Reflection: Education and Pedagogical Insights

Enhancing Computer Students' Technological and Entrepreneurial Skills Through Industry-Supported Bread Proofer Learning

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ABSTRACT

This study explores the potential of an industry-supported bread proofer as a practice-based learning platform for enhancing computer students' technological and entrepreneurial skills. The study employed a qualitative descriptive approach involving five computer students who participated in learning activities using an industry-supported bread proofer. Data were collected through observation, semi-structured interviews, and student reflections and analyzed using thematic analysis. The findings indicate that interaction with the bread proofer helped students connect computer-related knowledge with a real industrial production process. Students developed a broader understanding of sensors, automation, data collection, Internet of Things (IoT), monitoring, and system control. The learning activities also stimulated entrepreneurial thinking, particularly in identifying technological problems, recognizing business opportunities, developing technology-based solutions, and considering value creation for bakery businesses. The findings further indicate that industry-supported equipment can function as more than laboratory infrastructure; it can serve as an authentic cyber-physical learning environment that connects technological education, problem solving, innovation, and entrepreneurship. The study highlights the potential of industry–university collaboration to provide authentic and industry-relevant learning experiences for computer students. Although the findings cannot be generalized due to the qualitative design and limited participants, they provide an initial foundation for integrating industrial equipment from non-computing sectors into interdisciplinary computer education.

Keywords: Industry-Supported Learning; Experiential Learning; Computer Education; Technological Skills; Entrepreneurial Skills; Bread Proofer; Industry–University Collaboration; Cyber-Physical Systems; IoT; Practice-Based Learning

Field: Computer Science Education; Information Technology Education

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INTRODUCTION

The rapid transformation of the global labor market has increased the need for higher education institutions to prepare students with technological competencies that extend beyond conventional classroom learning (Kopackova et al., 2024). The World Economic Forum Future of Jobs Report 2025, based on the perspectives of more than 1,000 employers representing over 14 million workers across 55 economies, projects that 39% of workers' existing skill sets will be transformed or become outdated between 2025 and 2030. At the same time, artificial intelligence and big data, networks and cybersecurity, and technological literacy are identified as the three fastest-growing skill areas. Analytical thinking, creative thinking, resilience, flexibility, and lifelong learning are also expected to increase in importance. These developments indicate that computer education needs to move beyond teaching isolated programming or software skills toward learning experiences in which students can integrate digital technologies with real-world systems and business problems.

The growing importance of technological competencies is also closely associated with the transformation of non-technology industries (Shonubi, 2025). Digital technologies, artificial intelligence, automation, sensors, and data-driven decision-making are increasingly being integrated into sectors such as manufacturing, agriculture, food processing, logistics, and hospitality. The World Economic Forum reports that technological change is the major driver of skill disruption and that the integration of AI, information processing, automation, and digital access is increasing the importance of technological literacy and systems thinking. Consequently, computer science graduates are increasingly expected not only to develop software but also to understand how digital technologies interact with physical processes, machines, users, and business operations.

This challenge creates an opportunity for higher education institutions to introduce practice-based and interdisciplinary learning environments (Abo-Khalil, 2024). Rather than limiting students to simulations or virtual programming exercises, learning with physical equipment can provide opportunities to observe real processes, collect operational data, identify problems, develop technological solutions, and evaluate their effectiveness. UNESCO emphasizes that technology can function not only as a means of delivering education but also as a learning input, a skill, a planning tool, and a context for social and professional development. However, UNESCO also notes that evidence regarding the educational value of technology depends strongly on how the technology is integrated into teaching and learning rather than simply on the presence of technological equipment.

One promising approach is the utilization of industrial equipment as an authentic learning platform (Rentzos et al., 2014). A bread proofer, for example, is conventionally viewed as equipment used in bakery production to control the environmental conditions required during dough fermentation. However, from a computer education perspective, a proofer can represent a small-scale cyber-physical system involving temperature, humidity, time, sensors, actuators, control mechanisms, data collection, monitoring, and potentially Internet of Things (IoT) technologies. Students can therefore use the equipment to connect concepts from programming, databases, sensor systems, automation, human–computer interaction, data analytics, and system design with an actual production process (Renaldo et al., 2022).

