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Description and Utilization of an Educational Platform for Clean Production in Mechanical Engineering

Milica Barac^{1,*}, Nikola Vitković¹, Zorana Stanković², Milena Rajić², Rajko Turudija¹

¹ Department of Production Information Technologies, Faculty of Mechanical Engineering in Niš, University of Niš, Aleksandra Medvedeva 14, 18000 Niš, Serbia

² Department of Management in Mechanical Engineering, Faculty of Mechanical Engineering in Niš, University of Niš, Aleksandra Medvedeva 14, 18000 Niš, Serbia

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ABSTRACT

This study introduces a novel educational mentoring platform that emphasises clean manufacturing techniques and is intended to support engineering education and mentorship. The mentoring platform provides practical, project-based learning opportunities in an educational environment. The platform's foundation lies in a mentoring approach through conducting sessions and defined projects. This paper will outline the primary components of a new educational mentoring platform and highlight some of its most important use cases. The mentoring platform enables the creation of programs like the Sustainable Manufacturing Innovation Program, which is showcased in this paper, equipping students with the knowledge to enhance sustainability in mechanical engineering and foster cleaner production startups. The paper briefly overviews the Novel Educational Methodology (NEM) integrated into an e-learning platform for personalized and adaptive learning materials and courses. The combined use of e-learning and mentoring platforms represents a comprehensive educational system, enhancing developmental outcomes while promoting and achieving clean production practices. Both platforms, e-learning and mentoring, are highly adaptable, facilitating the creation of diverse online course materials and mentoring programs across various scientific disciplines.

1. Introduction

Industrial pollution is a significant global problem due to its negative effects on ecosystems, human health and climate change, as conducted by Lu et al., [1]. For these reasons, it is imperative to reduce the negative impact of industries on the environment. As a research interest, green manufacturing has continuously increased since 2015, as evidenced by a bibliometric review of papers on this topic from 2010 to 2020 conducted by Khandelwal et al., [2]. Therefore, numerous researchers currently explore similar concepts in the context of sustainability. Thus, these concepts

* Corresponding author.

E-mail address: milica.barac@masfak.ni.ac.rs

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of sustainability, green practices, clean production, and eco-friendly manufacturing are all interconnected, as noted by several authors [3-6]. Generally, these terms can be viewed as closely related concepts within environmentally conscious practices in manufacturing and production. Each of them refers typically to approaches that aim to minimise environmental impact, promote resource usage efficiency, and ensure long-term ecological balance. In fact, a number of frequently mentioned terms, as can be seen in [7-10], include cleaner production, environmentally friendly, green or sustainable manufacturing. While these terms may have nuanced differences in emphasis or scope, they are often used interchangeably or in complementary ways to describe similar goals. These practices aim to integrate themselves into environmentally conscious economic development, ensuring an equilibrium between economic growth and socioenvironmental responsibility, as noted by Ceylan et al., [3] and Al-Yousfi et al., [6].

Relating to the ideas of Industry 4.0, cleaner production is emphasized to achieve sustainable and eco-friendly manufacturing processes. In Satyro et al., [11], the authors identify and analyze possible cleaner production strategies connected with Industry 4.0 to optimize manufacturing systems and reduce environmental impacts of companies. In addition, optimizing shop floor scheduling algorithms can significantly enhance the efficiency of the production process [12], and even optimizing individual production processes [13] can contribute to creating more environmentally friendly and sustainable manufacturing practices. A case in point is the mass-customization trend, which necessitates the designing and manufacturing of custom-made products with high efficiency which approaches that of mass-production facilities. This represents a new industrial reality, according to Zdravković and Korunović [14]. This trend is increasingly related with the cleaner production, more sustainable design and manufacturing processes which meet environmental standards and customer expectations.

Specialized education is crucial in promoting and implementing cleaner production, sustainability, and eco-friendly processes in mechanical engineering and green manufacturing. Recent research emphasizes the importance of integrating sustainability principles into engineering education to address current challenges in energy inefficiency, resource utilization, and environmental impact, as highlighted by Herrmann et al., [15] and Tseng et al., [16]. Concepts like Cradle to Cradle and Emergy-based sustainability evaluation methods provide frameworks for designing economically viable and environmentally sustainable products alongside manufacturing systems, as discussed by Peralta et al., [17] and Yang et al., [18]. Thereafter, the shift towards sustainable manufacturing requires putting focus on educating students on sustainable practices, life cycle management, and decision-making in order to cultivate future leaders who can drive innovation towards meeting society's needs, while minimizing negative environmental and social impacts, according to Tseng et al., [16] and Haapala et al., [19]. Therefore, integrating sustainability into engineering education ensures more sustainable future in mechanical engineering and manufacturing.

