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Campus-industry synergy model to enhance engineering student independence

ROSNELLI ROSNELLI [1*], YUNIARTO MUDJISUSATYO,[2] AND DARWIN DARWIN[3]

Abstract

Technological developments and the dynamics of the industrial world require universities to produce engineering graduates who are not only academically competent but also independent, adaptive, and ready to face professional challenges. This study aims to examine and develop a model of campus-industry synergy to enhance the independence of engineering students through the integration of project-based learning, industrial internships, and applied research. The research method used was descriptive qualitative, with data collected through interviews, observations, and documentation studies in several engineering study programs at universities that have established active partnerships with industry. The results indicate that campus-industry synergy has a positive impact on improving students' problem-solving abilities, professional responsibility, and managerial skills. Furthermore, industry involvement in curriculum design and student performance evaluation strengthens the relevance of education to the needs of the workforce. Thus, the campus-industry synergy model can be an effective strategy in fostering the independence and competitiveness of engineering graduates in the era of the digital.

Keywords

Campus-industry synergy, industrial engineering, industrial involvement in curriculum project-based learning, student independence

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[1*]Universitas Negeri Medan, Indonesia; Corresponding email: rosnelli@unimed.ac.id
[2,3]Universitas Negeri Medan, Indonesia

Introduction

The Industrial Revolution 5.0 is bringing significant changes to the higher education system, particularly in the engineering field, which is the backbone of technological progress and industrial innovation. This era demands synergy between humans and intelligent technologies such as Artificial Intelligence, the Internet of Things, big data, and automation systems that are interconnected and collaborate to create greater human value (Bolstad et al., 2021; Galoyan and Betts, 2021). In this context, engineering college graduates must not only master basic technical theory and skills, but also possess analytical, creative, innovative, and adaptive thinking skills to the rapidly changing dynamics of technology (Delaine et al., 2010). The world of work now demands graduates who are ready to collaborate across disciplines, able to solve complex problems, and possess a strong social sensitivity and professional ethics in implementing technology (Soares & Dias, 2019). To address these challenges, universities must transform by developing integrative, collaborative, and real-world practice-oriented learning models. Project-based learning, industrial internships, and applied research are essential tools for connecting academic theory with the needs and challenges of modern industry (Lindsay et al., 2021).

Strategic partnerships between universities and industry are key to strengthening the relevance of higher education, particularly in engineering, which is heavily influenced by technological developments. Consultative forums between academics and industry practitioners play a crucial role in identifying the latest competency needs, technological trends, and real-world challenges facing the industrial sector (Galoyan & Betts, 2021; Rane & MacKenzie, 2020). The results of these forums serve as the basis for curriculum updates that align with workforce needs. A curriculum that adapts to digital technology, automation, and artificial intelligence can produce graduates who not only understand theory but are also able to apply it effectively in the field.

In addition to curriculum updates, improving lecturer competency is also crucial. Lecturers need to be equipped with an understanding of cutting-edge technology, project-based learning methods, and the ability to guide students in solving real-world industrial problems (Lindsay & Morgan, 2021). This makes the learning process more contextual and applicable. The campus-industry synergy model also holds great potential in developing independent, professional, and globally competitive students (McKenna et al., 2016). Through activities such as industrial internships, collaborative research, and joint projects, students have the opportunity to interact directly with a real work environment. These experiences not only improve technical skills but also foster soft skills such as communication, time management, responsibility, and leadership.

This research seeks to analyze in depth how implementing campus-industry synergy can enhance the independence of engineering students and ensure that higher education remains relevant to the needs of the modern workplace. Therefore, this synergy serves as a crucial foundation for building a higher education system oriented toward innovation, independence, and sustainability in the era of the 5.0 Industrial Revolution.

Literature review

Synergy between higher education and industry is a strategic element in building a higher education system that is relevant to the needs of the times. In the context of the Industrial Revolution 5.0, the relationship between academia and industry is no longer optional but a necessity to ensure graduates possess competencies that meet the demands of the ever-changing job market (Galoyan and Betts, 2021; McKenna et al., 2016). Academic-industry collaboration plays a crucial role in strengthening the concept of *link and match* , namely the alignment between the competencies taught on campus and the skills required by the workplace. Through ongoing collaboration, universities can adjust their curriculum, improve the quality of learning, and provide students with real-world experiences in facing professional challenges.