The educational value becomes particularly relevant when the equipment is supported or donated by an industrial partner (Damaševičius, 2025). Industry-supported equipment provides students with access to technologies that reflect actual workplace environments while simultaneously creating opportunities for universities and companies to collaborate in developing industry-relevant competencies. Such collaboration can reduce the gap between theoretical knowledge and practical application by allowing students to encounter authentic technological constraints, operational requirements, quality considerations, and user needs. This is consistent with the growing emphasis on collaboration among education institutions, businesses, and governments to address skills gaps. The World Economic Forum identifies the skills gap as a major barrier to business transformation, with 63% of employers reporting it as a significant obstacle.

Beyond technical competencies, the use of an industrial bread proofer may also provide an opportunity to develop entrepreneurial skills among computer students (Riaz et al., 2025). Entrepreneurship in the digital era increasingly involves identifying opportunities at the intersection of technology and conventional industries. Students can be encouraged to examine the operational problems of small and medium-sized bakeries, identify opportunities for digitalization, design monitoring or automation solutions, estimate production costs, evaluate potential markets, and develop technology-based business models. Thus, the learning process can shift from "how to program a system" toward "how to identify a problem, develop a technological solution, and create value from that solution." This orientation is particularly important because digital technologies are increasingly recognized as drivers of innovation, job creation, and the development of data-driven solutions across non-IT industries.

The potential of such an approach is particularly significant for computer students because the future workforce increasingly requires a combination of technological and human capabilities (Mhaske et al., 2025). The World Economic Forum projects that technological skills will grow faster than other categories of skills, while creative thinking, analytical thinking, leadership, collaboration, and adaptability will remain important. A learning environment centered on an industry-supported bread proofer can bring these competencies together: students may need to analyze production problems, design a digital solution, work collaboratively, communicate with industry users, evaluate system performance, and consider the commercial feasibility of their innovation (Renaldo et al., 2021).

However, despite the increasing emphasis on industry-oriented and technology-enhanced education, there remains a need for empirical evidence concerning how industry-supported physical equipment can be transformed into meaningful learning experiences for computer students (Liang et al., 2024). Much of the discussion surrounding educational technology focuses on digital platforms, online learning, artificial intelligence, or virtual environments, while physical industrial equipment is less frequently examined as a pedagogical resource for computer education. This creates an important research opportunity to investigate whether exposure to an industry-supported bread proofer can contribute to students' technological and entrepreneurial competencies.

Therefore, this study aims to examine the use of an industry-supported bread proofer as a practice-based learning platform for computer students. Specifically, the study focuses on how learning activities involving the equipment can enhance students' technological competencies and entrepreneurial skills. By connecting computer education with a real industrial production system, this study seeks to demonstrate how industry–university collaboration can create authentic learning experiences and contribute to the development of graduates who are not only technically capable but also able to identify opportunities, develop technology-based solutions, and create entrepreneurial value.

LITERATURE REVIEW

Experiential Learning in Higher Education

Experiential learning has increasingly been recognized as an important pedagogical approach for connecting theoretical knowledge with practical application (Daniels et al., 2025). Unlike conventional learning models that emphasize the transmission of knowledge from instructors to students, experiential learning places students in situations where they can engage with real problems, perform tasks, reflect on outcomes, and develop solutions. This approach is particularly relevant in technology-oriented education because technological competence cannot be developed solely through conceptual understanding; students also need opportunities to interact with systems, tools, data, and real operational problems.

In entrepreneurship education, experiential learning is especially important because entrepreneurial competencies are difficult to develop through passive classroom instruction alone. A systematic literature review by Motta and Galina found that experiential learning contributes positively to entrepreneurial intention and the development of entrepreneurial skills and competencies. The review further emphasizes that different experiential activities can generate different learning benefits depending on how they are designed and implemented. Similarly, Carpenter and Wilson's systematic review found evidence supporting the effectiveness of experiential programs in higher education, although they also identified methodological limitations in much of the existing entrepreneurship education literature.

For computer students, experiential learning can therefore provide a mechanism for transforming abstract concepts into practical technological capabilities. Instead of learning programming, sensors, databases, or automation as separate subjects, students can encounter a real system in which these technologies must operate together. Such learning environments encourage students to analyze problems, test solutions, interpret data, and evaluate technological performance.

