

# Enhancing Digital Skills for Sustainable Engineering: A Simulation-based Approach in Process Design

M. Ugrina,<sup>a\*</sup> N. Vukojević Medvidović,<sup>a</sup> and M. Bulić<sup>b</sup>

<sup>a</sup>University of Split, Faculty of Chemistry and Technology,  
Ruđera Boškovića 35, 21 000 Split, Croatia

<sup>b</sup>Faculty of Humanities and Social Sciences Split, Poljička cesta 35, 21 000 Split, Croatia

This work is licensed under a  
Creative Commons Attribution 4.0  
International License



5<sup>th</sup> ZORH  
CONFERENCE

## Abstract

Engineering education is increasingly focused on developing both digital skills and sustainability awareness. To meet modern workforce demands, engineers must be proficient in using digital tools while designing environmentally responsible processes. The “Process Design” course at the Faculty of Chemistry and Technology integrates COCO (Cape-Open to Cape-Open) and ChemSep simulation software to enhance students’ digital competencies and deepen their understanding of sustainable chemical engineering. These free tools allow simulation of chemical processes, thermodynamic calculations, and optimisation of energy-efficient designs, enabling environmentally conscious decision-making. COCO, built on the CAPE-OPEN standard, includes modules for flowsheeting, unit operations, and reaction modelling, while ChemSep is used for simulating distillation columns. Together, they enable students to assess environmental impacts and design more sustainable processes. For this purpose, a survey was conducted among students to assess the software’s usability and its role in developing technical and soft skills such as creativity, critical thinking, and teamwork. The results showed that students recognised the value of the opportunity to simulate real-world processes, particularly in the context of sustainability. They found the tools accessible and effective in bridging theoretical knowledge with practical application. Students also emphasised the need for increased practical exercises and the incorporation of more complex simulation tasks. The integration of COCO and ChemSep proved beneficial in preparing students to address sustainability challenges through practical and digital competencies in process design, offering a free and accessible alternative to commercial simulation software, which is often limited by high costs and licensing constraints.

## Keywords

Digital skills, digital tools, engineering education, process design, simulation

## 1 Introduction

Since the adoption of the Lisbon Strategy<sup>1</sup> in 2000, the European Union has emphasised the crucial role of information and communication technologies (ICT) in education. Croatia’s Strategy for Education, Science, and Technology<sup>2</sup> also highlights the need to expand ICT use in learning, while the European Commission’s Digital Education Action Plan<sup>3</sup> directs education systems towards the effective integration of digital technologies and the development of competencies essential for the digital transformation of society. These policy documents underscore the necessity of systematically implementing digital technology in higher education, where educators must combine subject expertise with pedagogical knowledge and digital skills to ensure effective teaching. Contemporary students – often described as digital natives – expect active engagement in learning and seek competencies that promote employability, lifelong learning, and social inclusion.

Consequently, higher education institutions must prioritise active learning methods, practical training, and sim-

ulation-based teaching to enhance student competencies. The European Commission consistently stresses the importance of digital technologies in improving educational quality, accessibility, and inclusiveness while encouraging the development of digital skills among both educators and learners.<sup>3,4</sup> In addition to technical and digital abilities, the comprehensive development of skills, including critical thinking, problem-solving, communication, and teamwork, is essential to prepare students for the demands of a dynamic labour market.<sup>3</sup> Simulation-based learning is particularly valuable in disciplines such as chemical engineering, where understanding and optimising complex processes are critical. Simulations provide a safe and controlled environment in which students can experiment and translate theoretical knowledge into practical application. European higher education frameworks, including the European Higher Education Area<sup>5</sup> and the European Green Deal<sup>6</sup>, strongly advocate aligning curricula with sustainable development and digital transformation goals. These frameworks promote innovative teaching methods that foster digital competencies and sustainable practices, ensuring that future engineers are equipped to address societal and economic challenges. Integrating simulation tools into chemical engineering education therefore represents a significant pedagogical advancement, cultivating professionals with both strong technical expertise and transversal skills that support sustainable and innovative industrial development.

\* Corresponding author: Assoc. Prof. Marin Ugrina, PhD  
Email: [mugrin@ktf-split.hr](mailto:mugrin@ktf-split.hr)

**Note:** The investigations in this paper were presented at the 5<sup>th</sup> International ZORH conference of scientists, professionals and students – “Environmental Protection, Sustainable Production and Examples of Best Practice” held on April 9–11, 2025 at the Faculty of Chemistry and Technology University of Split, Croatia.

