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# Exploration and Application of an Interdisciplinary Learning-Focused Factory Education Model — A Case Study of the Mechatronics Program

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**Abstract**

This study explores the curriculum design and implementation of an interdisciplinary learning-focused factory model within the Mechatronics program. Through strategies such as modular design, task-driven instruction, and project-based learning, the curriculum encompasses the complete process from customer needs analysis to product development, machining and assembly, and sales promotion, emphasizing the organic integration of theory and practice. Compared with international practices, the study examines the model's localized innovations, particularly its adaptability to local economic needs and its unique approach to promoting school-enterprise collaboration. Results indicate that the interdisciplinary learning-focused factory education model not only effectively enhances students' professional competencies and comprehensive skills but also provides valuable insights for curriculum development and teaching model innovation in China's vocational education.

**Keywords:** Learning-Focused Factory, Interdisciplinary Education, Mechatronics, Vocational Education, Curriculum Design, Localization Innovation

## Introduction

The concept of the learning-focused factory can be traced back to the late 1980s with the establishment of the CIM learning factory in Germany(Reith, 1988),though it was relatively unknown at the time. It was later formally introduced in the United States in 1994 as an engineering curriculum facility based on new practices supporting product realization. Its primary goal was to strengthen collaboration between universities and industrial enterprises, fostering practical skills in engineers(Jorgensen et al., 1995).In the 21st century, the concept of the learning-focused factory began to rise in Europe and quickly gained momentum(Abele et al., 2015; Micheu & Kleindienst, 2014; Wagner et al., 2012). Academic and industrial sectors increasingly collaborated to advance the research and application of learning factories, leading to the establishment of initiatives such as the European Institute for Learning Factories (IELF), the Network of Innovative Learning Factories (NIL), and the CIRP Learning Factory Working Group. Today, learning factories demonstrate a global trend, with the founding of the International(Abele et al., 2024). In academic research, definitions of learning factories vary widely, but they are generally described as learning environments closely resembling industrial production settings, designed to simulate real production processes and provide hands-on training for students across various subjects and skill levels(Abele et al., 2015; Barton & Delbridge, 2001; Cachay & Abele, 2012; Tisch et al., 2016; Tisch et al., 2013).

In recent years, as the demands for vocational education and training have evolved, the application of learning-focused factories has expanded within both vocational education and the industrial sector. A learning factory is not merely a supplement to traditional teaching methods but a complex and highly conceptualized process involving the optimization of space and teaching methodologies(Kreß et al., 2021). Particularly in manufacturing-related fields, learning factories have become effective tools for equipping students to adapt to new manufacturing trends, such as Industry 4.0(Baena et al., 2017). Against this backdrop, the learning-focused factory model in the Mechatronics program, as a prime example of interdisciplinary education, is gradually becoming a core model in vocational education. The Mechatronics program integrates multiple fields, including mechanical engineering, electronics engineering, and control engineering, allowing students to acquire comprehensive skills ranging from design and manufacturing to systems management in a real industrial environment through practical training in the learning factory.

Despite the significant achievements of learning factories in educational and industrial applications, current research still faces certain limitations. Most studies remain focused on single disciplines or specific application scenarios, lacking comprehensive interdisciplinary research(Martinez et al., 2020; Pittich et al., 2020; Vijayan et al., 2019). In practice, the effective application of learning factories requires the integration of knowledge and methods from multiple fields, such as pedagogy, management, and engineering, to address the complex and dynamic challenges in modern industrial environments. This interdisciplinary integration is especially critical in the field of Mechatronics, as it not only enhances students' technical skills but also develops their comprehensive ability to solve real-world problems in complex industrial settings.

Therefore, this study aims to systematically analyze learning factories from an interdisciplinary perspective and propose a new theoretical framework or model to explain the application and advantages of learning factories in multidisciplinary fields. Specifically, within the context of the Mechatronics program, we will explore how the teaching model of learning factories can enhance students' comprehensive skills and meet the modern industry's demand for highly skilled, multi-talented professionals. Through this research, we hope to offer fresh insights into the theoretical development and practical application of learning factories, as well as to guide future research directions.

**Literature Review**

As a practice-oriented curriculum and physical facility, the learning factory aims to provide an enhanced educational experience, emphasizing the interdependence of manufacturing and design within a business environment(Abele et al., 2019; Abele et al., 2015; Abele et al., 2024; Lamancusa et al., 1997). This model is widely applied in education and training, simulating real production settings to help students and employees acquire hands-on operational skills and theoretical knowledge(Abele et al., 2019; Abele et al., 2015; Centea, Singh, et al., 2019; Lamancusa et al., 1997; Maarof & Bohari, 2023; Pittich et al., 2020; Tisch & Metternich, 2017). Learning factories are often established through collaborations among universities, government laboratories, and enterprises to address rapidly changing market demands and technological advancements(Centea, Elbestawi, et al., 2019; Centea, Singh, et al., 2019; Lamancusa et al., 1997; Maarof & Bohari, 2023).

