

Creating Educational Solutions for Optimizing Learning Factory Operations and Outcomes

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ABSTRACT

The rapid development of industrial education has prompted a growing need for effective Learning Factory (LF) management systems that integrate educational principles with industrial practices. This paper investigates the development of educational information systems tailored to optimize learning factory operations. The study aims to design an innovative information system and e-learning platform that streamlines the operational management of learning factories, ensuring effective resource allocation and maximizing the educational value of these settings. A mixed-methods approach, combining qualitative interviews with industry experts and quantitative surveys from educational institutions, was used to gather data on the needs and effectiveness of current management tools. Additionally, a prototype system was developed using agile software development methodologies. The findings reveal that the proposed system significantly improves the management of resources, enhances the learning experience, and bridges the gap between theoretical education and practical industrial applications. Moreover, the e-learning platform supports continuous knowledge transfer and facilitates real-time decision-making in the factory environment. The study concludes that the integration of tailored information systems and e-learning platforms in learning factories not only optimizes operational efficiency but also enriches the educational outcomes for students. This research offers valuable insights for educational institutions and industries aiming to align their training programs with the latest industrial advancements.

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1. INTRODUCTION

The rapid evolution of industrial education has led to the development of innovative models that bridge the gap between theory and practice. One such model is the Learning Factory (LF), which provides a hands-on environment where students can engage with real-world industrial processes [1]. Learning factories simulate industrial operations, allowing students to apply theoretical knowledge in a controlled, practical setting. These environments are critical for developing the necessary skills for modern industries, particularly in fields like manufacturing, engineering, and logistics [2]. However, while learning factories offer significant educational value, they also face challenges in managing resources, ensuring operational efficiency, and meeting educational objectives. As a result, there is a growing need for specialized educational information systems designed to streamline the management of learning factory operations, optimize resource allocation, and enhance the

overall educational experience [3]. This research aims to develop such a system, focusing on integrating both industrial operations and educational processes in a seamless manner.

Managing a learning factory involves coordinating various resources, including machinery, raw materials, personnel, and learning materials, while simultaneously ensuring that the educational goals are met [4]. These environments require a balance between operational efficiency and the delivery of meaningful educational experiences. Traditional educational management systems often fail to address the complexities inherent in learning factory environments, where industrial processes and educational goals must work together harmoniously. In this context, a specialized information system is needed to integrate the various components of learning factory management [5]. This system must provide tools to manage industrial operations such as production scheduling, equipment monitoring, and resource allocation while also supporting the educational objectives, such as knowledge transfer, skill development, and continuous learning.

Educational information systems have been widely used in academic institutions to streamline administrative tasks such as student registration, course scheduling, and grading. These systems have proven to be effective in improving the operational efficiency of educational institutions. However, learning factories have unique needs that go beyond the capabilities of traditional educational systems. A comprehensive system for learning factories must integrate both the educational and industrial aspects of the environment [6]. For instance, it should allow for the coordination of production activities, manage student participation in industrial tasks, and monitor learning outcomes. The information system must also enable instructors to provide feedback in real-time, track students' progress, and adjust the curriculum based on the actual challenges students encounter in the factory setting. By addressing both the operational and educational needs, such a system can improve the overall efficiency of learning factory management while also enhancing student learning outcomes.

In addition to managing industrial operations, the integration of digital learning platforms is essential for enhancing the educational experience in learning factories [7]. E-learning platforms offer students the flexibility to access educational materials, collaborate with peers, and participate in assessments outside of the physical classroom or factory setting. When integrated with an educational information system, these platforms can provide continuous learning opportunities, enabling students to reinforce their knowledge and engage with the content at their own pace [8]. Moreover, e-learning platforms can support instructors in monitoring students' progress, providing personalized feedback, and adapting instructional strategies to meet the individual needs of learners. This combination of real-time industrial experience and digital learning platforms ensures that students gain both practical skills and theoretical knowledge, making them better prepared for the demands of the modern workforce.