In recent years, the development of digital competencies and sustainability awareness has gained increasing recognition in engineering education. For example, *Sahlodin and Sotudeh-Gharebagh*<sup>7</sup> investigated the influence of digital technologies on the quality of chemical engineering education and their potential to enhance students' professional skills. They concluded that, despite challenges such as the need for infrastructure and training, the effective implementation of digital technologies significantly enhances students' understanding, practical experience, and engagement. Integrating digital elements into university curricula has thus become essential to prepare students for the complex demands of modern industry, which is increasingly oriented toward sustainable development. Many teachers have also emphasised the importance of incorporating sustainability topics in engineering education, which are often presented theoretically, with limited practical application through problem-based simulations and tasks.<sup>7,8</sup> *Udugama et al.*<sup>9</sup> investigated the types of digital tools perceived by chemical engineering educators as most suitable for teaching various fundamental and applied courses, based on a survey conducted among Heads of Departments and members of the IChemE digitalisation committees. The results showed that simpler tools such as Excel and scripting languages are preferred due to their accessibility and ease of use, while broader adoption of advanced tools, like Virtual and Augmented Reality, is limited by both technical and non-technical constraints. *Nuraini et al.*<sup>10</sup> analysed strategies for acquiring skills in simulation programmes such as Aspen HYSYS, Matlab, and AutoCAD P&ID for chemical engineering graduates using a literature review methodology. The results of their study highlight that integrating free simulation software into chemical engineering education effectively strengthens both technical and soft skills, better preparing students for evolving professional demands and enhancing their employability. Furthermore, *Kong et al.*<sup>8</sup> explored the integration of CHEMCAD process-simulation software into a Chemical Engineering Thermodynamics course at Sunway University as a replacement for traditional lab exercises. The results of student survey indicated a positive learning experience, with enhanced understanding of thermodynamic concepts and real-world applications, while also identifying areas for improvement, such as software access and deeper engagement.

Although the simulation tools mentioned previously offer advanced functionality, their high cost and licensing requirements often limit their accessibility, particularly for institutions with restricted financial resources. As part of the "Process Design" course at the Faculty of Chemistry and Technology, University of Split, an innovative integration of two free and open-source simulation tools, COCO (Cape-Open to Cape-Open) and ChemSep was introduced.<sup>11–14</sup> The objective was to enhance students' digital skills and promote a more comprehensive understanding of sustainable process design. COCO, built on the CAPE-OPEN standard, offers modules for process flowsheeting, thermodynamic calculations, unit operations, and reaction management. ChemSep complements COCO by enabling the simulation and optimisation of distillation columns and other separation processes. Together, these tools allow students to analyse process energy efficiency, calculate ther-

modynamic properties, perform mass and heat balances, simulate separation processes such as distillation, explore the influence of operating conditions, and compare alternative process designs, thereby reinforcing the principles of sustainable chemical engineering. Although COCO and ChemSep do not directly quantify environmental impact (e.g., CO<sub>2</sub> emissions, ecotoxicological potential, or LCA indicators), they enable the assessment of parameters that are critical to environmental performance. For example, COCO and ChemSep contribute to the assessment of environmental impact in an indirect but meaningful way by enabling the analysis of key process parameters, such as energy efficiency, choice of working substances, mass and heat balances, and comparison of alternative scenarios. The simulation of energy consumption in units such as heaters, coolers, and distillation columns, enables students to optimise process design to reduce energy use and, consequently, the carbon footprint. The software also allows comparison of chemicals and operating conditions, supporting the selection of less harmful substances in terms of health and environmental effects. Detailed mass and heat balance calculations can help identify potential inefficiencies or material losses, while comparing multiple process variants facilitates the selection of designs that minimise waste and resource consumption. Thus, although not intended for direct environmental modelling, COCO and ChemSep, provide valuable insights that support more sustainable process design.

Several studies have confirmed the successful application of COCO software to process simulations such as gasification, refrigeration systems, membrane separation, distillation, environmental processes, and reaction engineering. For instance, *Tangsatitkulchai et al.*<sup>15</sup> applied COCO to simulate batch slow pyrolysis of biomass materials using a process-flow diagram. Similarly, *Moliner et al.*<sup>16</sup> successfully applied COCO to simulate gasification of agricultural residues. *Gohil et al.*<sup>17</sup> demonstrated COCO's capabilities in modelling a complete ammonia-water cooling system, including flowsheet, and component simulations. *Alqaheem and Alobaid*<sup>18</sup> integrated a membrane module in COCO for CO<sub>2</sub> separation, highlighting the software's flexibility for custom unit operations. *Zalazar-Garcia et al.*<sup>19</sup> combined COCO simulations with LCA tools (SimaPro) for a full exergo-ecological assessment of agro-waste pyrolysis, while *Carvalho De Sousa et al.*<sup>20</sup> simulated sugarcane bagasse pyrolysis in COCO, demonstrating its application in bioenergy processes. *González-Zafra and Santafé-Moros*<sup>21</sup> conducted uncertainty and global-sensitivity analysis for a biogas-upgrading membrane process in COCO. These examples collectively illustrate that COCO can be effectively used not only for conventional process simulations but also for analysing complex systems, ultimately supporting more informed and sustainable process design decisions. Although COCO and ChemSep are not industry-standard software, they provide a practical and accessible environment for learning process simulation. They closely follow the workflow and modelling logic of commercial tools such as Aspen Plus and HYSYS.<sup>22</sup> By working with COCO and ChemSep, students acquire process-simulation skills that are directly transferable to industry-standard software, gaining hands-on experience in thermodynamics, flowsheet development, and process modelling.