In the field of pedagogy, learning factories achieve educational objectives through interdisciplinary teamwork and real-world problem solving. For example, Pennsylvania State University and the Technical University of Darmstadt have developed multiple courses through learning factory projects, achieving significant outcomes in competency-based education programs(Lamancusa et al., 1997; Lindvig & Mathiasen, 2020; Pittich et al., 2020). Additionally, learning factories in Canada and Denmark have integrated physical and digital environments, utilizing virtual reality technology to enhance personalized learning outcomes(Lindvig & Mathiasen, 2020; Nellemann et al., 2022; U. Wagner et al., 2015). These studies demonstrate advances in teaching methodologies and skill development within learning factories and highlight their essential role in interdisciplinary and international collaboration(Enke et al., 2020; Ziarsolo et al., 2023).

In the field of management, the training content in learning factories encompasses aspects such as management, employee engagement, and work organization(Kreimeier et al., 2014; P. Wagner et al., 2015). Through training in real production environments, participants can master complex business processes and improvement methods, enhancing their managerial decision-making skills(Jooste et al., 2020; Kreimeier et al., 2014). Particularly in the context of Industry 4.0, learning factories effectively improve management skills, resource efficiency, and organizational capabilities through interdisciplinary collaboration and systematic design(Karre et al., 2017; Schallock et al., 2018).

In the field of engineering, research on learning factories focuses on technological innovation, automation, and smart manufacturing, particularly through the use of virtual reality, 5G, and AI technologies to enhance teaching effectiveness and student satisfaction(Al Khatib et al., 2023; Gopal, 2022; Lindvig & Mathiasen, 2020; Nellemann et al., 2022; Riemann et al., 2020; Riemann et al., 2021a, 2021b). The application of these technologies not only drives innovation in teaching methods but also achieves significant results in engineering management and the integration of automated systems, equipping students with practical skills for modern industrial production(Al Khatib et al., 2023; Gopal, 2022; Lindvig & Mathiasen, 2020; Nellemann et al., 2022; Riemann et al., 2020; Riemann et al., 2021a, 2021b).

Interdisciplinary research integrates knowledge and methods from different fields to address complex problems and advance both academic and practical domains(Aboelela et al., 2007; Spelt et al., 2009). For instance, learning factories at Purdue University and the

University of Alberta facilitate interdisciplinary collaboration, helping students master complex, cross-disciplinary knowledge and enhance their practical application skills(Athinarayanan et al., 2019; Gillani et al., 2022). These cases illustrate that interdisciplinary integration models significantly improve students' understanding and application of complex knowledge(Athinarayanan et al., 2019; Gillani et al., 2022).

Driven by new technologies, learning factories are trending toward intelligence and sustainability. The integration of digital technologies and virtual reality enables students to master complex industrial processes within realistic production environments(Chen et al., 2022; Cioffi et al., 2020; Gorecky et al., 2017; Gwangwava, 2021; Hildesheim et al., 2023; Kreß et al., 2020; Larsen et al., 2019; Li et al., 2019). Additionally, the concept of Industry 4.0 has further promoted the application of learning factories in technology transfer and management skills development(Erol et al., 2016; Romeral et al., 2021). These emerging technologies continuously enhance the educational functions of learning factories, providing robust support for ongoing innovation in manufacturing(Chen et al., 2022; Cioffi et al., 2020; Erol et al., 2016; Gorecky et al., 2017; Gwangwava, 2021; Hildesheim et al., 2023; Kreß et al., 2020; Larsen et al., 2019; Li et al., 2019; Romeral et al., 2021).

**Theoretical Framework**

*Theoretical Basis of Interdisciplinary Education*

Interdisciplinary education is defined as the ability to integrate knowledge from two or more disciplines to achieve cognitive advancement. It is a complex cognitive skill composed of multiple sub-skills(Spelt et al., 2009). For example, integrated courses combining engineering and management not only enhance engineers' managerial abilities but also meet the demands of high-skill jobs, thereby fostering professionals with well-rounded competencies(Banerjee et al., 2020; Froyd & Ohland, 2005; Liu, 2021). In learning factories, interdisciplinary integration is especially important; in the Mechatronics program, for instance, students must master knowledge across mechanical engineering, electronic engineering, and control engineering. This multidisciplinary educational approach helps students apply learned skills in real industrial environments to solve complex engineering problems.

