Frank Bünning, Christian Blobner, Guenter Podlacha (Eds.)

AI in TVET

Reflections and Implementations Across Academia, Industry, and Policymaking

OTTO VON GUERICKE UNIVERSITÄT MAGDEBURG

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Preface

F. Huebler

Artificial intelligence (AI) is redefining the way we learn, work and live. For Technical and Vocational Education and Training (TVET), this shift brings its own share of opportunities and challenges. AI can help make learning more engaging and adaptive, strengthen links between training and labour markets, and foster innovation. At the same time, it raises important questions about the future of teaching and learning and how education systems can respond to technological change.

UNESCO has been supporting Member States in addressing these issues, starting with the Beijing Consensus on AI and Education in 2019 and continuing through global consultations, guiding frameworks and policy recommendations on the ethical use of AI. These efforts aim to ensure that AI supports learning and development while upholding the principles of equity and inclusion.

Within this global effort, UNESCO-UNEVOC and the UNEVOC Network have advanced the discussion on what AI means for the future of skills development. The Otto von Guericke University Magdeburg has been a valuable contributor to this process. In cooperation with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and Fraunhofer IFF, as part of the UNEVOC Centre "TVET for Sustainable Development", the university has created an ecosystem for research and knowledge sharing on digital transformation in TVET. The benefits of this ecosystem were evident during the Expert Meeting on AI and TVET that was held in Magdeburg in February 2025.

The event called attention to the importance of empowering educators and designing AI tools tailored to learners' needs, in line with UNESCO's call for a human-centred approach to AI. As human understanding struggles to keep pace with technological advances, peer learning and international cooperation have emerged as vital components of shared progress.

This publication was developed on the foundation of those exchanges. It combines perspectives that offer insight into current AI research and policy recommendations. The contributions examine frameworks for AI integration in higher education, centering on whether we are bridging gaps or building walls. The case studies focus on teacher preparation and generational adaptation, including practical experiences from in-service training programmes, AI-enhanced learning material development and the use of AI tools for transferring expert knowledge.

Looking ahead, TVET institutions will be expected to leverage the full potential of AI, so that TVET remains relevant, agile and accessible to all learners. I hope this volume will support that effort and inspire further cooperation within the global TVET community.

Friedrich Huebler — Head of UNESCO-UNEVOC

AI in TVET: Bridging Gaps or Building Walls in Education?

G. Spöttl

This paper demonstrates that it is not sufficient to prepare skilled workers for employability alone when using AI (artificial intelligence). Rather, it is the responsibility of vocational education and training to clarify what is required in the age of AI to ensure that those people/workers are purposefully taught how to use AI in their professional lives.

With the purpose of showing how digital media and AI can be used to make vocational education and training the subject of learning in terms of content and skills, the chapter on ethical issues and the development of AI contains a fundamental discussion. This leads to the recommendation to develop literacy frameworks for vocational education and training based on work processes, which are understood as a framework for curriculum development. With regard to vocational education and training, it is therefore emphasized that technology-related frameworks fall short and must be expanded to include both work and environmental dimensions.

1 Introduction

In the context of digitalization, work organization and work-processes, the learning process will adapt alongside ongoing automation and real-time control of production and society. The same is true of work content and the interaction and communication between humans and machines, which have many consequences for users and providers throughout technical vocational education and training (TVET).

As conveyed in the opening lines of this paper, the idea that basic machines, which are used, controlled, and operated by humans, will no longer dominate the workplace but rather highly complex systems, equipped with various intelligent technologies, will eventually overcome the Fordist production regime. Innovation, flexibility, and adaptability in production are at the forefront. The scientific approach to these areas not only develops technology further, resulting in significant changes to work in industry and craft, but also reproduces social insights, connections, behaviors, and ways of living. It is therefore understandable why demands are summarized in the assertion that 'the human must retain control' [01, p. 15].

The importance of this demand is underpinned by the position of the Council of the European Union (CEU). It states that our world is entering the digital age, "with current technological advances rapidly changing our current lives and our outlook for the future. Streaming services, carpooling apps, smart homes and personalized healthcare are already with us. Artificial intelligence (AI) is changing every single aspect of our lives." [02, p. 2] The Council assumes that AI will not only revolutionize education, but will also challenge education policy to ensure employability and a more meaningful existence for people [cf. ibid., 03]. At this point, vocational education and training is also faced with crucial tasks, all of which go far beyond employability alone. In addition to ethical standards, it is necessary to clarify which challenges VET must overcome in order to equip people with the core skills needed in the workplace to guarantee their contribution to society. It is therefore necessary to analyze in more depth what is required in the workplace and how vocational education should prepare for this. The development status of AI plays a central role here. In order to specify skills development in the context of AI for vocational education and training, it will be shown how digital tools and literacy frameworks can be used to initiate vocational education and training-specific learning. This work should take into account longer-term developments in AI for the purpose of shaping skills development in vocational education and training efficiently.

Before moving on to discuss in more depth the topic of this article, it should be clarified which understanding of the term AI is used as the basis for the VET discussion. Ethical questions will also be addressed.

2 Ethical principles

The current discussion around AI is based on a very broad understanding. This article specifically addresses the use of AI from the perspective of a vocational education user and the ethical question is discussed from precisely this perspective. To ensure conceptual clarity, the definition by Minsky [04, p. 2], who is considered a pioneer of AI research, is used. For him, "Artificial intelligence ... is the study of the methods that enable computers to solve tasks that require intelligence when performed by humans." [ibid.]

This definition brings AI back to the core question and establishes a link to human intelligence. The focus is on the prominent role of humans as participants. It is not claimed that computers or programs are intelligent. It is pointed out that computers have achievements that are associated with intelligence in human behavior. It is noteworthy that, contrary to the German term "Künstliche Intelligenz" (artificial intelligence), which encompasses characteristics such as intuition, creativity, and cognition, the English understanding of "intelligence" solely relates to reasoning based on given facts. From this, it can be concluded that it is fundamentally false to believe that machines can think, which is more a case of misinformation!

Based on the above definition, it is clear that machines, with the support of software, must be provided with facts so that they can draw conclusions independently. This conceptual approach that places the human-machine interface at the center of design, regardless of the degree of complexity or autonomy of technical systems that have become players in the various networks, is a concern for humans. In many areas of society, "hybrid constellations populated by human actors and (partially) autonomous machines" are emerging [05, p. 35]. A further increase in the independence of AI systems and computers can be observed, which has led to a new level of technical development. This has a significant impact on many types of social and economic organizations and as a result we are experiencing a massive phase of social transformation, namely that from the "knowledge society ... to a post-humanistic hybrid society" [ibid., p. 35 f.]. Unlike traditional computers and AI systems, where tasks were still determined and controlled by humans, today's intelligent information systems and artificial intelligence (AI) are capable of making decisions independently. This leads to a new quality in the division of labor between humans and machines and raises two questions

- Which technology should be used? and
- How much human input is (still) allowed?

a new weight.

Krüger's understanding of AI goes far beyond this: "We usually refer to AI as computer systems that support, replace, or even go beyond certain human performance." [06] This means that AI systems develop new skills with humans and open up new perspectives through intelligent interaction with the environment and the development of social and/or emotional intelligence.

However, even if this situation is monitored, it is important that people take responsibility for further advancements and the design of the human-machine interface. This is necessary to prevent AI from making decisions for and about humans that lead to human discrimination [07, pp. 219 ff.].

The legitimate question of whether the above definition is still viable at all in the context under discussion should be answered in the affirmative here. This is due to the fact that the question of technology design and the interface between man and machine remains highly relevant, especially when a technology-centered automation strategy is clearly dominant. The overriding goal of a technology-centric strategy is to eliminate humans as a source of interference. This means that the aforementioned new form of hybridization of society leads to a dissolution of boundaries between man and machine. In the best-case scenario, humans and machines meet as powerful units that can control and substitute for each other. As long as a symmetry between humans and technology is guaranteed and humans retain the freedom to shape their own actions, they also retain sufficient freedom to shape technology in such a way that they do not come under its unreasonable control. As early as 2008, Kündig & Bütschi [05] pointed out the need to prevent technological determinism by coordinating social and technical developments. However, this is not yet the case with AI. Ethical aspects, as called for by the Council of the European Union [02], have also received little consideration to date.

The AI law (European Artificial Intelligence), the AI Act of 2024[1] [08] of the European Union, therefore rightly refers to four risk categories in the application of AI:

- unacceptable risk,
- high risk,
- limited risk,
- low or no risk.

1 The law came into force on August 1, 2024, and is applicable without restriction after 24 months.

In principle, applications that pose an unacceptable risk are therefore prohibited. This includes, for example, deceptive methods to influence people's opinions to help them make "suitable" choices. Techniques that exploit people's vulnerabilities (e. g., age, disabilities, lack of information, etc.) in order to take advantage are also prohibited.

High-risk AI technologies include autonomous driving, access to education and evidence evaluation. Before they are used, high-risk AI systems are subject to strict regulations.

Specific transparency obligations apply to the use of AI technologies with limited risk, for example, so that people are aware that they are interacting with a machine when using chatbots.

Free use of AI systems is permitted if it can be assumed that the risks are low. The vast majority (e. g., video games) of AI systems currently used in the EU fall into this category.

For all risk categories, the ethical aspects of AI must be taken into account and appropriate controls must be put in place [ibid.]. According to the author's perspective, the EU's positioning follows a "human scenario" in which people should maintain their capability of shaping work-processes and carrying responsibility and sustainability. Immanuel Kant's Golden Rule, in which he defines three moral categories[2] has already created a basis for a large framework for this viewpoint. The Categorical Imperative is important in the context of AI:

> "Act as you would wish all other rational people to follow, as it were a universal law" [09].

The Categorical Imperative is a clear indication that humans must dominate the design and control of AI in order to ensure that only developments that are accepted by all people take place. In other words, AI should be prevented from being misused or behaving in unpredictable and potentially harmful ways [02]. In education and vocational education, a common basis of values and accepted ethical framework conditions must be sought in order to ensure trust and transparency in the use of AI [08, 10] The greatest difficulty here is to determine the independence of the systems in relation to system boundaries and the effects that exceed these. A decisive feature for characterizing the intelligence of technical systems and thus of AI is the precise understanding of the term intelligence. A definition of the term as above is not sufficient for this. Turing's characterization from 1950 [11] still seems to be the most solid approach for identifying smart systems or intelligent systems. With a view to vocational education and the technical systems found there, Becker et al. [12] have formulated seven characteristics that can be used to check whether a technical system behaves in such a way that it can be attributed to intelligence. The seven characteristics in detail [13, 14, 15, 16]:

2 Kant formulates the categorical imperative in several versions, but the best known is: "Act only according to that maxim through which you can at the same time will that it become a universal law." (Immanuel Kant, Groundwork of the Metaphysics of Morals, 1785).

1. Ability to take in, process, and translate information into behavior appropriate for the situation (informing).
2. Ability to store functions in a "memory"; retrieval (networking).
3. Ability to learn from changing systems and environmental conditions (learning).
4. Ability to make appropriate decisions based on changing systems and environmental conditions (decision making).
5. Ability to independently plan actions based on experience and characteristics of systems and environmental conditions (planning).
6. Increasing communication capability between systems and the human-system complex (communicating) and
7. Ability to focus on the environment when acting in systems (interacting).

The seven points are used to decide whether a technical system behaves intelligently. If the result is positive, caution is advised when using the system.

3 Vocational education and AI

Vocational education is characterized by a wide range of activities. This is due to the fact that the qualification of skilled workers for professional tasks is not a simple process. This also applies to training for simple tasks. Table 1 provides an overview of the broad field and the very different topics in vocational education and training. AI plays a role here as an independent topic, but can also be integrated into the individual subject areas.

Table 1: Diversity of topics in vocational education

Continuous Requirements	**Medium-Term Requirements**	**Long-Term Requirements**
• AI and digitalization • Validation and Guidance • Efficiency and financing • International dimension • Flexibility and responsiveness **Excellence** • Supporting innovation • Regional development • Regional economic strategies • Initial and continuing VET-LLL	Changing world of work Digitalization, Industry 4.0, AI Teacher Training New methods for teaching and learning *Sustainability and green development* • UN Decades • Environment • Natural resources • Categorical Imperative • AI	• AI • Broadening access • Social mobility • Guidance • Validation • Leaving No One Behind • Inclusion

The topics were divided into three stages of time (continuous requirements, medium-term requirements, and long-term requirements), in order to show that each individual topic has a unique dynamic, which has a considerable influence on the prioritization of qualification processes. The wide range of topics also indicates that vocational education and training is already facing significant challenges due to the rapidly expanding field of AI.

Figure 1 provides examples of production related fields of application that are significantly affected by AI, even if AI as an independent topic is still less of an issue. The aforementioned applications make extensive use AI, which has corresponding implications for skilled workers. The unique aspect of this situation is that the skills in question are context-specific and relevant to the respective application. However, the use cases are generally quite diverse, such as

- remote maintenance,
- software support,
- process visualization,
- additive manufacturing,
- innovative management and others.

One consequence of this is that context-specific skills cannot be transferred at will and AI applications differ greatly from case to case. The specific applications of AI in production are usually based on digitalization. In this case, AI and digitalization are inextricably linked. The demand from practitioners with regard to these applications is: "The software must be such that workers can handle it; the process must be supported, the know-how for welding must be mapped there." (Statement of a master craftsman)

Vocational education is currently influenced by a variety of developments and is undergoing a profound evolution driven by

- complex work-processes and the rapid advancement of technologies,
- AI-driven generative technologies,
- digitalization, and
- sustainability.

The consequence of these developments is that qualified specialists with a higher level of skills are generally required so that they can respond appropriately to the expanded and diverse challenges.

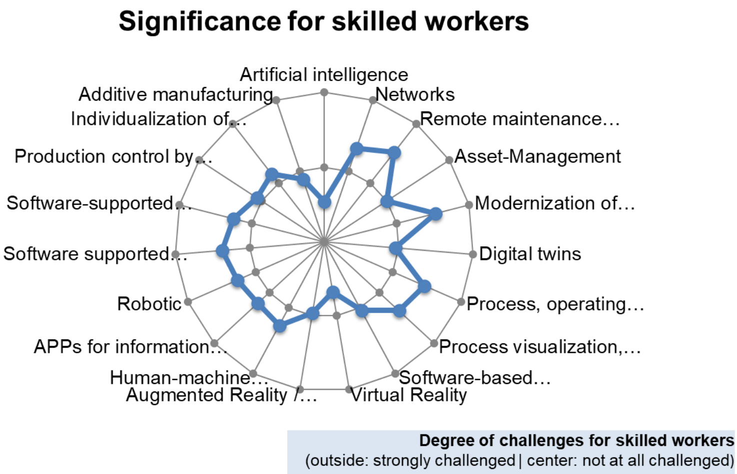

Figure 1: Digitalization and AI in practice [44]

- MES and ERP permeate the shop floor—but Industry 3.0 is a better choice over 4.0
- MES = Manufacturing Execution System
- ERP = Enterprise Resource Planning

AI approaches are used in the following fields in particular.[3] These are highly relevant in vocational education.