The purpose of this paper was to analyse the integration of free and accessible simulation tools, COCO and ChemSep, into the chemical engineering curriculum. It emphasises not only the development of digital and process-related skills but also the alignment of teaching strategies with student expectations, fostering a more student-centred and sustainability-oriented learning environment, serving as an advanced learning model.<sup>23</sup> To that end, a student survey was conducted to assess the usability of the software and its effectiveness in developing both technical and soft skills, including creativity, critical thinking, and teamwork.

## 2 Methodology

### 2.1 Research instrument and participants

The research employed a structured questionnaire (entry and exit) as the measurement instrument, consisting of four parts. The first part examined the respondents' socio-demographic characteristics, including study programme, gender, and type of completed secondary education. The second part focused on prior experience with simulation software tools. The third part contained statements evaluated using a five-point Likert scale, addressing respondents' self-assessed prior knowledge, development of soft skills, preferred social form of work, and the adequacy and quality of the teaching materials prepared for the course. The fourth part of the questionnaire represented a reflective segment of the exit survey, encompassing the assessment of satisfaction with personal engagement during the seminar and perceptions regarding the difficulty and applicability of the simulation tasks.

The applied methodology included the evaluation of the integration of digital tools into the "Process Design" course, implemented during the academic year 2024/2025 at the University of Split, Faculty of Chemistry and Technology for second-year students of the master's study of Chemical Technology (Materials and Environmental Protection) and first-year students of the master's study of Food Technology. A total of 36 students participated consisting of 35 female and one male. The study was conducted with the approval of the Ethics Committee of the Faculty of Chemistry and Technology and in accordance with the ethical principles outlined in the Helsinki Declaration, ensuring the anonymity and confidentiality of all participants. The surveys are provided in the Appendix.

### 2.2 Initial survey

The initial survey examined students' basic knowledge of simulation software, their attitudes toward digitalisation in engineering, and their expectations regarding skill development and practical applications. Specifically, the survey aimed to explore students' prior experience with process simulation tools, their perception of the importance of digital competencies in modern engineering practice, and their expectations related to learning outcomes from the upcoming seminars. The survey included both multiple-choice and open-ended questions, enabling the collection of quantitative data on general trends as well as

qualitative insights into individual perspectives. This comprehensive approach enabled the tailoring of seminar content to students' existing knowledge and interests, while also supporting continuous improvement of the teaching methodology.

### 2.3 Seminar implementation

Following the initial survey, a seminar was conducted as a part of the "Process Design" course, combining theoretical classes with the practical application of COCO and ChemSep simulation tools. The seminar structure began with an introduction to the simulation tools, where students attended theoretical classes focused on understanding the functionalities and capabilities of the selected software. In the practical part, students simulated distillation columns, calculated energy efficiencies, and analysed the environmental impacts of different process designs. The seminars concluded with collaborative tasks, in which students were required to design sustainable chemical processes. These tasks encouraged teamwork, critical thinking, and problem-solving skills, promoting the practical application of theoretical concepts. The seminar was intentionally designed to align with sustainability goals by incorporating real-world scenarios and encouraging innovative, environmentally responsible engineering solutions.

### 2.4 Final survey

The final survey collected feedback on the perceived usefulness of the tools, self-assessed progress in digital and sustainability-related skills, and suggestions for improving the seminar structure. Students were encouraged to reflect on any challenges encountered, as well as to identify specific areas for enhancement. This feedback was instrumental in evaluating the educational impact of the seminars and informing future improvements in course design.

## 3 Results

### 3.1 Initial survey findings

The results of the initial survey conducted among students enrolled in the "Process Design" course revealed that the majority (72.2 %) had previous experience with simulation software tools in the field of chemical engineering. Students reported experience with the following simulation software tools: Simcet, Pitops, Mathcad, Matlab (including Simulink), Python, and AutoCAD. Moreover, more than 70 % of students expressed a high level of interest in learning the practical application of digital tools (Fig. 1). Reflecting their strong interest, students also reported high expectations regarding the acquisition of competencies and skills in simulation tools. Their primary expectation was to deepen their understanding of chemical engineering processes, followed by an emphasis on developing problem-solving abilities, preparing for professional roles in the industry, and acquiring foundational digital competencies, alongside heightened awareness of sustainability and ecological considerations in engineering practices (Fig. 2).

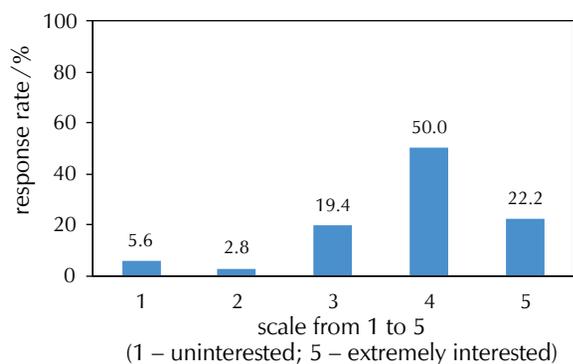


Fig. 1 – Rate of interest in working with process simulation tools  
Slika 1 – Postotak zainteresiranosti za rad s alatima za simulaciju procesa

