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MARTINA MANDAKOVA
HENRIETA HRABLIK CHOVANOVÁ
KRZYSZTOF WITKOWSKI

Integrating VR, AR and AI into corporate employee training: A study of mixed methods towards personalized learning design

Abstract

Research background and purpose: Digital transformation and the emergence of Industry 4.0 and 5.0 intensify the need for innovative, efficient, and human-centred approaches to employee training in industrial enterprises. Immersive technologies—virtual reality (VR), augmented reality (AR), and artificial intelligence (AI)—offer new possibilities for enhancing experiential learning, personalization, and workplace safety. The main purpose of this article is to present a comprehensive model for integrating VR, AR, and AI into corporate employee training, based on an extensive literature review and empirical research conducted in Slovakia and the Czech Republic.
Design/methodology/approach: The study applies a mixed-methods design combining theoretical analysis with empirical inquiry. The theoretical component synthesizes current knowledge on immersive learning, AI-supported personalization, and instructional design principles. The empirical part consists of a quantitative survey carried out between 2024 and 2025 among 106 industrial enterprises, supplemented by pilot testing in Slovak and Czech companies. The survey examined organizational readiness, perceived benefits, barriers, and existing use cases related to VR, AR, and AI in employee training programs.
Findings: Results indicate that although technological awareness is high, actual adoption of immersive tools in industrial training remains limited. Companies recognize substantial benefits, including the ability to simulate risk-intensive tasks safely, increase engagement, reduce training time, and support personalized learning through AI-driven analytics and adaptive content. However, several barriers hinder wider implementation: high equipment and development costs, limited hardware availability, insufficient digital competences among employees, and a lack of systematic training strategies. Based on the research outcomes, a structured framework for designing personalized and immersive training programs was developed.
Value added and limitations: The main value added by this study is the integration of theoretical insights with practical findings, resulting in a comprehensive framework to guide organizations in adopting immersive and intelligent technologies. The conclusions can support strategic decision-making in HR development, technological investment, and training process optimization. The primary limitation lies in the composition of the survey sample, which includes predominantly medium and large industrial enterprises from two countries, potentially reducing representativeness. Future research should extend the sample, incorporate longitudinal evaluation, and analyse industry-specific applications of VR, AR, and AI.

Keywords: *virtual reality, augmented reality, artificial intelligence, educational design, educational technologies*

JEL Classification: O33, J24, M53, M15

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Martina Mandakova
Institute of Industrial Engineering and Management, Faculty of Materials Science and Technology in Trnava, Slovak University of Technology in Bratislava, Slovak Republic
ORCID: 0009-0004-3755-8240

Henrieta Hrablik Chovanová
Institute of Industrial Engineering and Management, Faculty of Materials Science and Technology in Trnava, Slovak University of Technology in Bratislava, Slovak Republic
ORCID: 0000-0001-9459-4193

Krzysztof Witkowski ✉
Department of Logistics and Information Systems, University of Zielona Gora, ul. Podgorna 50, 65-246, Zielona Gora, Poland; email: k.witkowski@wez.uz.zgora.pl
ORCID: 0000-0003-2257-3777

1. Introduction

As industries continue to evolve under the influence of digitalization and the emergence of Industry 4.0 and 5.0 paradigms, the need for agile, efficient, and human-centered employee training has never been more pressing. Traditional training models, while essential, often lag behind in addressing the dynamic and technologically enriched realities of today's workplaces (Bonfield et al., 2020; Sung et al., 2022). In response, organizations are increasingly exploring how educational technologies, especially immersive ones such as virtual reality (VR), augmented reality (AR), and artificial intelligence (AI), can transform corporate training into an interactive and personalized learning experience (Radianti et al., 2020).

Immersive technologies provide unique affordances that allow learners to engage with content in a more meaningful way – simulating real-life scenarios, improving sensory perception, and personalizing content in real time based on learner data. In particular, AI offers the ability to tailor content and feedback according to individual performance metrics and learning preferences, opening up new possibilities for data-driven personalized learning design (Holmes et al., 2019; Zawacki-Richter et al., 2019). Recent studies demonstrate that VR-based training can significantly enhance knowledge retention and behavioral transfer in complex, high-risk domains, confirming its relevance for industry-based training programs (Radianti et al., 2020; Makransky et al., 2022). Similarly, the application of AR in technical training has shown promise in improving conceptual understanding and skill development through mixed-method approaches that combine performance analytics with qualitative insights (Shah et al., 2021).

At the same time, research on user acceptance of immersive technologies suggests that employees' perception of usefulness and ease of use plays a decisive role in long-term adoption. This resonates with findings in academic contexts, where experts also highlight ambivalent perceptions of AI as both an opportunity and a disruption of established teaching practices (Verboom et al., 2025). Studies in higher education have found that while VR-based tools are positively received initially, perceived usefulness may decline without sustained pedagogical alignment and organizational support (Huang et al., 2021; Rahman et al., 2024). These findings resonate with corporate contexts, where financial constraints, technology readiness, and workforce preparedness add further complexity to adoption (Ifenthaler & Schumacher, 2016; Pimmer et al., 2021). Despite the growing number of studies examining immersive learning tools and AI-supported education, current research lacks an integrated and empirically validated framework for applying VR, AR and AI specifically within industrial employee training. Existing studies often focus either on technological design, pedagogical affordances, or organizational acceptance in isolation, without addressing their combined impact on personalized learning design in industrial settings. In addition, research on the adoption of immersive technologies in Central European industrial enterprises remains limited, creating a geographic and contextual gap that this study aims to address.

The main objectives of this study are as follows:

(1) to analyse theoretical foundations related to immersive learning and AI-supported instructional design;
(2) to identify the current level of adoption, perceived benefits, and barriers related to VR, AR and AI in industrial enterprises in Slovakia and the Czech Republic;
(3) to propose a structured framework for integrating immersive and intelligent technologies into personalized employee training.