Education concerning cleaner production for mechanical engineers is increasingly important because it is one of the only ways to equip students with the appropriate knowledge and skill set at an early age. In this process, universities play a vital role. They facilitate advancements in eco-friendly production practices by bridging the gap between academia and industry, offering highly impactful research opportunities, and providing consulting services to companies and governments, as highlighted by Gutierrez et al., [20]. Subsequently, this leads to reduced negative environmental impact, improvement in conservation of resources, and compliance with environmental regulations. Educational initiatives should also focus on disseminating the benefits of eco-friendly production, including efficient use of resources, waste reduction, and pollution prevention to various stakeholders, as mentioned by Prigozhin et al., [21]. Fostering innovation in eco-friendly technologies

drives corporate social responsibility and can provide a competitive advantage in the market. By integrating cleaner production concepts into curricula and research programs, educational institutions can significantly adopt and implement these practices in industrial sectors worldwide, according to de Mello Santos et al., [22].

The United Nations' Sustainable Development Goals emphasize the importance of collaboration between individuals, businesses, governments, and educational institutions to achieve economic growth, encourage social commitment, and promote environmental protection, including in the field of mechanical engineering, as noted by Llopis-Albert et al., [23]. In this context, learning and mentoring platforms may offer online courses, virtual labs, seminars, and professional mentoring to enhance the education and career development of individuals. As such, they can provide resources for skill development, personal development, collaboration, and continuous learning. Through these activities engineers stay updated with the latest technologies, trends, regulations, and industry practices. The end result lies in fostering a new generation of engineers fully dedicated to minimizing negative environmental impact.

The integration of further education on these topics is essential both in existing higher education programs for current and future students and in providing continuous learning opportunities for graduated engineers and other professionals in the field, as highlighted by Nand [24]. Simultaneously, educating startups on fundamental principles and the latest advancement in these fields is also crucial in order to empower them to establish clean production processes and implement sustainable manufacturing concepts effectively from the beginning of their life cycle.

This paper presents a novel combination of two educational platforms. In this paper, we will discuss the Novel Educational Methodology (NEM), developed by Vitković et al., [25] which is integrated into an e-learning platform to create personalized and adaptive learning materials and courses. The second platform has been developed as part of a project on virtual mentoring (mentoring platform). The first platform (e-learning) provides a knowledge base which can increase the efficiency of mentoring provided by the mentoring platform. Without a doubt, the integrated use of these two platforms provides a comprehensive system for personalized learning and adaptive mentoring, enhancing educational and developmental outcomes.

The mentoring platform, introduced in this article, allows the creation of various mentoring programs across different scientific fields. For example, the paper introduces a short and intensive mentoring program promoting cleaner production, titled the Sustainable Manufacturing Innovation Program. With courses and programs on such topics, current and graduated students can acquire state-of-the-art knowledge. For entrepreneurship, an educational mentoring platform can facilitate specialized training, examples of successful projects, showcase good practices, research on the latest sustainable technologies, expert mentorship, and networking opportunities.

2. Methodology

Establishing a comprehensive, sustainable, and inclusive educational system in the field of cleaner production and also other scientific domains that meet the specific needs of individual trainees, startups, and established companies while simultaneously providing standardized and certified guidelines from mentors (experts across various domains), is key to advancing education and further development of products and processes by emerging mechanical engineers.

By using both e-learning and mentoring platforms, participants will be able to access cutting-edge content, materials, and programs aligned with societal, industrial, and university needs, adaptable to diverse needs of learners and domains of scientific fields, facilitating work-based learning and lifelong

learning through continuously updated courses and mentorship programs across various scientific disciplines.

2.1 Novel Educational Methodology (NEM) for Personalized Learning Materials

Developed by Vitković et al. [25], the Novel Educational Methodology (NEM) creates a personalised learning platform by integrating traditional and e-learning elements. By integrating thorough student feedback, concentrating on learning contexts, and providing a variety of teaching styles, it solves the drawbacks of current adaptive education and intelligent tutoring systems.

NEM supports mentors in developing cutting-edge courses and facilitating personalised learning pathways by utilising cutting-edge learning strategies including Molecule-Based Learning (MBL), Smart-Sequence Learning (SEL), and Intelligent Content Creation (ICC). Table 1 displays the essential elements of NEM, which were taken and adapted from Vitković et al., [25].

Table 1
Key components of NEM

Key Component	Concept	Application
Molecule-Based Learning (MBL)	Learning content is presented in small units called "molecules," which consist of different variants of the same core material (nucleuses). These can include text, audio, video, and other media.	Enables the creation of flexible learning processes adapted to different target groups. Each molecule can be used individually or combined, allowing for customized learning experiences.
Smart-Sequence Learning (SEL)	Learning sequences are personalized by combining molecules of knowledge from various domains. This can be done manually or through machine learning techniques, creating a sequence that best suits the learner's needs.	New courses can be developed by aggregating existing molecules, ensuring that the learning material is comprehensive and personalized.
Intelligent Content Creation (ICC)	Learning materials are dynamically created based on the preferences of both the learner and the teacher. This involves the use of digital avatars for teachers and Natural Language Processing (NLP) techniques to interpret and generate content.	Allows for the automated or semi-automate creation of personalized learning materials, enhancing the adaptability and relevance of the courses.