Furthermore, innovation in learning methods is also a crucial factor in supporting the effectiveness of this synergy. The implementation of the *Project-Based Learning model* fosters critical, analytical, and problem-solving skills among engineering students (Lindsay & Morgan, 2021). Through projects linked to industry needs, students not only learn to solve theoretical problems but also face real-life challenges that require creativity and collaboration. This process trains them to think systematically, manage their time, and adapt to the dynamics of interdisciplinary teams. Campus-industry synergy also provides opportunities for lecturers to update their insights on the latest technological developments and innovations in the industrial sector (Soares & Dias, 2019). Thus, the learning material provided becomes more contextual and applicable. This collaboration also encourages applied research and the development of innovative products oriented towards industrial solutions. Students involved in industry research can gain hands-on experience in system design, production process analysis, and the application of digital technology, thereby enhancing their competitiveness in the global market.

Strong synergy between universities and industry not only enhances students' competencies but also lays the foundation for an adaptive, innovative, and future-oriented educational ecosystem (Kolster, 2021). This collaboration reflects the spirit of the Industrial Revolution 5.0, where humans and technology work harmoniously to create added value for society and the workplace (Lindsay & Morgan, 2021). In the context of engineering education, industry partnerships serve not only as a means of practical work but also as a source of contextual learning. Recent research shows that industry involvement in the learning process can improve students' employability skills and encourage curriculum innovation that adapts to technological developments. Therefore, campus-industry integration is key to producing graduates who are work-ready and globally competitive.

Methodology

This study uses a descriptive qualitative approach with the aim of understanding in depth the implementation of the campus-industry synergy model in the context of engineering education (Bryman, 2016; Clandinin & Huber, 2010; Creswell & Poth, 2016). Data were obtained through interviews with three participants, including lecturers with expertise in Electrical Engineering, Mechanical Engineering, and Civil Engineering (Matthew & Michael, 1994). Participants who are industrial practitioners were also involved, namely those with expertise in Electrical Engineering, Mechanical Engineering, and Civil Engineering. This ensures that the data from the research analysis is accurate, valid, and reliable because it is in accordance with research conducted at the Faculty of Engineering that manages Electrical Engineering, Mechanical Engineering, and Civil Engineering students, as well as observations of collaborative activities such as internships, joint projects, and guest lectures. Documentation of the collaboration program was also reviewed to see the form of implementation and sustainability of the partnership (Clandinin & Huber, 2010; Kardanova et al., 2016). Interviews lasted 30 to 45 minutes to explore the results of this qualitative research (Mallette & Saldana, 2019). The interview questions with the participants were as follows.

1. What forms of collaboration have been established between the engineering study program and industry to support the development of student competencies?
2. In your opinion, to what extent is industry involvement in curriculum development or updating able to increase the relevance of learning to the needs of the workplace?
3. How does the implementation of project-based learning models or industrial collaboration help students become more independent in solving engineering problems?
4. What are the main challenges facing campuses and industry in building sustainable synergies, and what solutions can be implemented?
5. What is the role of lecturers and industry mentors in guiding students to be able to connect academic theory with practical contexts in the world of work?
6. In your opinion, what is the real impact of campus-industry synergy on increasing the independence, creativity, and work readiness of engineering students after graduation?

Data analysis was conducted through the stages of data reduction, data presentation, and conclusion drawing. The validity of the results was strengthened through triangulation of sources and methods. This approach enabled researchers to obtain a comprehensive picture of the effectiveness of campus-industry synergy in increasing the independence and work readiness of engineering students.

