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DEVELOPMENT MATURITY OF EDUCATIONAL INSTITUTIONS IN INDUSTRY 5.0: AN EVALUATION FRAMEWORK

Abstract. *The advent of Industry 5.0, characterized by the convergence of cutting-edge technologies like artificial intelligence, Internet of Things, and robotics, necessitates a re-evaluation of the role of educational institutions in preparing future professionals. This paper presents an evaluation framework aimed at assessing the development maturity of educational establishments within the landscape of Industry 5.0. The framework encompasses key dimensions including curriculum adaptation, technological infrastructure, faculty readiness, research and innovation initiatives, industry collaboration, and student outcomes. Through a structured evaluation of these dimensions, educational institutions can gauge their level of preparedness in fostering the skills and competencies demanded by Industry 5.0. This framework not only serves as a diagnostic tool but also facilitates the identification of areas for improvement and strategic intervention. By enhancing their development maturity, educational institutions can effectively contribute to the advancement of Industry 5.0 and ensure the future readiness of the workforce. As Industry 5.0 emerges with the integration of advanced technologies such as artificial intelligence, Internet of Things, and robotics into manufacturing processes, the role of educational institutions in preparing the workforce becomes paramount. This paper proposes a comprehensive framework for assessing the development maturity of educational establishments within the context of Industry 5.0. The framework encompasses multiple dimensions, including curriculum alignment, experiential learning opportunities, technology infrastructure, faculty expertise and training, research and innovation, industry engagement, and graduate outcomes. Through a systematic evaluation of these dimensions, educational institutions can gauge their readiness and effectiveness in equipping students with the skills and competencies required for success in Industry 5.0. Furthermore, this assessment facilitates identification of areas for improvement and strategic investment to enhance the role of education in driving innovation, economic growth, and workforce development in the era of Industry 5.0.*

Keywords: Industry 5.0; educational institutions; development maturity; workforce preparation; curriculum alignment; experiential learning; technology infrastructure; faculty expertise; research and innovation; industry engagement; graduate outcomes

Introduction

The world stands at the precipice of a new industrial revolution – Industry 5.0. Defined by seamless human-machine collaboration, the intelligent application of artificial intelligence (AI), and a focus on human well-being, this era demands a paradigm shift in education.

Traditional educational approaches, designed for a bygone industrial age, will struggle to equip future generations with the skills and knowledge they need to succeed in Industry 5.0. This paper proposes a novel framework to evaluate the development maturity of educational institutions (EIs) in their journey towards Industry 5.0 readiness.

This framework provides a crucial tool for EIs to assess their current state in relation to Industry 5.0 principles; identify areas for improvement and develop targeted strategies for successful integration; benchmark their progress against best practices and industry needs.

By utilizing this framework, EIs can embark on a transformative journey, ensuring they graduate future-ready individuals equipped to thrive in the dynamic and collaborative landscape of Industry 5.0.

This paper delves into the core components of the framework, outlining key evaluation criteria for each aspect. We will explore how EIs can foster vision and strategy, incorporate relevant curriculum and learning content, utilize innovative pedagogy, leverage robust infrastructure, and build strong industry collaboration. Finally, we will discuss effective assessment and evaluation practices to measure student learning outcomes in the context of Industry 5.0.

Literature review

The Framework for Digitally Mature Schools (FDMS) and its assessment instrument help schools measure their digital maturity and identify areas for improvement, supporting their integration of digital technologies in teaching, learning, and organizational practices [1].

The primary focus of this paper is to propose a methodology for prioritizing the elements in the Digital Maturity Framework for Higher Education Institutions (DMFHEI) and assessing the digital maturity level (ML) of HEIs in Croatia. Developing the DMFHEI requires the application of a sophisticated methodology, which includes a set of methods, techniques, and instruments. Some of the analyses performed are qualitative, such as the comparison of similar frameworks and strategic documents, while others are quantitative, such as the Q-sorting method, focus groups, and multi-criteria decision-making methods. In the framework development phase, the well-known multi-criteria decision-making method the analytic hierarchy process/analytic network process (AHP/ANP) was implemented to prioritize the main areas and elements identified in the framework [2].