In line with these heightened expectations, 86.1 % of students reported an affirmative attitude towards using simulation tools to understand sustainable processes in chemical engineering, while the remainder expressed no clear opinion. The results indicated that, despite engaging in practical work with simulation tools, students continued to show a strong reliance on instructor-led learning. Namely, nearly half of the respondents (47.2 %) preferred lectures and teacher demonstrations as their primary method for acquiring skills in using simulation software. This preference may reflect a need for further development of their professional competencies required for independent work on more complex practical tasks. Additionally, 27.8 % of students expressed interest in independent and hands-on tasks, suggesting potential for fostering greater autonomy in learning and problem-solving. Conversely, the relatively low percentage of students (22.2 %) who favoured group work and team projects highlights the need to strengthen collaborative learning and teamwork skills. Students also reported a lack of self-confidence, alongside concerns about the challenges they may encounter when using simulation tools. Insufficient prior knowledge and difficulties in understanding and adapting to the use of simulation tools were identified as key issues. As these competencies are crucial for successful integration into the modern labour market, their systematic development through teaching activities and project-based learning is recommended.

### 3.2 Post-seminar survey findings

The results of the post-seminar survey, conducted after the implementation of the process simulation seminar within the “Process Design” course, indicated a high level of student satisfaction with the seminar’s organisation and delivery. Specifically, 96.5 % of students reported a high or very high level of satisfaction with the overall experience. More than two-thirds of the students (65.5 %) stated that the seminar largely met their expectations regarding the acquisition of skills in using simulation tools, while 27.6 % indicated that their expectations were fully met. The perceived difficulty level of the seminar was also evaluated positively. Namely, 82.8 % of students considered the complexity of the seminar to be appropriately aligned with their prior knowledge and competencies. In contrast, 13.8 % of students found the seminar insufficiently demanding, while 3.4 % perceived it as too demanding. The most valued outcomes of the seminar, as identified by students, included preparation for future professional roles in the engineering field, acquisition and development of digital skills, development of sustainable engineering solutions in process design, and a deeper understanding of chemical engineering processes (Fig. 3).

Survey results indicated that the simulation tools COCO and ChemSep were generally perceived as easy to use. Specifically, 31 % of respondents rated them as relatively easy, 31 % as very easy, and 37.9 % as extremely easy. The most useful functionalities of simulation programmes, according to students, included quick calculations of thermodynamic data (48.3 %), process design (34.5 %), environmental impact analysis (10.3 %), and energy efficiency assessment (6.9 %). Moreover, the majority of students realised that simulation programmes helped them understand sustainable solutions in process design. In terms of task complexity, 75.9 % of students considered the simulation tasks appropriately demanding, whereas 24.1 % perceived them as too simple.

The survey results also indicated a high level of student satisfaction across several dimensions of the seminar’s implementation. A total of 82.8 % of students reported that they were very satisfied with the support provided by the professor during the seminar, while the remaining 17.2 % were mostly satisfied. This highlights the critical role of instructor presence and guidance in facilitating student en-

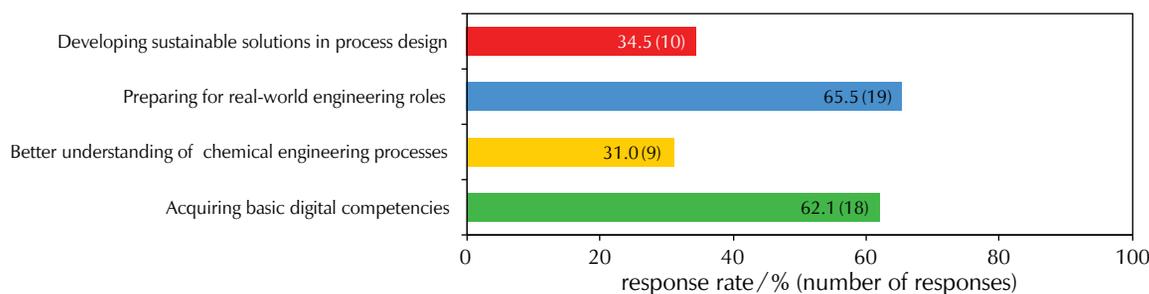


Fig. 2 – Expectations related to working with process simulation tools  
Slika 2 – Očekivanja vezana za rad s alatima za simulaciju procesa

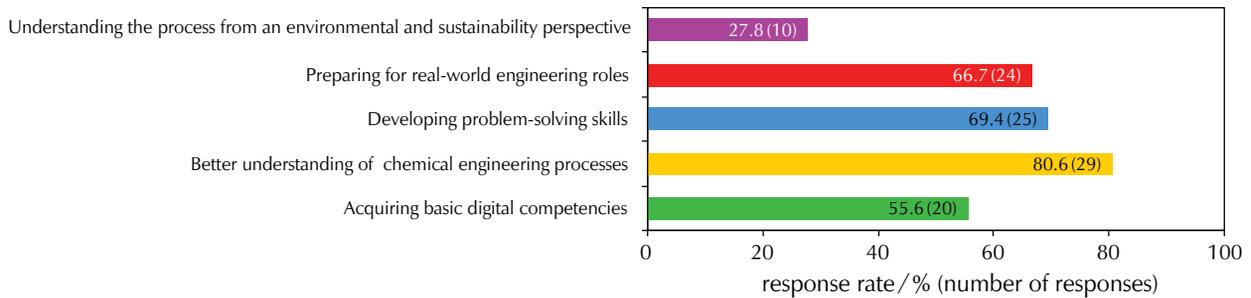


Fig. 3 – Most interesting/useful aspects of the seminar  
Slika 3 – Najzanimljiviji/najkorisniji aspekti seminara