The NEM platform, developed by Vitković et al. [25], incorporates Moodle, Unity, and Blender among other tools for content creation and delivery. This includes defining molecules and nucleuses and organising the information into courses that can be customised to the preferences of the learners.

Based on the developed methods and the current state of research, three types of courses can be defined, as shown in Table 2, which were adapted from the study by Vitković et al., [25].

Table 2
Type of courses

Type of Course	Description
Generic Courses	Standardized courses are created based on the specifications of the trainer. These follow the traditional approach but are structured using NEM principles.
Learner-Defined Courses	Courses tailored to the specific needs of learners. These are manually created by learners using selected nucleuses or molecules of knowledge.
Recommended Courses	Courses generated based on AI-driven recommendations. The system uses a supervised learning approach to suggest which nucleuses learners should focus on, creating a custom learning path.

Overall, NEM enhances the creation and delivery of learning materials by making them customisable, adaptive, and interactive. The integration of MBL, SEL, and ICC within an e-learning platform ensures that learners receive the most relevant and effective education tailored to their specific needs and preferences, as established by Vitković et al., [25].

This platform serves to create an advanced database of educational materials necessary for conducting the mentoring program.

2.2 Description of the Mentoring Program

This section outlines the flexible structure and integral roles within the mentoring framework.

The mentoring program can be designed to be either short and intensive (1-2 months) or long and comprehensive (3-8 months), depending on the specific goals and time availability of the participants. The Supporting Organization is responsible for organizing mentorship sessions and aligning the availability of startups and mentors. These sessions can be conducted online or in person.

Each startup is paired with two types of mentors:

- i. Horizontal Mentor: Selected based on the startup's sector, this mentor typically has experience as a startup advisor or founder in the same industry. The horizontal mentor engages in multiple mentoring sessions, addressing various aspects of the startup, such as the business model, product roadmap, and go-to-market strategy.
- ii. Vertical Mentors (Domain Experts): These mentors are specialists in specific areas like digital innovation, legal issues, IP strategy, and the fundraising process. They provide targeted guidance on these topics.

Mentorship sessions are monitored by a coach from the Supporting Organization, who can adjust the development plan and mentorship types according to the startup's progress and evolving needs.

2.3 The Mentoring Process (Software Application)

The mentoring process is a complex feature of the program, which includes several entities and focuses primarily on sessions and projects. The session is a means of communication between mentors and trainees supervised by the organization coach. These facilitate an opportunity for actions and activities defined for each project.

The mentoring software application's primary entities include the User (Mentor, Trainee, Admin, Coach, and Program Manager), Program, Project, and Session.

In the database of the mentoring platform, the main relations are as follows:

- i. The Program can have multiple Projects (1 : N)
- ii. The Program can have multiple Sessions (1 : N)
- iii. Sessions can be associated with multiple Projects and vice versa (N : M)

The Program use case, as shown in Figure 1, includes the following steps:

- i. The Program is defined.
- ii. The Program Manager selects the Mentor(s).
- iii. The Program Manager selects a Coach from the organization which owns the Program.
- iv. The Program Manager defines the description of the Program.
- v. The organization Coach or Program Manager identifies the required Projects, creates them in the application, and connects them with a Program.
- vi. A Session is connected to Projects, themes, and messages.
- vii. A Session is also connected to Project actions and activities.
- viii. The Coach or Program Manager can connect actions and activities defined for specific Projects to Session(s).

The mentoring program should include all entities defined in the app, as illustrated in the Program Use Case shown in Figure 1.