This research aims to develop a comprehensive educational information system that integrates both the industrial and educational management components of learning factories. The system will streamline operations, optimize resource management, and enhance the educational experience by incorporating an e-learning platform [9]. The primary objective is to design a solution that aligns industrial processes with educational goals, ensuring that learning factories operate efficiently while providing students with valuable hands-on experience. A mixed-methods approach will be used in this study, combining qualitative interviews with industry professionals and educational experts, as well as quantitative surveys from students and instructors [10]. The prototype system developed will be tested in real-world learning factory settings to evaluate its impact on both operational efficiency and educational outcomes. The findings of this research will contribute to the development of effective management tools for learning factories, offering insights into how technology can enhance the integration of education and industry [11]. This study will provide a framework for educational institutions and industries looking to implement similar systems, ultimately improving the quality and effectiveness of learning factory operations and preparing students for the evolving needs of the industrial workforce.

2. LITERATURE REVIEW

2.1. Learning Factory Models and Their Educational Impact

Learning factories have become increasingly popular as an educational model that bridges the gap between theoretical learning and practical application in industrial environments. These models enable students to experience real-world industrial processes and engage with cutting-edge technologies, which enhances their ability to apply academic knowledge in a practical setting [12]. A learning factory typically simulates an industrial production environment, allowing students to interact with automated systems, production lines, and manufacturing technologies in real-time. Learning factories offer an environment where students can engage in

hands-on activities, improving their skills in areas such as process optimization, quality control, and industrial automation [13]. Moreover, these environments help foster the development of essential skills such as problem-solving, critical thinking, teamwork, and innovation, which are highly valued in modern industries [14].

Recent studies have highlighted the significant educational benefits of learning factories. Emphasizes that learning factories provide an immersive environment where students not only develop technical skills but also gain insights into the broader industrial ecosystem, including supply chain management, resource allocation, and production planning [15]. These educational experiences align well with the goals of vocational training and workforce development, ensuring that students are well-prepared for the demands of the industry. Furthermore, learning factories have been found to promote active learning, a pedagogical approach that encourages students to take responsibility for their learning while engaging in real-world problem-solving tasks [16]. As such, learning factory models are seen as a critical tool in developing industry-ready graduates capable of adapting to rapidly changing technological and market conditions.

2.2. Educational Information Systems in Industry-Oriented Education

Educational information systems (EIS) have been widely adopted across educational institutions to manage various administrative functions, such as student data management, course scheduling, and assessment tracking. However, when applied to industry-oriented educational models like learning factories, the role of EIS expands to include the management of both educational and industrial operations. EIS in learning factories must not only handle traditional educational tasks but also monitor and manage industrial processes, such as resource allocation, production scheduling, and real-time performance monitoring [17]. Integrating industrial management functions into educational systems helps ensure that the learning environment is both efficient and aligned with industry standards. The system must track students' involvement in industrial activities, assess their learning progress, and facilitate communication between instructors and students to optimize the learning experience [18].

Emphasize the need for educational information systems to be adaptable and scalable to meet the diverse and dynamic needs of learning factories [19]. A successful EIS should integrate various modules that handle different aspects of learning factory operations. These include modules for production planning, inventory management, equipment monitoring, and student progress tracking. The integration of such modules enables the system to streamline both industrial and educational processes, facilitating a more efficient learning environment. Furthermore, highlight the importance of providing real-time data to instructors and students, enabling them to make informed decisions based on actual factory conditions [20]. The integration of real-time data from industrial processes into the educational framework ensures that students are learning from actual production scenarios, thus enhancing their practical knowledge and skills.

2.3. Role of E-Learning Platforms in Learning Factories

E-learning platforms have revolutionized the way education is delivered, offering flexibility and accessibility to students who can access learning materials anytime and anywhere [21]. In the context of learning factories, e-learning platforms play a crucial role in complementing the hands-on experiences that students gain in the factory environment. Argue that integrating e-learning platforms into learning factory models enhances the overall educational experience by providing students with additional resources, such as instructional videos, reading materials, and quizzes, that support their learning beyond the physical factory floor [22]. These platforms allow students to deepen their understanding of theoretical concepts and industrial practices at their own pace, helping them reinforce the knowledge they gain during practical sessions in the factory.

Moreover, e-learning platforms offer a collaborative learning environment, enabling students to engage with their peers and instructors through discussion forums, group projects, and peer assessments. Found that such platforms can foster student engagement and improve knowledge retention by encouraging interaction and feedback between students and instructors [23]. The integration of e-learning into learning factory systems also enables instructors to track student progress and provide personalized support based on individual learning needs. This combination of traditional industrial training and digital learning tools enhances the learning experience and prepares students for the challenges of modern industries. Furthermore, e-learning platforms can also help bridge geographical gaps, allowing students to continue their education in remote or hybrid settings, which is particularly valuable in the context of globalized education [24].