agement with complex digital tools. An identical proportion of students (82.8 %) positively evaluated the quality and usefulness of the teaching materials, emphasizing their importance in supporting the acquisition of competencies required for working with the COCO and ChemSep software tools. Regarding the time allocated for mastering the intended learning outcomes, 72.4 % of students considered the duration of instruction to be sufficient, whereas 27.6 % found it insufficient. These findings suggest that extending the duration of practical exercises could further enhance the learning experience and allow for deeper exploration of the simulation tools. In the final section of the survey, students were invited to reflect on their learning process, experiences, and achievements, with the aim of encouraging critical thinking, self-assessment, and personal growth. According to the collected responses, 34.5 % of students reported that they were extremely satisfied with their progress in using simulation tools, while 41.4 % indicated they were very satisfied with their overall achievements during the seminar (Fig. 4).

These findings confirm the positive impact of simulation-based instruction in higher education, particularly in fostering digital competencies and empowering students to take an active role in solving real-world engineering problems.

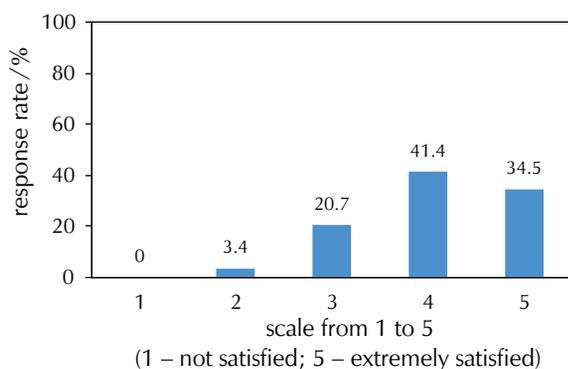


Fig. 4 – Satisfaction with personal progress in working with process simulation tools

Slika 4 – Zadovoljstvo vlastitim napretkom u radu s alatima za simulaciju procesa

Slightly more than half of the surveyed students (51.7 %) indicated that engaging with simulation programs contributed to the development of their soft skills such as teamwork, creativity, and critical thinking. Ultimately, students proposed future guidelines for improving teaching, such as the introduction of more complex simulation tasks (44.8 %), more time for practice (27.6 %), and individual work on projects (13.8 %).

## 4 Discussion

### 4.1 Impact of simulation seminars

The results of this study indicated that simulation-based seminars significantly contributed to the development of students' digital and engineering competencies, as well as to their overall engagement in the learning process. Through the use of tools such as COCO and ChemSep, students demonstrated notable progress in independently using digital simulation platforms as well as increased confidence in applying acquired knowledge to solve practical engineering problems. Furthermore, the findings suggest that the seminars fostered innovative and creative thinking, particularly in the context of sustainable engineering design. By working on real-world problem-based tasks, students exhibited the ability to integrate technical and environmental considerations into their process design solutions, highlighting the educational value of this teaching approach.

Ultimately, the seminars effectively bridged the gap between theoretical knowledge and practical application. The combination of lectures, hands-on exercises, and project-based learning enabled students to apply theoretical concepts within a simulated industrial context, thereby reinforcing their understanding and enhancing their problem-solving skills. Overall, the seminar format promoted a more integrative and applied learning experience, supporting both academic development and professional readiness.

These findings align with previous research that emphasizes the importance of integrating digital tools into higher education as a means of developing both technical and transversal skills. For instance, *Sanz-Angulo et al.*<sup>24</sup> highlighted the role of digital simulation tools in fostering professional

autonomy and digital literacy, while *Kefalis et al.*<sup>25</sup> underlined their potential to stimulate innovation and sustainability-oriented thinking among engineering students. Similarly, *Escobar-Castillejos et al.*<sup>26</sup> confirmed that combining theoretical instruction with practical digital environments increases student motivation and improves learning outcomes in engineering education.

#### 4.2 Challenges identified

Despite the overall positive outcomes, several challenges were identified during the implementation of the seminars. One of the most commonly reported issues was the limited time available for hands-on practice, which restricted students from fully exploring the range of functionalities offered by the simulation tools. This time constraint often led to a more superficial engagement with the software, especially for those with no prior experience. In addition, some students suggested introducing more technically complex simulations. This implies the need for a more detailed and structured revision of teaching materials that would support independent learning. Addressing these issues could significantly improve the learning experience and further support students in acquiring technical and problem-solving competencies.

#### 4.3 Alignment with educational goals

The integration of simulation tools into the “Process Design” course demonstrated clear alignment with contemporary educational goals in engineering education. Through the use of platforms such as COCO and ChemSep, students gained valuable practical experience with industry-relevant digital tools, bridging the gap between academic knowledge and real-world application. This hands-on exposure not only enhanced their technical competencies but also prepared them for future professional roles where digital literacy and process modelling are essential.