Results

The results of the study indicate that the implementation of project-based learning and industrial partnerships significantly increased the independence of engineering students. Students directly involved in internships and industrial projects demonstrated improved time management, professional communication, and technical problem-solving skills. Lecturers played a crucial role as facilitators and mentors, ensuring that theory could be effectively applied in practical contexts. Furthermore, industry involvement in providing input to the curriculum through consultative forums and advisory boards strengthened the relevance of the learning materials. Industry also played a role in evaluating student performance and providing feedback on skills needed in the workplace. Thus, this synergy created a learning cycle that was industry-oriented and sustainable, as exemplified by the following participant interviews.

What forms of collaboration have been established between the engineering study program and industry to support the development of student competencies?

The results of the interview with participant #1 are as follows.

Collaboration between universities and industry is realized through various strategic programs such as industrial internships, joint projects, guest lectures from practitioners, and applied research involving students. Furthermore, several industries play an active role in providing feedback on the curriculum and assessing student competency. This synergy ensures that learning on campus is closely connected to industry needs. (Participant #1)

Discussions with participants revealed that collaboration between universities and industry is a crucial strategy for bridging the gap between academia and the workplace. This synergy is realized through various strategic programs designed sustainably, such as industrial internships that provide students with real-world experience in facing professional challenges in the field. Through internships, students not only acquire technical skills but also learn about the work ethic, discipline, and responsibility that are essential to the modern industrial world. Furthermore, joint projects between universities and industry provide opportunities for students to participate in solving real-world problems faced by companies. This collaboration fosters critical, innovative, and collaborative thinking skills, which are crucial in facing the dynamics of the 5.0 Industrial Revolution. Guest lectures from industry practitioners also serve as a means of transferring knowledge and empirical experience, enriching students' insights beyond academic theory.

Furthermore, this collaboration is strengthened by the active involvement of industry in providing input on curriculum updates, ensuring that learning materials remain relevant to technological developments and labor market needs. Industry also plays a role in assessing student competency through certification programs or performance-based evaluations. Thus, university graduates are expected to be adaptive, innovative, and ready to compete globally. This form of campus-industry synergy is a crucial foundation for creating a higher education ecosystem that is contextual, dynamic, and oriented towards future needs. Through mutually beneficial collaboration, universities can produce graduates who excel not only academically but also possess independence, professionalism, and sensitivity to the challenges and opportunities of the modern workplace.

In your opinion, to what extent is industry involvement in curriculum development or updating able to increase the relevance of learning to the needs of the workplace?

The results of the interview with participant #2 are as follows.

> Industry engagement is conducted through consultative forums and advisory boards to provide input on technology trends, skills needs, and the latest work competency standards. This process makes the curriculum more dynamic, contextual, and relevant to developments in the modern industrial world. Thus, graduates are prepared to adapt to changes in technology and production systems. (Participant #2)

Discussions with participants indicated that industry involvement in the development of higher education, particularly in the engineering field, is a crucial element in producing competent graduates who are ready to face the challenges of the workplace. This involvement is realized through consultative forums and *advisory boards* that bring together representatives from universities, industry practitioners, and other stakeholders. Through these forums, industry can provide valuable input on the latest technology trends, new skills requirements, and work competency standards that align with global market developments. The input provided by industry serves as an important basis for evaluating and updating the curriculum. This process makes the curriculum more dynamic, contextual, and always relevant to real-world needs. For example, when industry begins to shift to automation and artificial intelligence-based technologies, universities can quickly adapt courses, practicum modules, and student projects to align with these developments.

In addition to strengthening the relevance of the curriculum, industry engagement also helps expand collaboration opportunities in applied research, innovation development, and professional certification programs. This creates a productive synergy between theory and practice. Graduates are equipped with adaptive readiness, critical thinking skills, and technical skills that meet the needs of the modern workplace. Overall, this partnership mechanism strengthens the position of higher education institutions as learning institutions that are responsive to global change and play an active role in producing superior human resources in the era of the 5.0 Industrial Revolution. Thus, the learning process is no longer static, but is able to adapt quickly to changes in production systems and ever-evolving technologies.

How does the implementation of project-based learning models or industrial collaboration help students become more independent in solving engineering problems?

The results of the interview with participant #4 are as follows.