Skill-based systems

“Classic” automation, defined as manual skills being performed by increasingly computerized machines, had a significant influence on the first three industrial revolutions and the associated work environments [21, 22]. This type of automation leads, as a further development, to the class of skill-based systems, in which computerized approaches are combined with artificial intelligence. From today’s perspective, it is remarkable that this aspect of automation has primarily resulted in workers having higher qualifications [23]. For instance, professions like mechatronics technicians and warehouse logistics specialists are equally well-received training occupations as they are employment opportunities in the labor market [24]. However, it should not be forgotten that many low-skilled jobs have also been eliminated [25, 26]; the developments have also led to a reduction in physically demanding activities, increasing people’s stress-strain exposure [27].

The situation differs in three additional fields of technology: knowledge-based systems, learning-oriented systems, and simulation-oriented systems. The implications of the emergence of associated technologies on skilled workers are only now becoming apparent. However, changes in the roles of skilled workers can already be identified, which can be characterized by a focus on AI. How to respond to this in the training of skilled workers is a question that has not yet been conclusively discussed.

Knowledge-based systems

“Expert systems are programs designed to emulate the specialized knowledge and reasoning skills of qualified experts in narrowly defined task areas” [28, p. 2]. Such systems have been used since the 1970s in a wide variety of fields, for example, medicine, as well as in production [29], assembly, or automotive diagnostics [30, 31]. The original idea of skilled operation of technical systems (the technical systems replace more difficult tasks of skilled labor) has been largely done away with as these systems have evolved over the last 50 years. Instead, the approach is now limited to very specific areas (agents) and, through human support (assistance systems), makes suggestions rather than decisions. This is why the generic term “knowledge-based systems” has become widely accepted.

3 The following four sections were published slightly modified in German in Becker, Spöttl & Windelband, ZBW 2022 [16]

Learning-oriented systems

"Machine learning (ML), as the core technology of artificial intelligence, offers an alternative to conventional programming. Instead of a program with a calculation rule, the computer is given sample data. Learning methods or algorithms extract statistical regularities from this data and represent them in the form of models. These models can react to new, previously unseen data by categorizing it, generating predictions or suggestions" [32]. Learning-oriented systems are based on approaches with which learning processes can be simulated by machines. As the focus is on handling data in practical applications, automatically evaluated data structures are created that are used in production applications to routinely adapt or optimize systems and facilities— as well as production processes—to changing conditions. One example is image and pattern recognition, which helps to sort components or can instruct robots to grip parts correctly. This "learning process" is implemented using neural networks. The information technology embedded in these systems is not the subject of specialized work, but rather the application created with it. As a result, the skilled worker must intervene at the relevant level if patterns are misinterpreted or external disturbances impair machine learning.

Simulation-oriented systems

The use of simulations increased dramatically in the third industrial revolution in the form of machine processing simulations through to simulations of entire digital factories. Simulation, as a work aid, was used to plan and reproduce advanced and optimized manufacturing and production processes in order to eliminate errors. Today the digital twin model is the focus of Industry 4.0 [33, 34, 35]. Digital twins are digital representations of the object (product, system, or process) and represent reality using software. In most cases, the original operator terminal or human-machine interface (HMI) is used in the applications (i. e., in contrast to simulation, not as a separate simulation program), and hence, it is possible to switch between real-time production control and simulation processes. It is precisely in this form that digital twins are already being used by specialists in Industry 4.0 contexts with the aim of planning, optimizing, and making production more flexible on machines and in production systems as a whole.

In the age of "Industry 4.0", the intelligence of technical systems is assuming an increasingly significant role in the aforementioned technological domains. The concept of networking continues to grow, encompassing the entire value creation process from planning to customer delivery, interconnected both from within (a "smart" factory) and from outside the company. The basis for Industry 4.0 lies in the real-time availability of all relevant information through the networking of all stakeholders involved in value creation, both internally within the company and externally among all suppliers and customers. This connection among people, objects, and systems fosters the development of dynamic, self-organizing, real-time optimized cross-company value creation networks that can be enhanced according to various criteria such as costs, availability, and resource consumption [36].

As a result, it is evident that AI is becoming increasingly more widespread and gaining recognition. The concepts of Industry 4.0 support this process. It can be seen that

- AI needs new and more collaborative endeavors.
- New forms of collaboration between people and technology are emerging, with an increasing number of interdisciplinary teams of commercial and academic professionals working together.
- AI facilitates the networking of knowledge from the most diverse fields (machines, tools, and software), which in turn influences skilled work locally and globally in the most varied forms (in the machine, on the cloud, and distributed within the company and to machine manufacturers), becoming the focus of work.
- In the context of AI, various approaches to the human-machine interface are discussed, such as "human-machine interface as a singular projection unit", "human machine as part of an automated process", the "human who intervenes when necessary", or even the "human who is no longer present in the fully automated process". Here it becomes clear that the focus of human-oriented work design is still in a dynamic stage of development [16, 44]. The results of this discussion will have a considerable influence on the role that humans and, therefore, skilled workers will play in the future. The international debate on the design of cyber-physical production systems with the help of AI is taking on a broad scope [ibid.]. Vocational qualifications are playing an increasingly important role in this discussion [17], especially when it comes to questions of implementation in AI as part of skills development.

Various studies conducted in relation to skilled work in companies have shown that AI has significantly altered the skills required by those with professional qualifications and that the job structure guiding how some of them now perform work-related tasks has completely changed. However, there are still unanswered questions [12, 16]:

- As with digitalization, the question arises as to whether the influence of AI will result in new, independent, or rather integrative competence criteria for vocational-specific work. For instance, should independent learning subjects such as "machine learning" be dealt with in vocational education, or should the professional duties impacted by AI be at the core of learning?
- The growing autonomy of technology, along with its impact on action frameworks, is leading to the replacement of professional skills, some professional qualifications, and perhaps in some cases, entire professions. As with the question of the automation dilemma [38], it now appears to be under the influence of AI: If skills, experience, and decision-making support offered in certain contexts of action are "absorbed" into machines, how can these then be prepared for learning processes and, in turn, transferred to subsequent (skilled worker) generations?
- Will the influence of AI-supported technologies give rise to entirely new or hybrid professions? Following the introduction of production technologists, which arose

more from the concept of an optimal production organization, asset managers are currently seen as a replacement for industrial mechanics, at least in the area of maintenance. The criteria for such an occupational profile would be met by an objectively defined range of duties.
- The notion of AI-influenced skilled work suggests a certain degree of autonomy in addition to the degree of information processing by machines, which is characteristic of digitalization. The latter is usually described from a technological perspective as "machine autonomy"[4][39], but can also be related to human autonomy. The latter applies not only to the relaxing effect of automating manual tasks but also to the new freedom that skilled workers experience when cognitive skills are automated. So what do the new and changed job roles and skill requirements look like when influenced by AI?

4 Status of AI – what can be expected for TVET?

"The complexity of the world and the associated change in knowledge, work, and communication processes is constantly increasing."[18] This development is described by the acronym VUCA world (volatility, uncertainty, complexity, ambiguity). The acronym for the dynamic processes taking place describes the challenges facing individuals in their lives together with the challenges faced by the labor market and educational institutions. According to Lévesque [19, p. 19 ff.], "volatility describes transience. New technologies, ideas, or adaptations often undergo rapid innovation processes, so that familiar stabilities and routines are frequently overturned. This is associated with great uncertainty, because planning certainty is taken away and dealing with what cannot be planned becomes central. Complexity is constantly increasing. Work and business processes are becoming more digital, more networked, and more dynamic. Social contexts are becoming more difficult to penetrate and it is often only possible to clarify connections between cause and effect in retrospect. Finally, ambiguity is increasingly presenting individuals with major challenges, as the common (knowledge) canon is becoming less and less reliable. The environment in which we work and live is changing rapidly, dynamically, often fundamentally, and disruptively. School should enable learners to participate in this very world and society." [18]

This description characterizes the effects on the current situation in the workplace, which are likely to be significantly amplified by AI. If the comprehensive study by Grace et al. [20], which involved the surveying of 2778 experts, is taken into account, then it is to be believed that AI will continue to develop undisrupted: "The chance of unaided machines outperforming humans in every possible task was estimated at
- 10 per cent by 2027 and
- 50 per cent by 2047."

4 Drawing on the debate surrounding the increasingly monitoring oriented role of skilled workers resulting from rising levels of automation, Ohno [39] designed the term 'autonomation' to describe the opposite trend of increasing machine autonomy.

The development of AI will have a significant impact on work design. There are findings on development trends, but concrete prerequisites are still lacking, as discussed by Windelband, 2023.

"A study by the German Institute for Employment Research (IAB) and the German Federal Institute for Vocational Education and Training (BIBB) shows the impact of digitalization in a differentiated way. According to the study, the manufacturing industry will probably witness the heaviest loss in employment due to digitalization. Around 130,000 workplaces are likely to be lost. On the other hand, the study expects that the sector 'information and communication' could probably be the winner in terms of employment with a forecasted 120,000 additional workplaces [40]. The current study 'Automation, Skills Use, and Training', conducted by the Organization for Economic Cooperation and Development (OECD), fears that 14 % of all jobs could be lost in the future due to the fact that robots or algorithms are taking over the tasks. Another 32 % of occupational profiles in the OECD member states would witness a radical change." [41] ([42, p. 209]).

There is currently extensive discussion and speculation around the impacts and specific applications of AI, although the topic has long been covered by daily newspapers and publications, which are attempting to establish themselves. What is certain is that professions are directly affected by these developments. Felten et al [43] consequently developed a model to derive how AI-driven "language models such as ChatGPT will affect occupations, industries, and countries."[5] (cf. Table 2) Findings from the application of the model with regard to developments in 20 occupations are presented: "We find that the top occupations exposed to language modeling include telemarketers and a variety of post-secondary teachers such as English language and literature, foreign language and literature, and history teachers. We also find the top industries exposed to advances in language modeling are legal services and securities, commodities, and investments. We also find that occupations with higher wages are more likely to be exposed to rapid advances in language modeling." [ibid., p. 8]

Table 2: List of occupations sorted by language modeling exposure score [43]

Rank	Occupation Title	Language Modeling AIOE
1	Telemarketers	1.926
2	English language and literature teachers, postsecondary	1.857
3	Foreign language and literature teachers, postsecondary	1.814
4	History teachers, postsecondary	1.813
5	Law teachers, postsecondary	1.802
6	Philosophy and religion teachers, postsecondary	1.800
	Up to position 774	

5 No explanation of the underlying investigation model will be provided.

Studies by Felten et al. confirm that numerous professions are affected by AI and, above all, by AI-controlled language models. The need to address the associated challenges can no longer be ignored. When dealing with AI in the workplace, the question is not so much what type of products—such as self-driving cars, care robots, etc.—are available, but rather what can be described and recorded in well-structured datasets and how this influences the workplace and everyday working life. So far, the insurance and finance sectors, administration, accounting, production, services, and much more have been affected. With AI, the focus of automation is no longer on "physical work" in production, but on "mental work" in office or integrated shop and office floors. The following statement provides an example of this:

> "After digitalization, former white-collar tasks that are still necessary will no longer be performed by white-collar employees, but by blue-collar workers. They will largely perform these tasks using iPads or other digital tools. The result of this process is that the office floor and store floor are increasingly merging. The long information chain as documented in the vertical production pyramid will probably no longer be necessary. Hierarchies in companies will dissolve and the pyramid will be replaced by a flat network. Massive increases in efficiency are expected as a result.
>
> A key feature of this flat structure is that orders will be placed directly on the store floor and workers will be able to make production changes directly. In one example, this form of reorganization reduced the delivery time for a tool from four days to four hours. This was made possible by fully automating the indirect processes. Of around twenty employees, twelve remained in the production area in question. These twelve employees are blue collar workers and are located on the store floor. The white-collar employees have left their former jobs and are now performing other tasks." (Expert 14, specialist for production automation in EVA study) [44].

Up to now, automation in offices has repeatedly reached its limits, meaning that skilled jobs have been retained and new ones created. With AI, however, office work in particular is vulnerable to the new threat of software-based mechanization and rationalization. While rationalization is already well advanced on the factory floor and AI is becoming increasingly widespread, the actual revolution in office work is still to come. Non-standardized, demanding tasks will also be affected by AI. However, the focus will mainly be on, formalizable, well-structured, unstructured, and diffused data and information. AI is particularly powerful where well-structured data and information is available [45]. This means that whenever unstructured and diffused data and information is available, the use of AI is unlikely to be successful and qualified specialists will be required for monitoring and regulation in production, just as they are for office work. However, the quantitative shifts cannot yet be reliably estimated.

> "In industrial production, it has been shown that highly automated technical systems require and will continue to require qualified specialists for monitoring and regulation. Qualification is not synonymous with 'more' systematic, scholastic, and academic knowledge. Theoretical knowledge is important, but not sufficient. A special empirical knowledge of the respective subject areas and processes is just as essential. However, we still need more knowledge about what constitutes experiential knowledge in 'office work with AI'. It is still relatively unclear how skills such as judgment are linked to this. So we need a new look at human work and human work capacity." [ibid., p. 3].

5 AI literacy framework for learning

The need for skills and qualifications, depending largely on the structure of working environments and how work is organized within these environments, will determine how technology is used. This means that the vocational education and higher education systems must provide the highest standard of qualifications for different target groups like

- on the shop floor
- in the engineering department
- for training of teachers and
- for administration, management and others purposes.

Thus, the orientation of requirements in a skilled worker's profile has changed based on the use of AI in industry and the ever-increasing network of work and business processes in companies. Aspects of communication and reasoning within networked systems are increasingly playing an important role for skilled workers on the shop floor [46, 47]. Increasing use of AI in production is leading more and more to a change in the vocational tasks of skilled workers: They have to complete their tasks with digitalized tools, operate the production facilities via human-machine interfaces, and develop their professionalism with the help of digitalized media, assistance systems, and cooperative work structures. More and more, the ongoing merger of information technology and classical production processes can be observed. The decentralized intelligence within the framework of AI leads to a higher availability of highly process-relevant data, which is analyzed, processed, and worked on by skilled workers for the optimization of work processes and problem-solving [42].

This demonstrates that the goal should not be for learners to use AI to calculate and deliver a final result without ever going through the typical learning process. It is simply not enough presenting a final product without being able to show how the result was achieved. The focus must be on the learning process. Being able to produce the end product without having gone through the process is what Nuxoll [48] calls "skill shipping." "It is about acquiring knowledge and skills yourself—through research, critical thinking, and independent formulation. The learning process is what constitutes sustainable education." [ibid.] Despite this requirement, it should be noted that AI can be used anywhere as a basis for learning. Learning can take place both within or outside of "regulatory systems":

Critical

- school and the classroom as learning environments are becoming less important,
- learning from teachers/instructors is losing its significance,
- learning through work-processes (core of the "Dual System") is being replaced by digital media & AI.