Based on the identified research gap and the review of existing literature, the study addresses the following research questions:

RQ1: What is the current state of awareness, adoption and perception of VR, AR and AI in industrial employee training?
RQ2: What benefits and barriers do industrial enterprises associate with the implementation of immersive and AI-supported training tools?
RQ3: How can VR, AR and AI be systematically integrated into personalized learning design in industrial training environments?

Moreover, recent advances in combining immersive technologies with AI highlight the potential for adaptive learning analytics and personalized pathways. For example, integrating intelligent tutoring systems into VR/AR environments enables monitoring of learners' cognitive states and the provision of adaptive feedback, thereby enhancing training outcomes (Martins et al., 2021; Alhajri et al., 2023). Such approaches align with the growing call for evidence-based frameworks that bridge immersive technologies, AI-driven analytics, and human-centered instructional design in workforce development.

The remainder of this article is structured as follows. Section 2 provides a comprehensive literature review on immersive learning technologies, including virtual reality, augmented reality, and artificial intelligence, with an emphasis on their pedagogical, technological, and organizational implications. Section 3 presents the mixed-methods research design, detailing both the theoretical analytical component and the empirical survey conducted among industrial enterprises in Slovakia and the Czech Republic. Section 4 reports the empirical findings related to the adoption, perceived benefits, and barriers associated with VR, AR, and AI in industrial employee training. Section 5 offers a discussion of the results, interpreting them through the lens of educational design principles, technology adoption frameworks, and organizational readiness. Section 6 concludes the article by summarizing the key contributions, practical implications, limitations of the study, and recommendations for future research.

2. Theoretical background

Technological progress is currently significantly affecting education and shaping its future. Virtual reality, simulations, and mixed reality, and their inclusion in the educational process are increasingly current issues. Simulations, virtual reality (VR), and mixed reality (MR) are software-dependent tools that provide an interface between a human and a software-generated virtual environment. These technologies are characterized by enabling users to visualize, utilize the virtual environment, and interact with it through the senses.

Simulation software tools, virtual reality, and augmented reality offer a variety of opportunities for application in the educational process. Thanks to dynamic animations and graphical representations of phenomena or subjects under study, these tools become the digital equivalent of traditional education in the form of an educational platform involving human perceptions and senses (Formanek & Filip, 2020). Similarly, multiple studies emphasize that mixed reality tools provide educators with new ways to engage students and create interactive teaching methods, with teachers positively perceiving its potential to enhance the educational experience (Marín-Díaz & Sampedro-Requena, 2023). Another analysis confirms that virtual reality dramatically improves learning by allowing students to experience complex concepts through realistic simulations, thus increasing their engagement and understanding of the subject matter (He & Tan, 2023; Suryodiningrat et al., 2023).

Research on the educational effects and user satisfaction with mixed reality-based simulators shows high learner satisfaction and a positive impact on decision-making skills, particularly in challenging technical and medical fields (Zechner et al., 2024; Hamilton et al., 2020; Holstein et al., 2018). The use of VR and simulation technologies also offers flexibility and opportunities for both students and educators to overcome the constraints of traditional education in terms of distance and time (Mentsiev et al., 2023). A bibliometric review confirms the growing interest and increasing number of publications on augmented, virtual, and mixed reality in education, documenting the latest trends and innovative applications in this area (Ispir et al., 2024).

The development of digital education has led to an increased adoption of immersive technologies that offer student-centred experiential approaches. Immersive technologies such as VR and AR provide opportunities for students to engage in realistic simulations and gain context-rich feedback, promoting greater engagement and retention (Radianti et al., 2020; Poggianti et al., 2025). VR enables the creation of three-dimensional training scenarios in which students can interact with complex systems in a risk-free environment, while AR overlays digital content with the real world, improving contextual learning (Lee & Wong, 2020; Poggianti et al., 2025).

The use of VR and AR technologies brings an immersive training experience, simplifying the preparation of the environment. The ability to connect and leverage the assets of the digital/cyber/virtual and physical worlds can bring significant time savings in different areas of production (for example: design, logistics, maintenance, etc.). Current technologies such as XR could act as the missing link realizing this bridging, but at the same time, they can introduce new features, such as increasing the flexibility of time spaces. In addition to the immersive training experience, the great advantage is the safety of education using VR and AR technologies.

These enable the simulation of real scenarios, in which trained operators, as well as crisis managers, can practice their skills or master them. Virtual environments enable safe yet realistic training and education across a wide range of contexts, including student training in various subjects through virtual experience, employee training for emergencies, complex work operations on expensive equipment, and tasks involving hazardous chemicals (Mandáková, 2025; Sümer & Vaněček, 2025).

Constructive simulations create an interface between human and computer-generated virtual environment and its hardware and software tools. The processes of the computer program simulate the investigated phenomena in real or specified time and environment with the aim of inducing the impression of a real situation in the trainees, to which they must respond adequately (Halúsková, 2022; Avula et al., 2025).

At the same time, artificial intelligence (AI) is increasingly being used to analyse student behaviour, personalize instructional content, and provide real-time feedback, contributing to more personalized and effective learning experiences (Zawacki-Richter et al., 2019; Holmes et al., 2019). AI technologies, such as smart tutoring systems and learning analytics platforms, can support decision-making in an educational context by identifying patterns in student performance and optimizing content delivery (Ifenthaler & Yau, 2020; Nazarenko et al, 2025).

This development is in line with current learning design principles that emphasize student-centred learning, adaptability, and data-driven customization. Educational design as a pedagogical and technological practice focuses on structuring learning experiences that align with specific learning outcomes and respond to student needs (Laurillard, 2012). Combined with artificial intelligence and immersive technologies, educational design becomes a powerful framework to support personalized, engaging, and outcome-oriented training in a professional setting.

2.1. Specific aspects of generative AI

In personalized employee learning, generative AI technologies bring new possibilities for automation, personalization, and interactivity in corporate education. Generative AI, which includes large language models (LLMs), multimodal generators, and other applications, enables the creation of advanced learning materials and simulations that are tailored to each employee's individual needs and goals. Artificial Intelligence (AI) is rapidly transforming various sectors, and education is no exception. As AI technologies continue to advance, their potential to reshape the educational landscape becomes increasingly apparent (Yim & Su, 2024).