2.4. Integration of Industry and Education through Learning Factory Systems

The integration of industry and education is a central theme in the development of learning factories [25]. In today's fast-evolving job market, there is a growing demand for graduates who possess both theoretical knowledge and practical experience. Learning factories provide a platform where students can gain both, but the successful integration of these two components requires sophisticated management systems. Explores how learning factories can integrate industrial practices with educational goals through information systems [26]. These systems must align the goals of the educational institution with the needs of the industry, ensuring that students not only acquire technical skills but also understand the operational and strategic aspects of industrial processes.

The integration of real-time data from industrial systems into educational platforms provides students with a unique opportunity to analyze and adapt to actual production scenarios [27]. This approach fosters a deeper understanding of the challenges faced by industries and helps students develop problem-solving skills that are directly applicable to their future careers [28]. Moreover, the integration of industry and education through learning factory systems can enhance collaboration between academic institutions and industrial partners. By involving industry experts in the development and implementation of learning factory models, educational institutions can ensure that their curricula remain relevant and aligned with the latest industry trends and technologies [29].

2.5. Challenges in Managing Learning Factories

Despite the significant advantages of learning factory models, their management presents several challenges, particularly in terms of balancing the needs of education and industry. Highlight that learning factory managers face the difficult task of coordinating industrial operations with educational goals while maintaining operational efficiency [30]. Issues such as resource allocation, equipment scheduling, and student progress monitoring require careful attention. Furthermore, the integration of advanced manufacturing technologies with educational frameworks introduces additional complexity. Effective management of learning factories requires information systems that can handle both industrial and educational functions simultaneously. The development of specialized educational information systems is essential for addressing these challenges [31]. These systems must offer features that support real-time monitoring of factory operations, enable efficient resource management, and track student performance, all while ensuring that educational outcomes are met. Moreover, ensuring that learning factory models remain adaptable to industry needs and technological advancements is another significant challenge. The rapid pace of technological change means that learning factory systems must be flexible and capable of evolving in response to new industrial trends [32]. The ability to update curricula, integrate new tools, and incorporate feedback from industry partners is essential for maintaining the relevance and effectiveness of learning factories. In conclusion, while learning factories present significant educational benefits, their management requires sophisticated systems that can balance the demands of education and industry while addressing the operational challenges inherent in such environments [33].

3. RESEARCH METHODOLOGY

3.1. Research Design

The research adopts a mixed-methods approach, which allows for the integration of both qualitative and quantitative data to provide a deeper understanding of the challenges and needs of learning factories [34]. This approach helps to gather comprehensive insights into the operational and educational processes in learning factories, enabling the development of a more effective educational information system. The methodology consists of several stages. It begins with a needs assessment phase, where researchers identify the requirements and challenges faced by learning factories in managing both industrial operations and educational activities. Based on the findings from this assessment, a system design phase follows, involving the creation of a tailored educational information system and e-learning platform specifically for the context of learning factories. After the design is finalized, a prototype is developed to bring the system to life, followed by a prototype testing phase in real-world learning factory settings to evaluate its influence on operational efficiency and educational outcomes. Finally, an evaluation phase is conducted by collecting feedback from key stakeholders—such as instructors, students, and industry partners—to assess the overall effectiveness and relevance of the implemented system.

3.2. Data Collection Methods

To ensure the robustness and validity of the research findings, multiple data collection methods were employed. For qualitative data, semi-structured interviews and focus group discussions were conducted with industry experts, instructors, and managers of learning factories. These discussions aimed to identify operational challenges and educational needs, as well as to explore the feasibility and specific requirements for implementing an integrated educational information system. The qualitative approach provided in-depth insights into the expectations and potential impact of such a system on the learning factory environment.

In parallel, quantitative data were collected through a survey distributed to students and instructors involved in learning factory programs. The survey was designed to measure the effectiveness of current learning factory management practices, the extent of technology usage, and participants' perceptions of the educational information system's potential benefits. The quantitative results were analyzed to identify patterns and trends, particularly regarding participant satisfaction with existing systems and openness to digital integration.