A maturity model is a widely used tool in software engineering and has mostly been extended to domains such as education, health, energy, finance, government, and general use. It is valuable for evaluations and continuous improvement of business processes or certain aspects of organizations, as it represents a more organized and systematic way of doing business. In this paper, we only focus on college higher education. For this reason, we present a novel approach that allows detecting some gaps in the existing maturity models for universities, as they are not models that address the dimensions in their entirety [3].

A Maturity Model is a widely used technique that is proved to be valuable to assess business processes or certain aspects of organizations, as it represents a path towards an increasingly organized and systematic way of doing business. A maturity assessment can be used to measure the current maturity level of a certain aspect of an organization in a meaningful way, enabling stakeholders to clearly identify strengths and improvement points, and accordingly prioritize what to do in order to reach higher maturity levels. However, in order to make that possible, maturity assessments must be performed. Doing that can range from simple self-assessment questionnaires to full blown assessment methods, such as recommended by the ISO15504 or the SEI CMMI. [4].

This paper proposes using semantic technology to automate maturity models assessment methods, enabling stakeholders to identify strengths and improvement points, and prioritize actions for reaching higher maturity levels in organizations. [5].

Education 5.0 promotes digital competencies, including content, communication, and data literacy, to prepare individuals for Industry X.0 and its innovative value chain. [6].

Digital maturity in education is crucial for determining appropriate strategies for digital transformation, and this paper analyzes international and Russian evaluation inventories to enhance heuristic potential of existing assessment methods. [7].

Industry 5.0 complements Industry 4.0 by focusing on people, organization, and technology, shifting research aims from sustainability to human-centricity [8].

Structure of Evaluation Framework

The rapid advancements of Industry 5.0, characterized by human-centric collaboration with intelligent machines and artificial intelligence (AI), necessitate a paradigm shift in education. To prepare future generations for this new era, educational

institutions (EIs) need to adapt and evolve. This framework proposes a way to evaluate the development maturity of EIs in their journey towards Industry 5.0 readiness.

Framework Components presented on the fig. 1.

Assessing the sophistication and effectiveness of AI implementation within educational environments involves examining various dimensions (Fig. 2)

By examining dimensions presented on the fig. 2, educational institutions can gauge the level of sophistication and effectiveness of AI implementation within their environment and identify areas for improvement and innovation.

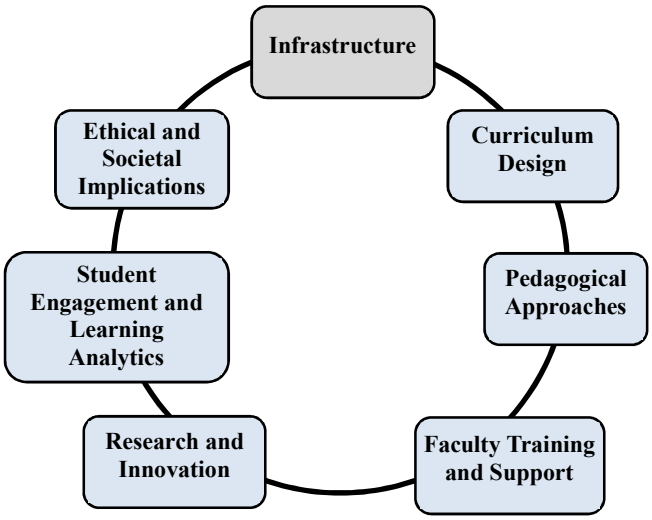

Figure 2 – AI implementation within educational environments examining various dimensions