Technological Skills Through Real-World Systems

Technological competence in contemporary computer education increasingly extends beyond programming proficiency (Rahmawati et al., 2025). Students are expected to understand how software, hardware, sensors, communication technologies, data, and physical processes interact within integrated systems. This is particularly relevant in the context of Industry 4.0, where digital technologies increasingly connect physical production processes with computational systems.

A physical production device such as a bread proofer can therefore be conceptualized as a cyber-physical learning platform. The equipment contains a physical process that can potentially be monitored and controlled using sensors, actuators, embedded systems, data acquisition, programming, and IoT technologies. From an educational perspective, students can use such a system to understand the relationship between physical variables and digital information (Suyono et al., 2021).

Research on cyber-physical systems in higher education suggests that CPS-supported learning can facilitate interdisciplinary learning and allow students to develop competencies across technological domains. Prasetyono et al., for example, discuss the integration of cyber-physical systems with higher education curricula as a means of supporting interdisciplinary competency development and student-centered learning.

Consequently, the educational value of an industrial bread proofer does not necessarily lie in its function as bakery equipment alone. Its value can emerge when students are encouraged to observe, measure, analyze, program, control, and improve the system. Such activities provide a practical context for applying computer-related knowledge to a physical production environment.

Industry–University Collaboration as a Learning Mechanism

Industry–university collaboration has become increasingly important as higher education institutions face pressure to produce graduates whose competencies are relevant to rapidly changing labor markets (Liu et al., 2025). Collaboration can take several forms, including internships, joint projects, guest lectures, curriculum development, research partnerships, and provision of industrial equipment.

Recent systematic-review evidence indicates that university–industry collaboration can support employability skills development by connecting educational activities with workplace requirements. Vlachopoulos and Tsitiridou emphasize that employability development should be understood in relation to pedagogical design and collaboration between universities and industry.

The value of industrial collaboration is particularly relevant when students gain access to authentic equipment rather than simulated learning environments. An industry-supported bread proofer can expose students to the types of operational problems encountered in actual production. Students may investigate temperature and humidity control, process consistency, energy efficiency, monitoring systems, automation, data collection, and user requirements. In this context, the industrial partner does not merely function as a donor but becomes part of the educational ecosystem.

Such an arrangement also changes the role of physical equipment within higher education. Rather than treating donated equipment as infrastructure that is used only for demonstrations, institutions can transform it into a platform for project-based learning, experimentation, technological innovation, and entrepreneurship.

Entrepreneurship Education and Entrepreneurial Skills

Entrepreneurship education has evolved from teaching students how to establish businesses toward developing broader entrepreneurial competencies, including opportunity recognition, creativity, innovation, problem solving, risk management, and the ability to transform ideas into value-creating solutions (Kumari & Sudha, 2026).

A systematic review of 129 studies on entrepreneurship education found that practical-oriented courses are particularly aligned with entrepreneurial learning because they engage students in acquiring entrepreneurial competencies rather than merely increasing theoretical awareness. Similarly, a systematic review of 1,531 publications found that entrepreneurship education research has increasingly shifted from traditional educational approaches toward outcomes such as entrepreneurial intention, motivation, attitude, behavior, innovation, and entrepreneurial learning.

More recent evidence reinforces the importance of experiential approaches. Motta and Galina's systematic review concludes that experiential learning can positively influence entrepreneurial intention and entrepreneurial competencies. Meanwhile, a 2025 systematic review by Branca et al. specifically examines the learning strategies and tools used to develop key entrepreneurial competencies, highlighting the continuing importance of pedagogical design in determining entrepreneurship education outcomes.

For computer students, entrepreneurship education can be particularly meaningful when it begins with a real technological problem. Instead of asking students to develop hypothetical business ideas, instructors can ask them to identify opportunities surrounding an existing industrial process. For example, students may investigate how a bakery could benefit from IoT-based monitoring, predictive maintenance, automated environmental control, cloud-based production records, or intelligent decision-support systems.

Integrating Technological and Entrepreneurial Competencies

Technological and entrepreneurial competencies should not necessarily be treated as independent learning outcomes (Sorokin & Chernenko, 2022). In contemporary digital entrepreneurship, technological knowledge can constitute the foundation for identifying opportunities and developing innovative products or services. Conversely, entrepreneurial thinking can help students determine which technological problems are worth solving and how technological solutions can generate value.