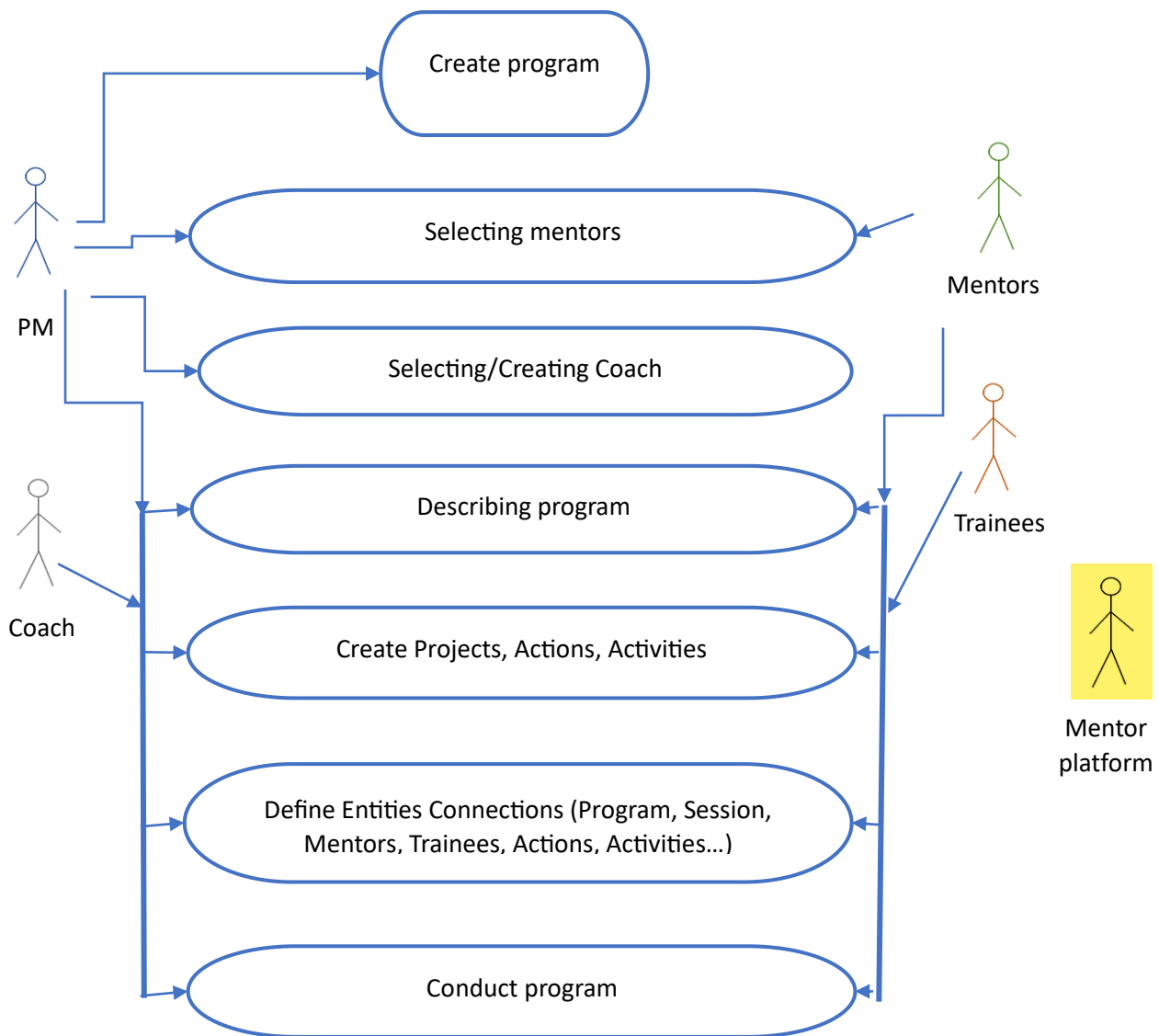


Fig. 1. Program Use Case

The process of conducting a Session, as shown in Figure 2, is as follows:

- i. The Program Manager defines a Session – sets the title and provides a description of a Session.
- ii. The Program Manager selects vertical and horizontal Mentors.
- iii. The Program Manager defines a Coach for the Session.
- iv. The Program Manager defines Projects related to the Session. Creates new Projects or connects them to existing ones.
- v. The Coach and Mentors define or establish connection(s) to Project(s) actions and activities.
- vi. The Program Manager selects Trainees for the Session.
- vii. Session(s) are conducted using online meeting tools or in person.

- viii. Session(s) can be connected to themes and messages if it is essential to record general discussion. The Project establishes the connection, meaning themes and messages are project-related.