Moreover, the course provided a structured framework for addressing sustainability challenges through engineering design. By engaging students in projects focused on optimising energy use, reducing environmental impact, and designing sustainable processes, the seminars fostered a mindset oriented toward innovative and responsible problem-solving. Hence, the course supported the development of both technical and transversal skills, in line with the broader goals of higher education of future engineers capable of responding to complex, real-world issues with creativity, critical thinking, and ethical awareness.

#### 4.4 Comparison of pre- and post-seminar data

The comparison of data collected from the initial and final surveys revealed several positive shifts in students’ perceptions, competencies, and overall learning experience. There was a notable increase in students’ confidence and proficiency in using simulation tools (reported by 75.9 % of respondents), indicating that the seminars effectively enhanced their practical digital skills. In addition to technical

competencies, students expressed a greater appreciation for the development of soft skills, such as teamwork, creativity, and critical thinking, which were fostered through collaborative project assignments and problem-solving tasks. The results also showed a heightened awareness of the role of sustainability in engineering practice, suggesting that the integration of real-world, sustainability-focused challenges significantly contributed to students’ understanding and engagement with this essential topic. Finally, the findings underscored a growing recognition of the value of integrating free and accessible simulation tools, such as COCO and ChemSep, into the academic curriculum. Students highlighted the practicality, user-friendliness, and relevance of these tools for both current studies and future professional applications, reinforcing the importance of their continued use in engineering education.

## 5 Recommendations for further improvements

### 5.1 Course improvements

Based on student feedback and observations during seminar implementation, several recommendations can be made to enhance the overall effectiveness and impact of the course. One of the key suggestions is to extend the duration of practical exercises. Students expressed a clear need for more time to engage with the simulation tools in depth, emphasising that longer exercises would allow for a more comprehensive understanding of functionalities and greater confidence in using the software independently.

In addition to extending practice time, it is recommended to enhance the quality and clarity of teaching materials. Providing step-by-step guides, video tutorials, and annotated examples could significantly lower the learning barrier, especially for students encountering simulation software for the first time. Well-structured resources would support self-paced learning and serve as useful references during and after the course.

Lastly, students would benefit from increased faculty involvement during practical exercises. The presence of instructors or teaching assistants who are readily available to answer questions, provide guidance, and troubleshoot technical issues can greatly improve the learning experience. Personalised support not only reduces frustration but also fosters a more interactive and engaging learning environment. Overall, these improvements would contribute to a more effective integration of digital tools in engineering education, ultimately leading to better learning outcomes and student satisfaction.

### 5.2 Broader implementation

Beyond the immediate context of this course, several important recommendations emerged for expanding the use of simulation tools and sustainability-focused digital learning across engineering education. One key suggestion is to promote the adoption of free and accessible simulation software, such as COCO and ChemSep, within other en-

engineering programmes. These tools provide cost-effective yet powerful platforms that can democratise access to advanced digital skills, enabling a wider range of students to develop competencies that are highly relevant to industry demands.

Additionally, fostering collaboration among educators and institutions is essential to maximise the benefits of integrating sustainability and digital skills into engineering curricula. Sharing best practices, instructional materials, and successful project examples can accelerate the development of innovative teaching approaches and encourage a consistent emphasis on sustainability across different disciplines and programmes.

Finally, it is recommended to conduct further research to evaluate the long-term impacts of such educational interventions on student learning outcomes and employability skills. Understanding how exposure to simulation tools and sustainability principles influences graduates' professional performance and adaptability will provide valuable insights to refine curricula and support continuous improvement. This evidence-based approach will ensure that educational strategies remain relevant and effective in preparing engineers for the evolving challenges of their profession.

## 6 Conclusion

The integration of simulation seminars into the "Process Design" course significantly enhanced students' learning experiences by fostering the development of digital competencies, innovative thinking, and practical problem-solving skills, as reported by 75.9 % of the survey respondents. By using accessible and industry-relevant tools such as COCO and ChemSep, students were able to bridge theoretical knowledge with real-world application, aligning their learning with contemporary engineering practices and sustainability goals. Despite these positive results, challenges were also identified, including limited time for hands-on practice, and the need for more technically complex tasks. Addressing these limitations by extending the duration of exercises, improving teaching materials, and increasing teacher support could further improve the effectiveness of such seminars. Ultimately, this research has demonstrated the potential of simulation-based learning in bridging the gap between academic theory and real-world application. Moreover, the use of COCO and ChemSep familiarised students with the same conceptual framework employed in commercial process-simulation tools, thereby facilitating the direct transfer of acquired competencies to industry-standard software. Future efforts should focus on refining teaching methodologies, expanding tool applications, and further aligning educational practices with sustainability goals.

## ACKNOWLEDGEMENTS

The results presented in this paper were funded by institutional funds of the Faculty of Chemistry and Technology, University of Split, Croatia.