This relationship creates an opportunity to integrate computer education and entrepreneurship through real industrial technology. In the context of a bread proofer, students can progress through a sequence such as:

Industrial problem → data collection → technological analysis → system development → prototype/testing → performance evaluation → business opportunity → value creation.

This sequence combines technical competencies with entrepreneurial competencies. Technical activities may include sensor integration, programming, data acquisition, IoT connectivity, automation, visualization, and system evaluation. Entrepreneurial activities may include opportunity recognition, customer-needs analysis, innovation, cost estimation, business-model development, and commercialization.

Such integration is consistent with the literature suggesting that practical and experiential entrepreneurship education is more closely associated with competency development than purely theoretical instruction.

Industry-Supported Equipment as an Educational Innovation

The use of industry-supported equipment provides an opportunity to combine the strengths of experiential learning, technology education, and entrepreneurship education (Wolf et al., 2025). The equipment provides an authentic physical context, while students provide the computational and analytical capabilities needed to investigate and potentially improve the system.

The novelty of this approach lies not simply in using a bread proofer in education, but in reconceptualizing industrial equipment as an interdisciplinary learning platform for computer students. A bread proofer can become a practical environment in which students learn how digital technologies interact with physical production systems while simultaneously exploring the commercial potential of technology-based solutions.

This approach also responds to a persistent challenge in higher education: ensuring that students develop competencies that are meaningful beyond the classroom. Recent research on university–industry collaboration emphasizes that employability development is strengthened when educational practices are connected to authentic workplace contexts.

Research Gap

Although previous studies have established the value of experiential learning (Bonnell & Chewinski, 2027), entrepreneurship education (Yuan et al., 2026), cyber-physical learning (Li et al., 2026), and university–industry collaboration (Çalıkuşu et al., 2026), these strands of research have generally been examined separately. Entrepreneurship education literature has extensively investigated entrepreneurial intention and competencies, while technology education has focused on digital, programming, IoT, and cyber-physical competencies. Meanwhile, university–industry collaboration research has primarily examined employability, work-integrated learning, and institutional partnerships.

There is comparatively limited research examining industry-donated physical production equipment as an integrated learning platform for computer students, particularly equipment originating from the food-processing sector. This creates a research gap concerning whether exposure to authentic industrial equipment can simultaneously facilitate technological and entrepreneurial competency development.

The present study addresses this gap by examining industry-supported bread proofer learning as an experiential educational intervention for computer students. The study positions the bread proofer not simply as bakery equipment but as a real-world technological system through which students can apply computational knowledge, engage in problem solving, develop technological solutions, and identify entrepreneurial opportunities.

Conceptual Positioning

Based on the literature, the study can be positioned as:

Industry Support

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Access to Authentic Bread Proofer

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Experiential / Practice-Based Learning

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Technological Skills

(programming, sensors, IoT, data, automation, system analysis)

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Entrepreneurial Skills

(opportunity recognition, innovation, problem solving, value creation)

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Industry-Ready Computer Graduates

METHODOLOGY

Research Design

This study employed a qualitative descriptive research design to explore how the use of an industry-supported bread proofer contributed to the development of technological and entrepreneurial skills among computer students. A qualitative approach was selected because the study focused on understanding students' experiences, perceptions, learning processes, and reflections during their interaction with the equipment (Kitchin, 2001).

Participants

The participants were computer students who participated in learning activities involving an industry-supported bread proofer. The participants were selected using purposive sampling. Students were selected because they directly participated in activities involving observation, operation, technological analysis, or development of technology-based solutions related to the bread proofer. A total of 5 students participated in the study.

Learning Activities

The learning activities were conducted using an industry-supported bread proofer as a real-world learning object. Students were introduced to the basic functions and operation of the proofer and were subsequently encouraged to identify technological problems and opportunities associated with the equipment.

The activities included:

1. observing the operation of the bread proofer;
2. identifying relevant technological components and variables;
3. discussing possible applications of sensors, automation, data collection, and IoT;
4. analyzing potential improvements to the system;
5. developing ideas for technology-based solutions; and
6. discussing potential entrepreneurial opportunities arising from these solutions.

These activities were designed to connect students' computer-related knowledge with an authentic industrial application.

Data Collection

Data were collected through observation, semi-structured interviews, and student reflections. During the learning activities, researchers observed students' participation, problem-solving processes, technological discussions, and interactions with the equipment. After completing the activities, semi-structured interviews were conducted with selected students to explore their experiences and perceptions.