To effectively integrate these interdisciplinary skills in the teaching process, appropriate instructional strategies are essential. Methods such as interdisciplinary research, project-based learning, and teamwork allow students not only to deepen their understanding of each field but also to appreciate each other's domains, enhancing the overall learning experience(Ali, 2019; Banerjee et al., 2020; van den Beemt et al., 2020). These strategies enable students in learning factories to organically combine knowledge from engineering, management, and pedagogy through real projects and team collaboration, achieving the intended outcomes of interdisciplinary education. Particularly in a mechatronics learning factory, these integrated educational strategies help students develop comprehensive skills in areas like systems design, production management, and technical optimization.

*Example of Curriculum Design Framework*

In the mechatronics learning factory, the curriculum design is structured around pedagogy-based teaching strategies, management-based teaching content, and engineering-based teaching content. It comprises eight customer-oriented learning modules: Customer

Requirements, Product Development, Workflow Planning, Processing Planning, Machining, Mechanical Assembly, Electromechanical Assembly, and Sales Promotion (Figure 1).

The first step in the learning process is the "Customer-Oriented Learning Module." In this stage, students first learn how to conduct market research and analyze customer needs, developing customer reception skills through scenario-based training. The core task of this module is for students to translate customer requirements into specific product design criteria, fostering their market awareness and product planning abilities in the process.

After clarifying customer needs, students move on to the "Product Development Learning Module." This module, focused on engineering content, primarily covers the core theoretical knowledge of product design and development. Students apply this theory to create specific product plans and conduct preliminary feasibility analyses.

Upon completing the product design, students enter the "Workflow Planning Learning Module." This module focuses on project management and cost control knowledge from the field of management, guiding students in developing a detailed work plan.

The "Processing Planning Learning Module" intersects management and engineering. In this module, students need to integrate production management principles with technical requirements to develop a specific processing plan. This module requires students to understand production management theory while mastering the technical details of engineering processes, such as processing sequences, scheduling, and resource requirements.

Following the processing plan, students enter the "Machining Learning Module," a core engineering module. Here, students perform machining operations to manufacture parts within a real or simulated factory environment.

Next are the "Mechanical Assembly Learning Module" and the "Electromechanical Assembly Learning Module." These modules further deepen practical engineering content, teaching students to assemble processed parts and perform integrated debugging on electromechanical systems. Through these modules, students acquire fundamental skills in assembly techniques and systems integration, as well as an understanding of how to ensure product functionality and reliability.