## References Literatura

1. European Council, Presidency Conclusions: Lisbon European Council, 23 and 24 March 2000, URL: [https://www.europarl.europa.eu/summits/lis1\\_en.htm](https://www.europarl.europa.eu/summits/lis1_en.htm) (29. 9. 2025.)
2. Ministry of Science and Education, New colors of knowledge – Strategy of Education, Science and Technology, Zagreb, Ministry of Science, Education and Sports, 2014, URL: <https://mzom.gov.hr/UserDocImages/dokumenti/Obrzovanje/Strategy%20for%20Education,%20Science%20and%20Tehnology.pdf> (29. 9. 2025.)
3. Digital education action plan: policy background. European Commission, Brussels, Belgium, 2018, URL: [https://ec.europa.eu/education/education-in-the-eu/digital-education-action-plan\\_en](https://ec.europa.eu/education/education-in-the-eu/digital-education-action-plan_en) (29. 9. 2025.)
4. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the digital education action plan, European Commission, Brussels, Belgium, 2018, URL: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52018DC0022> (29. 9. 2025.)
5. European higher education area (EHEA). URL: <https://ehea.info/> (29. 9. 2025.)
6. The European Green Deal, European Commission, Brussels, Belgium, 2019, URL: <https://eur-lex.europa.eu/summary/SR/4438420> (29. 9. 2025.)
7. A. M. Sahlodin, R. Sotudeh-Charebagh, Role of digital technologies for improving chemical engineering education, *IJJE* **26** (2024) 67–92, doi: <https://doi.org/10.22047/ijee.2024.446961.2060>.
8. Z. Y. Kong, A. A. Omar, S. L. Lau, J. Sunarso, Introducing process simulation as an alternative to laboratory session in undergraduate chemical engineering thermodynamics course: A case study from Sunway University Malaysia, *DChe* **12** (2024) 100167, doi: <https://doi.org/10.1016/j.dche.2024.100167>.
9. I. A. Udugama, M. Atkins, C. Bayer, J. Carson, D. Dikicioglu, K. V. Gernaey, J. Glassey, M. Taylor, B. R. Young, Digital tools in chemical engineering education: the needs and the desires, *Educ. Chem. Eng.* **44** (2023) 63–70, doi: <https://doi.org/10.1016/j.ece.2023.05.002>.
10. A. Nuraini, D. A. Setyowati, V. E. Kurniyanto, F. Fitriah, K. P. Ni'mah, N. Aliffiantika, A. B. Pusvitasari, D. A. Sari, Simulation program skills for chemical engineering graduates, *Jurnal Pendidikan Glasser* **8** (2024) 129–138, doi: <https://doi.org/10.32529/glasser.v8i1.3207>.
11. J. van Baten, H. Kooijman, R. Taylor, Flowsheeting for free with COCO, *CACHE News*. 2007, URL: [https://www.cocosimulator.org/downloads/Winter07\\_Taylor\\_Flowsheeting.pdf](https://www.cocosimulator.org/downloads/Winter07_Taylor_Flowsheeting.pdf) (17. 7. 2025.)
12. COCO software system. URL: <https://www.cocosimulator.org/> (17. 7. 2025.)
13. H. A. Kooijman, R. Taylor, *The ChemSep book*, 2<sup>nd</sup> ed., 2019, URL: <http://chemsep.org/book/docs/book2.pdf> (17. 7. 2025.)
14. J. Perić, N. Vukojević Medvidović, Projektiranje procesa, Sveučilište u Splitu, Kemijsko-tehnoški fakultet, Split, 2022, pp. 400–410.
15. C. Tangsathikulchai, N. Punsuwan, P. Weerachanchai, Simulation of batch slow pyrolysis of biomass materials using the process-flow-diagram COCO simulator, *Processes* **7** (2019) 775, doi: <https://doi.org/10.3390/pr7110775>.
16. C. Moliner, F. Marchelli, F. Bosio, E. Arato, Simulation of the gasification of agricultural residues using COCO simulator,