The interview questions focused on three main areas:

1. students' understanding of technology and the bread proofer;
2. technological skills developed through the learning activity; and
3. entrepreneurial skills and opportunities identified by students.

Students were also asked to provide short written reflections about what they learned and how the experience differed from conventional classroom learning.

Data Analysis

The collected qualitative data were analyzed using thematic analysis (Rustan et al., 2025). The analysis consisted of four simple stages. First, the researchers read the observation notes, interview transcripts, and student reflections repeatedly to become familiar with the data. Second, meaningful statements related to technological and entrepreneurial learning were identified and coded. Third, similar codes were grouped into broader themes. Finally, the themes were interpreted to identify patterns in students' learning experiences.

The analysis focused particularly on two main dimensions: technological skills and entrepreneurial skills. Technological skills included understanding of sensors, automation, programming, data, IoT, and system analysis, while entrepreneurial skills included opportunity recognition, creativity, innovation, problem solving, and value creation.

Trustworthiness

To enhance the credibility of the findings, data triangulation was applied by comparing information obtained from observations, interviews, and student reflections. The researchers also compared the emerging themes among participants to identify consistent and divergent experiences.

Ethical Considerations

Participation was voluntary, and students were informed about the purpose of the study before data collection. Participants' identities were kept confidential, and the collected information was used solely for research and educational purposes.

RESULTS AND DISCUSSION

Results

Students' Initial Perceptions of the Bread Proofer

The learning activity initially revealed that most students perceived the bread proofer primarily as a piece of bakery equipment rather than as a technological learning platform (Addanki et al., 2022). Because the participants came from a computer-related background, their previous learning experiences were generally associated with programming, software development, databases, and digital systems.

However, direct interaction with the equipment changed students' perceptions. Students began to recognize that the bread proofer involved several technological concepts that were closely related to computer science, including temperature monitoring, humidity control, sensors, automation, data collection, and system control (Renaldo et al., 2023).

One student explained:

"At first, I thought the proofer was only a machine for making bread. After learning about the system, I realized that sensors and programming could be used to monitor and control the process."

This finding suggests that authentic physical equipment can help students establish connections between abstract technological concepts and real-world applications. Rather than learning technology in isolation, students were able to observe how computational concepts could be embedded within a physical production system (Junaedi, Hestia, et al., 2025).

Development of Technological Skills

The second major theme concerned the development of students' technological understanding. Interaction with the bread proofer encouraged students to identify technological components and consider how digital systems could be integrated into the equipment (Marimuthu Murugesan et al., 2026).

Students discussed potential applications involving sensors, Internet of Things (IoT), automation, data visualization, and remote monitoring. For example, students proposed using temperature and humidity sensors to collect real-time data and transmitting the information to a computer or smartphone (Delyana Rahmawany Pulungan et al., 2025).

One participant stated:

"We can add sensors so that temperature and humidity can be monitored in real time. The data could then be displayed through an application."

The observation data also indicated that students became more active in discussing possible system improvements after they understood the relationship between the physical process and digital technologies. They moved from simply observing the machine toward asking how the machine could be monitored, controlled, and improved.

This finding is consistent with the principles of experiential learning, in which students develop knowledge through concrete experiences followed by reflection and application. Experiential learning is particularly valuable when students are required to apply theoretical knowledge to authentic problems rather than simply reproduce information.

The activity also encouraged systems thinking. Students had to consider how sensors, controllers, software, users, and the physical proofer could operate as an integrated system. This is important for computer education because contemporary technological applications increasingly require students to understand interactions between digital and physical components.

Development of Entrepreneurial Skills

A third theme emerging from the data was the development of entrepreneurial thinking. After understanding the technological possibilities of the proofer, students began identifying potential problems faced by bakery businesses that could be addressed through digital technologies (Melesse & Orrù, 2025).

Students identified several potential opportunities, including:

1. remote monitoring of the proofer;
2. automatic temperature and humidity control;
3. mobile-based monitoring applications;
4. production data recording;
5. notification systems when operating conditions change; and
6. intelligent optimization of the fermentation process.

These discussions indicate a shift from technology-oriented thinking toward opportunity-oriented thinking. Students were no longer asking only, “How does the system work?” but also, “What problem can this technology solve?”