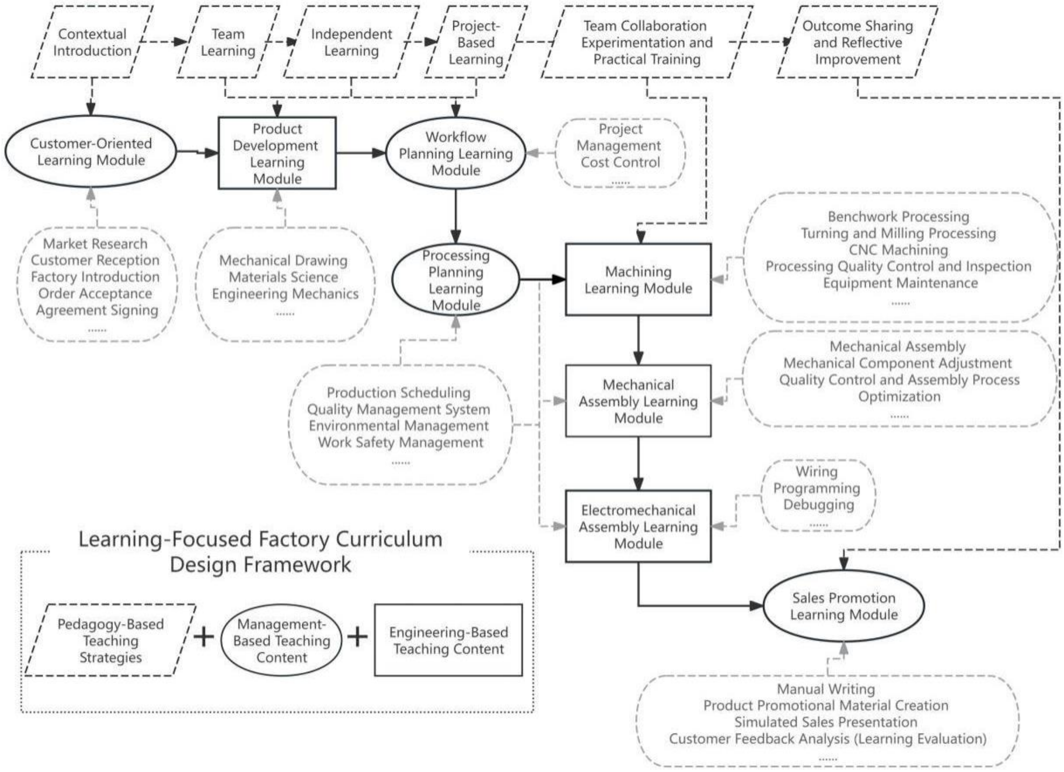


Figure1:Learning Factory Curriculum Design Framework

The final stage is the "Sales Promotion Learning Module," a management-focused module where students learn how to bring a product to market. Through studies in marketing management and sales strategies, students are tasked with writing product manuals, developing a market promotion plan, designing promotional materials, and conducting simulated sales presentations. This module aims to develop students' marketing and business communication skills, enabling them to effectively market technical products. Periodic evaluations of learning outcomes are also conducted in this phase.

**Case Introduction**

In April 2014, Dongguan Technician College, in collaboration with Germany's bbw Education Group (Bildungswerk der Wirtschaft in Berlin und Brandenburg), established the "bbw Learning Factory." This initiative was developed within the context of adapting Germany's "dual system" vocational education model to local needs. The project's goal is to innovate and implement a skilled talent development model tailored to the demands of local enterprises through educational reform. The college's educational objective is to train high-quality, professionally skilled talent who can meet the needs of local companies.

Dongguan Technician College's learning factory model spans multiple disciplines, particularly engineering, management, and education. Through in-depth partnerships with various real companies, it integrates hands-on and management skills in areas such as product design, machining, electromechanical assembly, and sales and marketing. By engaging in authentic production and business management processes, students gain comprehensive vocational training, fostering mutual growth and value creation between the school and enterprises.

The learning factory comprises three main areas: the design studio, electromechanical assembly room, and marketing room. Additional sections include a reception area, product display area, benchwork assembly area, conventional lathe and milling area, CNC lathe and milling area, machining center, tool library, materials library, and theoretical learning stations. During the learning factory training process, a real-world assessment system is employed, establishing a set of rules and regulations for attendance, assessment, safety, labor protection, and daily employee conduct. These structures lay a foundation for cultivating students' professional ethics and workplace competencies (Figure 2)

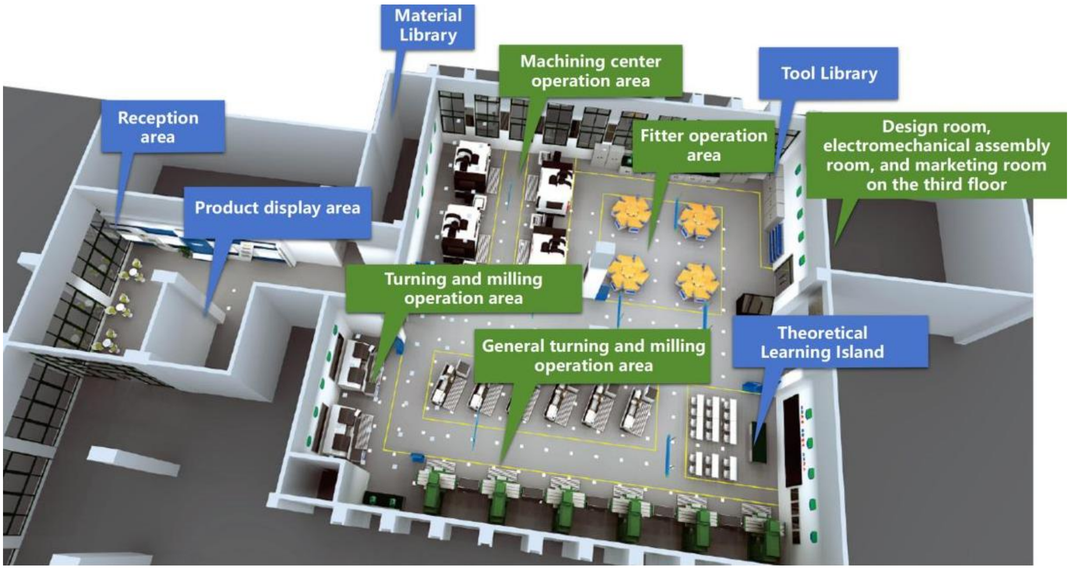


Figure2:Functional Layout Diagram of Dongguan Technician College Learning Factory

The curriculum design of the learning factory is divided into multiple functional learning modules, employing task-driven and modular teaching strategies to tightly integrate theoretical learning with hands-on practice, comprehensively covering key aspects of business operations. The curriculum includes modules such as Customer Needs Analysis, Workflow Planning, Product Design and Development, Machining, Mechanical Assembly, Electromechanical Assembly, Project Management, and Sales Promotion. Each module targets specific disciplinary content—such as engineering design, manufacturing technology, and management strategies—ensuring that students systematically acquire relevant knowledge and skills at each stage.