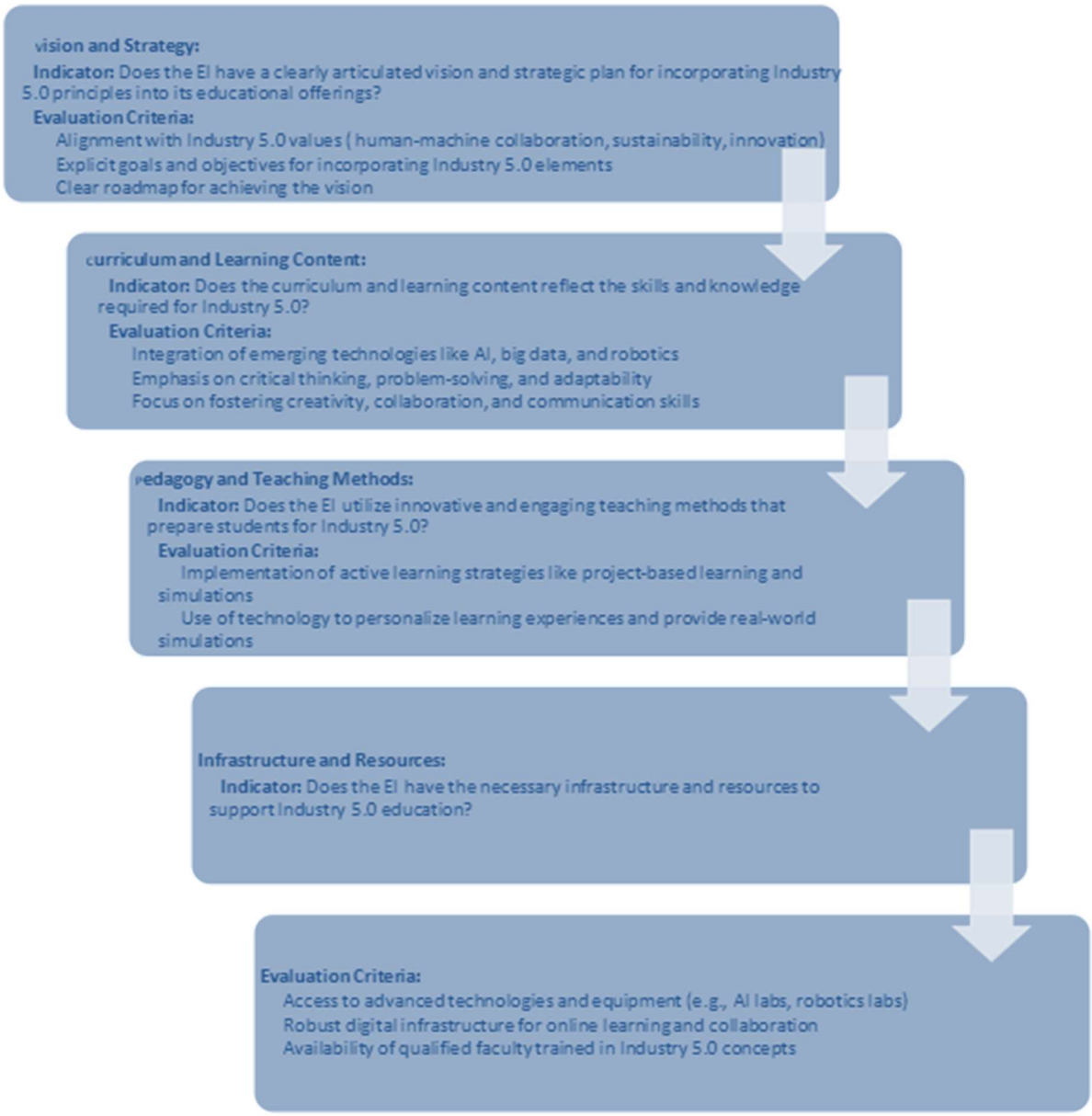

Figure 1 – Framework Components

Case study

Evaluation of Artificial Intelligence Integration into the Master's Programme in Project Management at Kyiv National University of Construction and Architecture.

This case study examines the maternity program transformation at Kyiv National University of Construction and Architecture (KNUCA), specifically within the Department of Project Management. The study focuses on how effectively the program is incorporating Artificial Intelligence (AI) into its curriculum.

Five experts evaluated key areas crucial for a successful maternity program, using a 10-point scale. The areas assessed included:

Infrastructure

Curriculum Design

Adaptive Learning Systems (potentially including AI)

Faculty Training and Support

Research and Innovation (related to AI implementation)

Student Engagement and Learning Analytics (potentially involving AI tools)

Ethical and Societal Implications (of using AI in education)

The case study analyzes the evaluation results (provided separately) to assess KNUCA's project management program's strengths and weaknesses in its AI integration process. It aims to identify areas for improvement and highlight best practices for incorporating AI effectively into educational programs. Average Scores on a 10-Point Scale are given in tables 1–7.