Generative AI and its application in personalized learning brings specific benefits such as:

1. Automated creation of personalized learning materials. Generative AI, such as large language models (LLMs) (e.g. GPT), enables the automated creation of learning materials that are tailored to the individual needs of employees. By analysing data on performance, preferences, and prior knowledge, AI can generate (Koh & Doroudi, 2023):
   - *Dynamic modules:* Learning materials that adapt to the employee's current knowledge. For example, if an employee already knows the basic concepts, the AI will skip the introductory sections and focus on advanced topics.
   - *Multimedia Content:* Generate content in multiple formats, such as texts, videos, infographics, or interactive quizzes. This ensures that education caters to different learning styles. An example of an application is the integration of generative AI into learning management systems (LMS) that can create personalized training plans in real-time based on an individual's goals.

Similar capabilities are demonstrated in GPTutor, which adapts content and practice exercises to individual goals, and generative AI–powered intelligent tutoring systems (ITS) that deliver real-time feedback and customized learning paths (Maity & Deroy, 2024; Sajja et al., 2023).

2. Generate realistic scenarios and case studies. One of the biggest strengths of generative AI is its ability to create realistic scenarios and simulations that mimic real-world work situations. This feature is especially useful in the area of soft skills, such as:
   - *Communication simulations*: Generating conversational scenarios that allow employees to practice skills such as negotiation, conflict resolution, or customer support.
   - *Critical decision-making:* AI can create complex case studies in which employees must analyse a situation, make decisions, and understand the consequences of their decisions.
   - *Security training*: Generating crisis scenarios to help employees prepare for unexpected events such as cyberattacks or emergencies.

These simulations can work in combination with VR/AR technologies, further enhancing their effectiveness. Research on AI-driven educational agents illustrates how multiple AI personas can deliver adaptive simulations—such as "PitchQuest," a venture pitching simulator—providing personalized mentorship and feedback (Mollick et al., 2024).

3. Promoting reflection and mentoring through conversational agents. Conversational agents powered by generative AI are a breakthrough in

mentoring and reflection. These systems can: Provide instant feedback: Employees can interact with AI agents who analyse their responses, suggest improvements, and provide advice based on best practices. AI can ask questions to encourage deeper thinking about the tasks at hand. For example: "How could you improve your approach to this situation?" Interactive mentoring: Generative AI can simulate the role of a mentor who guides an employee through the training process. Applications allow for the creation of flexible and accessible mentoring environments that complement traditional training methods (Bandi, 2023). This aligns with intelligent assistant frameworks like AIIA, which streamline cognitive load and adapt learning paths using AI and NLP (Sajja et al., 2023).

4. Streamlining administrative work. Use of conversational agents to address repetitive queries and automate the generation of training materials and scenarios saves time for both instructors and learners. (Pappas, 2025).
5. Improved engagement, adaptability, and accessibility. Interactive and realistic simulations enhance motivation, while AI tailors pace and content to individual styles. The flexibility of AI allows training to occur anytime, anywhere—boosting accessibility (Mollick et al., 2024; Pappas, 2025).

3. Review studies of the use of VR, AR, AI in employee education

Extensive research by PwC and other research institutions from 2023 documents the significant benefits of virtual reality in professional education. Randomized controlled trials involving managers from different industries compared three training methods: traditional classroom training, e-learning, and immersive VR training. Key findings include that VR-trained employees achieve up to 40% better results compared to traditional methods; learning speed increases up to 4 times, allowing completion of tasks normally taking 2 hours in class in just 30 minutes in a VR environment. Self-confidence in applying acquired skills increases by 275%, while 94-96% of participants express a positive attitude towards VR training and demand more VR courses (PwC, 2024; Zechner et al., 2024; Mentsiev et al., 2023). In alignment, a 2021 study published in the Harvard Business Review highlighted VR's effectiveness in soft skills training, showing employees trained with VR exhibited up to a 275% increase in self-confidence compared to traditional methods. Furthermore, economic analysis revealed VR training achieves cost parity with traditional training methods at 375 participants, and becomes 52% more cost-effective when reaching 3000 participants (Meister, 2021).

Another study published in the Journal of Applied Psychology in 2023 examined the integration of AI into training programs. The researchers analysed how AI contributes to the personalization of content based on the individual performance and needs of the participants. They found that employees who received AI-powered personalized content achieved higher results and higher levels of engagement than those who were provided with standard content (Tang et. al., 2023).

4. Methods

The current digital transformation and the complexity of the work environment place increased demands on innovations in the field of employee education. Therefore, it is essential that we take into account the latest research supporting the use of VR, AR and AI when designing and implementing training programs.

The study uses a mixed-methods research approach that integrates qualitative theoretical analysis with quantitative research to comprehensively explore the use of virtual reality (VR), augmented reality (AR) and artificial intelligence (AI) in employee education in industrial enterprises in Slovakia and the Czech Republic.

The qualitative component consisted of an extensive literature review and theoretical analysis of current frameworks and scientific papers related to immersive learning technologies and AI-supported educational design. This step provided the foundational understanding needed to contextualize the empirical exploration and develop relevant research tools. The review drew on established educational theories and recent advances in digital education to identify key opportunities and challenges associated with integrating immersive technologies into business education (Laurillard, 2012; Radianti et al., 2020; Zawacki-Richter et al., 2019).

The quantitative component included a structured questionnaire distributed among industrial enterprises in Slovakia and the Czech Republic. The aim of the survey was to capture data on organizational readiness, technology adoption, perceived benefits, and barriers related to the implementation of VR, AR, and AI in employee training programs. Among the respondents were trained managers, HR specialists, and operations staff with direct experience in training processes. The collected data was analysed using descriptive and inferential statistics to identify trends and correlations that inform best practices for personalized learning design in an industrial context.

This blended methodological approach aligns with mixed-method research standards, facilitating both depth and breadth in understanding the complex dynamics of implementing immersive technologies in corporate education (Creswell, 2014; Flick, 2018). By triangulating theoretical knowledge with empirical evidence, the study contributes to large-scale findings that support the development of a human-centric framework for technology-driven employee training.