Project-based learning is employed in the curriculum implementation, with students working on real production projects to enhance their professional competencies and practical skills in a simulated work environment. The modular design enables the curriculum to adapt flexibly to different learning needs, incorporating real-world business processes such as order management, design, machining, assembly, and delivery, thereby strengthening students' comprehensive application abilities. Additionally, reflective learning permeates the entire educational process, especially in the concluding phase, where students consolidate their knowledge and improve complex problem-solving skills through reflection and discussion.

The entire learning process is fully student-centered, with curriculum design emphasizing student initiative and engagement. Teachers act primarily as guides and facilitators, promoting students' self-directed learning and reflective abilities through task challenges and project execution. This approach not only enhances students' professional skills but also strengthens their capacity to address complex problems in real work environments.

In addition, Dongguan Technician College's learning factory collaborates with real enterprises, improving vocational skills training through on-campus business integration and off-campus internship bases for real product production and job training. However, given that this paper focuses on the interdisciplinary curriculum design framework of the learning factory, details on the operational model are beyond the scope of this discussion.

**Discussion**

In the curriculum design of the mechatronics learning factory, the entire process begins with "customer-oriented" requirements, moving through product development, workflow planning, machining, assembly and debugging, and finally to sales promotion. This sequence of learning modules reflects both the logical structure and innovative nature of the curriculum design.

Each step in the curriculum is tightly connected, forming a cohesive product development and market promotion process. Every module not only covers core content from engineering, management, and pedagogy but also ensures seamless integration of theory and practice. Starting from customer needs analysis, students progress through product design, manufacturing, and finally to market promotion, achieving a spiral advancement of knowledge and a gradual enhancement of skills.

Innovation in interdisciplinary integration is exemplified in the organic combination of management and engineering content. Particularly in the Processing Planning Learning Module, students are required to master both production management theory and technical details of engineering processes. This interdisciplinary approach not only deepens students' understanding of each field but also strengthens their ability to apply integrated knowledge in real production environments. Additionally, the use of project-based learning and contextualized teaching strategies enables students to develop professional competencies and problem-solving skills in a setting that closely mirrors an industrial environment.

However, compared to international practices, China's learning factories emphasize the direct integration of actual production processes into teaching content, especially in alignment with local economic needs. The case of Dongguan Technician College illustrates how localized adaptation can combine Germany's "dual system" model with China's vocational education demands and specific industry characteristics, creating a skills training model that effectively supports regional economic development.

**Conclusion**

This study makes important theoretical and contextual contributions to the field of vocational education and interdisciplinary learning factory research. From a theoretical perspective, it constructs a new interdisciplinary framework that integrates pedagogy, engineering, and management within a unified model. By proposing the 'three-dimensional capability spiral'—technical capability, managerial capability, and market capability—the study expands the theoretical boundaries of learning factory models beyond single-skill training. This integration emphasizes how the learning factory serves not only as a physical environment but also as a pedagogical and organizational system that enables multi-domain competence formation. It enriches existing theories of action-oriented learning and interdisciplinary education by demonstrating how these principles can co-exist and reinforce one another in real-world vocational contexts. Contextually, the research provides a practical pathway for the localization of Germany’s dual system within China’s vocational education system. Through the 'factory-in-school and school-in-factory' model, the Dongguan case demonstrates how international educational paradigms can be effectively adapted to local economic structures and industrial clusters. This approach not only strengthens the integration of teaching, production, and enterprise needs but also creates a replicable model for developing countries seeking to modernize vocational training through contextual innovation. The study’s findings therefore bridge the gap between global learning factory practices and the realities of developing economies, offering both policy and implementation implications under the 'Made in China 2025' initiative. In sum, this research contributes to theoretical advancement by introducing a holistic interdisciplinary model, and to contextual innovation by validating a localized, production-driven educational practice that advances the modernization of vocational education.

**Theoretical and Contextual Contribution**

This paper conducts an in-depth analysis of the curriculum design of a mechatronics-oriented learning factory, exploring its logic and innovation in interdisciplinary integration and practical teaching. The study shows that through modular design and task-driven strategies, the learning factory has successfully achieved an organic combination of theory and practice, cultivating students' ability to solve complex problems in real industrial environments. Furthermore, by comparing this model with international practices, it is found to exhibit unique innovation in its localization, particularly in meeting local economic needs and promoting school-enterprise cooperation.