Consequence

- The "Dual Concept" of learning in school and at work is losing its "identity"

These widely debated issues [cf. 49, 50] must be addressed in such a way that future education

- be set up in cyber-physical environments,
- take place in an integrated manner both at school and in the workplace, and
- take place directly on digital devices or during production using AI-powered machines.

In order to design learning as a successful process that involves in-depth knowledge and reflection, the design model shown in Figure 2 is a suitable approach. The focus is on designing a learning process in which AI, digital systems, and organizational frameworks are to be developed with learning in mind.

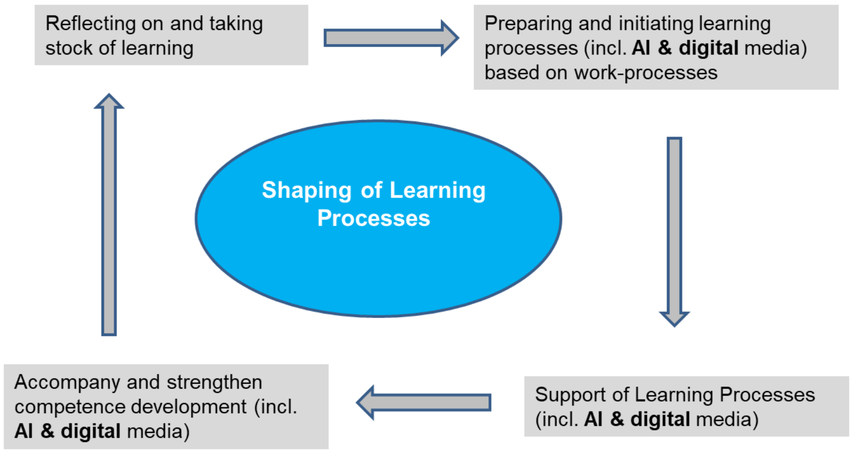

Figure 2: Design model for learning and teaching

A prerequisite for the design of learning processes is the selection of relevant content. An "AI Literacy Framework" can provide assistance with regard to vocational education as a starting step. Several approaches for this were analyzed by Stolpe & Hallström [51]. The framework of "AI Literacy for Technical Education" is of particular interest in vocational education and training. On the one hand, this adheres to a structurally classic framework design through the use of categories such as knowledge, skills, and competences; on the other hand, central elements that define the context and spectrum of learning content are highlighted. Figure 2 exemplifies several characteristic features of "AI Literacy for Technical Education", such as

- a three-part heuristic framework for technology,
- unified framework adjusted in the context of education and technology,
- three dimensions (knowledge, skills, and competences) to describe the quality of the context and depth of ability to use, manage, assess, and understand technology,

- connection to conceptual, procedural, and technological knowledge, and the
- questions of "what?", "how?", and "why?" for the identification of technological scientific knowledge, AI-related technical skills as well as the discussion of ethical implications,
- "Technical skills and practical work with AI are identified as procedural, technological knowledge within the framework of AI literacy. This category describes how one makes things work. In this context, it is also to design and make programs work and solve problems using AI." [51, p. 6]

In the author's opinion, the framework for AI competence in technology education (Table 3) is important for further research in this area. AI competence is now indispensable and requires knowledge, skills, and ethical judgment in relation to these topics [ibid.]. Stolpe and Hallström argue that AI competence should also be considered part of this technological multi-competence. The three dimensions of technological competence [51]: the ability to use technology, knowledge and understanding of technology, and awareness and appreciation of the relationships between technology, society, and the environment could all be illustrated by various components of AI competence (see Table 3). In this regard, this framework is well suited as an analytical tool for defining AI competence more clearly for technology education. Table 3 suggests that the focus on AI competence for students is linked to technological and scientific knowledge (e. g., knowledge about AI and how AI works as part of a technological system) and socio-ethical technical understanding [cf. ibid.].

Table 3: A framework of AI literacy for technological education [51]

	Technological scientific knowledge	**Technical skills**	**Socio-ethical technical understanding**
Epistemological stance Description of the category	Conceptual knowledge Conceptual aspects Definitions Understanding why thinks work or not	Procedural knowledge Skill or ability to make things work Problem-solving Coding	Contextual knowledge Critical thinking, Relating technology to society/the human world, and the environment
Source of knowledge	Technology, engineering, science, and computer science	Experience, trial and error, Practical work, practice, rules of thumb in computing and technology	Humanities and social sciences, philosophy
Analytical question	What?	How?	Why?
Examples from AI literacy	Defining AI Recognising AI Understanding AI Role of data in AI Computational thinking Design thinking Systems thinking	Programming Data literacy, e. g., data use Product development	Consequences? Human role in AI AI ethics AI's impact on society and the environment Privacy, integrity, and cyber security Bias

However, for vocational education and training, especially for TVET, work and work organization are important in addition to technology. This means that the development of technological skills alone is not far-reaching enough. It must be expanded to include work and work organization and vocational competences must be developed that demonstrate the ability to shape the relationship of work and technology and to use, manage, assess, and understand work requirements.

The design of an AI literacy framework in VET can be managed with reference to work processes, which also ensures the connection to technologies. Figure 3[6] outlines the key points of a "work-process related framework of AI literacy for TVET". The work dimensions (with tools, work methods, and skilled work) are at the core of the framework alongside the competencies. The levels are listed vertically, with VET graduates primarily assigned to levels 3, 4 and 5.

When designing the AI Literacy Framework for TVET, particular consideration must be given to the degree of autonomy granted to professionals in their actions. In addition to the technological dimension, social, personal, and ethical components as well as values and sustainability must also be taken into account, as these influence the design of human-machine interfaces and the action structures that people want and can handle.

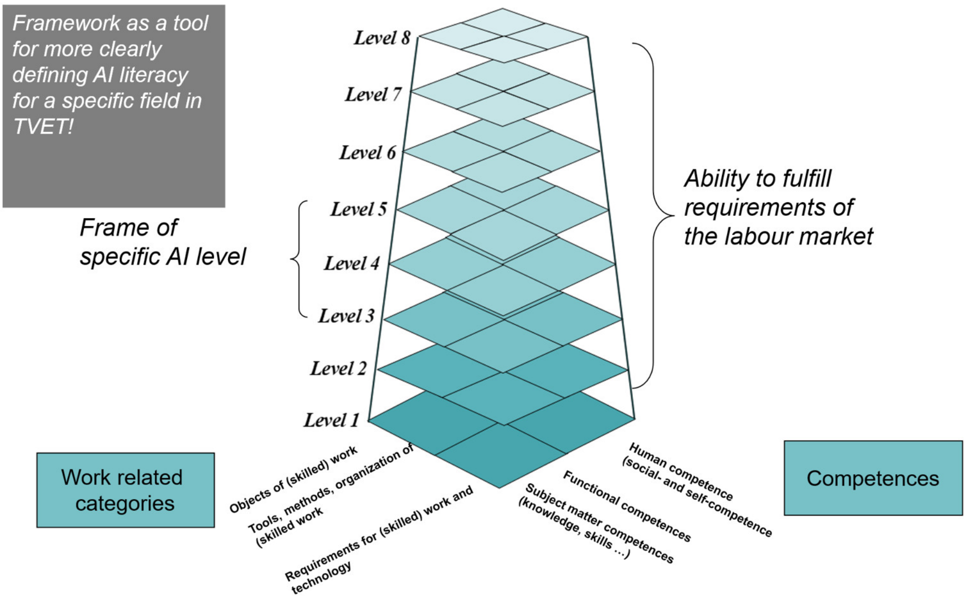

Figure 3: Dimensions of a work-process related framework of AI literacy for TVET [52]

6 A detailed description of the framework is not provided here, as development work is still required.

A core aspect of AI is the change in autonomy levels on the vertical level between the human and the autonomous system. In autonomy levels 0 to 2 (see Table 4), there is a certain ability to perform (partial) autonomous actions. However, these are limited in their scope and the human is always in active control and still bears central responsibility. In stages four and five, the system assumes responsibility—initially for partial areas and partial aspects, then for the entire system, and the human largely plays a passive role [36, 37].

Stages four and five could lead to a serious loss of jobs, particularly at the skilled worker level; at the same time, the question arises as to whether the ability of skilled workers to deal with complex situations will disappear as AI takes over decision-making. Stage three can be seen as a transition from “more human” to “more machine” [51].

Table 4: Overarching definition of the levels of autonomy in industrial production that are not/little influenced by AI [36]

Level 0	*No autonomy,* *Person has full control without assistance.*
Level 1	*Assistance with selected functions,* *Person is always responsible and makes all decisions*
Level 2	*Temporary autonomy in clearly defined areas,* *People are always responsible and set (partial) targets*
Level 3	*Limited autonomy in larger sub-areas,* *System warns of problems, human confirms proposed solutions from the system or acts as a fallback level*
Level 4	*The system works autonomously and adaptively within certain system limits, humans can monitor or act in emergency situations*
Level 5	*Autonomous operation in all areas, also in cooperation and in changing system boundaries, humans can be absent.*

Ultimately, the major challenge lies in mastering the complexity of these systems. Data and information must be interpreted and evaluated appropriately, whereby this is increasingly being realized using machine learning methods and yet specialists still have to make decisions and help shape complex production processes responsibly. The human interface will therefore play a decisive role.

6 Implementation steps of a AI literacy framework for TVET

It is recommended to promote the implementation of an “AI Literacy Framework for TVET” as a framework for curriculum development. One of the supporting pillars in a first step can be UNEVOC, because this institution is able to establish “Alliances for Promoting AI in Vocational Education Training & Learning”. These Alliances should have the intention to make sure that all interdependences in our lives are geared towards a human centered orientation.

The advantage of an alliance is that stakeholders with different backgrounds can work together to secure the content framework of the AI Literacy Framework for TVET, which in turn is a prerequisite for curriculum development. With the help of UNEVOC, it is also possible to initiate ideas and proposals for the framework from different countries around the world in order to guarantee a valid framework.

When designing the AI Literacy Framework for TVET, it is important to align it with work processes and AI that are relevant to TVET. This would create the prerequisites for curriculum development that is human-centred and can take AI, digitalization, and sustainability into account in a corresponding manner.

As part of curriculum development, the first step is to clarify which occupational profiles are particularly affected by AI and how specialists should be qualified for them. Secondly, it is important to clarify how to respond to the increasing autonomy of AI, which is increasingly using intelligent technologies in learning processes and in the design of learning processes. The question is how humans can remain competitive. And thirdly, it needs to be clarified: If competences, experiences, and decision-making are "absorbed" into machines, how can these then be prepared for learning processes?

The challenges for the development of curricula for vocational education are therefore considerable. However, this is not surprising, as it is also about the simple question of whether humans will still have a place in the world shaped by AI in the future.

7 Summary

The explanations deal with the use of AI at the level of skilled work and the consequences for the design of learning in vocational education and training. The central objective is to develop a "Critical & Reflexive AI Competence" [53] and to ensure that people have sovereignty over the use of technological developments. What consequences this has for the design of learning, is the focus of the previous explanations. It is clear that one of the first and important steps has so far been underexposed, namely developing curricula for the fields of work that are the focus of vocational training. As a first step, it is therefore proposed that AI literacy frameworks for TVET be developed in order to provide a content framework for curriculum work. Clarification is required as part of this development:

a) How skilled work is changing in individual sectors due to technological and work organization changes and what this means for skills development.
b) Based on the knowledge gained in how and which occupational profiles are to be established.
c) Another point to be clarified is how learning and action-based learning can and should be organized as technology continues to become increasingly autonomous.
d) Whether job profiles, professional skills, or even entire professions should be redesigned or replaced also needs to be clarified.

In all work and especially in curriculum development, there is a confrontation with a completely new situation: Competencies, decisions and actions are being shifted to AI-supported process sequences of machines. In this case, answers must be found as to how to qualify for these new circumstances.

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UNESCO AI Framework in Higher Education: Implementation and Results

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Artificial intelligence (AI) is rapidly transforming educational systems, requiring new competencies for learners and educators. This pilot study examines the application of UNESCO's AI Competency Framework in a master's-level course at Otto von Guericke University Magdeburg. The course integrated AI tools, open-source technologies, and ethical considerations into a Quantitative Research Methods module for future vocational educators. The evaluation with twelve graduate students used pre-post surveys and qualitative feedback to assess competency development. While quantitative measures showed no significant changes, qualitative evidence revealed strong engagement, perceived learning benefits, and development of critical AI literacy. Students demonstrated increased confidence in AI use and ethical awareness. The study highlights the potential of open-source AI in education and suggests that sustained, long-term integration across curricula is necessary for measurable competency gains. Findings offer practical insights for institutions implementing AI in teacher training programs.

Introduction

Artificial intelligence (AI) is rapidly transforming economies and workplaces, driving an urgent need for educational systems to adapt [1, 2]. In vocational and higher education, AI-driven automation can enhance productivity and create new opportunities, but it also poses challenges such as job displacement and changing skill requirements [1, 3]. These developments place pressure on technical and vocational education and training (TVET) institutions and universities to equip learners with 21st-century skills, including critical thinking, problem-solving, digital literacy, and AI literacy, that enable them to thrive alongside intelligent machines [4–6]. AI integration in education must therefore be guided by humanistic values and ethical considerations to ensure technology augments human capabilities rather than replaces them [7]. UNESCO's 2019 Beijing Consensus on AI in Education and its Recommendation on the Ethics of AI (2021) emphasize that AI should be used to promote equity and quality in education while safeguarding human rights, transparency, and privacy [7]. In response, international and European policymakers have outlined frameworks to harness AI for inclusive and sustainable progress, aligning with broader digital transformation agendas [2, 8]. Against this backdrop, UNESCO has developed AI competency frameworks to guide the integration of AI into teaching and learning. In 2024, UNESCO released a comprehensive competency framework for teachers, advocating that AI knowledge, ethics, and pedagogical applications be embedded across curricula rather than taught in isolation [9]. The framework outlines key competency areas from fostering a human-centered mindset and understanding AI ethics to applying AI in pedagogy and professional development at progressive levels of mastery [10]. It provides a valuable blueprint for higher education programs that prepare future educators. At the same time, UNESCO-UNEVOC's initiatives on "TVET in a Digital World" reinforce the need for institutions to actively address digital and AI-driven changes, ensuring that learners are prepared for the evolving world of work [11].

This article examines the application of the UNESCO AI competency framework in a higher education context. We present the theoretical and didactic background for integrating AI in higher and vocational education, justify an open-source implementation approach, and outline a pilot course that applied these ideas. We then report on pilot evaluation findings and discuss their implications. The work builds on prior research and practical projects by Tegelbeckers and colleagues, including curriculum design strategies for AI in teacher training and open educational resource development [12–14]. By synthesizing these efforts, we aim to provide an outline of how AI competencies can be incorporated into higher education curricula, describe an implementation case at the Otto von Guericke University Magdeburg, and share insights from its preliminary evaluation. Ultimately, this study offers lessons learned for educators and institutions looking to responsibly integrate AI in teaching and learning, aligning with UNESCO's vision for augmenting human capacity through technology [7].