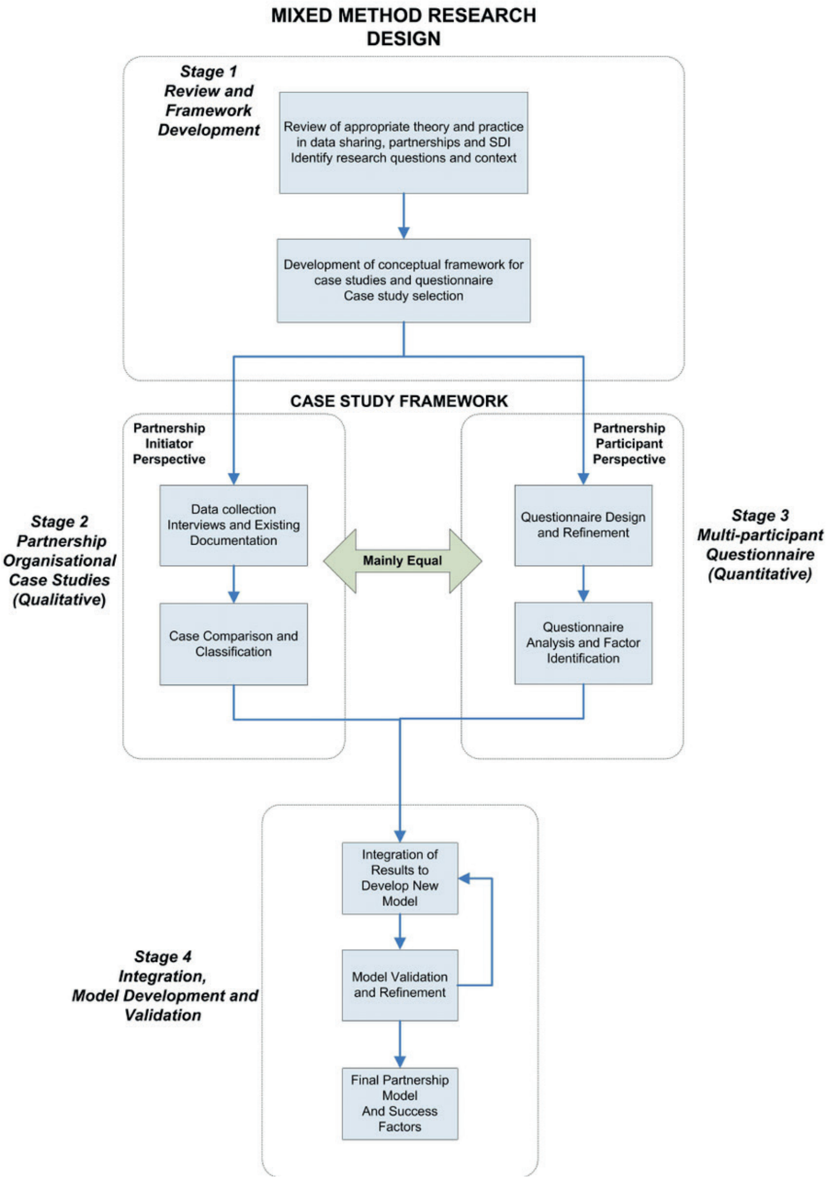

Figure 1. **Methodological structure of the study combining theoretical analysis and empirical research**

Source: own elaboration

The diagram (Fig. 1) illustrates the complexity of mixed-method research and all its interconnected components in the context of VR, AR, and AI in industrial training.

The research design consists of four interconnected stages aimed at developing and validating a partnership model and identifying success factors. These stages integrate both qualitative and quantitative methods to ensure a comprehensive approach.

Stage 1. Review and framework development. This stage begins with a review of appropriate theory and practice in data sharing, partnerships, and spatial data infrastructure (SDI). The primary goal is to identify the research questions and context. Based on this, a conceptual framework is developed to guide the study, including the selection of case studies and the design of the questionnaire.

Stage 2. Partnership organizational case studies (qualitative). This stage employs a case study framework and is divided into two perspectives:

1. Partnership Initiator Perspective:
   - data is collected through interviews and existing documentation,
   - the findings are analysed through case comparison and classification.
2. Partnership Participant Perspective:
   - a questionnaire is designed and refined based on the study's context,
   - the results undergo questionnaire analysis and factor identification.

Both perspectives are given equal weight in the research process.

Stage 3. Multi-participant questionnaire (quantitative). The quantitative component involves deploying a multi-participant questionnaire to gather data from a broader audience. This complements Stage 2 and provides insights from additional participants, allowing for the identification of patterns and factors influencing partnerships.

Stage 4. Integration, model development and validation. In this final stage, the results from the qualitative and quantitative analyses are integrated to develop a new partnership model. The model undergoes validation and refinement to ensure its robustness and applicability. The final output is a validated partnership model along with key success factors that can guide future initiatives.

This mixed-method approach ensures a comprehensive, balanced analysis by combining qualitative depth with quantitative breadth, resulting in actionable insights for partnership development and success.

5. Adoption of VR, AR, and AI in industrial workforce training: survey findings from Slovakia and the Czech Republic

In today's dynamic business environment, characterized by constant change and high managerial demands, employee education is becoming a key factor in improving work performance and maintaining competitiveness.. With the advent of Industry 4.0 and the vision of Industry 5.0, it is essential for businesses to constantly renew and expand the knowledge and skills of their employees. Modern digital technologies, including VR, AR, and AI, offer innovative opportunities for effective learning and human capital development, enabling the creation of an immersive and personalized learning environment with immediate feedback. These technologies are changing traditional approaches to learning and revolutionizing the way employees acquire new knowledge and skills. However, the successful implementation of these tools requires, in addition to mastering technological challenges, thorough management of the entire educational process, including the preparation of documentation and compliance with ethics.

The pilot survey was carried out in order to obtain real information about the current state of education in industrial enterprises in the Slovak and Czech Republics and about the degree of use of digital methods in employee education. The subject of the research was industrial enterprises in both countries.