3.3. System Development Process

The development of the educational information system follows a user-centered design (UCD) methodology, ensuring that the system meets the needs of all stakeholders, including students, instructors, and industry professionals. The development process consists of the following steps:

- **Requirement Analysis:** A detailed analysis of the needs of learning factory stakeholders was conducted. This analysis focused on both the educational and industrial components of the learning factory, ensuring that the system would support real-time production management and student progress tracking.
- **System Design and Architecture:** Based on the requirements, the system architecture was designed, with an emphasis on modularity, scalability, and real-time integration with industrial systems. The e-learning platform was designed to complement the educational goals by offering continuous access to resources, online collaboration tools, and performance tracking functionalities.
- **Prototyping:** A prototype of the system was developed, which integrated both industrial management functions and educational tools. The prototype was built using modern software development frameworks, ensuring flexibility and adaptability to future updates.
- **Testing and Feedback:** The prototype was tested in real-world learning factory settings. Feedback was gathered from students and instructors to identify any issues and make necessary improvements. Testing involved both functional and usability testing to ensure that the system met both operational and educational objectives.

3.4. Evaluation and Analysis

To evaluate the effectiveness of the developed system, a combination of qualitative and quantitative methods was applied. User feedback was collected from instructors, students, and industry partners to gain insights into their experiences and levels of satisfaction with the prototype. This feedback played a vital role in identifying strengths and areas for improvement, ensuring that the system was aligned with the practical needs of its users.

In addition to subjective feedback, objective performance metrics were also analyzed. Operational data were gathered to assess the system's impact on various aspects of learning factory management, such as resource allocation, production scheduling, and overall operational efficiency. Key performance indicators (KPIs) were used as benchmarks to determine whether the system contributed positively to the performance and outcomes of the learning factory. The combination of these qualitative and quantitative analyses provided a comprehensive evaluation of the system's effectiveness.

3.5. Research Procedure

The research procedure follows a systematic approach from data collection to analysis. Initially, a thorough literature review was conducted to identify current practices and challenges in learning factory management. This was followed by a needs assessment through qualitative interviews, which helped gather insights from relevant stakeholders. Based on the findings from the needs assessment, the educational information system was designed, and a prototype was developed. To ensure its effectiveness, the prototype was tested in a real-world learning factory environment. Feedback was collected from users to evaluate the system, allowing for continuous refinement and improvement of the prototype.

3.6. Research Tools

The research employed a range of tools to support both data collection and system development processes, ensuring methodological rigor and practical implementation. To facilitate the distribution and collection of survey responses from students and instructors, survey software was utilized. This software allowed for efficient dissemination, real-time data gathering, and structured storage of responses, which streamlined the quantitative data collection process and enabled easier integration into analysis tools.

For qualitative data collection, semi-structured interview guides were carefully developed and used during discussions with key stakeholders, including instructors, industry partners, and learning factory managers. These guides ensured consistency across interviews while still allowing flexibility for participants to elaborate on their experiences and perspectives, thus enriching the depth of the qualitative data.

In the development phase, prototyping tools played a central role. A combination of modern web and mobile development platforms was employed to design and build the educational information system. These tools enabled the research team to create an interactive and functional prototype that could be tested in real-world settings. Additionally, to analyze the quantitative data gathered from surveys, statistical software was used. This software supported a variety of analytical methods, including descriptive statistics and regression analysis, helping researchers to uncover meaningful trends and validate the system's effectiveness. Together, these tools provided a solid foundation for both the empirical and technical components of the research.

3.7. Data Analysis

Once the data was collected, both qualitative and quantitative data were analyzed using appropriate methods. For the qualitative data, interviews and focus group discussions were transcribed and examined using thematic analysis. This approach allowed the researchers to identify recurring themes and insights related to the operational challenges of learning factories, as well as the anticipated benefits and requirements of implementing an educational information system.

Meanwhile, the quantitative data obtained from the surveys were analyzed using statistical techniques. Descriptive statistics were used to summarize the general trends and responses, while regression analysis was employed to explore relationships between variables and to assess the effectiveness of the proposed system. These analytical methods provided a comprehensive understanding of both the subjective experiences and measurable outcomes associated with the research.