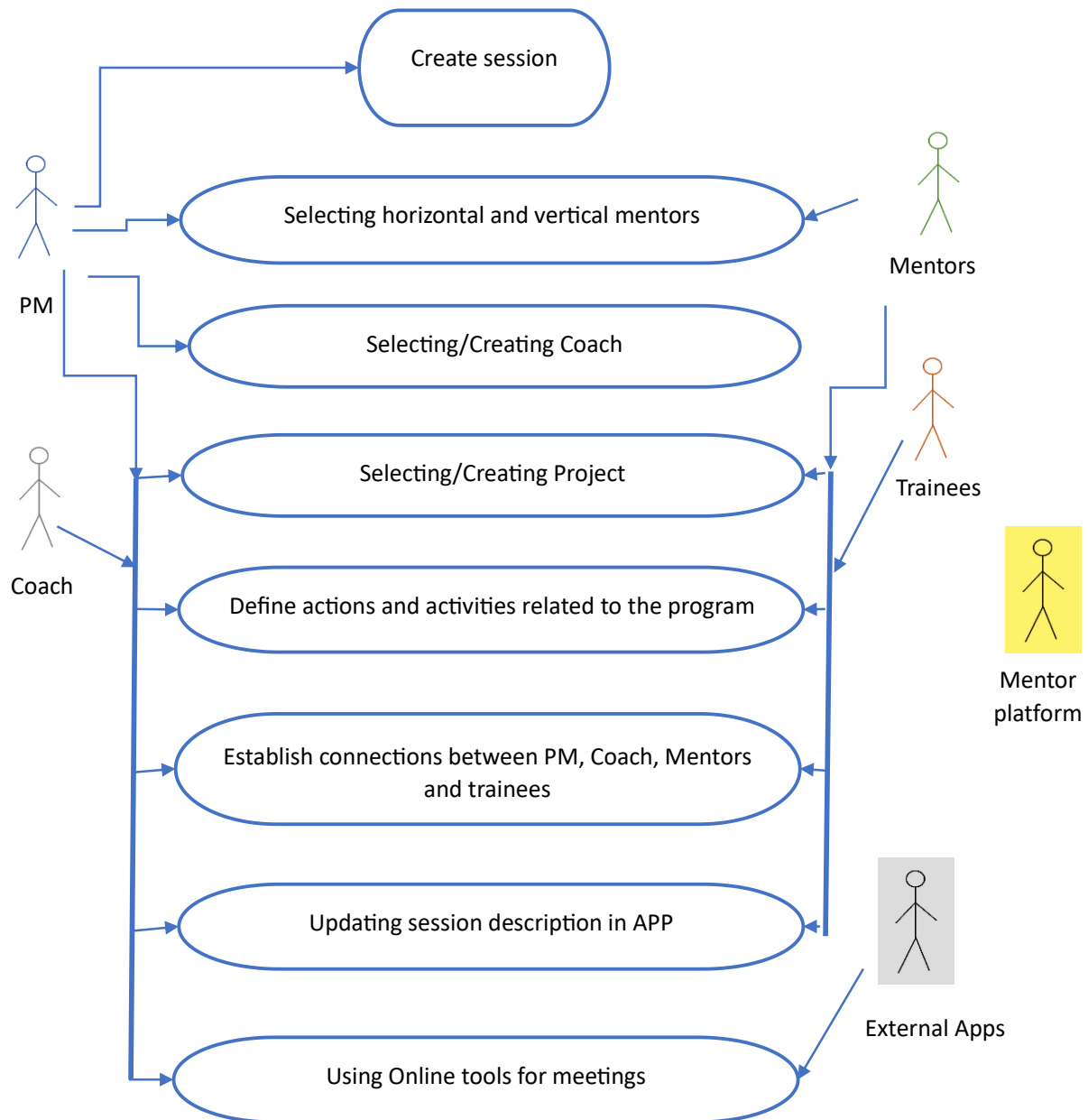


Fig. 2. Program Session Use Case

3. Results

Based on the analysis, presentation, and description of the e-learning and mentoring platforms for green production in mechanical engineering, the key results of this study include the completion of the courses on the e-learning platform. Furthermore, students have already created, used, and validated several courses on the e-learning platform successfully.

As an example, Sustainable Manufacturing Innovation Program course was created in order to support the mentoring program of the same title created on the mentoring platform, as shown in Figure 3. The aforementioned program can be found on the e-learning platform among many others.

The screenshot shows the CALLME Educational Database interface. At the top, there is a navigation bar with links: Home, Companies, Courses, Data, Candidates, Surveys, Questionnaires, Users, Login, Logout, and the user profile 'Vltkovic - nikola.vitkovich@gmail.com'. Below the navigation bar is a header with the text 'CALLME Educational Database' and the quote 'Atomic knowledge is a path to a Universal Knowledge'. The main content area features a search bar for 'Atomic Courses' with a 'SEARCH' button. Below the search bar is a table titled 'Courses' with a 'NEW COURSE' button in the top right corner. The table has columns for 'Id', 'Name', 'Created At', 'User', 'Company', and 'Actions'. There are five rows of course data.