AI Integration and Competency Needs in Education

The introduction of AI and advanced digital tools is driving a profound shift in the competency requirements for both learners and educators. In vocational sectors, often termed "Industry/Training 4.0," technologies like robotics, drones, and AI-powered systems are augmenting or replacing traditional tasks, necessitating new digital skills alongside core domain skills [7, 11]. For example, in the construction trades, routine tasks such as surveying and measurements can now be performed with drone imaging and AI analysis, greatly improving efficiency and precision, but the workforce must learn to operate these tools and interpret their outputs [11]. As routine procedures become automated, greater emphasis falls on higher-order cognitive skills: problem-solving, critical thinking, and data-driven decision-making [4, 5]. These so-called 21st-century competencies are widely recognized as essential across all fields in the AI era [5, 15].

In the context of teacher education, integrating AI requires not only imparting technical knowledge of AI applications but also reshaping pedagogical approaches. Teachers are challenged to blend traditional instructional expertise with new digital competencies, ensuring that technology is used to enrich learning rather than distract or widen equity gaps [7]. Research indicates that simply adding isolated modules on digital skills is insufficient; instead, effective curricula embed digital and AI competencies throughout subject content and pedagogical training [16]. For instance, Ehlers and colleagues highlight the importance of integrating open educational resources and digital tools into everyday teaching practice to build educators' capacity. Consistent with this view, many educators argue that digital and AI tools should be treated as integral components of the curriculum rather than as standalone topics [ebds.]. This implies, for example, teaching engineering education students not only the theory of their discipline but also how to leverage AI-based tools (like simulation software or intelligent tutors) in their future classrooms in tandem with hands-on techniques. Such an integrative approach is echoed at the policy level: UNESCO-UNEVOC's "Digital Transformation in TVET" initiative calls on institutions to embed digital literacy and AI awareness across vocational curricula to prepare learners for a technology-rich workplace [11]. UNESCO's guidance further underscores that AI integration in education must be accompanied by strengthening "human" skills and ethical awareness [7]. The UNESCO AI and Education Guidance for Policymakers stresses developing learners' capacity for critical evaluation of AI outputs and ensuring that teachers can guide students in understanding both the potential and limitations of AI. In practice, this means curricula should cover foundational AI concepts (what AI can and cannot do), data literacy, and the social implications of AI. It also means fostering a mindset where AI is seen as a tool to enhance human learning, for example, through personalized learning or intelligent tutoring systems, while maintaining the teacher's role in providing context, mentorship, and moral guidance [7, 3]. Recent studies of AI in the workforce similarly emphasize that AI's ultimate impact depends on how well humans are prepared to work alongside these systems [6, 17]. Thus, education systems must evolve to cultivate adaptive, lifelong learners who can continuously reskill in the face of AI-driven change [6].

UNESCO AI Competency Framework for Educators

A key development in articulating these new competency needs is the UNESCO AI Competency Framework for Teachers [10]. This framework (released in 2024) provides a structured outline of the knowledge, skills, and attitudes educators should develop to effectively harness AI in educational settings. It identifies five core competency domains for teachers: (1) Human-Centered Values and Mindset, (2) Ethics of AI, (3) AI Knowledge and Application, (4) AI in Pedagogy, and (5) Professional Development with AI. Within each domain, competencies are further described at three ascending levels from basic awareness ("Acquire"), to practical integration ("Deepen"), to leadership in innovation ("Create") [10]. For example, under the Ethics of AI domain, a teacher at the "Acquire" level is expected to understand basic ethical principles and risks of AI (such as issues of bias or privacy), at "Deepen" to analyze ethical implications of using AI tools in their own teaching context, and at "Create" to actively develop or enforce ethical guidelines for AI usage in their institution [10]. Similarly, the AI Pedagogy domain progresses from understanding how AI can support teaching and learning (basic level), to adapting teaching methods with AI support (intermediate), and finally to designing innovative AI-enhanced pedagogical approaches (advanced level).

This framework builds on prior UNESCO initiatives like the ICT Competency Framework for Teachers [18] but updates the focus to AI-specific challenges and opportunities. Crucially, UNESCO advocates that these AI competencies should not remain abstract ideas but be embedded in teacher training curricula and professional development programs [9]. In other words, universities and training institutes need to redesign their courses so that future teachers progressively achieve these competencies. For instance, a teacher education program might include activities where students critically reflect on the benefits and limitations of AI in their subject area (addressing the human-centered mindset and ethics), get hands-on experience with educational AI tools (addressing AI applications in pedagogy), and learn to use AI for their own learning (e. g., using AI for lesson planning or research, addressing professional learning). By aligning curricula with the UNESCO framework, institutions ensure that graduating teachers are not only comfortable with using AI tools but can do so in an ethical, pedagogically sound manner that prioritizes human agency and equity [9, 10]. Notably, UNESCO has also introduced an AI competency framework for students, with parallel goals of cultivating AI-ready graduates who possess basic AI literacy, technical skills, and an understanding of AI ethics [9]. Both frameworks emphasize that AI competencies should be integrated across disciplines. In vocational contexts, for example, healthcare students might learn about AI-driven diagnostic tools as part of their training, or automotive apprentices might explore how machine learning is used in modern vehicle systems [9]. This holistic approach reflects a broader consensus in the literature: effective AI integration in education is not achieved by one-off courses on AI but by weaving AI-related knowledge and critical thinking throughout the fabric of existing curricula [19, 20].

Open-Source Approaches and Didactic Strategies

Implementing AI in education brings practical and ethical considerations regarding the choice of technologies. One significant strategy highlighted in the literature is the use of open-source AI tools and open educational resources (OER) in order to ensure accessibility, adaptability, and sovereignty over educational content [16, 21]. An open-source approach aligns with UNESCO's recommendation to leverage OER for inclusive and equitable education, as formalized in the 2019 UNESCO OER Recommendation [16]. By using open-source AI systems, educational institutions can benefit from what UNESCO-UNEVOC describes as the "core freedoms" of open software: the freedom to use the technology without restrictive licenses, to study and understand its workings, to modify it for local needs, and to share improvements with the community [21]. In practical terms, these freedoms translate into greater autonomy and transparency for educational AI deployments [21]. For example, if a university adopts an open-source AI tutoring system, it can inspect the algorithm for biases, host the system on its own servers to protect student data privacy, localize the content to the native language, and contribute new features or modules that address its specific curriculum. This stands in contrast to proprietary AI platforms, which often function as "black boxes" and may raise concerns about data security, algorithmic opacity, ongoing costs, and dependency on vendors [22]. Recent discussions in Europe have underscored such concerns; for instance, Germany's data protection authorities have questioned whether popular proprietary services like ChatGPT comply with privacy laws, prompting interest in self-hosted AI solutions [22]. Besides ethical and legal advantages, open-source AI can offer cost reduction and collaborative innovation benefits for the education sector. Without license fees, institutions can redirect funds to infrastructure or training. Educators worldwide can collaboratively develop and share AI-enhanced teaching materials when they are built on open platforms [16]. This community-driven model has precedent in the OER movement, which has produced freely available textbooks, curricula, and multimedia resources across disciplines [16]. In the context of AI, a notable example is the emergence of large repositories like Hugging Face, which hosts millions of open models that can be fine-tuned or adapted for educational purposes [21]. Such an ecosystem enables even resource-constrained institutions to experiment with state-of-the-art AI tools (given adequate technical support) and contributes to the democratization of AI in education.

From a didactic perspective, using open-source AI and OER aligns with constructivist and learner-centered approaches. Instructors can tailor open-source AI tools to fit their pedagogical design, embedding them seamlessly into learning activities. For instance, an engineering pedagogy course could incorporate an open-source code analysis AI to help students debug programming exercises, with the instructor modifying the AI's knowledge base to align with the exact curriculum content. This flexibility supports self-directed learning and inquiry; learners can explore AI-driven modules at their own pace, while educators retain oversight and can continuously improve the content [14]. The authors describe such a strategy in the context of a teacher training curriculum: they integrated various digital tools (programming microcontrollers, data analysis software, etc.) using an open-source strategy, which allowed pre-service teachers to experience and tinker with technologies in a sandbox environment. The focus was on enabling hands-on, self-regulated learning experiences, where students take initiative in using tools to solve problems, reflecting the role shift from teacher as knowledge-deliverer to facilitator of learning [14]. This approach not only builds technical skills but also impacts the learning environment and the teacher's self-image; educators learn to become co-learners with technology, comfortable in exploring and even creating new digital learning solutions. In summary, the literature advocates for a confluence of: (a) theoretical frameworks (like UNESCO's) to define what competencies are needed in the AI era; (b) curriculum integration strategies that embed those competencies into authentic learning contexts; and (c) open, human-centered technological approaches that ensure the integration is ethical, inclusive, and adaptable. The next sections of this paper turn to a practical application of these principles: a pilot implementation in a master's-level course, which incorporated the UNESCO AI competency framework into its design and utilized open-source tools and AI-enhanced methods to enrich learning.

Methodology

The pilot course was implemented within the master's program International Technical Vocational Education and Training (ITVET) at Otto von Guericke University Magdeburg during the winter semester 2024/25. The selected module, Quantitative Research Methods, is a one-semester course designed to introduce graduate students, primarily future TVET educators and researchers, to the fundamentals of research design, statistical analysis, and the use of R for data processing. For the pilot, the course was systematically re-designed to embed competencies from the UNESCO AI Competency Framework for Teachers [10] while maintaining its original focus on methodological literacy. Targeted competencies included fostering a human-centered perspective on AI, basic ethical awareness, practical skills in AI-supported research processes, pedagogical application of AI in teaching, and the use of AI for professional productivity. To integrate these competencies without compromising methodological content, a blended design was adopted. Each week conventional lectures and exercises were combined with AI-enhanced activities. For example, in early sessions, students learned the basics of R while simultaneously practicing prompt engineering with a generative AI system to support coding and interpretation tasks. Dedicated sessions on AI prompting introduced interaction strategies with language models, first through instructor-provided examples and later through self-directed prompt design. Students were granted continuous access to a locally deployed AI chatbot, which they could consult for clarifications, practice problems, or alternative explanations. Documenting these interactions in weekly assignments encouraged reflective engagement and aligned with the framework's emphasis on AI-supported continuous professional learning.

The course was delivered via LiaScript, an open-source authoring tool that enables interactive learning materials in Markdown [23]. All course materials were produced as open educational resources, including lecture notes, quizzes, and code examples. LiaScript's affordances for embedding quizzes, surveys, and live code execution facilitated the integration of interactive AI elements. One innovation involved the semi-automated generation of weekly self-test quizzes: key lecture points were extracted and processed by a fine-tuned open-source language model trained on educational Q&A data. The resulting items were reviewed and refined by the teaching team before inclusion, thus modeling "human-in-the-loop" approaches to AI-assisted pedagogy and illustrating for students how AI can support material generation while still requiring critical oversight. The decision to employ open-source and locally hosted AI models was deliberate, addressing concerns about privacy, data protection, and institutional dependency on proprietary systems [22, 21]. A distilled 7-billion-parameter transformer model, comparable to LLaMA and adapted to educational contexts, was deployed within the university's secure environment. Although less powerful than commercial systems, it was adequate for factual assistance and hint generation. This approach balanced functional utility with regulatory compliance and pedagogical transparency, while technical support ensured equitable access for students.

Assessment was explicitly aligned with the AI integration. Students were evaluated on R coding accuracy (30 %), interpretation of results and methodological tasks (30 %), AI prompt development and usage (20 %), and a final paper (20 %). The inclusion of prompt development as a graded component required students to submit weekly documentation of their AI interactions, including the rationale for prompts, evaluation of responses, and reflection on the tool's usefulness. This practice encouraged critical engagement with AI outputs and built competencies for professional use of AI in teaching and research. The course culminated in a group-based research project in which students investigated an aspect of AI in TVET or education, combining quantitative methods with AI-supported workflows such as literature summarization or data visualization. Ethical use of AI in academic writing was emphasized throughout, requiring verification of AI outputs and appropriate citation, thereby reinforcing competencies in both ethics and professional learning.

Evaluation Methods

To evaluate the effectiveness of the AI-integrated course design, a pilot study was carried out using a pre-post survey combined with the university's standard course evaluation tools. The central questions guiding this evaluation were whether the integration of AI and UNESCO framework competencies contributed to improvements in students' AI-related skills or attitudes, and how students assessed the added value of AI in their learning experiences after completing the course. A total of twelve graduate students participated, representing backgrounds in education, engineering, and vocational training. All students consented to take part in the evaluation. Their initial exposure to AI in educational contexts was diverse; while all had at least heard of tools such as ChatGPT, only about one-third reported having actively employed AI for learning or teaching tasks before enrolling in the course, as indicated in the preliminary survey. The survey instrument was specifically developed for this evaluation and drew upon the UNESCO AI Competency Framework as well as established research on AI acceptance [20, 24]. The questionnaire employed a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) and included items designed to capture different aspects of competency development. These included familiarity with AI in educational practice (e. g., "I understand how AI can be applied in teaching and learning"), intention to integrate AI into future academic or professional work (e. g., "I plan to incorporate AI tools in my professional practice"), attitudes toward the voluntary use of AI (e. g., "I would voluntarily use AI to assist with complex tasks even if not required"), and ethical awareness (e. g., "I am aware of the ethical implications and risks of using AI in an educational context"). Together, these constructs reflected key competency domains such as knowledge of AI, intent to apply it, mindset toward its use, and awareness of ethical considerations. The questionnaire further invited open-ended reflections, encouraging participants to share their experiences with the AI tools introduced in the course.

As stated, the survey was administered as a pre-post test at two points in time, once at the beginning of the semester and once during the final week. In addition to these instruments, the university's standardized course evaluation form was collected, providing both a summative rating of the course and qualitative insights into aspects students considered most and least useful. For the quantitative data, paired statistical tests were planned to assess potential changes between the two measurements. Given the small sample size and evidence of non-normal response distributions from initial checks, the analysis relied on non-parametric tests, specifically the Wilcoxon signed-rank test, to evaluate the Likert-scale responses. Hypotheses were formulated for each of the competency domains. These included the expectation that students would demonstrate significantly higher familiarity with AI after the seminar compared to the beginning (H1.1, with the null hypothesis being no difference), that their intention to engage in AI-related opportunities or use AI in their careers would increase (H1.2), that attitudes toward voluntarily using AI tools would become more positive (H1.3), and that ethical awareness concerning AI in education would be strengthened (H1.4). The significance level for statistical tests was set at $\alpha = .05$. Normality checks on the pre-test scores using the Shapiro-Wilk test were also performed to guide test selection and interpretation of outcomes. The qualitative material from open-ended survey items and the course evaluation was analyzed thematically. Responses were coded to identify recurring patterns such as the perceived usefulness of AI assistance, challenges encountered in applying the tools, and suggestions for further improvement. This qualitative analysis complemented the statistical findings, offering a deeper understanding of how learners experienced the didactic design and allowing for a more comprehensive assessment of the course's effectiveness.