Table 1 – ***Infrastructure***

N	Characteristic	Evaluation
1	AI integration	8,25
2	Hardware	7,50
3	Software	9
4	Networking capabilities	8,50
5	Cloud-based platforms	8
6	Robust data analytics tools	7

Average 8.04

Table 2 – ***Curriculum Design***

N	Characteristic	Evaluation
1	Development of AI-specific courses	7
2	Integration of AI concepts	8,50
3	Alignment with educational standards	9,25
4	Learning objectives	9,25

Average 8.04

Table 3 – ***Adaptive Learning Systems***

N	Characteristic	Explanation	Evaluation
1	Personalization	Use of neural networks: For more accurate assessment of individual characteristics, prediction of academic performance, selection of optimal learning trajectory.	7,25
2	Adaptation	Introduction of virtual assistants: To dialog with the student, answer questions, and help with assignments.	7
3	Automation	Development of content generation systems: To create personalized learning materials, selection of assignments, and tests.	8
4	Use of AI	Creating open source systems: To make algorithms transparent, modifiable, and adaptable to specific needs.	7,75
5	Accessibility	Mobile App Development: To provide access to the system from any device.	7,50
6	Security	Use of differential privacy techniques: To protect data privacy.	8
7	Efficiency	Conducting long-term research: To assess the impact of the system on long-term learning outcomes.	8,25

Average 7.68

Table 4 – ***Faculty Training and Support***

N	Characteristic	Explanation	Evaluation
1	Technology Integration	Focus on pedagogical strategies: Equip faculty with strategies to integrate AI effectively into their teaching, regardless of the specific platform.	9
2	Technical Skills	Focus on AI literacy: Develop a broader understanding of AI capabilities and limitations to foster informed decision-making about AI use in teaching.	8,5
3	One-Size-Fits-All Approach	Personalized Professional Development: Provide differentiated training pathways based on faculty roles, prior knowledge, and teaching styles.	7,75
4	Limited Support Systems	Create Communities of Practice: Foster collaboration and knowledge sharing among faculty through online forums, workshops, or mentoring programs.	8
5	Focus on Short-Term Needs	Incorporate Sustainable Integration: Integrate AI-related professional development into existing professional learning cycles.	8,25
6	Ethical Considerations	Incorporate Ethical Frameworks: Equip faculty with frameworks for ethical considerations around data privacy, bias in algorithms, and transparency in AI-powered assessments.	9

Average 8.42

Table 5 – ***Research and Innovation***

N	Characteristic	Explanation	Evaluation
1	Focus on Technical Advancement	Shift towards Human-Centered AI: Integrate research on human-computer interaction, ethical considerations, and social impact alongside technical advancements.	9
2	Limited Collaboration	Promote Interdisciplinary Research: Encourage collaboration between computer scientists, engineers, ethicists, educators, and social scientists to address complex AI challenges.	8
3	Data Availability and Privacy	Develop Synthetic Data Generation Techniques: Create realistic and diverse synthetic data sets to enhance research capabilities while protecting individual privacy	8,50
4	Explainability and Transparency	Focus on Explainable AI (XAI): Develop AI systems that can explain their reasoning and decision-making processes to foster trust and address concerns about bias.	9
5	Bias and Fairness	Develop Fair and Equitable AI Techniques: Implement methods for de-biasing data sets, building fairness into algorithms, and mitigating discriminatory outcomes.	8,75
6	Evaluation and Measurement	Develop Robust Evaluation Frameworks: Create comprehensive frameworks to evaluate AI systems not only for technical performance but also for social, ethical, and economic impact.	8,50
7	Open Access and Reproducibility	Promote Open Science Practices: Encourage open access to research findings and data where feasible, and develop platforms for reproducible research methods.	9,25

Average 8.71

Table 6 – ***Student Engagement and Learning Analytics***

N	Characteristic	Explanation	Evaluation
1	Data Collection	Integrate Diverse Data Sources: Combine traditional data with sentiment analysis from communication tools, facial recognition for engagement levels, and eye-tracking for attention patterns.	8
2	Limited Analysis Capabilities	Advanced Analytics with AI: Utilize AI techniques like machine learning and natural language processing to extract deeper insights from diverse data sources, identify at-risk students, and predict future learning needs.	7,75
3	Focus on Quantifiable Outcomes	Holistic Engagement Metrics: Develop metrics that go beyond grades to measure factors like active participation, collaboration, self-directed learning, and intrinsic motivation.	8