Table 1. Research Data Collection Methods

Method	Purpose	Participants	Data Collection Tool
Semi-structured Interviews	To gather in-depth insights from industry experts, instructors, and managers about the challenges faced by learning factories and the needs for an educational information system.	Industry experts, instructors, learning factory managers	Interview guides
Focus Group Discussions	To gain collective perspectives on the operational and educational challenges of learning factories.	Instructors, students, learning factory managers	Discussion protocols
Surveys	To collect quantitative data on the effectiveness of current learning factory management practices and technology usage.	Students, instructors in learning factory programs	Online survey

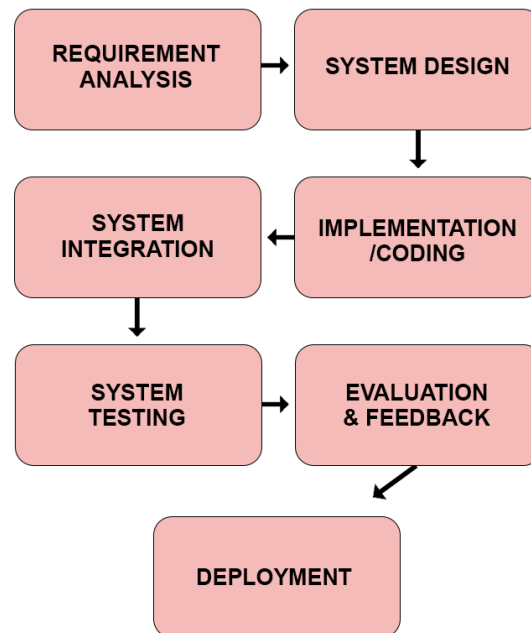


Figure 1. System Development Flowchart

Figure 1 is a flowchart outlining the system development process, from requirement analysis to system testing and evaluation.

3.8. Summary

In summary, this research uses a mixed-methods approach to develop and evaluate an educational information system for learning factories. The research is structured into multiple stages, starting with a needs assessment, followed by the design and development of a prototype system, and concluding with prototype testing and evaluation. The methodology allows for a comprehensive understanding of the challenges and needs of learning factories while ensuring that the developed system is practical, scalable, and user-centered. The combination of qualitative and quantitative data collection methods, along with a user-centered design approach, ensures that the final system meets the operational and educational needs of all stakeholders involved in learning factory management.

4. RESULT AND DISCUSSION

4.1. Needs Assessment Findings

The first step in the research was the needs assessment, which aimed to identify the challenges faced by learning factories and the requirements for an educational information system. The needs assessment was based on qualitative data collected through semi-structured interviews and focus group discussions with industry experts, instructors, and learning factory managers.

The key challenges identified during this phase included

- **Resource Management:** Learning factories faced difficulties in effectively allocating and utilizing resources, such as machinery, materials, and human resources, to meet both educational and industrial objectives.
- **Operational Efficiency:** Managers reported challenges in optimizing production scheduling and monitoring real-time data related to factory operations, which led to inefficiencies in resource allocation and delays in production processes.

- **Tracking Educational Outcomes:** Instructors expressed the need for a system that could track student progress in real-time, monitor their participation in industrial activities, and provide timely feedback on their performance.
- **Integration of Education and Industry:** There was a strong need for an integrated solution that could bridge the gap between educational goals and industrial processes, ensuring that students were gaining both theoretical knowledge and practical experience simultaneously.

4.2. System Design and Development

Based on the findings from the needs assessment, the design of the educational information system focused on addressing the identified challenges. The system was designed with the following key features:

- **Resource Management Module:** This module allows for the efficient scheduling and allocation of resources, ensuring that machinery, materials, and human resources are utilized optimally.
- **Production Scheduling and Monitoring:** The system includes tools for real-time production scheduling and monitoring, allowing learning factory managers to track production progress, identify bottlenecks, and optimize workflows.
- **Student Progress Tracking:** A module for tracking student participation in industrial activities and their performance was integrated. This module provides instructors with real-time insights into student progress and allows for personalized feedback.
- **E-learning Integration:** The system includes an e-learning platform that provides students with continuous access to learning resources, such as instructional videos, readings, quizzes, and collaborative tools, supporting their learning outside of the factory environment.