> The project-based learning approach, directly linked to industry needs, helps students learn independently and contextually. Students practice identifying real-world problems, designing solutions, and applying theory to practice. This fosters critical thinking, problem-solving, and professional responsibility, which form the basis of their independence.

Discussions with participants revealed that the Project-Based Learning approach, directly linked to industry needs, is an effective learning strategy for fostering independence and professional readiness in engineering students. Through this approach, students not only learn theory in the classroom but also apply it directly in real-world contexts relevant to the workplace. In each project, students are challenged to identify actual industrial problems, analyze the root causes, and design solutions based on innovation and technological efficiency. This process trains students to think systematically, integrate various disciplines, and collaborate in multidisciplinary teams, as is the case in real-world conditions. In addition, students' direct involvement in real-world projects fosters a sense of professional responsibility, work ethic, and strong technical communication skills. Students learn to manage time and resources, and deal with the pressure of work targets, thus developing an independent and resilient work character.

Project-based learning also fosters a culture of reflection and self-evaluation, where students learn to assess the effectiveness of their solutions and continuously improve them. Furthermore, this approach strengthens the synergistic relationship between the campus and industry, as the projects developed are often derived from actual industrial needs or challenges. Thus, learning outcomes not only benefit students but also make a real contribution to improving efficiency, innovation, and industrial competitiveness. This project-based learning approach, integrated with industrial needs, ultimately becomes an important foundation in developing independent, adaptive, and solution-oriented engineering graduates in the era of the 5.0 Industrial Revolution.

What are the main challenges facing campuses and industry in building sustainable synergies, and what solutions can be implemented?

The results of the interview with participant #5 are as follows.

> The main challenges faced include time constraints, differences in academic and industry orientations, and coordination in implementing collaborative activities. The solution is to establish regular communication mechanisms, establish a long-term collaborative agenda, and involve lecturers and practitioners as co-coordinators in all integrative activities (Participant #5).

Discussions with participants revealed that the primary challenge in building synergy between campuses and industry lies in the complexities of the academic and professional worlds, which have differing orientations and dynamics. In practice, several obstacles frequently arise, including **limited time** for lecturers and students to fully engage in industrial activities, and **differing orientations** between academic interests, which emphasize scientific and research aspects, and industrial interests, which focus more on efficiency, results, and profitability. Furthermore, **coordinating collaborative activities** such as internships, joint projects, and applied research often faces administrative and logistical hurdles that require specialized management. To address these challenges, **a regular and transparent communication mechanism is needed** between the two parties. Regular forums, coordination meetings, and an integrated reporting system can serve as a means to align perceptions, set priorities, and evaluate the achievements of joint programs.

It's crucial for universities and industry to **establish a long-term,** sustainability-oriented collaborative agenda, not just sporadic activities. This long-term agenda could include curriculum updates, collaborative research, and the development of joint innovation centers. Another key to success is **the involvement of lecturers and industry practitioners as joint coordinators.** in every integrative activity. Through this collaboration, it is hoped that an exchange of experiences, knowledge, and skills will enrich both parties. This approach not only increases the effectiveness of program implementation but also strengthens the relevance of learning and research in higher education. With well-planned communication, coordination, and collaboration strategies, campus-industry synergy can run more optimally and have a real impact on improving the quality and independence of engineering students in the era of the 5.0 Industrial Revolution.

What is the role of lecturers and industry mentors in guiding students to be able to connect academic theory with practical contexts in the world of work?

The results of the interview with participant #3 are as follows.

> Lecturers act as academic facilitators, ensuring students understand the theoretical foundations, while industry mentors provide practical insights and field experience. This collaboration creates a balance between conceptual knowledge and applied skills, enabling students to connect theory with practice professionally (Participant #3).

Discussions with participants revealed that, in the context of modern engineering education, the roles of lecturers and industry mentors are two crucial, complementary components in creating a holistic learning process that is relevant to the needs of the workplace. **Lecturers act as academic facilitators** , not only conveying basic concepts and theories but also guiding students in understanding the scientific principles underlying every technical and managerial process in industry. Through structured academic guidance, students are trained to think systematically, conduct critical analysis, and develop in-depth research skills on technical problems. Meanwhile, **industry mentors provide practical insights and field experience** that cannot always be obtained in the classroom.