This interdisciplinary learning factory education model offers valuable insights for the development of vocational education in China. Its successful practices in curriculum development, teaching model innovation, and vocational education reform provide clear direction for further modernization of vocational education and the cultivation of highly skilled talents. In the future, the application of the learning factory model is expected to expand into more vocational education fields and contribute significantly to the continuous improvement of China's vocational education system.

This study achieves important breakthroughs on both theoretical and practical levels: theoretically, it constructs for the first time an interdisciplinary learning factory framework targeting the mechatronics field, proposing a “three-dimensional capability spiral” training model (technical capability – management capability – market capability), breaking through the limitations of traditional single-skill training. Practically, through the “factory-in-school and school-in-factory” collaborative mechanism, it provides a feasible path for the localization of Germany’s “dual system” in China. These innovations not only fill the research gap of learning factory systems in developing countries but also demonstrate a model effect under the "Made in China 2025" policy — the Dongguan case has already been promoted in the manufacturing clusters of the Pearl River Delta, and its “real production-driven teaching” mechanism offers new ideas for global vocational education in response to technological iteration.

## References

Abele, E., Metternich, J., & Tisch, M. (2019). Learning factories. Concepts, Guidelines, Best-Practice …. https://doi.org/10.1007/978-3-319-92261-4

Abele, E., Metternich, J., Tisch, M., Chryssolouris, G., Sihn, W., ElMaraghy, H., Hummel, V., & Ranz, F. (2015, 2015/01/01/). Learning Factories for Research, Education, and Training. Procedia CIRP, 32, 1-6. https://doi.org/https://doi.org/10.1016/j.procir.2015.02.187

Abele, E., Metternich, J., Tisch, M., & Kreß, A. (2024). Historical Development, Terminology, and Definition of Learning Factories. In *Learning Factories: Featuring New Concepts, Guidelines, Worldwide Best-Practice Examples* (pp. 81-96). Springer.

Aboelela, S. W., Larson, E. L., Bakken, S., Carrasquillo, O., Formicola, A. J., Glied, S., Haas, J. P., & Gebbie, K. (2007). Defining interdisciplinary research: conclusions from a critical review of the literature. *Health services research, 42 1 Pt 1*, 329-346. https://doi.org/10.1111/j.1475-6773.2006.00621.x

Al Khatib, A., Malhaire, J. M., Dauvé, S., & Fougères, A. J. (2023). Project-based learning for engineering students in the context of industry 4.0: application to automotive assembly system. Proceedings of the Design Society, *3*, 2965-2974. doi:10.1017/pds.2023.297

Ali, A. K. (2019). A case study in developing an interdisciplinary learning experiment between architecture, building construction, and construction engineering and management education. *Engineering, Construction and Architectural Management 4 September 2019; 26 (9): 2040–2059. https://doi.org/10.1108/ECAM-07-2018-0306*

Athinarayanan, R., Newell, B., Garcia, J., Ostanek, J., Diao, X., Sundararajan, R., Zhang, H., & Richards, G. (2019). Learning in Context with Horizontally & Vertically Integrated Curriculum in a Smart Learning Factory. Procedia Manufacturing, https://doi.org/10.1016/j.promfg.2019.03.015

Baena, F., Guarin, A., Mora, J., Sauza, J., & Retat, S. (2017). Learning Factory: The Path to Industry 4.0 [Article]. *Procedia Manufacturing, 9*, 73-80. https://doi.org/10.1016/j.promfg.2017.04.022

Banerjee, R., Zgalai, W., & Boukareva, B. (2020). Curriculum Integration of engineering with business to enhance engineer's management competency- A multidisciplinary to interdisciplinary approach. *2020 Advances in Science and Engineering Technology International Conferences (ASET)*, 1-5. doi: 10.1109/ASET48392.2020.9118306.

Barton, H., & Delbridge, R. (2001). Development in the learning factory: Training human capital [Article]. *Journal of European Industrial Training, 25*(9), 465-472. https://doi.org/10.1108/03090590110410313

Cachay, J., & Abele, E. (2012). Developing competencies for continuous improvement processes on the shop floor through learning factories - Conceptual design and empirical validation. Procedia CIRP, https://doi.org/10.1016/j.procir.2012.07.109

Centea, D., Elbestawi, M., Singh, I., & Wanyama, T. (2019). SEPT Learning Factory Framework. In *Lecture Notes in Networks and Systems* (Vol. 47, pp. 354-362). Springer. https://doi.org/10.1007/978-3-319-95678-7_40

Centea, D., Singh, I., & Elbestawi, M. (2019). SEPT Approaches for Education and Training using a Learning Factory. Procedia Manufacturing, 31, 109-115. https://doi.org/10.1016/j.promfg.2019.03.018

Chen, M.-Y., Lughofer, E. D., & Eğrioğlu, E. (2022). Deep learning and intelligent system towards smart manufacturing. *Enterprise Information Systems, 16*, 189 - 192. https://doi.org/10.1080/17517575.2021.1898050

Cioffi, R., Travaglioni, M., Piscitelli, G., Petrillo, A., & De Felice, F. (2020). Artificial Intelligence and Machine Learning Applications in Smart Production: Progress, Trends, and Directions. *Sustainability (Switzerland), 12*, 492.