Distribution and target group: The questionnaire was distributed electronically via email (300 companies were addressed) and shared on the professional LinkedIn portal. The survey was primarily focused on industrial enterprises and was aimed at managers and specialists responsible for managing education and introducing innovations.

Sample and yield: 106 enterprises replied to the questionnaire, representing a return of 35,33 %. The final sample of 106 enterprises is methodologically sufficient for exploratory mixed-methods research of this scope. Given the focus on industrial organizations in two countries, the sample provides adequate variability in company size, sector, and technological readiness to identify patterns and generate generalizable insights.

Pilot testing: Before data collection, the questionnaire underwent content validation through an expert review process involving three specialists in corporate training and digital technologies. Their feedback ensured clarity, relevance, and alignment with the study's objectives. In addition, the questionnaire was pilot-tested in three Slovak and two Czech industrial enterprises, which confirmed the appropriateness of the items and resulted in minor wording adjustments.

Structure of the questionnaire: The questions were divided into four main areas:

- organizational characteristics (1-3): capturing the distribution of organizations by sector, location, and size,
- strategic education approach (4-8): evaluation of strategic education management,
- use of VR, AR, and AI technologies (9-17): exploring experiences with and attitudes toward the use of modern technologies. Contact information (18): for respondents interested in receiving the survey results. Out of 106 companies, eight took advantage of this opportunity, indicating potential for further research collaboration.

Data collection: The survey ran from 1 November 2024 to 28 February 2025. The results of the survey provided valuable insights into the state of education and the perception of modern technologies in industrial enterprises:

1. **Organizational characteristics of respondents:**
   - subject of activity: Industrial enterprises were the most represented (83), followed by sales of products and services non-manufacturing sector (6), education (5), energy (2) and others (3),
   - geographical representation: 70% of the companies are based in Slovakia and 30% in the Czech Republic,
   - size of the enterprise: Medium-sized enterprises (54%, i.e. 57 companies) and large enterprises (43%, i.e. 46 companies) were the most represented.
2. **Strategic education management.** This section examines the level of strategic education management among industrial enterprises. Only 25% (26 companies) fully agreed with the statement that their organization has a clearly defined strategy for employee development and education. The weighted average score of responses was 3.65 on a five-point Likert scale, indicating a generally low or insufficient level of strategic maturity in employee education. Despite the limited presence of formal education strategies, the majority of companies (96%) reported providing training activities beyond mandatory legislative requirements. However, these activities are often not systematically managed or evaluated. Nearly half of the surveyed companies (45%) indicated that they do not use any tools to collect feedback from completed training programs, pointing to significant gaps in the strategic management and continuous improvement of education processes. A summary of the key indicators related to strategic education management is presented in Table 1, which highlights the discrepancy between the widespread provision of training and the limited use of structured strategies and evaluation mechanisms.

Table 1. **Strategic education management practices**

Indicator	Result
Companies fully agreeing they have a defined education strategy	25% (26 companies)
Weighted average (1–5 scale)	3.65
Companies using training beyond legal requirements	96% (102 companies)
Companies relying only on compulsory training	4% (4 companies)
Use of instructor-led training	86%
Companies collecting training feedback	55% (58 companies)
Companies not collecting training feedback	45% (48 companies)

Source: own elaboration based on empirical research results

This fact points to significant gaps in the system setting of education. These results illustrate the current level of strategic readiness among industrial enterprises, providing context for further analysis in relation to RQ1 and RQ2.

3. **Use and perception of VR, AR, AI in education.** This section focuses on organizational awareness, adoption, and perceptions of VR, AR, and AI technologies in employee education. The results show that awareness of immersive and AI-based learning technologies is relatively high, with 81% of organizations reporting familiarity with VR, AR, or AI-supported education. However, actual adoption remains limited.

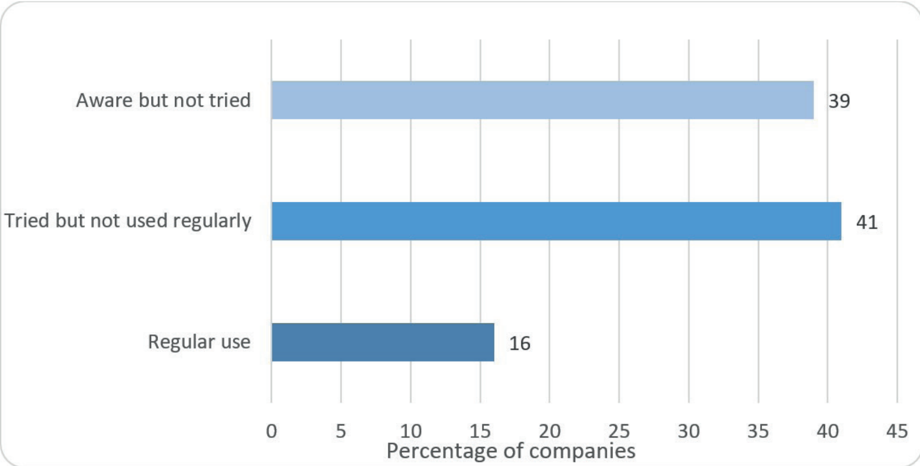

Figure 2. **Adoption and experience with VR, AR, AI**

Source: own elaboration based on empirical research results

As illustrated in Figure 2, only 16% of companies currently use VR, AR, or AI technologies regularly in employee training. A further 41% have had the opportunity to try these technologies but do not use them on a regular basis, while 39% are aware of them but have not yet gained practical experience. This highlights a clear gap between technological awareness and real-world implementation.

Despite the current low adoption rate, interest in future implementation is evident. Forty percent of companies stated that they would consider introducing VR, AR, or AI technologies within the next year. Organizations perceive the greatest potential for these technologies in occupational safety and health training (77%) and in training for emergency situations (71%).

Respondents also identified a wide range of perceived benefits associated with VR, AR, and AI-based training, including increased safety, cost reduction, the ability to simulate otherwise inaccessible situations, time savings for instructors, greater training effectiveness, higher participant motivation, and flexibility in content adaptation.