Ende Table 6

4	Limited Actionable Insights	Personalized and Adaptive Interventions: Use AI to recommend personalized learning pathways, provide targeted learning resources, and deliver real-time feedback based on individual needs and engagement levels.	7,75
5	Privacy Concerns	Develop Privacy-Preserving Techniques: Implement anonymization, differential privacy, and secure data storage practices to ensure student data privacy while enabling valuable learning analytics.	8
6	Transparency and Explainability	Develop Explainable AI tools: Create systems that explain their reasoning and decision-making processes to foster trust and address concerns about potential biases in analytics.	8,50

Average 8.0

Table 7 – ***Ethical and Societal Implications***

N	Characteristic	Explanation	Evaluation
1	Bias and Fairness	Develop Fair AI Techniques: Implement methods for de-biasing data sets, building fairness into algorithms, and mitigating discriminatory outcomes. This may involve techniques like counterfactual fairness analysis and fairness-aware machine learning.	6,25
2	Transparency and Explainability	Focus on Explainable AI (XAI): Develop AI systems that can explain their reasoning and decision-making processes. This can involve techniques like LIME (Local Interpretable Model-Agnostic Explanations) and SHAP (Shapley Additive exPlanations).	8,25
3	Privacy Concerns	Develop Privacy-Preserving Techniques: Implement anonymization, differential privacy, and secure data storage practices to ensure data privacy while allowing valuable AI development and applications. Invest in research on federated learning, where data remains on individual devices and only anonymized models are shared.	8,00
4	Job displacement	Focus on AI-Human Collaboration: Explore ways for AI to complement human workforce skills, leading to human-AI partnerships with enhanced capabilities. Invest in retraining programs and reskilling initiatives to adapt the workforce to changing job demands.	8,50
5	Algorithmic Accountability	Develop Frameworks for Algorithmic Accountability: Establish transparent and responsible AI development practices, including ethical guidelines and human oversight mechanisms. This may involve creating AI ethics boards and regulatory frameworks for specific AI applications.	8,75
6	Social and Economic Inequality	Promote Equitable AI Development and Access: Focus on inclusive AI development that benefits all segments of society. This may involve ensuring access to AI education and training, promoting responsible AI deployment in developing countries, and addressing potential biases in AI applications that could further marginalize certain groups.	8,25

Average 8.0

Table 8 – ***Average Scores on a 10-Point Scale for Key Areas***

Infrastructure	8,04
Curriculum Design	8,50
Adaptive Learning Systems	7,68
Faculty Training and Support	8,42
Research and Innovation	8,71
Student Engagement and Learning Analytics	8,00
Ethical and Societal Implications	8,00