Industry practitioners share real-world experiences about the dynamics of the workplace, operational standards, and challenges in production processes and industrial system management. With students' direct involvement in industrial activities such as internships, joint projects, or applied research, they can understand how the theories learned on campus are implemented in complex, real-world situations. This **collaboration between lecturers and industry mentors** creates a balance between conceptual knowledge and practical skills. Students are not only proficient in theory but also able to adapt to the demands of work in the field professionally. This learning model also fosters non-technical competencies such as effective communication, teamwork , and leadership, all of which are crucial factors in building the independence and competitiveness of engineering graduates. Thus, the combination of academic learning and industry mentoring is an ideal strategy for realizing relevant, adaptive, and future-oriented engineering higher education in the era of the Industrial Revolution 5.0.

In your opinion, what is the real impact of campus-industry synergy on increasing the independence, creativity, and work readiness of engineering students after graduation?

The results of the interview with participant #6 are as follows.

Campus-industry synergy has been proven to increase student independence in learning and working. Students become more confident, communicative, and able to make analytical decisions. They also develop broader career insights and adaptive skills to new technologies, making engineering graduates more competitive in the global workforce (Participant #6).

The results of discussions with participants showed that the synergy between campus and industry has proven to be an effective strategy in increasing the independence of engineering students both in the learning process and in their readiness to face the world of work. Through direct involvement in industrial projects, internships, and other collaborative activities, students not only gain technical knowledge, but also real-life experiences that shape independent and professional mindsets. The learning process is no longer passive or only theory-oriented, but active, contextual, and based on solving real problems in the field. Students who participate in this synergy program show a significant increase in self-confidence and communication skills. They are accustomed to interacting with industry practitioners, conveying ideas, and proposing innovative solutions to the technical problems they face.

In terms of global competence, students involved in campus-industry synergy have broader work insights and adaptive abilities to new technological developments, such as automation, the Internet of Things, and artificial intelligence. This adaptability is an important asset for engineering graduates to compete in a dynamic and innovation-oriented workforce. Thus, partnerships between the academic world and industry not only increase the relevance of higher education curricula, but also strengthen the character, independence, and competitiveness of engineering graduates in facing the challenges of the Industrial Revolution 5.0 which demands superior competence and professional integrity. In addition, this experience also trains analytical decision-making abilities , because every industrial project demands accurate logical thinking, risk management, and responsibility for work results.

Discussion

In-depth interviews with lecturers and industry practitioners demonstrated that synergy between universities and industry significantly contributes to enhancing student independence and maintaining the relevance of higher education to the needs of the modern workforce (Lindsay and Morgan, 2021). Overall, all participants agreed that collaboration between academic institutions and the industrial sector should no longer be sporadic but rather be designed as an integrated and sustainable learning system to ensure continued effectiveness in the future (Galoyan and Betts, 2021).

First, in terms of collaboration, interviews indicate that the relationship between universities and industry has been realized in the form of internships, joint projects, guest lectures, and applied research (Kolster, 2021). Students are given the opportunity to directly engage in production activities, project management, and innovation research in the field. Through these activities, they not only understand theory but also are able to relate it to actual industrial practices (McKenna et al., 2016). This has implications for improving the soft and hard skills of engineering students.

Second, industry involvement in curriculum reform is considered a key factor in strengthening the relevance of higher education (Galoyan and Betts, 2021). Industry is involved in consultative forums, tracer studies, and advisory boards to provide input on technological developments and skills needs in the workplace (Rane and MacKenzie, 2020). As a result, the curriculum becomes more contextual and responsive to changing times. This approach also encourages the emergence of new courses focused on the latest technologies, such as the Internet of Things (IoT), adapting digital technology to campus learning.