In the following Table 2, the barriers to the implementation of VR/AR and AI reported by the respondents are presented.

Table 2. **Barriers to VR, AR, and AI implementation**

Barrier	Percentage (Companies)
High cost of technology	62% (64 companies)
Limited availability of equipment	49% (51 companies)
Lack of technical knowledge	33% (34 companies)
Negative employee attitudes	21% (22 companies)

Source: own elaboration based on empirical research results

Taken together, these findings provide a comprehensive picture of the current use, perception, and readiness for VR, AR, and AI adoption in industrial education, directly addressing research question RQ1.

6. Results

This section presents the empirical findings from industrial enterprises in Slovakia and the Czech Republic. The results are organized according to the research questions and describe the observed patterns without interpretation.

6.1. Statistical characteristics of respondents (related to RQ1)

A total of 106 enterprises participated in the survey, representing a response rate of 35.33% from 300 contacted organizations. Of the participating companies, 70% were based in Slovakia and 30% in the Czech Republic. Industrial enterprises constituted the largest group (n = 83), followed by non-manufacturing product and service providers (n = 6), educational institutions (n = 5), energy companies (n = 2), and other sectors (n = 3).

In terms of size, medium-sized enterprises accounted for 54% (n = 57), large enterprises for 43% (n = 46), and small enterprises for the remaining share. These descriptive statistics provide the demographic and structural context necessary for addressing RQ1, which focuses on the current state of awareness and adoption of VR, AR, and AI in industrial training.

6.2. Strategic management of employee training (related to RQ1)

When asked whether the company has a defined strategy for employee development, 25% (n = 26) indicated full agreement, with an overall weighted mean of 3.65 on a five-point scale. A total of 96% (n = 102) of respondents stated that their organizations provide training beyond mandatory legislative requirements, while 4% rely solely on compulsory training.

Instructor-led training was the most common format, preferred by 86% of enterprises. Furthermore, 45% (n = 48) reported that they do not use tools to collect feedback from completed training, while 55% (n = 58) confirmed the existence of such tools.

These results describe the organizational readiness and existing practices relevant to RQ1.

6.3. Awareness and adoption of VR, AR, and AI (RQ1)

Awareness of immersive technologies was high, with 81% (n = 86) of organizations reporting familiarity with VR, AR, or AI-based learning tools (Figure 3). However, regular use remained limited.

A total of 41% (n = 43) had tried these technologies but did not use them systematically, 39% (n = 41) were aware of them but had not used them, and 16% (n = 17) reported active use of VR/AR/AI in employee training.

Interest in implementation was expressed by 40% (n = 42) of enterprises that would consider adopting immersive technologies within one year.

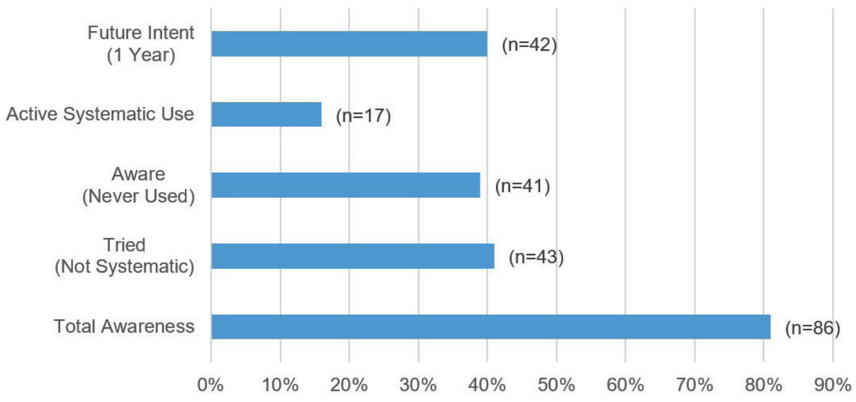

Figure 3. **Technology adoption lifecycle**

Source: own elaboration based on empirical research results

These findings directly address RQ1 by outlining current awareness and usage levels.

6.4. Implementation preferences and areas of application (RQ2)

Regarding preferred implementation methods, 47% (n = 49) indicated interest in externally delivered VR/AR/AI training services, 44% (n = 46) preferred a combined approach, and 9% (n = 9) preferred acquiring their own system.

Enterprises identified the greatest application potential in occupational safety and health (77%) and emergency situation training (71%).

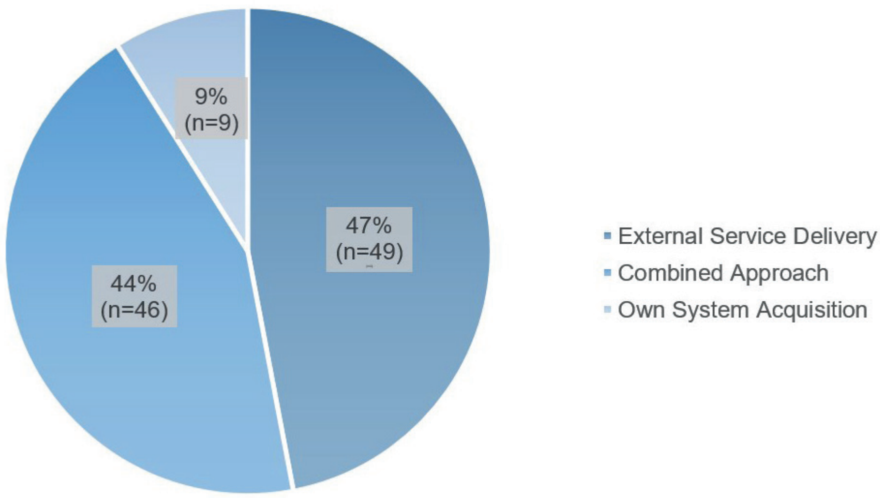

Figure 4. **Implementation preferences**

Source: own elaboration based on empirical research results

These results contribute to answering RQ2 by identifying the organizational preferences and application domains associated with VR/AR/AI adoption.

6.5. Perceived benefits of VR, AR, and AI (RQ2)

Respondents reported several perceived benefits of immersive technologies. The most frequently mentioned were the ability to simulate real situations unavailable in physical training environments, increased safety during training, material and time savings, improved participant motivation, and flexibility in modifying training content.