Results

The analysis of pre- and post-survey data revealed no statistically significant changes in students' competencies or attitudes toward AI, even though slight increases in mean scores could be observed across most items. In the case of familiarity with AI (H1.1), the composite index rose from a mean of 3.0 to 3.3 on a five-point scale, yet the Wilcoxon test confirmed that the change was not significant ($p > .05$). Similarly, students' intention to use AI in their professional careers (H1.2) showed a small increase from an average of approximately 3.5 to 3.7, though again this difference was not significant. Attitudes toward voluntary use of AI tools (H1.3) remained consistently high, with means of 4.2 at the start and 4.3 at the end, indicating stable enthusiasm rather than measurable growth. Ethical awareness (H1.4) was also relatively strong from the outset, with a pre-course mean of about 4.0, and only a modest, non-significant rise to around 4.2 following the intervention. Taken together, these findings suggest that while the direction of change was positive, none of the hypothesized improvements reached statistical significance at the conventional 5 % threshold. This outcome underscores the possibility that a single-semester course, even one explicitly designed around AI integration, may not suffice to substantially alter self-perceptions of competencies or attitudes, especially within a small pilot group. It may also reflect the fact that participants already entered with comparatively high baseline awareness, thereby limiting the scope for measurable gains.

Normality testing of pre-test distributions confirmed non-normal patterns for certain measures, such as familiarity and intention, with Shapiro-Wilk values indicating deviations from normality ($p < .05$). This justified the choice of non-parametric statistical methods and also highlighted the limitations in detecting changes with such a small sample. Ceiling effects may also have influenced outcomes, particularly in the domain of attitudes, where participants already expressed strong curiosity and openness toward AI before the course began. A small upward trend in ethical awareness was observed, a domain emphasized in the curriculum through discussions and case-based activities, but again the variability was insufficient to yield significant results. Given the exploratory nature of the pilot and the limited sample size, the quantitative results should be treated cautiously. Rather than indicating the absence of any effect, they point to the need for longer-term, more intensive interventions in order to produce measurable changes in teacher candidates' competencies and perspectives on AI. They also highlight the necessity of complementing statistical outcomes with qualitative evidence to obtain a more comprehensive understanding of impact. Despite the absence of significant shifts in the numerical indicators, students' subjective evaluations reflected strong appreciation of the course and its integration of AI. The overall rating of the seminar in the final course evaluation was high, with an average of 4.1 on a five-point scale, a median of 4.1, and a standard deviation of 0.6. All participants rated the course as either good or excellent, a result that exceeded the typical departmental average and suggested that the experimental design enhanced rather than diminished their learning experience.

The qualitative feedback revealed several recurring themes. Many participants highlighted increased engagement, noting that the AI activities and interactive LiaScript elements made the course more dynamic. One student commented that the weekly AI activities made statistical content feel less dry and sustained their motivation. Others emphasized perceived learning benefits, explaining that the AI tools often provided simplified explanations or concrete examples when lecture content was difficult to grasp. In this sense, the AI functioned effectively as a supplementary tutor, reflecting findings from the literature on intelligent tutoring systems [25]. A number of students also reported improvements in their confidence with AI use, describing a newfound ability to employ such tools effectively and with caution. They frequently pointed out the importance of verifying AI outputs, particularly when working with R coding tasks, illustrating the development of a critical and reflective mindset that the course aimed to foster. Time management and workflow improvements were also noted, with several students explaining that the AI helped them save time on technical tasks and allowed them to focus more on conceptual learning, although others acknowledged an initial learning curve in formulating effective prompts.

Some challenges were also recorded. A small number of students mentioned technical issues, such as occasional timeouts of the local AI model or compatibility problems with LiaScript in older browsers, which caused temporary frustrations. Suggestions for future iterations included offering alternative access options to AI tools in case of technical failures. A few participants also found the concurrent introduction of R and AI demanding, proposing that the AI component might be introduced later in the semester to allow for gradual acclimatization. From both instructors' observations and students' deliverables, it became evident that several dimensions of the UNESCO framework were actively addressed during the course. By its conclusion, all students were able to articulate at least one ethical consideration concerning AI, with issues such as bias in training data and data privacy emerging spontaneously in their discussions and written work. Students also demonstrated preliminary abilities in AI pedagogy, for instance through a project that designed a chatbot-assisted lesson plan to support automotive mechanic apprentices in learning technical English. Furthermore, professional learning was evident in the way participants employed AI in their own academic work, including tasks such as summarizing research articles or generating quiz items for peer activities. Although these outcomes were largely anecdotal and qualitative in nature, they indicate that the course contributed to meaningful skill development and mindset shifts, even if these changes were not fully captured in the self-report scales. The combination of positive feedback, demonstrated application of AI in educational scenarios, and a heightened critical awareness of both the potential and the limitations of AI suggests that the intervention achieved important aspects of its intended learning outcomes.

Discussion

The pilot implementation of an AI-integrated course provides several non-surprising insights for applying the UNESCO AI competency framework in higher education, particularly in teacher training contexts. First, the lack of statistically significant change in survey measures suggests that building true "competence," especially in areas like ethical awareness or mindset does require more than a single module; it likely needs reinforcement across a program and real-world practice. This aligns with broader findings that developing complex competencies (like digital ethics or reflective thinking) is a gradual process [26]. Future iterations might extend the intervention duration or integrate follow-up activities in subsequent courses to strengthen the impact. The high baseline interest and positivity toward AI among students is both an opportunity and a caution: on one hand, there is enthusiasm to harness (they were eager to use AI tools), but on the other hand, high initial comfort could lead to overconfidence. We observed that some students were prone to trust the AI's answers early on; only after prompting from instructors did they recognize errors and learn to verify. This underscores the importance of embedding critical evaluation skills whenever AI tools are introduced [7, 3]. In the pilot, having a dedicated component for prompt development and requiring reflection on AI output quality was one strategy to address this. In the future, even more structured reflection could be incorporated, such as a required journal where each student records an instance of the AI being wrong or biased and how they dealt with it. This could further solidify the ethical and human-critical competencies.

The positive qualitative feedback and high satisfaction ratings indicate that integrating AI in the curriculum, when done thoughtfully, can enhance student engagement and perceived learning. Importantly, this integration did not detract from core content learning (in this case, quantitative methods). On the contrary, students might have gained a deeper understanding of research concepts by approaching them from multiple angles (lecture, practice, and AI-assisted exploration). This points to a potentially synergistic relationship between AI tools and traditional teaching: AI can provide personalized, just-in-time support (e. g., explaining a concept differently), while human instructors and peers provide context and depth [25]. The challenge for educators is to design activities that leverage AI's strengths (like rapid information retrieval, generation of examples, and endless patience in tutoring) without giving it free rein to possibly mislead or without letting it replace essential cognitive efforts by students. In our course, we balanced this by keeping human grading of reasoning and by making AI use transparent (students had to show how they used it). This likely prevented over-reliance on the AI for answers, and instead, students used it as a learning aid. Future research could formally examine whether such integration affects learning outcomes on the primary subject matter (did these students learn statistics as well as or better than a control group without AI?).

From an implementation perspective, the open-source approach proved feasible and aligned with the values of both the institution and UNESCO's educational agenda. By using open-source AI components, we not only navigated data privacy requirements but also demonstrated to students (future educators) that powerful educational tools can be built and used in a commons-based paradigm. One student noted in feedback, "I didn't know there were open alternatives to commercial AI, as a teacher, I find it good that there are free tools I could actually use in my classroom without legal issues." This comment highlights a seldom-quantified outcome: raising awareness of open educational technologies. In a landscape often dominated by commercial EdTech solutions, showing tomorrow's teachers that community-driven tools exist and can be effective is valuable. It resonates with UNESCO-UNEVOC's advocacy for OER and open innovation in education [16]. However, one trade-off we observed is that open-source AI, especially local models, may lag behind cutting-edge proprietary models in capability or ease-of-use. Some students naturally compared our local AI assistant to ChatGPT (which a few had used outside class) and found it a bit less fluent or knowledgeable on niche questions. This suggests that as educators we must carefully evaluate the maturity of open tools we deploy. In our case, the gap was not significant for the tasks at hand, and it sparked a good discussion as to why we chose a local model, directly tying into ethical reasoning. But for scalability, one could imagine using a hybrid approach: e. g., relying on open models for most interactions and perhaps allowing a vetted use of a cloud API for particularly complex queries, all while educating students on the privacy implications.

The study's limitations warrant discussion. The sample size was small and context-specific, so findings may not generalize. The evaluation focused on short-term self-reported metrics; it did not track longer-term retention of skills or actual classroom behavior, which would be the true test of whether the competency framework training "sticks." Additionally, the absence of a control group means we cannot isolate the effect of the AI integration from other factors (e. g., novelty effect, instructor enthusiasm, etc.). Future studies should compare similar courses with and without AI integration to empirically measure differences in learning outcomes and attitudes. There is also a possibility of response bias in the surveys; since the instructor was promoting AI usage, students may have felt pressure (even unintentionally) to respond favorably about AI in their feedback. We tried to mitigate this by anonymizing surveys and emphasizing honest feedback, but it remains a consideration.

Reflection on AI Support in Academic Writing

A further dimension of this study concerns the role of AI not only in teaching but also in the academic practices of educators themselves, as illustrated by the preparation of this article. In drafting the manuscript, the authors systematically experimented with multiple generative AI systems – ChatGPT, Claude AI, Perplexity, and Consensus AI – each deployed strategically according to its distinct capabilities. This multi-model approach served as both a practical workflow enhancement and a test case for the current affordances of AI in scholarly writing, while modeling ethically transparent research practices. ChatGPT was primarily utilized for initial brainstorming, structural outlining, and generating provisional summaries of frameworks such as UNESCO's competency model [27]. Claude AI was employed for tasks requiring greater analytical depth, including critical synthesis of theoretical perspectives, conceptual refinement, and substantive revision of arguments for coherence and precision [28]. Perplexity was consulted for rapid literature scanning and identification of recent developments in AI-supported pedagogy, leveraging its real-time web search capabilities [29]. Consensus AI facilitated systematic review of empirical research, particularly for identifying scholarly consensus and emerging patterns across multiple studies in the field [30]. The rationale for using different models reflects a pragmatic recognition that contemporary AI systems exhibit varied strengths: ChatGPT excels at generative fluency and structural suggestion; Claude demonstrates more sophisticated reasoning and nuanced analytical capabilities; Perplexity provides efficient access to current information; and Consensus AI specializes in academic literature synthesis. By matching tool to task, the authors aimed to optimize both efficiency and quality while avoiding over-reliance on any single system.

The experience revealed both utility and limitations across all platforms. While AI tools expedited early drafting, literature identification, and stylistic variation, the generated text consistently required substantive human correction for factual accuracy, analytical depth, and disciplinary precision. This aligns with emerging evidence that large language models can accelerate routine academic writing processes yet remain dependent on human expertise for scholarly rigor. All outputs were critically reviewed, verified against source material, and substantially revised to ensure accuracy, conceptual alignment, and stylistic coherence. In acknowledging these contributions, we follow principles of ethical disclosure and attribution: as students in our course were asked to document their AI use, we as authors likewise report the involvement of multiple language models as auxiliary writing instruments, citing them according to APA guidance on non-retrievable AI communications [27, 28, 29, 30]. This reflective exercise demonstrates that AI can serve as a form of professional augmentation within academic knowledge work, contributing to efficiency and creativity while underscoring the indispensability of critical human oversight. It thus exemplifies the UNESCO framework's Professional Learning Competency, highlighting how educators may responsibly integrate AI into their own scholarly workflows while upholding standards of integrity, transparency, and accountability.

Conclusion

This paper presented a case study on applying the UNESCO AI Competency Framework in higher education through the design, implementation, and pilot evaluation of an AI-integrated course for future TVET educators. The rationale for the course stemmed from the increasing demand for new competencies in education (technical skills, ethical awareness, and pedagogical innovation) as outlined by UNESCO and related frameworks. By embedding AI activities into a Quantitative Research Methods course, the project sought to align human-centered, open-source teaching practices with those competencies. Strategies included the use of an AI assistant for learning support, training in prompt engineering, reliance on open platforms such as LiaScript and local AI models to ensure privacy and adaptability, and the integration of AI into assessment and reflective elements of the course. The pilot results were mixed but offered valuable insights. Quantitative measures did not show statistically significant changes in students' AI familiarity, attitudes, or intentions over the course's short duration, although positive trends were observed. Qualitative evidence, however, indicated strong engagement, perceived learning benefits, and the development of critical and reflective approaches to AI use. Students not only acquired confidence in applying AI tools but also demonstrated ethical awareness and creative ideas for pedagogical applications. The overall high course evaluation suggests that integrating AI into the curriculum can enhance satisfaction and motivation by making learning more interactive and relevant. These outcomes point to the importance of viewing AI integration as a longitudinal process. A single course can initiate change and spark awareness, but long-term exposure across multiple modules is necessary to achieve sustained competency development, following the UNESCO "Acquire-Deepen-Create" trajectory [10]. The pilot also underscores the potential of open-source AI in higher education. While technical limitations were noted, the success of locally hosted AI tools demonstrates a feasible alternative to relying solely on proprietary systems, enabling institutions to safeguard values of equity, transparency, and collaboration [16]. Beyond the classroom, this article also reflected on the role of AI in academic writing, where tools like ChatGPT can function as junior assistants, useful for idea generation and drafting but requiring supervision and critical refinement. Such human-AI collaboration exemplifies the professional practices likely to become commonplace in academia and other knowledge sectors [17].

In conclusion, applying the UNESCO AI Competency Framework in higher education is both viable and worthwhile. While measurable shifts in competencies may take time to manifest, our pilot demonstrates that carefully designed integration can foster engagement, ethical reflection, and practical skill development. We encourage other programs to experiment with similar approaches, adapted to their specific contexts, and to share open educational resources that accelerate collective progress. As AI continues to transform society, education systems must not merely respond passively but actively shape its use through robust pedagogical design, open collaboration, and adherence to guiding frameworks. The pilot described here illustrates how such principles can be translated into practice, offering a starting point for broader research and cross-institutional initiatives to advance AI integration in education.

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Potentials and challenges for addressing the implementation of AI into TVET

H. Stolte

There is a consensus in the current international debate that artificial intelligence (AI) will have a significant impact on changes in production, work, and business processes. A parallel international effort is being made to derive the necessary consequences for training processes and content for the adequate development of workforce skills and competencies within the framework of vocational education and training. The following article analyzes the actual positions of relevant international stakeholders, with a specific focus on existing competency frameworks. Finally, an attempt is made to derive some conclusions and suggestions for international vocational education cooperation in this context.