One student reflected:

“If we can develop an application to monitor several proofers remotely, it could be useful for bakeries that have many machines or production locations.”

This finding demonstrates an important connection between technological and entrepreneurial learning. The physical equipment provided a concrete problem context, while students’ computer knowledge provided the technological resources for developing possible solutions (Junaedi, Sofyanto, et al., 2025).

The finding supports previous research emphasizing that experiential entrepreneurship education can facilitate the development of entrepreneurial competencies and opportunity recognition. Rather than teaching entrepreneurship exclusively through business theory, students were encouraged to discover opportunities through direct engagement with an existing technological system.

From Problem Solving to Value Creation

Another important finding was that students increasingly connected technological innovation with potential economic value (Khan et al., 2025). During discussions, several students considered not only how a system could be developed but also who might use it and why they would be willing to use it.

For example, students discussed the possibility of developing a low-cost monitoring system for small and medium-sized bakeries. They recognized that smaller businesses might not require an expensive industrial automation system but could benefit from affordable IoT-based monitoring.

This perspective represents a movement toward value creation, which is an important component of entrepreneurial competence. Students began to consider the relationship between a technological solution, customer needs, production efficiency, and potential business opportunities.

The experience therefore demonstrated that entrepreneurship education does not necessarily need to begin with the creation of a business plan. It can begin with the identification of a real problem and the development of a technological solution that creates value.

Role of Industry Support

The involvement of the industrial partner was also perceived as an important component of the learning experience (Sudarmanto et al., 2025). The presence of actual industrial equipment increased the authenticity of the learning environment and allowed students to work with a system that was directly connected to a real production context.

Students perceived the equipment differently from conventional laboratory simulations because the bread proofer represented an actual industrial application. This authenticity encouraged students to consider practical constraints such as operating conditions, user requirements, reliability, cost, and potential commercialization.

The industry-supported equipment therefore functioned as more than physical infrastructure. It became a bridge between university learning and industrial practice.

This finding reinforces the importance of university–industry collaboration in developing employability and workplace-relevant competencies. Industry participation can provide students with opportunities to experience real technologies and understand how academic knowledge is applied outside the university.

Integration of Technological and Entrepreneurial Learning

Overall, the findings indicate that the learning activity generated two interconnected outcomes: technological competency development and entrepreneurial competency development (Imjai et al., 2024).

The process can be summarized as follows:

Industrial Equipment

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Direct Observation and Hands-on Experience

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Identification of Technological Problems

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Application of Computer Knowledge

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Development of Technology-Based Solutions

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Identification of Business Opportunities

This relationship is important because technological skills and entrepreneurial skills were not developed independently. Instead, they reinforced one another. Students first used technological knowledge to understand the equipment and then used entrepreneurial thinking to consider how technological improvements could create value for users.

This integrated approach is particularly relevant in the context of Industry 4.0, where computer graduates are increasingly expected to operate at the intersection of software, hardware, data, automation, and business processes.

Discussion

The findings demonstrate that an industry-supported bread proofer can be transformed into an effective practice-based learning platform for computer students (Addanki et al., 2022). The most significant contribution is not the use of bakery equipment itself, but the opportunity to expose students to an authentic cyber-physical system.

The experience allowed students to connect concepts that are frequently taught separately. Sensors became connected to data; data became connected to software; software became connected to automation; and automation became connected to a real business problem. This integration created a more meaningful learning environment than isolated theoretical exercises.

The findings also suggest that authentic equipment can stimulate entrepreneurial thinking. When students encounter a real production process, they can identify inefficiencies, user needs, and opportunities for technological innovation. Thus, entrepreneurship emerges naturally from the process of problem identification and solution development.

The results are consistent with the broader literature on experiential learning, which suggests that students benefit when learning involves concrete experience, reflection, conceptualization, and experimentation. They are also consistent with entrepreneurship education research emphasizing the importance of practical experiences in developing entrepreneurial competencies.

Importantly, the study suggests a broader role for industry donations in higher education. Equipment donated by industry should not be regarded merely as an asset for laboratory use. With appropriate instructional design, such equipment can become a platform for interdisciplinary learning, technological innovation, entrepreneurship, and industry–university collaboration.