Additional benefits included cost reductions, space savings, and the possibility of simulating work with expensive equipment or hazardous materials.

These findings provide descriptive evidence for answering RQ2 concerning perceived advantages of immersive training tools.

6.6. Barriers to adoption (RQ2)

The most common barriers reported by enterprises were high technology costs (62%; n = 64) and limited availability of necessary hardware (49%; n = 51). Other reported obstacles included insufficient employee technical skills (33%; n = 34), negative employee attitudes toward new technologies (21%; n = 22), lack of experience with real use cases, UX issues, limited customization options without external programming, extended preparation times, and health-related limitations of some employees.

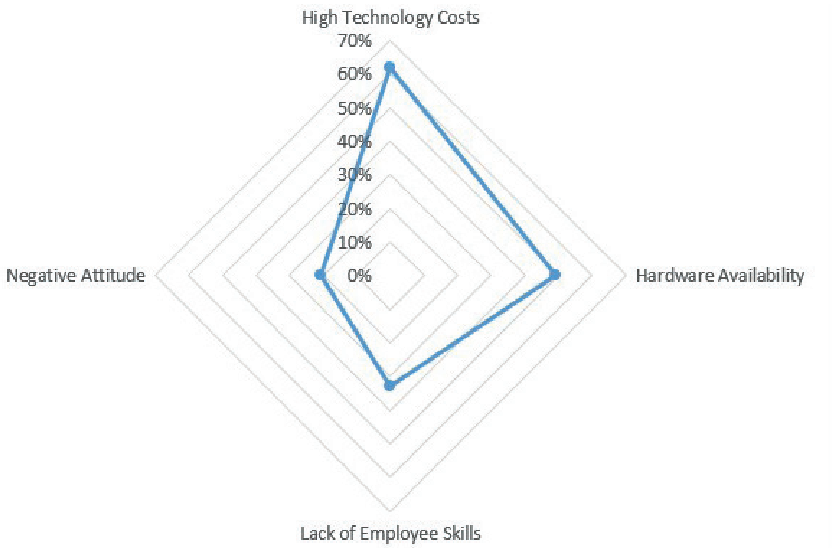

Figure 5. **Barriers to adoption**

Source: own elaboration based on empirical research results

These results complete the empirical basis for answering RQ2 by identifying the key constraints that affect implementation decisions.

6.7. Summary of findings with respect to research questions

RQ1: Findings show high awareness but low systematic adoption of VR/AR/AI, limited strategic readiness, and uneven use of feedback mechanisms.
RQ2: Organizations perceive strong benefits in safety, flexibility, and simulation capabilities but face financial, technical, and human-related barriers.
RQ3: This research question concerns the development of a framework for integrating VR/AR/AI. As this framework is derived from both empirical results and theoretical analysis, it is addressed in Section 5 (Discussion) and Section 6 (Conclusion), not in the purely descriptive Results section.

7. Discussion

This section interprets the empirical findings in relation to the research questions and existing literature. The discussion focuses on the implications of the results for the integration of VR, AR, and AI into employee training in industrial enterprises.

7.1. Interpretation of findings related to RQ1: awareness, adoption and readiness

The high level of awareness of VR, AR, and AI among enterprises, combined with comparatively low levels of systematic adoption, reveals a persistent discrepancy between technological interest and organizational readiness. This pattern aligns with previous research emphasizing that awareness of immersive technologies does not automatically translate into active implementation (Rahman et al., 2024; Ifenthaler & Schumacher, 2016). The limited use of feedback tools and the absence of well-defined training strategies in many enterprises further indicate that organizational learning systems are not yet fully aligned with the demands of immersive and AI-enhanced training.

The results suggest that enterprises in Slovakia and the Czech Republic are positioned similarly to other international contexts, where technological readiness is a gradual process influenced by strategic planning, digital maturity, and managerial support (Radianti et al., 2020; Poggianti et al., 2025). These findings reinforce the view that successful adoption of immersive technologies requires not only technical infrastructure but also stable internal processes and clear educational strategies.

7.2. Interpretation of findings related to RQ2: perceived benefits and barriers

The perceived benefits identified by the respondents correspond closely to those highlighted in the global literature, particularly the value of realistic simulations, improved safety, enhanced engagement, and time- and cost-saving potential (PwC, 2024; Mentsiev et al., 2023). The strong emphasis on occupational safety and emergency training indicates that companies prioritize immersive training primarily in scenarios where physical risk, complexity, or high operational costs limit traditional hands-on learning.

Simultaneously, the prominent barriers identified—high technology costs, limited availability of equipment, insufficient technical skills, and negative employee attitudes—mirror findings reported in similar studies across Europe and Asia (Pimmer et al., 2021; Sümer & Vaněček, 2025). These barriers represent not only financial constraints but also deeper organizational and cultural challenges, especially in environments where digital habits are still developing.

The coexistence of strong perceived benefits and substantial barriers reflects a transitional stage of adoption, in which immersive technologies are recognized as valuable but not yet embedded in organizational learning systems. This duality underscores the need for structured implementation frameworks that address both technological and human factors.

7.3. Interpretation of findings related to RQ3: Integrating VR, AR, and AI into personalized learning design

RQ3 focuses on developing a framework for integrating immersive technologies and AI into personalized employee training. The empirical findings support the relevance of such a framework by identifying clear needs: adaptive content, high-engagement learning methods, and safe simulation environments. The literature consistently highlights that immersive technologies, when combined with AI-driven analytics, can enable personalized learning pathways, real-time feedback, and learner-specific adaptation (Holmes et al., 2019; Martins et al., 2021; Zawacki-Richter et al., 2019).

The results of this study confirm that enterprises recognize the potential value of these capabilities, yet lack the internal mechanisms to implement them effectively. This reinforces theoretical claims that personalization and adaptive learning require not only advanced technologies but also pedagogically grounded design principles and cross-functional collaboration between HR, IT, and management (Laurillard, 2012; Ifenthaler & Yau, 2020).