1 Introduction

The discussion surrounding AI has recently increased enormously in intensity and scope. Combined with technological advances and the emergence of entirely new dimensions in AI's application possibilities, significant changes are expected, particularly in economic, production, and work processes.

Parallel to the technical development of AI, various facets have also developed regarding the understanding and theoretical concepts of AI.

Some experts define intelligence as the ability to adapt, solve problems, plan, improvise in new situations, and learn new things. Though these systems aren't a replacement for human intelligence or social interaction, today's AI systems demonstrate some traits found in human intelligence, including learning, problem-solving, pattern-finding, perception, and even a limited spectrum of creativity and social awareness. [1]

AI can handle repetitive, data-driven tasks and give data-based results. Human intelligence can work on creative, emotional and critically complex tasks.

AI involves the replication and enhancement of specific human cognitive processes. It is the field of computer science that focuses on creating systems capable of carrying out tasks that typically require human intelligence, such as learning, problem-solving, or decision-making.

It studies mental processes using computational models, aiming to mimic intelligent behavior through computational processes. This involves automating intelligent actions and responses and simulating human intelligence processes using computer systems.

Regarding the integration of AI in education – and specifically in vocational training – it is necessary to investigate which competencies are required for the actors in educational systems in order to adequately equip learners with the necessary skills and competencies to cope with the changes in production, work, and business processes associated with the use of AI.

2 Overview of the history of AI development and approaches to classifying AI applications

These systems interpret data, learn from it, and use the knowledge to adapt to new inputs and perform tasks. [2]

As described by [2], AI uses techniques such as machine learning, natural language processing, computer vision, and robotics, among others, to create systems capable of performing tasks that mirror human intelligence.

- Machine learning – enables systems to improve their performance on a task through exposure to data.
- Natural language processing – facilitates the interaction between computers and human language.
- Computer vision – allows machines to interpret and understand visual information.
- Robotics – enables the creation of machines capable of performing tasks in the physical world.

These techniques work together to develop systems that can undertake complex activities such as problem solving, recognizing patterns in data, understanding and responding to human language, interpreting visual information, decision making, and performing physical tasks. These closely resemble the cognitive capabilities typically associated with human intelligence.

AI seeks to imitate aspects of human thinking using algorithms and machine learning. However, AI's abilities are often constrained by predefined rules and lack the holistic understanding and creativity inherent in human intelligence. The goal of AI development is to complement human capabilities rather than completely replicate the complexity of human cognition.

As already mentioned above, developments and discussions about artificial intelligence have a long history.

The historical timeline shown in Figure 1 illustrates these developments and describes some relevant milestones [2]:

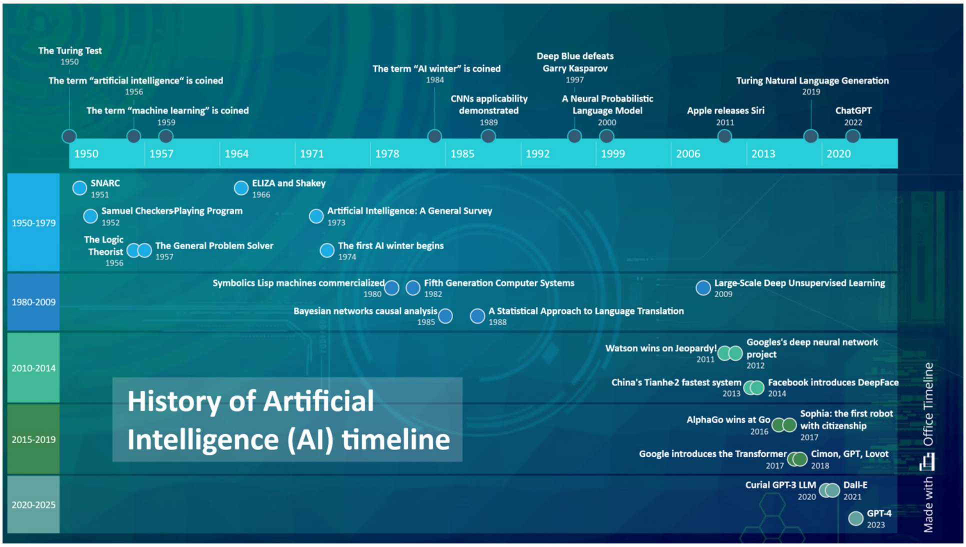

Figure 1: History of AI Source: [2] Malik (2023)

According to [2], the following milestones are significant throughout the historical development of AI:

Table 1: Milestones throughout historical development of AI (Source: [2])

1950	**Turing Test**: evaluates a machine's capability to exhibit intelligent behavior similar to or indistinguishable from a human.
1956	The term **"artificial intelligence"** is coined, and the field is officially established, marking the birth of this field of research.
1956	The **Logic Theorist** was developed and recognized as the pioneering artificial intelligence program.
1957	The **General Problem Solver** (GPS-I) was developed – a computer program intended to work as a universal problem-solving machine. **Lisp** was developed – a programming language popular in the AI industry and among developers.
1959	The term **"machine learning"** was popularized, explaining that computers can be programmed to surpass their programmer.
1966	**ELIZA** was created; an early NLP (natural language processing) computer program capable of engaging in conversations with humans. It is considered the first chatbot.
1980	**Symbolic Lisp machines** entered the market, sparking an AI revival, but the market later collapsed.
1982	Japan launches its **Fifth Generation Computer Systems project**, aiming to create computers with advanced AI and logic programming capabilities.
1988	**A Statistical Approach to Language Translation** was published, shaping a method in machine translation.
1997	**IBM's Deep Blue** defeats world chess champion Garry Kasparov, marking a significant milestone in the development of AI and computing power.

(Continuing Table 1)

2011	**IBM's Watson** defeats human contestants on the quiz show Jeopardy, demonstrating remarkable progress in natural language processing, machine learning and AI's potential to understand and respond to complex human queries. Apple introduces **Siri**, a voice-powered personal assistant, enabling voice-based interactions and tasks.
2012	**Google's deep neural network project** achieves a breakthrough in imagine recognition, demonstrating the potential of deep learning in various applications. This triggered the explosion of deep learning research and implementation.
2013	**DeepMind** shows impressive learning results using deep reinforcement learning to play video games, surpassing human expertise in games. **China's Tianhe-2 supercomputer** doubled the world's supercomputing speed, gaining and retaining the title of world's fastest system.
2014	**Generative adversarial networks** were invented, a type of machine learning framework applied to photo generation, image transformation, and deepfake creation.
2018	**OpenAI's GPT-1** (117 million model parameters) was introduced, laying the groundwork for future large language models (LLMs). **AI ethics** and **responsible AI** become major topics of discussion, with organiza-tions and governments focusing on creating guidelines and regulations for the ethical development and use of AI.
2019	Microsoft launched the 17-billion-parameter **Turing Natural Language Generation** model.
2021	OpenAI introduces **DALL-E**, an AI that can generate images from text.
2022	OpenAI launches ChatGPT, offering a chat-based interface to its GPT-3.5 LLM.
2023	OpenAI introduces the GPT-4 multimodal LLM for text and image prompts. Elon Musk, Steve Wozniak, and others call for a six-month pause in training more advanced AI systems.

Corresponding to the developments in AI, various approaches to classifying AI emerged. AI classification systems are diverse, reflecting the multifaceted nature of the field. Some of the key classification frameworks are:

a) Capability-Based Classification
   - Narrow AI (ANI): These are AI systems designed for specific tasks. They excel in one cognitive capability but cannot learn beyond their design. Examples include image recognition software and AI virtual assistants
   - Artificial General Intelligence (AGI): This is a theoretical form of AI that can learn, think, and perform a wide range of tasks at a human level. While still in development, technologies like supercomputers and generative AI products like ChatGPT are laying the groundwork for AGI
   - Artificial Superintelligence (ASI): This is a hypothetical type of AI that would surpass human intelligence and capabilities. It remains a concept in science fiction and speculation

b) Functionality-Based Classification
   - Reactive Machine AI: These systems respond to immediate inputs without storing memory or learning from experiences. They are useful for basic tasks like email spam filtering
   - Limited Memory AI: These AI systems can store past data and use it to make predictions. They form the majority of current AI applications, including chatbots and self-driving cars
   - Generative AI: This subset of AI uses generative models to produce new data such as text, images, or videos based on input prompts. Examples include ChatGPT, DALL-E, and Stable Diffusion

c) Application-Based Classification
   - Text-to-Text (TTT): Tools that generate or manipulate text
   - Text-to-Speech (TTS): Convert written text into spoken words
   - Text-to-Image (TTI): Generate images from text descriptions
   - Text-to-Video (TTV): Create videos based on text input
   - Speech-to-Text: Transcribe spoken words into written text
   - Natural Language Processing: Analyze and understand human language
   - Video Intelligence: Analyze and extract information from video content

3 International perspectives on the classification of AI in education and the development of corresponding competency frameworks

A report by the Organization for Economic Co-operation and Development (OECD) [3] also presents methods for classifying AI (using the International Standard Industrial Classification of All Economic Activities (ISIC)). By developing the framework for classifying AI, the OECD is focusing on important principles like:

Table 2: OECD Principles of AI (Source: [3])

Values-based principles for all AI actors	***Recommendations to policymakers for AI policies***
Principle 1.1. People and planet	*Principle 2.1.* Investment in R&D
Principle 1.2. Human rights, privacy, fairness	*Principle 2.2.* Data, compute, technologies
Principle 1.3. Transparency, explainability	*Principle 2.3.* Enabling policy and regulatory environment
Principle 1.4. Robustness, security, safety	*Principle 2.4.* Jobs, automation, skills
Principle 1.5. Accountability	*Principle 2.5.* International cooperation

In relation to the sector focused on education, the OECD describes AI application as the following:

Table 3: OECD Sample Applications of AI (Source: [3])

Sector	Description	Main applications of AI
Education	Includes private and public education, all levels from pre-school to higher education, adult education, sport education, literacy programs and more.	Personalizing learning with AI (e. g., adaptive tests and learning systems) Supporting special needs students with AI (e. g., wearables) Reducing dropout rates (e. g., predictive and diagnostic models) Structure of scoring of tests or exams Fraud detection during exams Chatbots

Summary and conclusion

There is quite a long history of AI development in parallel to the development of methods of a classification for future AI tools.

What these classification methods have in common is that they are largely technology-oriented or sector-oriented. However, they largely overlook specific aspects of the use of AI in educational processes, including teaching and learning methodologies related to pedagogy and the broader educational ecosystem. These elements are not considered to the necessary extent and intensity.

To explore the potential of AI in education – especially vocational education and training – and to analyze AI tools and the development of classification methods based on elements of the so-called educational ecosystem seem both feasible and appropriate. In this context, in addition to technological aspects, questions regarding the necessary competencies of the actors and stakeholders involved merit special attention.

Further discussion on this topic, based on this insight, is warranted, as is the need to summarize existing statements from international dialogue in order to derive some suggestions for international vocational education and training cooperation from this perspective.

Parallel to the rapid development of AI in recent times, there have also been various communications by relevant international organizations and stakeholders regarding the application of AI in the education sector and the associated challenges in exploiting its assumed potential.

The following are relevant statements from selected international stakeholders.

UNESCO

- Beijing Consensus on artificial intelligence and education [4]

The consensus was adopted during the International Conference on Artificial Intelligence and Education, which was held in Beijing from May 16 to 18, 2019. Entitled “Planning education in the AI era: Lead the leap”, the conference was attended by around 500 representatives from more than 100 countries and 10 international organizations.

The Beijing Consensus recommends governments and other stakeholders in UNESCO member states to take action in a range of areas, including AI planning in education policies, education management and delivery, teaching and teacher empowerment, learning assessment, development of values and skills for life and work in the AI era, lifelong learning, promoting equitable and inclusive use of AI in education, gender equality, ethical use of education data, monitoring, evaluation and research, and financing and international cooperation.

The consensus states that countries need to lead appropriate policy responses aimed at the systematic integration of AI and education to innovate education, teaching and learning, and at leveraging AI to accelerate the delivery of open and flexible education systems that enable equitable, relevant and quality lifelong learning opportunities for all that will contribute to achieving the Sustainable Development Goals (SDGs) and the shared future for mankind.

The consensus affirms that AI platforms and data-based learning analytics should be adopted as key technologies in building integrated, lifelong learning systems to enable personalized learning anytime, anywhere, and potentially for anyone. It stresses the need to ensure that AI promotes high-quality education and learning opportunities for all, irrespective of gender, disability, social or economic status, ethnic or cultural background, or geographic location.

In relation to this, vocational training points 17–19 of the consensus report are:

- "Be mindful of the systemic and long-term transformation of the labor market, including its gender dynamics, due to AI adoption. Update and develop mechanisms and tools to anticipate and identify current and future skills needs in relation to AI development in order to ensure the relevance of curricula to changing economies, labor markets, and societies. Integrate AI-related skills into the school curricula and qualifications of technical and vocational education and training (TVET) and higher education, taking into consideration the ethical aspects and interrelated humanistic disciplines."
- "Be cognizant of the emergence of a set of AI literacy skills required for effective human–machine collaboration, without losing sight of the need for foundational skills such as literacy and numeracy. Take institutional actions to enhance AI literacy across all layers of society."
- "Set up mid- or long-term plans and take urgent actions to support higher education and research institutions in developing or enhancing courses and research programs to develop local AI talent in order to create a massive pool of local AI professionals who have the expertise to design, program and develop AI systems."

The consensus also calls for efforts to support forward-thinking reviews of frontier issues that are related to the implications of emerging AI development and the facilitation of the exploration of effective strategies and practices for using AI to transform education, with a view to building an international community that shares a common perspective on AI and education.

- AI and Education: Guidance for policymakers [5]

The publication offers guidance for policymakers on how best to leverage the opportunities and address the risks presented by the growing connection between AI and education.

It starts with the essentials of AI: definitions, techniques, and technologies. It continues with a detailed analysis of the emerging trends and implications of AI for teaching and learning, including how we can ensure the ethical, inclusive, and equitable use of AI in education, how education can prepare humans to live and work with AI, and how AI can be applied to enhance education. It finally introduces the challenges of harnessing AI to achieve SDG 4 and offers concrete actionable recommendations for policymakers to plan policies and programs for local contexts.