Enke, J., Oberc, H., Riemann, T., Schuhmacher, J., Hummel, V., Kuhlenkötter, B., Metternich, J., & Prinz, C. (2020). Cooperation between learning factories: Approach and example. Procedia Manufacturing,

Erol, S., Jäger, A., Hold, P., Ott, K., & Sihn, W. (2016). Tangible Industry 4.0: A Scenario-Based Approach to Learning for the Future of Production. Procedia CIRP,

Froyd, J. E., & Ohland, M. W. (2005). Integrated Engineering Curricula. *Journal of Engineering Education, 94*.

Gillani, S. A., Abbasi, R., Martinez, P., & Ahmad, R. (2022). Ontology-based Interactive Learning Approach for Transdisciplinary Teaching in Learning Factory. *SSRN Electronic Journal*.

Gopal, A. (2022). FUTURE WORK REQUIRES FUTURE SKILLS: THE CSIR LEARNING FACTORY. *CSIR Science Scope*. https://doi.org/10.10520/ejc-csir_sci-v19-n2-a6

Gorecky, D., Khamis, M., & Mura, K. (2017). Introduction and establishment of virtual training in the factory of the future. *International Journal of Computer Integrated Manufacturing, 30*, 182 - 190.

Gwangwava, N. (2021). Learning Factories as an Opportunity for Industrialization in Africa. *International Journal of e-Education, e-Business, e-Management and e-Learning, 11*, 73-84.

Hildesheim, W., Holoyad, T., & Schmid, T. (2023). Machine learning in AI Factories – five theses for developing, managing and maintaining data-driven artificial intelligence at large scale. *it - Information Technology, 65*, 218 - 227.

Jooste, J. L., Louw, L., von Leipzig, K., Conradie, P. D. F., Asekun, O. O., Lucke, D., & Hagedorn-Hansen, D. (2020). Teaching maintenance plan development in a learning factory environment. Procedia Manufacturing,

Jorgensen, J. E., Lamancusa, J. S., Zayas-Castro, J. L., & Ratner, J. (1995). THE LEARNING FACTORY Curriculum Integration Of Design And Manufacturing. Proceedings of the Fourth World Conference on Engineering Education, St. Paul, Minneapolis, USA,

Karre, H., Hammer, M., Kleindienst, M., & Ramsauer, C. (2017). Transition towards an Industry 4.0 State of the LeanLab at Graz University of Technology [Article]. *Procedia Manufacturing, 9*, 206-213. https://doi.org/10.1016/j.promfg.2017.04.006

Kreimeier, D., Morlock, F., Prinz, C., Krückhans, B., & Bakir, D. C. (2014). Holistic learning factories - A concept to train lean management, resource efficiency as well as management and organization improvement skills. Procedia CIRP,

Kreß, A., Riemann, T., Klipfel, S., Metternich, J., & Grell, P. (2020). Requirements for the Implementation of Virtual Reality in Learning Factories.

Kreß, A., Wuchterl, S., & Metternich, J. (2021). Design approaches for learning factories–review and evaluation. Proceedings of the Conference on Learning Factories (CLF),

Lamancusa, J. S., Jorgensen, J. E., & Zayas-Castro, J. L. (1997). The learning factory—A new approach to integrating design and manufacturing into the engineering curriculum. *Journal of engineering Education, 86*(2), 103-112.

Larsen, M. S. S., Lassen, A. H., & Nielsen, K. (2019). Process Innovation in Learning Factories: Towards a Reference Model. IFIP Advances in Information and Communication Technology,

Li, F., Yang, J., Wang, J., Li, S., & Zheng, L. (2019). Integration of digitization trends in learning factories. Procedia Manufacturing,

Lindvig, K., & Mathiasen, H. (2020, 2020/01/01/). Translating the Learning Factory model to a Danish Vocational Education Setting. *Procedia Manufacturing, 45*, 90-95. https://doi.org/https://doi.org/10.1016/j.promfg.2020.04.077

Liu, D. e. (2021). Analysis on the Talent Training Mode of Management Science and Engineering from the Perspective of Multidisciplinary Integration. *Journal of Contemporary Educational Research*.