CONCLUSION

Conclusion

This study explored the use of an industry-supported bread proofer as a practice-based learning platform for enhancing computer students' technological and entrepreneurial skills. The findings indicate that direct interaction with the equipment helped students connect theoretical computer knowledge with a real industrial application. Students were able to identify technological elements such as sensors, automation, data collection, IoT, monitoring, and system control within the bread-proving process.

The learning experience also encouraged entrepreneurial thinking. Students began to identify potential problems in bakery operations and proposed technology-based solutions, including remote monitoring, automated environmental control, mobile applications, and production data management. These activities encouraged students to move beyond understanding technology toward recognizing opportunities and considering how technological solutions could create value.

Overall, the study suggests that industry-supported physical equipment can function as an authentic learning platform for computer education. A bread proofer can be transformed from conventional production equipment into a cyber-physical learning environment that connects technological learning, problem solving, innovation, and entrepreneurship. The findings further highlight the potential of industry–university collaboration to provide authentic learning experiences that are relevant to contemporary workforce requirements.

Implications

The findings suggest that universities can expand the use of industry-supported equipment beyond conventional laboratory activities. Industrial equipment can be integrated into project-based and experiential learning activities to provide students with authentic problems and contexts. For computer education, equipment from non-computer industries can also become valuable learning resources. This provides an opportunity to introduce interdisciplinary learning in which students apply computing knowledge to agriculture, food processing, manufacturing, healthcare, and other sectors.

For industry partners, providing equipment to universities can generate benefits beyond corporate social responsibility. Industrial equipment can become a platform for developing future talent and exposing students to actual industry problems. Industry partners may also obtain innovative ideas from students, particularly in areas such as automation, IoT, digital monitoring, and data analytics.

The learning model provides students with an opportunity to develop both technical and entrepreneurial perspectives. Students learn that computer technology is not limited to software development but can be applied to improve physical processes and solve problems in traditional industries. This perspective may help students recognize potential career and business opportunities in sectors that are not traditionally associated with computer science.

Limitations

This study has several limitations. First, the study employed a qualitative descriptive approach with a relatively limited number of participants. Therefore, the findings reflect the experiences and perceptions of the participating students and cannot be generalized to all computer students. Second, the study focused on a single type of industrial equipment, namely a bread proofer. The learning experience may differ when other industrial systems or technologies are used.

Third, the study primarily examined students' experiences and perceived development of competencies. It did not quantitatively measure changes in technological or entrepreneurial skills before and after the learning intervention. Finally, the study was conducted within a specific industry–university collaboration context. Differences in institutional resources, industrial partnerships, student backgrounds, and instructional approaches may influence the applicability of the findings to other educational settings.

Recommendations

Based on the findings, several recommendations can be proposed. First, higher education institutions should consider integrating industry-supported equipment into project-based learning rather than using donated equipment only for demonstration or routine practical activities. Second, instructors should design learning activities that explicitly connect the physical equipment with students' disciplinary knowledge. For computer students, activities can include sensor programming, IoT implementation, data visualization, automation, database development, and mobile monitoring.

Third, learning activities should incorporate entrepreneurial components. Students can be asked to identify industry problems, develop technology-based solutions, estimate implementation costs, identify potential users, and formulate simple business models. Fourth, industry partners should be involved not only in providing equipment but also in identifying authentic problems, providing technical guidance, and evaluating student projects. Such collaboration can strengthen the relevance of university learning to industry needs.

Future Research

Future studies should extend this research using a mixed-method or quantitative approach to measure changes in students' technological and entrepreneurial competencies. Pre-test and post-test designs could be used to examine whether participation in industry-supported learning activities produces measurable improvements. Future research could also compare students who participate in industry-supported equipment learning with students who receive conventional classroom instruction. This would provide stronger evidence regarding the educational effectiveness of the approach.

Another promising direction is to develop the bread proofer into a fully IoT-enabled cyber-physical learning laboratory. Future studies could examine students' ability to develop sensor systems, real-time dashboards, predictive models, automated control, and AI-based optimization. Research could also investigate whether participation in such activities influences entrepreneurial intention, innovation capability, employability, and students' willingness to develop technology-based businesses.

Finally, future studies should examine the model across different industrial sectors. Similar research could investigate whether equipment from agriculture, livestock, manufacturing, energy, or healthcare can provide comparable learning opportunities for computer students. Such research would help establish a broader framework for industry-supported interdisciplinary experiential learning in higher education.

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