- In: European biomass conference and exhibition proceedings, Copenhagen, Denmark, 2018, pp. 764–768, doi: <https://doi.org/10.5071/26thEUBCE2018-2CV.4.19>.
17. J. Gohil, S. P. Doshi, D. Chheda, A. Prasad, Simulation of Aqua-ammonia refrigeration system using the Cape-Open To Cape-Open (COCO) simulator, *Int. J. Sci. Technol. Res.* **6** (2017) 21–24.
  18. Y. Alqaheem, M. Alobaid, Development of a membrane process in Cape-Open to Cape-Open (COCO) simulator for carbon dioxide separation, *Results Eng.* **22** (2024) 102239, doi: <https://doi.org/10.1016/j.rineng.2024.102239>.
  19. D. Zalazar-Garcia, A. Fernandez, L. Rodriguez-Ortiz, E. Torres, A. Reyes-Urrutia, M. Echegaray, R. Rodriguez, G. Mazza, Exergo-ecological analysis and life cycle assessment of agrowastes using a combined simulation approach based on Cape-Open to Cape-Open (COCO) and SimaPro free-software, *Renew. Energy* **201** (2022) 60–71, doi: <https://doi.org/10.1016/j.renene.2022.10.084>.
  20. G. A. Carvalho De Sousa, N. Toscano Miranda, A. Bavaresco Rezende, U. M. Nascimento, R. Maciel Filho, M. R. Wolf Maciel, Simulation of sugarcane Bagasse pyrolysis using COCO simulator, *Chem. Eng. Trans.* **117** (2025) 955–960, URL: <https://www.cetjournal.it/index.php/cet/article/view/CET25117160>.
  21. J. M. Gozálviz-Zafrilla, A. Santafé-Moros, Uncertainty and global sensitivity analysis of a membrane biogas upgrading process using the COCO simulator, *Chem. Eng.* **9** (2025) 94, doi: <https://doi.org/10.3390/chemengineering9050094>.
  22. T. Oyegoke, COCO, a process simulator: methane oxidation simulation & its agreement with commercial simulator's predictions, *Chem. Prod. Process Model.* **18** (2023) 995–1004, doi: <https://doi.org/10.1515/cppm-2023-0035>.
  23. V. C. Tassone, P. den Brok, C. W. S. Tho, A. E. J. Wals, Cultivating students' sustainability-oriented learning at the interface of science and society: a configuration of interrelated enablers, *Int. J. Sustain. High. Educ.* **23** (2022) 255–271, doi: <https://doi.org/10.1108/IJSHE-01-2022-0014>.
  24. P. Sanz-Angulo, J. Galindo-Melero, S. De-Diego-Poncela, O. Martín, Promoting soft skills in higher engineering education: Assessment of the impact of a teaching methodology based on flipped learning, cooperative work and gamification, *Educ. Inf. Technol.* **30** (2025) 13463–13506, doi: <https://doi.org/10.1007/s10639-025-13322-0>.
  25. C. Kefalis, C. Skordoulis, A. Drigas, Digital simulations in STEM education: Insights from recent empirical studies, a systematic review, *Encyclopedia* **5** (2025) 10, doi: <https://doi.org/10.3390/encyclopedia5010010>.
  26. D. Escobar-Castillejos, I. Sigüenza-Noriega, J. Noguez, D. Escobar-Castillejos, L. A. Berumen-Glinz, Enhancing methods engineering education with a digital platform: usability and educational impact on industrial engineering students, *Front. Educ.* **9** (2024) 1438882, doi: <https://doi.org/10.3389/feduc.2024.1438882>.

## SAŽETAK

### Poboljšanje digitalnih vještina za održivi inženjering: pristup zasnovan na simulacijama u projektiranju procesa

Marin Ugrina,<sup>a\*</sup> Nediljka Vukojević Medvidović<sup>a</sup> i Mila Bulić<sup>b</sup>

Inženjersko obrazovanje sve više stavlja naglasak na razvoj digitalnih vještina i svijesti o održivosti. Da bi odgovorili na zahtjeve suvremenog tržišta rada, inženjeri moraju biti vješti u primjeni digitalnih alata te istodobno projektirati procese koji su okolišno prihvatljivi. Na kolegiju "Projektiranje procesa" na Kemijsko-tehnološkom fakultetu integrirani su simulacijski programi COCO (*Cape-Open to Cape-Open*) i *ChemSep* da bi se unaprijedile digitalne kompetencije studenata i produbilo razumijevanje održivog kemijskog inženjerstva. Ti besplatni programski alati omogućuju simulaciju kemijskih procesa, termodinamičke proračune i optimizaciju energetski učinkovitih rješenja, omogućujući donošenje odluka koje vode održivosti. COCO, temeljen na CAPE-OPEN standardu, uključuje module za izradu tijeka procesa, jedinične operacije i reakcijsko modeliranje, dok se *ChemSep* primjenjuje za simulaciju destilacijskih kolona. U kombinaciji omogućuju studentima procjenu utjecaja procesa na okoliš i projektiranje održivijih rješenja. U tu svrhu provedena je anketa među studentima radi procjene upotrebljivosti programskih alata i njihova utjecaja na razvoj tehničkih i mekih vještina poput kreativnosti, kritičkog mišljenja i timskog rada. Rezultati su pokazali da su studenti prepoznali vrijednost mogućnosti simuliranja procesa iz stvarnog svijeta, osobito u kontekstu održivosti. Smatraju programske alate pristupačnima i korisnima za povezivanje teorijskih znanja s praktičnom primjenom. Istaknuli su i potrebu za povećanjem broja praktičnih vježbi te uključivanje složenijih simulacijskih zadataka. Integracija COCO i *ChemSep* alata pokazala se korisnom u pripremi studenata za suočavanje s izazovima održivosti kroz razvoj praktičnih i digitalnih kompetencija u projektiranju procesa, nudeći besplatnu i dostupnu alternativu komercijalnim simulacijskim alatima, koji su često ograničeni visokim troškovima i licencijama.

#### Ključne riječi

Digitalne vještine, digitalni alati, obrazovanje u području inženjerstva, projektiranje procesa, simulacija

<sup>a</sup> Sveučilište u Splitu, Kemijsko-tehnološki fakultet, Ruđera Boškovića 35, 21 000 Split

<sup>b</sup> Filozofski fakultet Split, Poljička cesta 35, 21 000 Split

Izvorni znanstveni rad  
Prispjelo 13. listopada 2025.  
Prihvaćeno 27. studenoga 2025.