Maarof, M., & Bohari, M. (2023). Students Experience Using Learning Factory at the Faculty of Industrial Management. *Journal of Governance and Integrity*. https://journal.ump.edu.my/jgi/article/view/9652

Martinez, P., Vargas-Martinez, A., Roman-Flores, A., & Ahmad, R. (2020). A science mapping study on learning factories research. Procedia Manufacturing,

Micheu, H. J., & Kleindienst, M. (2014). A learning factory for practical knowledge transfer-modern education in the field of mechanical engineering and economics [Article]. *ZWF Zeitschrift fuer Wirtschaftlichen Fabrikbetrieb, 109*(6), 403-407. https://doi.org/10.3139/104.111160

Nellemann, C., Christiansen, L., Zhang, Y., & ... (2022). Learning Factory concepts and performance. *Proceedings of the …*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4072735

Pittich, D., Tenberg, R., & Lensing, K. (2020). Learning factories for complex competence acquisition [Article]. *EUROPEAN JOURNAL OF ENGINEERING EDUCATION, 45*(2), 196-213. https://doi.org/10.1080/03043797.2019.1567691

Reith, S. (1988). Außerbetriebliche CIM-Schulung in der „Lernfabrik ". Produktionsforum'88. Die CIM-fähige Fabrik: Zukunftssichernde Planung und erfolgreiche Praxisbeispiele. 8. IAO-Arbeitstagung 4./5. Mai 1988 in Stuttgart,

Riemann, T., Kreß, A., Roth, L., Klipfel, S., Metternich, J., & Grell, P. (2020). Agile implementation of virtual reality in learning factories. Procedia Manufacturing,

Riemann, T., Kreß, A., Roth, L., Metternich, J., & ... (2021a). Approach for conceptualization and implementation of virtual reality in learning factories. *Proceedings of the …*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3861474

Riemann, T., Kreß, A., Roth, L., Metternich, J., & ... (2021b). User-oriented design of virtual reality supported learning factory trainings: methodology for the generation of suitable design elements. *Proceedings of the …*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3861488

Romeral, P. A. d. A. F., Spínola, M. d. M., Gonçalves, R. F., & Zancul, E. d. S. (2021). Development of managerial and Information Technology skills in Learning Factories in the context of Industry 4.0: a case study. *Revista Gestão da Produção Operações e Sistemas*.

Schallock, B., Rybski, C., Jochem, R., & Kohl, H. (2018). Learning Factory for Industry 4.0 to provide future skills beyond technical training. Procedia Manufacturing,

Spelt, E. J. H., Biemans, H. J. A., Tobi, H., Luning, P. A., & Mulder, M. (2009). Teaching and Learning in Interdisciplinary Higher Education: A Systematic Review. *Educational Psychology Review, 21*, 365-378.

Tisch, M., Hertle, C., Abele, E., Metternich, J., & Tenberg, R. (2016). Learning factory design: a competency-oriented approach integrating three design levels [Article]. *International Journal of Computer Integrated Manufacturing, 29*(12), 1355-1375. https://doi.org/10.1080/0951192X.2015.1033017

Tisch, M., Hertle, C., Cachay, J., Abele, E., Metternich, J., & Tenberg, R. (2013). A systematic approach on developing action-oriented, competency-based Learning Factories. Procedia CIRP,

Tisch, M., & Metternich, J. (2017). Potentials and Limits of Learning Factories in Research, Innovation Transfer, Education, and Training [Article]. *Procedia Manufacturing, 9*, 89-96. https://doi.org/10.1016/j.promfg.2017.04.027

van den Beemt, A., MacLeod, M., van der Veen, J., Van de Ven, A., Baalen, S. J. v., Klaassen, R. G., & Boon, M. (2020). Interdisciplinary engineering education: A review of vision, teaching, and support. *Journal of Engineering Education, 109*, 508 - 555.

Vijayan, K. K., Mork, O. J., & Giske, L. A. L. (2019). Integration of a Case Study into Learning Factory for Future Research. Procedia Manufacturing,

Wagner, P., Prinz, C., Wannöffel, M., & Kreimeier, D. (2015). Learning factory for management, organization and workers' participation. *Procedia CIRP, 32*, 115-119.

Wagner, U., AlGeddawy, T., ElMaraghy, H., & Müller, E. (2012). The state-of-the-art and prospects of learning factories. Procedia CIRP,

Wagner, U., AlGeddawy, T., ElMaraghy, H., & Müller, E. (2015). Developing products for changeable learning factories [Article]. *CIRP Journal of Manufacturing Science and Technology, 9*, 146-158. https://doi.org/10.1016/j.cirpj.2014.11.001

Ziarsolo, U., Araiztegui, I., Irazabal, J., & ... (2023). Collaborative Learning Factory as An Integration Tool for the Learner Centric Advanced Manufacturing Platform. *Available at SSRN ….* https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4469793