Worth mentioning, among other things, are the views in the document on the changing roles of teachers through the use of AI in educational processes:

> "Despite the commercial aims of using intelligent tutorial systems to do teacher tasks, it is still unlikely that teachers will be replaced by machines any time soon. Nonetheless, the ambition of many AI developers is to relieve teachers of various burdens (such as monitoring progress and marking assignments) so that they may focus on the human aspects of teaching (such as social engagement, interacting with empathy, and offering personal guidance). However, as AI functionalities improve, they will inevitably relieve teachers of increasing numbers of burdens. Accordingly, as the AI tools take over the knowledge transmission tasks, facilitating students' lower-order thinking, teachers will play a reduced role. Theoretically, this will allow teachers to focus more on the design and facilitation of learning activities that require higher-order thinking, creativity, interpersonal collaboration, and social values – although, no doubt, AI developers are already working to automate these tasks too. Accordingly, to ensure that teachers continue their critical role in the education of young people, policymakers must review strategically how AI might transform teachers' roles and how teachers might prepare to work in AI-rich education environments."

- Guidance for generative AI in education and research [6]

The guidance presents an assessment of potential risks generative AI (GenAI) could pose to core humanistic values that promote human agency, inclusion, equity, gender equality, and linguistic and cultural diversity, as well as plural opinions and expressions.

It proposes key steps for governmental agencies to regulate the use of GenAI tools, including mandating the protection of data privacy and considering an age limit for their use. It outlines requirements for GenAI providers to enable their ethical and effective use in education.

The guidance stresses the need for educational institutions to validate GenAI systems on their ethical and pedagogical appropriateness for education. It calls on the international community to reflect on their long-term implications for knowledge, teaching, learning, and assessment.

The publication offers concrete recommendations for policymakers and educational institutions on how the uses of GenAI tools can be designed to protect human agency and genuinely benefit learners, teachers, and researchers.

Regarding vocational training contexts, the following aspects identified in the document are relevant:

"The latest developments of GenAI have further reinforced the urgent need for everyone to achieve an appropriate level of literacy in both the human and technological dimensions of AI, understanding how it works in broad terms, as well as the specific impact of GenAI. In order to do so, the following five actions are now urgently needed:

- Commit to the provision of government sanctioned AI curricula for school education, in technical and vocational education and training, as well as for lifelong learning. AI curricula should cover the impact of AI on our lives, including the ethical issues it raises, as well as age-appropriate understanding of algorithms and data, and skills for the proper and creative use of AI tools including GenAI applications.
- Support higher education and research institutions to enhance programs to develop local AI talent.
- Promote gender equality in developing advanced AI competencies and create a gender-balanced pool of professionals.
- Develop intersectoral forecasts of the national and global job shifts caused by the latest GenAI automation, and enhance future-proof skills at all levels of education and lifelong learning systems based on prospective shifts in demand; and
- Provide special programs for older workers and citizens who may need to learn new skills and adapt to new environments."

Based on analyses of teachers' ability to use GenAI, the following actions are recommended:

- "Formulate or adjust guidance based on local tests to help researchers and teachers to navigate widely available GenAI tools and steer the design of new domain-specific AI applications.
- Protect the rights of teachers and researchers and the value of their practices when using GenAI. More specifically, analyze teachers' unique roles in facilitating higher-order thinking, organizing human interaction, and fostering human values.
- Define the value orientation, knowledge, and skills that teachers need in order to understand and use GenAI systems effectively and ethically. Enable teachers to create specific GenAI-based tools to facilitate learning in the classroom and in their own professional development.
- Dynamically review the competencies needed by teachers to understand and use AI for teaching, learning, and for their professional development, and integrate emerging sets of values, understanding, and skills on AI into the competency frameworks and programs for training in-service and pre-service teachers."

Organization for Economic Co-operation and Development (OECD)

The OECD has made several statements and recommendations regarding the application of artificial intelligence (AI) in education and vocational training. These insights address opportunities, challenges, and strategies for leveraging AI effectively while ensuring inclusivity and equity. The OECD recognizes both the transformative potential of AI in education and vocational training as well as the challenges it poses. It advocates for inclusive policies, ethical guidelines, multi-stakeholder collaboration, and targeted investments to ensure that advancements in AI benefit learners equitably while addressing labor market needs effectively. Below are some samples of statements of the OECD in this context.

▸ OECD Digital Education Outlook 2023 – Towards an effective digital education ecosystem [7]

The publication focuses, among other things, on the integration of AI into the education sector and related requirements. The main findings are:

- AI can optimize human learning and teaching by combining human and artificial intelligence meaningfully. This includes personalized learning experiences, adaptive learning platforms, and tools for collaboration between students and educators.
- It emphasizes the need for ethical frameworks to guide the use of AI in education, ensuring that AI applications do not exacerbate inequalities or compromise data privacy.
- Within a guideline for use it is articulated that a collaboration between education authorities, teachers, and other stakeholders is essential for responsible AI integration. The OECD advocates co-creation approaches to develop evidence-based educational technologies that align with learning science theories.

With regard to vocational training, there is stated that modular training programs focused on data science, evidence-based practices, and AI literacy can help individuals and organizations better leverage AI technologies for vocational purposes.

▸ Training Supply for Green and AI Transitions: Equipping workers with the right skills, getting skills right [8]
  - The paper highlights the importance of upskilling and reskilling workers to adapt to AI-driven changes in labor markets. This includes aligning training programs with the skills required for increased AI adoption.
  - Governments are encouraged to invest in publicly funded training programs that focus on advanced AI skills while promoting general AI literacy to reach broader populations.
  - Financial incentives, such as subsidies or tax deductions, are often used to encourage employers to provide training. However, these initiatives frequently lack a direct focus on AI skills development.

- Targeted career guidance initiatives can help vulnerable groups transition into AI-related careers, though only a few countries currently have such programs specifically focused on AI.

World Economic Forum

▶ Shaping the Future of Learning: The role of AI in education 4.0 [9]

The World Economic Forum's report, *"Shaping the Future of Learning: The Role of AI in Education 4.0,"* outlines the transformative potential of AI in education while addressing its challenges. Below are some key statements and insights from the report:

1. Education 4.0 Framework

The *Education 4.0* framework emphasizes preparing students for a technology-driven future by focusing on four key skill sets: global citizenship, innovation and creativity, technology proficiency, and interpersonal skills.

It also promotes four types of learning experience: personalized and self-paced, accessible, problem-based and collaborative, and lifelong learning.

2. AI's Role in Transforming Education

- *Personalized Learning*: AI enables tailored educational experiences by adapting content to individual student needs, preferences, and learning paces.
- *Refining Assessments:* AI provides real-time feedback and analytics, helping educators identify strengths and weaknesses in students while improving instructional strategies.
- *Optimizing Educator Roles:* By automating administrative tasks (up to 20 % of clerical work), AI allows teachers to focus more on pedagogy, personalized instruction, and supporting students' emotional and social needs.

3. Addressing Global Challenges

- *Teacher Shortages*: AI can alleviate the burden of administrative tasks, enabling educators to dedicate more time to teaching.
- *Digital Skills Gap*: Integrating AI into curricula helps bridge the gap in digital literacy, preparing students for future career demands.
- *Inclusivity*: AI-powered tools can make education more accessible for marginalized groups, including students with disabilities or those in underserved regions.

4. Risks and Challenges

- *Data Privacy:* Safeguarding student data remains a critical concern as AI becomes more integrated into education systems.
- *Inequality:* Without equitable access to technology, AI risks widening existing educational disparities.
- *Ethical Concerns:* The report stresses the need for robust governance frameworks to ensure responsible use of AI in education.

5. Future Directions

- Collaboration among governments, businesses, educators, and civil society is essential for harnessing AI's potential responsibly.

- A focus on equity, inclusiveness, and ethical implementation is critical to ensuring that AI benefits all learners while maintaining the human element of teaching.

European Centre for the Development of Vocational Training (Cedefop)

Cedefop has provided several key insights and recommendations regarding the application of artificial intelligence (AI) in vocational education and training. These statements focus on the impact of AI on skills, training systems, and workforce readiness.

▸ Policy brief: Skills empower workers in the AI revolution [10]

This policy brief presents the first results of Cedefop's 2024 AI skills survey. Based on the findings of the survey, some policy recommendations highlighted were:

- *Promoting Inclusive AI Literacy*: Targeted vocational education and training initiatives should be designed in ways that overcome gender and age segregation in the use of AI technologies, given that female and older workers are less likely to use AI at work. With AI becoming a new transversal skill shaping the future of work, initial and ongoing vocational education and training systems should aim to further strengthen the integration of AI competencies into curricula and programs.
- *Empowering Social Dialogue in EU Workplaces*: Empowering social dialogue and a culture of workplace trust are critical factors in ensuring that AI diffusion will not result in worker resistance, quiet quitting, or other behavioral obstacles (e. g., lack of awareness, reservations against AI, or lack of proactivity).
- *Tackling the Productivity Paradox:* Cedefop's AI survey shows that as many as 54 % of AI users report they have not become better at doing their job thanks to AI technology. In this group, workers with lower levels of AI literacy and lower participation in AI education and training activities are over-represented. Such findings are concerning given that, without investing in people and their skills, AI is likely to undermine the potential of technology to protect Europe's social model.
- *Fostering a Human-Centered AI Revolution*: Most micro-, small-, and medium-sized EU enterprises are starting from an unfavorable digital maturity position. There are significant barriers to the take-up of AI technology in organizations. Notably, there is a need to overcome negative cost–benefit ratios, to confront and address legal and ethical issues, and to establish trust in AI systems by investing in their reliability and transparency. Making the leap towards an AI-driven organization also requires significant managerial competence and a workplace culture that promotes and rewards continued learning and experimentation. AI can only really flourish in a secure, safe, and ethical work environment.

International Labor Organization (ILO)

▸ Mind the AI Divide: Shaping a global perspective of the future of work [11]

The paper focuses in particular on the different disparities and capacities for the application of AI that can be found globally. It is warned that "without targeted and concerted efforts to bridge this digital divide, AI's potential to foster sustainable development and alleviate poverty will remain unrealized, leaving significant portions of the global population disadvantaged in the rapidly evolving technological landscape." It is highlighted that "it is thus critical to understand the potential for AI to affect labor demand and transform occupations."

Listed below are some the ILO's key points regarding the need for development of skills and competencies:

- There is a clear need for skills enhancement in developing countries to successfully benefit from AI.
- Skills in AI can improve the process of integrating the technology into the workplace.
- A worker-centric framework should closely examine the specific tasks and skills affected by AI, looking at both the nature and extent of these impacts.
- A well-structured skills and lifelong learning framework is crucial for developing tailored and targeted capacity and skills programs. By identifying the skills that require improvement or updating, stakeholders are better positioned to create educational and training initiatives that are both efficient and effective.
- A methodological framework, as illustrated in the figure below, enables the development of a nuanced understanding of the varying capacity development needs across different impact categories. By mapping out the specific requirements for reskilling, upskilling, and cross-skilling according to AI's potential impact on occupations, this approach can support the creation of customized and evidence-based AI capacity development programs and thus better prepare workers and enterprises for the possible transformations ahead.

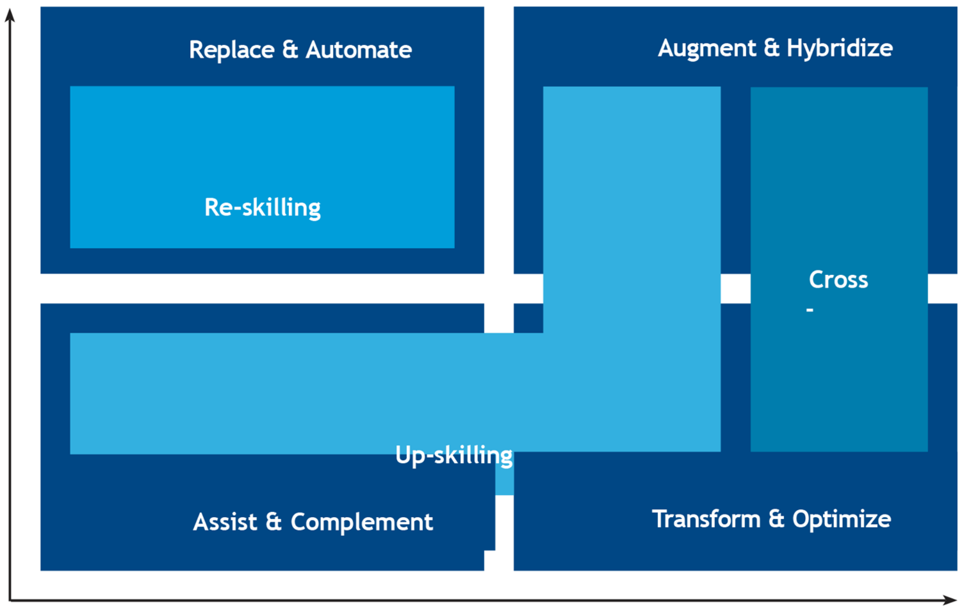

Figure 2: AI impact quadrant and corresponding skilling strategies (Source: [11])

Summary of findings

AI is seen as a key technology to be adopted and integrated into lifelong learning systems. It is recognized that AI has both transformative potential in education and TVET and that it poses some challenges and risks. Risks and challenges are combined with aspects such as data privacy, inequality (equitable access to technology), ethical concerns, etc.

It is argued that countries need to lead appropriate policy responses to AI and education to innovate teaching and learning. A human-centered AI application is encouraged in this context with a focus on how education can prepare humans to live and work with AI.

A clear need for skills enhancement to successfully benefit from AI, along with the requirement to attain an appropriate level of literacy in both the human and technological dimensions of AI, is recognized. Consequently, it can be contended that a well-structured skills and lifelong learning framework is crucial for developing tailored and focused publicly funded programs on AI literacy and skills development.

The changing role of teachers through the use of AI in educational processes is highlighted. It is suggested that emerging values, understanding, and skills related to AI and related didactical approaches should be integrated into training programs for both in-service and pre-service teachers.

4 Selected competency frameworks to guide teachers and learners in the application of AI in learning processes

UNESCO: AI competency framework for teachers [12]

As discussed in this document, there is a need for a re-examination of teachers' roles and the competencies they need in the era of AI with the view that AI has transformed the traditional teacher–student relationship into a teacher–AI–student dynamic. UNESCO's *AI competency framework for teachers* addresses this gap by defining the knowledge, skills, and values teachers must master in the age of AI.

As a global reference, this tool guides the development of national AI competency frame-works, informs teacher training programs, and helps in designing assessment parameters. It also provides strategies for teachers to build AI knowledge, apply ethical principles, and support their professional growth. The AI competency framework for teachers is intended to affirm their critical role in ensuring the ethical and effective adoption of AI in education. It also aims to inform policymakers, providers of teacher education programs, personnel of teacher education institutions, school leaders, and teachers themselves of the dynamic evolution of competencies that the transition of education in the AI era may require.