4.2.1. Prototype Testing and Evaluation

The prototype of the educational information system was tested in real-world learning factory settings, with feedback collected from students, instructors, and industry partners. The testing focused on evaluating the usability, functionality, and effectiveness of the system in managing both educational and industrial operations. The following key findings emerged from the prototype testing:

- **Improved Resource Management:** The resource management module significantly improved the allocation and utilization of machinery and materials. Managers reported fewer instances of resource conflicts, and production schedules were more efficient. This led to improved operational efficiency within the learning factory.
- **Enhanced Production Monitoring:** The real-time monitoring tools allowed managers to track production progress more effectively. The system enabled the identification of bottlenecks and delays in production, which could be addressed promptly, leading to smoother factory operations.
- **Better Tracking of Student Progress:** Instructors found the student progress tracking module to be invaluable in monitoring student participation and performance. The ability to view real-time data on student progress allowed instructors to provide timely feedback and adjust their teaching strategies to better support students.
- **Positive Impact of E-learning Platform:** The integration of an e-learning platform was highly appreciated by both students and instructors. Students reported that having access to learning resources outside of the factory setting enhanced their understanding of the material and provided flexibility in their learning. Instructors also found the platform useful for tracking student progress and providing additional learning materials.

4.2.2. Feedback from Stakeholders

Feedback from various stakeholders played a crucial role in evaluating the effectiveness of the educational information system, providing diverse perspectives that enriched the overall assessment. Students, as primary users, reported overwhelmingly positive experiences. They particularly valued the ability to access learning materials remotely, which allowed them to study at their own pace and revisit content as needed. The

provision of real-time feedback on their academic progress was also appreciated, as it helped them stay on track with their learning goals. Many students felt that the combination of hands-on experience in the factory setting and the structured guidance offered by the e-learning platform created a more holistic and effective educational experience.

Instructors also expressed satisfaction with the system, especially regarding its ability to streamline teaching processes. One of the most valued features was the real-time student progress tracking, which enabled instructors to promptly identify learners who needed extra support. This allowed for timely intervention and more personalized instruction. Moreover, the integration of industrial data into the educational framework was seen as a major advantage, as it helped instructors align academic content with actual industry needs and practices.

Industry partners who were involved in the testing phase of the system echoed these positive sentiments. They appreciated the platform's capacity to bridge the gap between industrial operations and educational objectives. The system allowed for more accurate monitoring of student involvement in industry-relevant tasks, which in turn facilitated a better understanding of how well student outcomes matched industry expectations. This alignment was seen as a promising step toward producing graduates who are not only knowledgeable but also industry-ready.

4.3. Impact on Operational Efficiency and Educational Outcomes

The development and implementation of the educational information system brought significant improvements to both operational efficiency and educational outcomes within learning factories. On the operational side, the system facilitated better resource allocation, minimized downtime, and enhanced production scheduling. Learning factory managers observed noticeable improvements in managing industrial activities, as the system allowed for real-time tracking and more precise control over various operational aspects. These enhancements led to smoother workflows, fewer interruptions, and overall improved performance of the learning factory environment.

In terms of educational outcomes, the system provided substantial benefits to both students and instructors. Through the integrated e-learning platform, students gained continuous access to learning materials, enabling them to engage with the content at their own pace and revisit key concepts as needed. This increased accessibility contributed to deeper learning and a more student-centered approach. Additionally, the system's capability to monitor student progress in real-time empowered instructors to deliver timely and personalized feedback, helping to ensure that learners met the intended educational objectives. By aligning industrial practices with academic goals, the system supported the development of both practical competencies and theoretical understanding, thereby enriching the overall learning experience.

4.4. Conclusion

The results of this research demonstrate that the proposed educational information system effectively addresses the challenges faced by learning factories. The system improved resource management, optimized production scheduling, and enhanced the tracking of student progress. Additionally, the integration of an e-learning platform provided students with continuous access to learning resources, further supporting their educational experience. Feedback from stakeholders confirmed the positive impact of the system on both operational efficiency and educational outcomes. The findings suggest that such systems can play a crucial role in optimizing learning factory operations and ensuring that students are well-prepared for the demands of modern industries.

Table 2. Feedback from Stakeholders

Stakeholder	Feedback	Impact on the System
Students	Positive response to e-learning platform and real-time feedback on progress.	Increased student engagement and improved learning outcomes.
Instructors	Appreciated progress tracking and real-time data integration.	Enhanced ability to monitor and support student progress.
Industry Partners	Noted better alignment between student outcomes and industry expectations.	Improved relevance of educational experience for industry needs.