Id	Name	Created At	User	Company	Actions
108	Sustainable Manufacturing Innovation Program	4/8/24	nikola.vitkovic	Faculty of Mechanical Engineering, University of Nis	View Edit Delete
89	Reverse Engineering of human skeletal system	9/7/23	nikola.vitkovic	Faculty of Mechanical Engineering, University of Nis	View Edit Delete
107	Radiation therapy technologies	8/23/23	nikola.vitkovic	Faculty of Mechanical Engineering, University of Nis	View Edit Delete
103	Personalized bone implants design and manufacturing	9/18/23	velibor	Faculty of Engineering, University of Kragujevac	View Edit Delete
105	Patient-specific mechatronics system in medical engineering	12/2/24	nikola.vitkovic	Faculty of Mechanical Engineering, University of Nis	View Edit Delete

Fig. 3. Created Courses on e-Learning Platform

Some of the key findings of the mentoring platform:

- i. A systematic approach to student analysis and monitoring: The platform allows for continuous monitoring of trainees' progress through defined projects and mentoring sessions, thereby enhancing learning efficiency and practical skill development.
- ii. Mentoring: The integrated mentoring approach provides direct support and guidance to trainees and startups in real-world scenarios, boosting their ability to apply acquired knowledge in practice.

So far, four mentoring programs have been successfully developed and completed, during which the needs and progress of startups were thoroughly analyzed and monitored by horizontal and vertical Mentors and Program Managers.

The mentoring programs created on the mentoring platform are shown in Figure 4.

The screenshot shows the COIN ECO mentoring platform interface. At the top, there is a navigation bar with links: Home, Dashboard, Workflows, Entities, Surveys, Users, References, Contact, and the user profile 'Nikola Vitkovic - nikola.vitkovic@masfak.ni.ac.rs - Administrator' with a 'Logout' button. Below the navigation bar is a search bar for 'Search programs' with a 'SEARCH' button. Below the search bar is a table titled 'Programs' with a 'NEW PROGRAM' button in the top right corner. The table has columns for 'Title', 'User', and 'Actions'. There are four rows of program data.

Title	User	Actions
Digital Innovation Accelerator Program	Nikola Vitkovic - nikola.vitkovic@masfak.ni.ac.rs	View Edit Delete
HealthTech Program	Nikola Vitkovic - nikola.vitkovic@masfak.ni.ac.rs	View Edit Delete
Sustainable Manufacturing Innovation Program	Nikola Vitkovic - nikola.vitkovic@masfak.ni.ac.rs	View Edit Delete
Entrepreneurial Leadership in Digital Innovation Program	Nikola Vitkovic - nikola.vitkovic@masfak.ni.ac.rs	View Edit Delete

Fig. 4. Created Programs on the Mentoring Platform

These findings highlight the significant role of educational platforms in promoting sustainable production, strengthening the link between theory and practice in engineering education, and supporting the development of young engineers and clean production-oriented startups. The integration of NEM and mentoring approaches enhances educational outcomes and contributes to long-term sustainability in the engineering sector.

3.1 Sustainable Manufacturing Innovation Program

Cleaner production in mechanical engineering is important for reducing environmental impact, enhancing resource efficiency, and ensuring regulatory compliance. It leads to cost savings, fosters technological innovation, improves health and safety, and boosts corporate social responsibility, ultimately contributing to sustainable development and competitive advantage.

The Sustainable Manufacturing Innovation Program exemplifies the platform's capacity to empower mechanical engineers with contemporary knowledge and skills, enabling them to innovate and implement sustainable manufacturing practices.

The Sustainable Manufacturing Innovation Program created on the mentoring platform, as shown in Figure 5, is a short and intensive mentoring program (1-2 months).