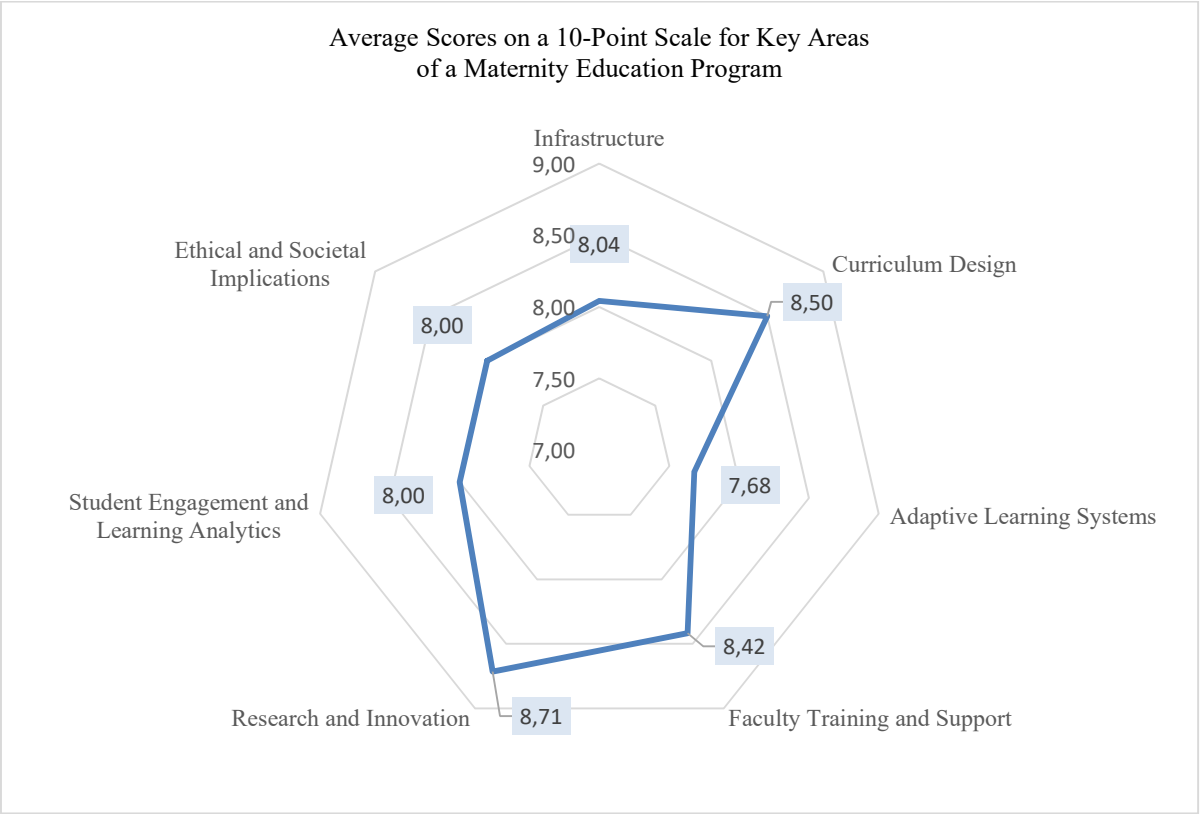

Figure 3 – Average Scores on a 10-Point Scale for Key Areas of a Maternity Education Program

Discussion

Overall, the scores appear to be positive, with most areas scoring above 8.0. This suggests that the curriculum design is generally well-rounded.

The highest score is in Research and Innovation (8.71). This could indicate a strong emphasis on developing and implementing new teaching methods.

The lowest score is in Adaptive Learning Systems (7,68). This could be an area for further investigation to see if there are ways to improve student engagement or make better use of learning analytics data.

It's important to remember that averages can sometimes mask underlying variation. For example, an area with a high average score could still have some weaknesses. Conversely, an area with a lower average score might have some pockets of excellence.

To get a more complete picture of the curriculum design, it would be helpful to look at the data behind the averages. This could include information on the specific criteria that were used to evaluate each area, as well as the range of scores that were given.

Based on average points, here's a breakdown of which areas seem strong, might need improvement, and warrant further investigation.

Good.

Curriculum Design (8.50). This score suggests a well-designed curriculum.

Faculty Training and Support (8.42). Strong faculty support is crucial for a successful program.

Research and Innovation (8.71). This is a high score, indicating a focus on continuous improvement.

Needs Improvement.

Infrastructure (8.04). While not a bad score, consider if the infrastructure adequately supports the program's needs.

Student Engagement and Learning Analytics (8.00). This score suggests room for improvement in engaging students and utilizing learning analytics effectively.

Needs Investigation.

Ethical and Societal Implications (8.00). While the score itself might be good, it's important to delve deeper. Are there any ethical concerns or societal impacts thoroughly addressed?

Adaptive Learning Systems (7.68). How can the learning systems be improved to match expectations of providing better learning outcomes?

Here's why.

Averages don't tell the whole story: Look within each category. Are there specific aspects excelling or lagging?

Context matters: What are your program's specific goals? Are some areas naturally more important for your case?

Here's what the University/Expert team can do.

Investigate further. Dig deeper into each area, especially those with a score of 8.00. Are there areas within these categories that need more attention?

Compare with benchmarks. Are your scores in line with industry standards or best practices?

Consider the goals. Tailor the analysis to the program's specific objectives.

Obviously, a good case study goes beyond averages. It's about analyzing strengths and weaknesses to identify areas for improvement and highlight best practices.