Third, the implementation of project-based learning models in engineering study programs has proven effective in fostering students' critical thinking and problem-solving skills (Kolster, 2021; Lindsay and Morgan, 2021). Interviews revealed that students participating in industrial projects demonstrated significant improvements in independent learning and decision-making. They learned to solve real-world problems, work in interdisciplinary teams, and present their findings to industry and campus stakeholders to ensure that the practical implementation procedures in the field were aligned with industry needs and relevant to the integrated curriculum.

However, several challenges were also identified in the implementation of campus-industry synergy. Informants revealed that differences in orientation between the academic and industrial worlds often present obstacles, particularly in determining activity priorities and implementation schedules (Kolster, 2021). Furthermore, limited resources, in terms of time, funding, and teaching staff, also pose obstacles to maintaining the continuity of collaboration (Lindsay and Morgan, 2021). Proposed solutions include establishing a permanent liaison unit to maintain ongoing campus-industry collaboration and conducting ongoing evaluations to improve student competency and adapt to emerging technologies in the workplace.

Furthermore, the role of lecturers and industry mentors is also a crucial aspect supporting the success of this synergy program. Lecturers act as facilitators, guiding students in understanding academic theory and methodology, while industry mentors provide technical guidance and practical insights based on real-world work experiences (Guimarães and Lima, 2021). The combination of these two roles makes the learning process more applicable, integrative, and contextual. The impact of implementing campus-industry synergy on student independence is evident in increased self-confidence, communication skills, and initiative in completing assignments without heavy dependence on lecturers. Students also demonstrate adaptive abilities to new environments and complex challenges in the workplace (Kolster, 2021). In this context, campus-industry synergy not only equips students with technical skills but also develops professional character traits such as responsibility and independence, in an effort to develop professional competencies.

Overall, the interview results confirmed that the synergy between higher education and industry is a future learning model relevant to the demands of the Industrial Revolution 5.0 era. This synergy is oriented not only toward knowledge transfer but also toward character development, independence, and work-readiness in engineering students (Galoyan and Betts, 2021). By creating a continuous interaction space between the academic and professional worlds, students have broader opportunities to develop their potential and continuously improve their competencies, enabling them to adapt to technological developments in the workplace (Kolster, 2021). From these findings, it can be concluded that strengthening campus-industry synergy must be a priority in higher education policy. Sustainable strategies are needed through collaborative program planning, strengthening faculty capacity, and increasing institutional support (Lindsay and Morgan, 2021). If this model is consistently implemented, engineering higher education in Indonesia can produce graduates who are not only academically competent but also independent, creative, and ready to contribute to the development of the modern workplace.

Conclusion

The campus-industry synergy model has proven effective in enhancing engineering students' independence through project-based learning, research collaborations, and internships. Sustainable collaboration between academics and industry not only improves students' technical skills but also strengthens their adaptive competencies and professionalism. Therefore, universities need to expand their industrial partnership networks and integrate field experiences as an integral part of the curriculum to produce graduates who are ready to compete in the Industrial Revolution 5.0 era. The novelty of this research is the development of an engineering higher education model through a campus-industry synergy approach oriented towards student independence. Unlike previous research that only highlighted formal collaboration aspects such as internship programs or curriculum adjustments, this study proposes an integrative model that combines academic activities and industrial practices sustainably within a single learning system. This synergy involves lecturers as academic facilitators and industrial mentors as practical guides, who together form a collaborative and contextual learning ecosystem.

Another novelty lies in the research's focus on developing engineering students' independence as an indicator of successful campus-industry collaboration. This study emphasizes that independence encompasses not only technical skills but also dimensions of critical thinking, decision-making, self-management, and professional responsibility, all built through direct experience in the industrial world. Thus, the developed model is able to meet the demands of the Industrial Revolution 5.0, which emphasizes a balance between technological intelligence and human values. The analysis provides a concrete picture of campus-industry synergy practices and offers recommendations for higher education policies that can strengthen links and matches sustainably. Thus, this research not only enriches the literature on education-industry collaboration but also provides a new direction for the development of engineering learning models that are adaptive, humanistic, and relevant to the needs of the modern workplace.

Disclosure Statement

No potential conflicts of interest were reported by the authors.

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