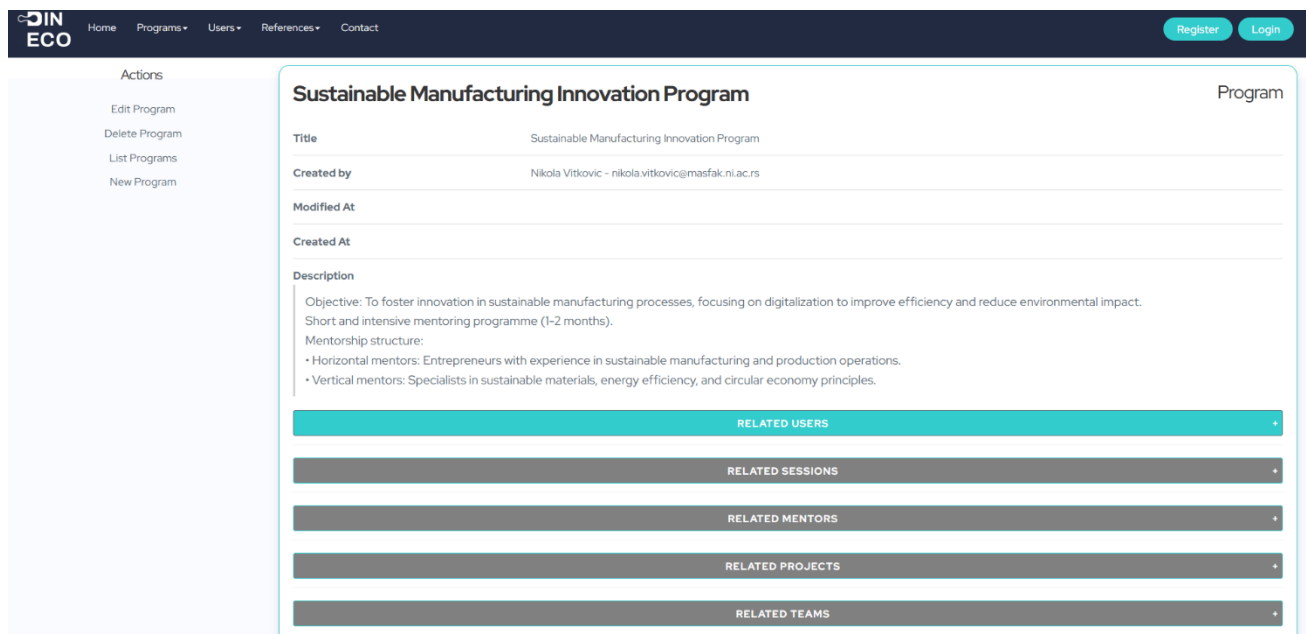


Fig. 5. Sustainable Manufacturing Innovation Program

The Sustainable Manufacturing Innovation Program aims to foster innovation in sustainable manufacturing processes, focusing on digitalization to improve efficiency and reduce environmental impact.

The mentoring structure of the sustainable production innovation program:

- i. Horizontal mentors: Entrepreneurs with experience in sustainable manufacturing and production operations.
- ii. Vertical mentors: Specialists in sustainable materials, energy efficiency, and circular economy principles.

Key actions of the Sustainable Manufacturing Innovation Program:

- i. Workshops/Sessions on sustainable manufacturing practices and digital tools for efficiency.

- ii. Mentoring on supply chain optimization and green logistics.

Action 1: Foundations of sustainable manufacturing:

- i. Activity 1 - Overview of sustainable manufacturing practices.
- ii. Activity 2 – Workshop/Session on digital tools for efficiency and sustainability.

Action 2: Product lifecycle and supply chain optimization:

- i. Activity 1 - Session on sustainable materials and lifecycle analysis.
- ii. Activity 2 – Workshop/Session on optimizing supply chains for sustainability.

Action 3: Energy efficiency and waste reduction:

- i. Activity 1 – Session on energy management and waste reduction techniques.
- ii. Activity 2 – Session on implementing circular economy principles in manufacturing.

Action 4: Market penetration and growth:

- i. Activity 1 - Marketing mix, analyzing competitors to understand market positioning, strengths, and weaknesses.
- ii. Activity 2 - Preparing for market entry with a sustainable product.

The Sustainable Manufacturing Innovation Program has already been successfully implemented with one startup. Consequently, this and other mentoring programs can be re-implemented with various startups. Additional Mentors can be incorporated based on the needs and goals of each startup. Goals, actions, and activities can be adjusted during sessions according to the agreements made between Mentors and Trainees.

3.2 Benefits of Using the Mentoring and e-Learning Platforms

It is essential to understand that utilizing both the e-learning and mentoring platforms in conjunction offers numerous advantages, especially in structured and effective mentorship programs. The key benefits include:

- i. **Enhanced Communication and Collaboration:**
Facilitates seamless interaction among Mentors, Trainees, Coaches, and Program Managers, promoting a collaborative learning environment. Provides a centralized communication mechanism through Sessions, ensuring clarity and consistency.
- ii. **Improved Organization and Management:**
- iii. **Enables efficient organization and management of courses and materials.** Allows Program Managers to oversee multiple Projects and Sessions within a single program by offering tracking and monitoring of progress associated with each Session and Project.
- iv. **Resource Optimization:**
Assists in the optimal allocation of learning resources by clearly defining the roles and responsibilities of Mentors, Trainees, and Coaches. Supports the identification and addressing of required projects and activities.
- v. **Structured Process:**
Offers a well-defined framework for the mentoring and learning processes, ensuring that all activities and interactions are goal-oriented and productive. Connects actions and activities to specific Projects and Sessions, promoting a targeted approach to mentoring.
- vi. **Data-Driven Insights:**
The program is able to provide data through analytics and reports. Insights from this data can aid in continuously improving learning and mentoring practices to ensure they are effective and aligned with goals. Enables data-driven decision-making for program managers and coaches, enhancing the overall effectiveness of the mentoring program.
- vii. **Scalability and Flexibility:**