Thus, the findings provide both justification and direction for the development of the framework proposed in this study, which aims to bridge technological functionality with instructional design and organizational strategy.

7.4. Implications for industrial enterprises

The integration of immersive and AI-supported training tools has implications at multiple organizational levels:

- *strategic level:* the absence of structured educational strategies suggests a need for aligning training with broader organizational goals,
- *operational level:* Barriers related to skills and technology availability highlight the necessity of building internal digital competence,
- *pedagogical level:* The desire for interactive, realistic, and adaptive training systems indicates a demand for experiential learning design principles.

Table 3. **Key recommendations for implementing VR, AR and AI in industrial employee training**

Area of implementation	Recommendation	Source / Theoretical framework
Technological infrastructure	Invest in interoperable, scalable, and secure systems that enable seamless deployment of VR/AR/AI solutions.	Radianti et al. (2020); Mandáková (2025)
Instructional design	Develop training modules based on principles of personalization, iteration, feedback, and evidence-based learning design.	Laurillard (2012); Zawacki-Richter et al. (2019)
Personnel development	Provide training for instructors, HR professionals, and managers in digital pedagogy and the use of AI-enhanced educational tools.	Ifenthaler & Yau (2020); Holmes et al. (2019)
Financing and return on investment	Conduct cost–benefit analyses to evaluate the economic viability and long-term return on investment of immersive technologies.	Mandáková (2025); Pimmer et al. (2021)
Employee engagement	Involve employees in co-creation of training content and pilot testing to build trust and increase acceptance of new technologies.	Pimmer et al. (2021); Ifenthaler & Schumacher (2016)
Decision support	Utilize learning analytics and AI-enabled insights to inform data-driven decisions on content development and individualized learning pathways.	Ifenthaler & Yau (2020); Zawacki-Richter et al. (2019)
Strategic planning	Integrate immersive technologies into long-term learning and development strategies in alignment with organizational goals.	Bonfield et al. (2020); Mandáková (2025)

Source: own elaboration

These implications resonate with international calls for human-centred, technology-enabled upskilling strategies to prepare industrial workforces for Industry 4.0 and 5.0.

Table 3 summarizes the key recommendations derived from the empirical findings and relevant theoretical frameworks. It outlines technological, pedagogical, organizational, and strategic factors that enterprises should consider when implementing VR, AR, and AI-based training.

7.5. Contribution to the literature

This study contributes to the existing body of knowledge in several ways:

- it provides empirical evidence on the status of immersive technology adoption in Central European industrial enterprises—an under-researched geographical context,
- it synthesizes organizational, pedagogical, and technological factors, expanding on prior studies that typically focus on only one dimension,
- it integrates empirical findings with theoretical frameworks to develop a practice-oriented model for personalized, immersive learning design.

These contributions position the study within international scholarly discussions on digital transformation and workforce development.

7.6. Transition to the conclusion

The findings discussed herein form the basis for the implications and recommendations presented in Section 6. They demonstrate how immersive technologies and AI can enhance industrial training, while also highlighting the strategic, financial, and human-centred factors that influence their adoption.

8. Conclusion

This study examined the integration of virtual reality (VR), augmented reality (AR), and artificial intelligence (AI) into employee training in industrial enterprises, combining theoretical analysis with empirical evidence from Slovakia and the Czech Republic. The research addressed three main questions related to awareness and adoption (RQ1), perceived benefits and barriers (RQ2), and the development of a framework for personalized learning design (RQ3).

With regard to RQ1, the findings show that although awareness of immersive technologies is high, their systematic adoption remains limited. Organizational readiness, insufficient feedback mechanisms and the absence of well-defined training strategies continue to constrain the ability of companies to use these technologies effectively. In relation to RQ2, the study identified several perceived advantages—

particularly increased safety, enhanced engagement, simulation-based learning and flexibility—alongside critical barriers such as high implementation costs, limited access to technology, insufficient digital competences, and inconsistent attitudes toward innovation. These results confirm both the potential and the constraints that shape the adoption of immersive learning tools in industrial settings. Finally, in response to RQ3, the study proposes a practice-oriented framework for integrating VR, AR, and AI into personalized training through a combination of technological infrastructure, instructional design principles, workforce development and strategic planning.

The study makes several contributions to the literature. It provides empirical insights from a geographical context that remains underrepresented in existing research, offers an integrated view combining technological, pedagogical and organizational dimensions, and proposes a structured model that can guide future implementation of immersive technologies in industrial training. These contributions align with current international discussions on the need for human-centred and technology-enabled approaches to workforce development in Industry 4.0 and 5.0 environments.

The practical implications of the findings indicate that successful adoption of immersive technologies requires more than technological investment. Organizations must ensure alignment between technological tools and instructional design, strengthen digital competences among employees, systematically collect feedback, and incorporate immersive technologies into long-term development strategies. Clear governance, ethical use of AI and cross-functional collaboration between HR, IT and management are essential to support responsible and effective deployment.

This study also has several limitations. The sample includes mainly medium-sized and large enterprises from two countries, which may restrict generalizability. The research relies on self-reported data, which may be influenced by subjective perceptions. Future research should therefore expand to other industries and countries, apply longitudinal assessment of learning outcomes, and test the proposed framework in real organizational settings. In addition, further work is needed to evaluate the impact of generative AI and adaptive analytics on personalized learning at scale.

Overall, the study highlights that immersive and intelligent learning technologies have significant potential to enhance corporate training, but their successful implementation depends on strategic readiness, educational design, employee competences and organizational support. Implementing VR, AR and AI should therefore be understood not merely as a technical upgrade, but as a long-term strategic transformation of corporate learning systems.

Authors' contribution

M.M.: article conception, theoretical content of the article, research methods applied, conducting the research, data collection, analysis and interpretation of results, draft manuscript preparation. **H.H.Ch.**: article conception, conducting the research, analysis and interpretation of results, draft manuscript preparation. **K.W.**: article conception, analysis and interpretation of results, draft manuscript preparation.

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Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used *ChatGPT 5.2* in order to check references (*APA7 style*). After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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