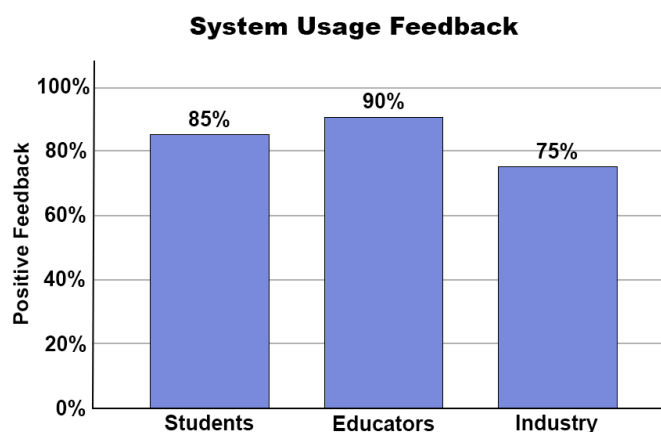


Figure 2. System Usage Feedback

This figure 2 presents the percentage of positive feedback received from various stakeholders regarding the system's functionality and impact. The data reveals that educators provided the highest positive feedback at 90%, indicating a high level of satisfaction with the system's ability to enhance the learning environment. Students followed closely with 85% positive feedback, reflecting their appreciation of the system's usability and its role in their learning process. Industry stakeholders, while still providing positive feedback, reported a slightly lower percentage at 75%, suggesting some areas for improvement in terms of practical applicability or user experience in the industry setting. These results highlight the system's overall effectiveness but also point to the need for further refinement to better meet the needs of all user groups.

In conclusion, the educational information system developed in this research significantly enhances the operational and educational effectiveness of learning factories, providing both academic and industrial stakeholders with tools that streamline processes and improve educational outcomes.

5. CONCLUSION

This research successfully developed and evaluated an educational information system designed to optimize learning factory operations and enhance educational outcomes. The system integrated both industrial management functions and educational tools, offering features such as real-time production monitoring, resource management, and student progress tracking. The prototype system demonstrated its potential to improve operational efficiency by streamlining resource allocation and optimizing production scheduling. Additionally, the integration of an e-learning platform proved to be valuable in providing students with continuous access to learning materials, thus supporting their educational growth both inside and outside the factory setting. The positive feedback from stakeholders, including students, instructors, and industry partners, affirmed the system's ability to address the key challenges faced by learning factories and its effectiveness in aligning educational outcomes with industry requirements.

This research answered the primary research questions regarding how an educational information system can optimize learning factory operations and improve student learning outcomes. The findings demonstrated that such a system not only enhances the operational management of the factory but also supports the educational objectives by providing real-time data on both industrial processes and student progress. However, there were some limitations in this study. One limitation was the scope of prototype testing, which was conducted in a limited number of learning factories, thus restricting the generalizability of the results to larger or more diverse industrial environments. Additionally, while the system showed positive results in terms of operational efficiency and educational support, further improvements could be made to refine its functionality, especially in areas such as scalability and user interface design. The data collected from stakeholders provided valuable insights but may not fully capture the experiences of all potential users, particularly in larger, more complex learning factory settings.

Future research should focus on expanding the testing of the educational information system in a broader range of learning factories to assess its applicability across different industries and educational set-

tings. It is recommended that future studies explore the scalability of the system, particularly its ability to handle larger numbers of students, instructors, and more complex industrial operations. Additionally, further research could investigate the integration of advanced technologies such as artificial intelligence (AI) and machine learning (ML) to enhance the system's predictive capabilities and further optimize resource management. Another avenue for future research is the exploration of how the system could be adapted for use in hybrid or fully remote learning environments, which would extend the benefits of the system beyond physical factory settings. Finally, it would be beneficial to conduct long-term studies to evaluate the sustained impact of such systems on both educational outcomes and industry collaboration.

6. DECLARATIONS

6.1. About Authors

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6.2. Author Contributions

Conceptualization: H and JJ; Methodology: SB; Software: JJ; Validation: H; Formal Analysis: SB; Investigation: H; Resources: JJ; Data Curation: SB; Writing – Original Draft Preparation: JJ and H; Writing – Review & Editing: SB; Visualization: H. All authors, H, SB, and JJ, have read and agreed to the published version of the manuscript.

6.3. Data Availability Statement

The corresponding author may provide the data from this study upon request.

6.4. Funding

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6.5. Institutional Review Board Statement

Not applicable.

6.6. Informed Consent Statement

Not applicable.

6.7. Declaration of Competing Interest

The authors state that none of their known conflicting financial interests or personal connections could have impacted the work published in this journal.

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