Conclusion

The rapid advancements of Industry 5.0, characterized by human-machine collaboration and intelligent automation, necessitate a significant shift in the educational landscape. This paper explored the concept of an evaluation framework to assess the development maturity of educational institutions in preparing students for this new industrial era.

Our findings revealed that educational institutions require a multi-pronged approach to achieve Industry 5.0 readiness. This includes:

– Curriculum Integration: Integrating Industry 5.0 concepts, such as artificial intelligence, big data, and the Internet of Things (IoT), into core disciplines.

– Pedagogical Innovation: Shifting instructional methods towards active learning, problem-solving, and fostering critical thinking skills.

– Infrastructure Development: Investing in digital infrastructure, including advanced simulation tools, virtual reality experiences, and collaborative learning platforms.

– Industry Collaboration: Building strong partnerships with industry leaders to provide students with real-world exposure and internship opportunities.

– Faculty Development: Equipping faculty with the necessary knowledge and skills to effectively teach Industry 5.0 concepts.

The evaluation framework presented in this paper provides a valuable tool for educational institutions to assess their current state and identify areas for improvement. By continuously monitoring and refining their approach, educational institutions can ensure they are graduating future-ready individuals who can thrive in the dynamic and intelligent environment of Industry 5.0.

Future Research:

– Developing a standardized evaluation framework that can be applied across diverse educational institutions.

– Conducting longitudinal studies to track the effectiveness of different strategies in fostering Industry 5.0 readiness.

– Investigating the impact of Industry 5.0 education on graduate career outcomes and industry needs.

By fostering a culture of continuous improvement and collaboration, educational institutions can play a pivotal role in shaping the workforce of tomorrow and ensuring a smooth transition towards a more human-centric and intelligent Industry 5.0.

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ЗРІЛІСТЬ РОЗВИТКУ ОСВІТНІХ ЗАКЛАДІВ В ІНДУСТРІЇ 5.0: СИСТЕМА ОЦІНЮВАННЯ

Анотація. *Поява Індустрії 5.0, яка характеризується конвергенцією передових технологій, таких як штучний інтелект, Інтернет речей і робототехніка, вимагає переоцінки ролі навчальних закладів у підготовці майбутніх фахівців. У цьому документі представлено структуру оцінювання, спрямовану на оцінку зрілості розвитку навчальних закладів у середовищі Індустрії 5.0. Структура охоплює ключові параметри, включаючи адаптацію навчальної програми, технологічну інфраструктуру, готовність викладачів, дослідницькі та інноваційні ініціативи, галузеву співпрацю та результати студентів. Завдяки структурованому оцінюванню цих параметрів навчальні заклади можуть оцінити свій рівень готовності до розвитку навичок і компетенцій, яких вимагає Індустрія 5.0. Ця структура не тільки служить діагностичним інструментом, але й полегшує визначення сфер для вдосконалення і стратегічного втручання. Підвищуючи зрілість свого розвитку, навчальні заклади можуть ефективно сприяти просуванню Індустрії 5.0 і забезпечити готовність робочої сили до майбутнього. З появою Індустрії 5.0 з інтеграцією передових технологій, таких як штучний інтелект, Інтернет речей і робототехніка, у виробничі процеси роль навчальних закладів у підготовці робочої сили стає першорядною. У цьому документі пропонується комплексна основа для оцінки зрілості розвитку навчальних закладів у контексті Індустрії 5.0. Структура охоплює кілька вимірів, включаючи узгодження навчального плану, можливості навчання на досвіді, технологічну інфраструктуру, досвід і навчання викладачів, дослідження та інновації, залучення промисловості та результати випускників. Завдяки систематичному оцінюванню цих параметрів навчальні заклади можуть оцінити свою готовність і ефективність у наданні студентам навичок і компетенцій, необхідних для успіху в Індустрії 5.0. Крім того, ця оцінка полегшує визначення сфер для вдосконалення і стратегічних інвестицій для підвищення ролі освіти в стимулюванні інновацій, економічного зростання та розвитку робочої сили в епоху Індустрії 5.0.*

Ключові слова: Індустрія 5.0; навчальні заклади; зрілість розвитку; підготовка робочої сили; узгодження навчальних програм; експериментальне навчання; технологічна інфраструктура; досвід викладачів; дослідження та інновації; залучення промисловості; результати випускників

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