peng *et al.* (2021), on underground urban space, shows that 11 of the 17 SDGs can be addressed in this type of project, requiring only that there be a collaborative approach between land administration, integrated planning, architectural design, and construction technologies.

Sukiennik *et al.* (2021) state that only continuous, effective, and eco-responsible education can include the circular economy on a global scale, and that the role of universities is to shape students' awareness of sustainable development integrated with the circular economy. In this regard, Samsudin *et al.* (2021) present a study showing that educational involvement strengthened students' understanding of accidents, in addition to increasing their awareness of occupational health and safety issues.

### 4.4 Characteristics of teachers who contribute to technical-citizen development

Firstly, Soeiro and Oliveira (2021) present the inclusion of a variety of subjects in the classroom, whose objective is the perception of ethical issues linked to sustainability. The goal is to work on the themes transversally within the various subjects of the civil engineering undergraduate course, given the need for more humanized and humanistic relationships inside and outside academia, with a view to sustainable development.

A study developed by Hermosilla *et al.* (2021) highlights the responsibilities of teachers for continuous improvement of education, as good grades obtained by students do not always represent their level of skill development within the course.

Therefore, showing civil engineers that ethical responsibility in the profession must exist holistically (CHANCE; DIREITO; MITCHELL, 2021) can be the first step towards more effective training that is compatible with sustainable development.

## 5 FINAL CONSIDERATIONS

Based on the current needs of society and the responsibilities of civil engineers due to the construction industry's interventions in the environment, the challenge arises to adapt teaching so that graduates will be better prepared when they leave universities.

This study made it possible to identify the importance of developing hard skills and soft skills in this new context of industrialization, as well as the relevance of active methodologies that build knowledge and discernment, especially when using a technologically advanced structure that enables future engineers to keep up with technological advances.

Although digital technology can offer a world of possibilities, innovations are most likely to be successful when they are designed to meet students’ particular needs and characteristics in specific contexts.

Regarding sustainability concepts incorporated into teaching, the training model for civil engineering courses must address the SDGs in a transversal way across all subjects that make up the curricular matrix, without overlooking that the formation of this teaching-learning process must be participatory, collaborative, problematizing, interdisciplinary, intergenerational, intercultural, and integrated within the academic body.

Sustainability should also be discussed throughout the course as a principle and not as a subject to be studied, particularly through immersion both outside of and within the academic environment, where contact with real situations makes students consider the community and its surroundings in the future.

Finally, as for the characteristics required of, the most important was the approach to ethics in the classroom, linking it to the concepts of sustainability and students’ awareness of the responsibilities that the civil engineering profession demands.

## 6 ACKNOWLEDGMENTS

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