- Supports the scalability of educational and mentoring programs to accommodate a growing number of users and diverse educational needs. Offers flexibility in defining and managing programs, Sessions, and Projects according to requirements. Enables the expansion of programs with flexible management of both e-learning courses and mentoring Sessions.
- viii. **Professional and Leadership Development:**
Promotes the professional growth of Trainees through structured guidance and support from Mentors while encouraging the development of leadership skills in Mentors and Coaches.
 - ix. **Alignment with Sustainability Goals:**
Integrates sustainability principles into both learning and mentoring processes, encouraging eco-friendly practices and aligning with broader sustainability goals.
 - x. **Holistic Development:**
Leveraging both platforms to provide a complete learning experience that combines structured courses with personalized mentoring, addressing both academic and personal growth.
 - xi. **Structured yet Flexible Learning Paths:**
Combining the structured approach of e-learning with the flexibility of mentoring to tailor learning experiences to individual needs and career goals.
 - xii. **Interactive Content:**
Integrating interactive elements such as quizzes, simulations, and discussions enhances engagement and deepens understanding.
 - xiii. **Accessibility:**
Enabling learners to access courses and materials anytime, anywhere, enhancing convenience and accommodating diverse schedules.
 - xiv. **Personalized Learning Paths:**
Offering customized courses and learning paths tailored to individual learner needs, maximizing engagement and knowledge retention.

Overall, the mentoring platform provides a robust and comprehensive solution for managing mentorship programs, ensuring efficient and effective mentoring processes that contribute to the growth and development of all participants. Combining the NEM e-platform with a mentoring platform creates a powerful synergy. This integration facilitates customized and adaptable learning paths while promoting effective communication, resource optimization, and data-driven decision-making.

3.3 Impact on innovation and resource management in entrepreneurship

The platform contributes in finding solution for proper resource management. It promotes innovation by providing opportunities for project-based learning and incorporating sustainability concepts, which support the new environmentally friendly technologies and procedures for both companies and students. The platform trains upcoming engineers and entrepreneurs in techniques that reduce environmental effect and increase resource efficiency, so promoting clean production. It offers a structured setting in which seasoned experts may advise entrepreneurs, assisting them in overcoming obstacles and more successfully introducing novel items to the market.

One other important advantage of the platform is resource optimization. By use of customized mentorship programs and individualized learning paths, the platform guarantees effective use of resources and provides startups with the assistance they require. This strategy maximizes their

chances of success. By facilitating corporate and academic cooperation, the platform also closes the knowledge gap between theory and real-world implementation. Together, these efforts produce creative ideas and improve the whole entrepreneurial environment. Furthermore, the site facilitates ongoing education by providing revised courses and mentorship Sessions, therefore enabling engineers and entrepreneurs to remain up to date on the most recent developments in clean production and sustainable manufacturing.

4. Conclusions

Based on the comprehensive analysis, this study highlights the central role of educational mentoring and e-learning platforms. These platforms efficiently facilitate individualised learning experiences and the development of practical skills by integrating the Novel Educational Methodology (NEM) into an e-learning framework and providing an organised mentoring environment. By offering specialised training, resources, and assistance on sustainable practices, educational mentoring and e-learning platforms can play a vital role in promoting cleaner production. Courses on environmentally friendly engineering methods, effective resource management, and cutting-edge technology that lower emissions and waste can be found on these platforms. Mentors can assist engineers in successfully implementing cleaner production processes by sharing best practices and real-world experiences. Platforms also encourage networking and teamwork, which promotes the sharing of concepts and solutions for problems in sustainable engineering.

In conclusion, the described platforms enhance educational outcomes by bridging theory and practice while cultivating a new generation of engineers capable of addressing global sustainability challenges. Their adaptive nature and versatile application across various scientific domains accentuate their significance in advancing cleaner production and fostering innovation in mechanical engineering education and practice.

5. Discussion

In the future research should aim at further development of such educational platforms, their safety, integrity and correctness. Moreover, any future development of such platforms must comply with the foreseen Artificial Intelligence Act drafted by the European Parliament [26] or other regulatory bodies. As stated in [27] artificial intelligence (AI) systems may offer effective support for both online and in-person learning. Not only in personalized learning, but also in automating routine tasks, empowering assessment and surveillance, and accessing a wider wealth of knowledge. Thus, future aims should identify gaps, potential risks and other challenges in the deployment of AI in education platforms. In this study, the concerns about AI usage are addressed by the human-in-the-loop approach provided by Mentors, Admins, Program Managers, etc. These precautions allow for supervision of AI-generated content, therefore maximizing the positive impact of AI usage while preventing negative effects.

Author Contributions

Conceptualization, M.B., Z.S., M.R. and N.V.; methodology, M.B. and N.V.; software, M.B. and N.V.; validation, M.B., R.T. and N.V.; formal analysis, M.B. and N.V.; investigation, M.B., R.T. and N.V.; resources, M.B., Z.S., M.R. and N.V.; data curation, M.B. and N.V.; writing—original draft preparation, M.B.; writing—review and editing, M.B., R.T. and N.V.; visualization, M.B. and N.V.; supervision, N.V.; project administration, N.V.; funding acquisition, N.V. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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