The AI competency framework for teachers of UNESCO is presented in a two-dimensional matrix:

Table 4: The AI competency framework high-level structure: aspects and progression levels (Source: [12])

Aspects	Progression		
	Acquire	Deepen	Create
1. Human-centred mindset	Human agency	Human accountability	Social responsibility
2. Ethics of AI	Ethical principles	Safe and responsible use	Co-creating ethical rules
3. AI foundations and applications	Basic AI techniques and applications	Application skills	Creating with AI
4. AI pedagogy	AI-assisted teaching	AI–pedagogy integration	AI-enhanced pedagogical transformation
5. AI for professional development	AI enabling lifelong professional learning	AI to enhance organizational learning	AI to support professional transformation

The UNESCO AI competency framework for teachers is based on the following principles:

- Ensuring inclusive digital futures
- A human-centered approach to AI
- Protecting teachers' rights and iteratively (re)defining teachers' roles
- Promoting trustworthy and environmentally sustainable AI for education
- Ensuring applicability for all teachers and reflecting digital evolution
- Lifelong professional learning for teachers.

The *five aspects* of the AI competency framework for teachers are intended to cover key domains of the competencies and reflect their complementary relationships. When training programs are designed to help teachers progress from 'Acquire' to 'Create', all five aspects should be targeted and integrated as a part of the expected competency development.

At this point, reference should be made to the interpretation on the topic of AI pedagogy:

> "AI pedagogy proposes a set of competencies required for purposeful and effective AI–pedagogy integration, covering comprehensive competencies to validate and select appropriate AI tools and integrate them with pedagogical methods to support course preparation, teaching, learning, socialization, social caring, and learning assessment. This aspect implies that teachers need to develop the ability to critically assess when and how to use AI in teaching and learning in an ethical and human-centered manner, as well as to plan and implement inclusive AI-assisted teaching and learning practices. Progressively, teachers need to enhance their capacity to critically adapt and creatively explore innovative practices in the context of advancing capabilities of emerging AI iterations."

The *progression levels* of the AI competency framework for teachers are designed to help assess teachers' existing AI competencies and to define expected professional learning objectives. Theoretically, the training and support at the 'Acquire' level targets teachers with limited or no prior AI knowledge or skills. Indeed, all teachers should have opportunities to access this level of training or guidance to acquire the most fundamental set of competencies specified in the framework. In other words, the first level aims to foster basic AI literacy for teachers. The 'Deepen' level targets teachers who already have some knowledge of AI and some experience of using it in education. This level aims to encourage teachers to engage more deeply with AI tools to maximize their capacity to enhance teaching and learning practices. The third level, 'Create', is for teachers who have strong AI knowledge and skills as well as rich experience in using AI in education. This level aims to foster expert teachers who have the competencies to explore the ethically and pedagogically sound, transformative application of AI in teaching and learning.

A detailed breakdown of the 5 aspects mentioned within the progression levels is described in [11] (pages 28–42).

UNESCO: AI competency framework for students [13]

As explained in this document, the AI competency framework for students aims to serve as a guide for public education systems to build the competencies required of all students and citizens for the effective implementation of national AI strategies. More specifically, the AI competency framework for students:

1. Provides a global reference framework on the core set of AI competencies for students to inform the design of national or institutional AI competency frameworks;
2. specifies typical attitudinal and behavioral performance relating to the key aspects of AI competencies at different levels of proficiency to help design AI-related curricular content for school students; and
3. recommends an open-ended roadmap to help plan the learning sequence of AI curricula across grade levels.

The AI competency framework for students serves as a global reference and is tailored to the diverse readiness levels of local education systems regarding curricula, the supportive learning environment for teaching AI, teacher preparedness, and the existing knowledge and abilities of specific student groups. It is aimed principally at policymakers, curriculum developers, providers of education programs, school administrators, teachers, and educational experts.

The AI competency framework for students charts an action-oriented program based on three basic assumptions about the role of education in responding to the universal adoption of AI:

- The education sector, rather than merely adapting to AI systems and tools, must be proactive in developing the competencies required to shape ethical and environmentally friendly AI.

- Students should be equipped with the competencies to act as both critical and responsible users and co-creators of AI, as well as leaders in defining and designing the next generation of AI technologies.
- Students' AI competencies are to be based around the convergence of a human-centered mindset and attitudes, adopted ethics of AI, transferable conceptual knowledge and skills on AI, as well as future-proof thinking relative to AI system design.

The AI competency framework for students of UNESCO specifies twelve competency blocks based on a matrix of two dimensions:

Table 5: The AI competency framework high-level structure: aspects and progression levels (Source: [13])

Competency aspects	Progression levels		
	Understand	Apply	Create
Human-centred mindset	Human agency	Human accountability	Citizenship in the era of AI
Ethics of AI	Embodied ethics	Safe and responsible use	Ethics by design
AI techniques and applications	AI foundations	Application skills	Creating AI tools
AI system design	Problem scoping	Architecture design	Iteration and feedback loops

The UNESCO AI competency framework for students is based on the following principles:

- Fostering a critical approach to AI
- Prioritizing human-centered interaction with AI
- Encouraging environmentally sustainable AI
- Promoting inclusiveness in AI competency development
- Building core AI competencies for lifelong learning

As outlined in the document, the AI competency framework for students specifies twelve competency blocks based on a matrix of two dimensions. The first dimension comprises of four interlinked aspects of AI competencies, while the second dimension includes three levels of progression or proficiency that students are expected to engage with iteratively.

While the AI competency framework for students anchors the definition of AI competency on three pillars that frame wider core competencies for students – namely, knowledge, skills, and values – it also aims to encourage an ethical understanding of human-led methods underlying AI systems. Based on this conceptualization, the framework defines four key constituent elements of students' AI competency: a human-centered mindset, ethics of AI, AI techniques and applications, and AI system design. These elements focus on fundamental values, social responsibilities to uphold ethical principles, foundational knowledge and skills, and higher order thinking skills for system design. While different elements can be developed through domain-specific learning and pedagogical methodologies, AI competencies are ultimately a set of interdisciplinary, general abilities and value orientations that extend beyond particular AI domains or tools.

The framework matrix spans the four aspects for each of the three levels of progression or proficiency (see Table 5). At the intersection of these levels and aspects are twelve constituent blocks of AI competencies whose characteristics underpin the critical thinking, ethical examination, practical use, and iterative co-creation of AI. These competency blocks should be understood as interlinked units for the framing of key components. Rather than considering them as fragmented and individual topics to be learned separately, they can be connected and woven together as the operational elements of AI competency.

A detailed breakdown of the 4 aspects mentioned within the progression levels is described in [12] (pages 27–52).

The matrix provides a blueprint for academic results at a minimum level of mastery within a certain competency block. More specifically, the matrix is designed to guide:

1. The scoping of main AI-related focus areas and expected mastery levels, tailored to local AI readiness and available instructional time;
2. the identification of AI-related learning content that can be integrated across existing curricula, subject areas, and grade levels;
3. the definition of proficiency levels and the development of assessment criteria to assess students' general AI competencies and progression; and
4. the design and exploration of age-appropriate and domain-specific versatile teaching and learning methodologies.

Additional competency frameworks for the application of AI in education and vocational training

European Framework for the Digital Competence of Educators (DigiCompEdu) [14]

As explained in [13] the **DigiCompEdu** is a scientifically sound framework describing what it means for educators to be digitally competent. It provides a general reference frame to support the development of educator-specific digital competencies in Europe.

DigCompEdu is directed towards educators at all levels of education, from early childhood to higher and adult education, including general and vocational education and training, special needs education, and non-formal learning contexts.

DigiCompEdu describes 22 competencies organized in six areas:

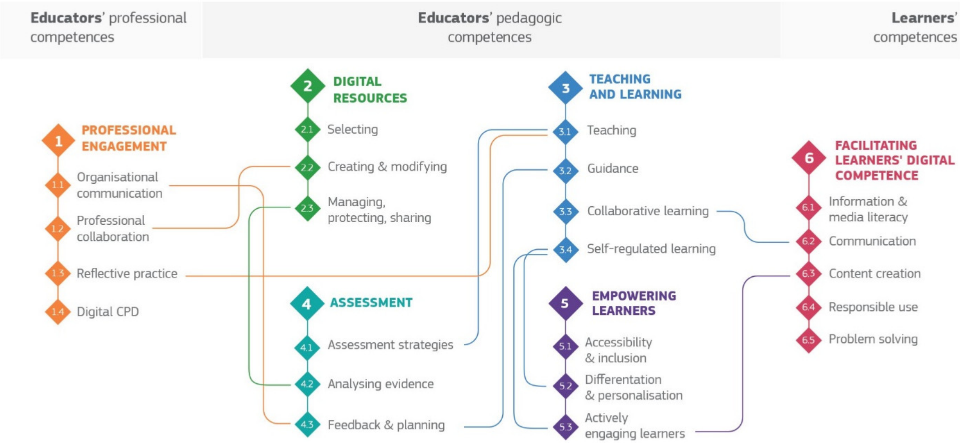

Figure 3: Overview of the DigiCompEdu framework (Source: [14])

Area 1 focuses on the professional environment;
Area 2 on sourcing, creating, and sharing digital resources;
Area 3 on managing and orchestrating the use of digital tools in teaching and learning;
Area 4 on digital tools and strategies to enhance assessment;
Area 5 on the use of digital tools to empower learners;
Area 6 on facilitating learners' digital competence.

Areas 2 to 5 form the pedagogic core of the framework. They detail the competencies educators must have in order to foster effective, inclusive, and innovative learning strategies, using digital tools.

Details of the competence categories in each of the six areas can be found in [14].

While not exclusively focused on AI, DigiCompEdu incorporates AI-related digital skills as part of broader digital education competencies. It can be expected that the EU will soon adapt DigiCompEdu directly to the specific requirements of AI or develop a special competency framework for it. A signal in this regard could be the funding by the EU Commission for the development of a draft "AI literacy framework for primary and secondary education" by the OECD.

Empowering learners for the age of AI: An AI literacy framework for primary and secondary education (Review draft) [15]

As explained in [14], the draft framework also aligns with the broader European Commission efforts to promote quality education and skills provision for the digital transformation in the context of the Digital Education Action Plan 2021–2027. In particular, the framework responds to the 2023 council recommendations on digital education and skills. It complements the 2022 ethical guidelines on the use of AI and data in teaching and learning for educators and DigComp 2.2: The Digital Competence Framework for Citizens. More broadly, the EU AI Act, the first comprehensive legislation on AI in the world, promotes a human-centered and risk-based approach to the adoption of AI systems. In particular, Article 4 of the Act requires both providers and deployers of AI systems to ensure that their staff and anyone using the systems on their behalf have an adequate level of AI literacy.

The structure of the framework comprises four domains, which represent different ways in which learners interact with AI. Learners can build proficiency across multiple domains without developing full proficiency in any single one. The four domains encompass 22 competencies.

Domain 1: *Engaging with AI* involves using AI as a tool to access new content, information, or recommendations. These situations require learners to first recognize AI's presence, then evaluate the accuracy and relevance of AI outputs. Learners must develop a fundamental understanding of AI's technical foundations in order to critically analyze its capabilities and limitations.

Domain 2: *Creating with AI* consists of collaborating with an AI system in a creative or problem-solving process. It involves guiding and refining AI output through prompts and feedback, while ensuring the content remains fair and appropriate. It also involves ethical considerations related to content ownership, attribution, and the responsible use of existing materials.

Domain 3: *Managing AI* requires intentionally choosing how AI can support and enhance human work. This includes assigning structured tasks to AI, such as organizing information, so humans can focus on areas requiring creativity, empathy, and judgment. AI systems can simulate a variety of roles, acting as an analyst, a debate partner, or a career guide. Learners who manage AI's actions learn to delegate tasks thoughtfully, guide AI outputs with clear instructions, and assess whether AI's role aligns with their goals and values. This domain helps learners build agency, ensuring that AI works for them and that its use remains ethical and human-centered.

Domain 4: *Designing AI* empowers learners to understand how AI works and connect it to its social and ethical impacts by shaping how AI systems function. Through hands-on exploration in an education context, students examine how data, design choices, and model behavior influence the fairness, usefulness, and impact of AI systems. The goal is not to develop commercial products or put them into service, but to build the confidence and capacity to shape AI for human good by understanding the principles underpinning the design of AI from an early age.

The AI Literacy Framework focuses in particular on the interrelationships between ***Knowledge, Skills, and Attitudes***

While competencies may evolve over time or in different contexts, the framework's competencies, knowledge, skills, and attitudes provide a solid foundation for AI literacy. They prepare learners to interact responsibly with existing technologies and navigate new ones as they arise. Each competence includes primary and secondary education learning scenarios that apply to various subject areas and educational contexts. These scenarios provide practical starting points for educators to include AI literacy in their own classrooms, with and without direct access to AI.

Sections related to *knowledge* in the framework focus on conceptual knowledge, outlining the technical and societal understandings that learners need to apply so as to engage with AI systems. These concepts include how AI processes data, how AI differs from human thinking, and how bias can emerge in AI systems.

Some of these key framework concepts on *knowledge* are identified as: the Nature of AI, AI Reflects Human Choices and Perspectives, AI Reshapes Work and Human Roles, AI's Capabilities and Limitations, and AI's Role in Society.

The competency *skills* demonstrates how fundamental abilities, such as critical thinking, creativity, and computational thinking, apply in an AI context. They guide learners in using AI effectively and ethically, ensuring that learners actively shape how AI fits into their lives.

Key areas noted in this competency are: *Critical Thinking:* Evaluate AI-generated content; *Creativity:* Collaborate with AI to create and refine ideas; *Computational Thinking:* Decipher problems and provide instructions; *Self and Social Awareness:* Recognize AI's influence; *Collaboration:* Work effectively with AI and humans; *Communication:* Explain how AI is used, and *Problem Solving:* Determine when and how to use AI.

The competency *attitudes* reflects mindsets and dispositions that prepare learners to engage with AI, not only with technical skills but also with an awareness of AI's impact on them and others. These include a sense of curiosity and adaptability in using AI systems, as well as a readiness to question outputs and show a commitment to using AI responsibly.

Key areas of the competency *attitudes* are identified as responsibility, curiosity, innovativeness, adaptability, and empathy.

Details regarding the highlighted competencies, knowledge, skills, and attitudes are described in [14] pages 19–23.

Combining knowledge, skills, and attitudes into corresponding competencies in specific scenarios is considered a suitable approach for dealing with AI in primary and secondary education.

Brief assessment/reflection of the analyzed competency frameworks

The UNESCO AI competency frameworks (for teachers and students) are preliminary versions that are currently undergoing extensive international deliberation. The OECD AI literacy framework still remains indraft form.

What these approaches have in common is that they focus on the specifics of AI and the associated challenges across fundamental dimensions. Coherent integration into educational ecosystems is either nonexistent or minimal.

The European Framework for Digital Competence of Educators (DigiCompEdu) provides a more comprehensive, holistic view of educational ecosystems. However, the specifics of integrating AI into educational processes and the associated competency requirements are not (yet) addressed here.

5 Conclusions

The previous analysis of educationally relevant competencies for the use of AI makes it clear that different approaches exist at different stages of development in the international debate. This seems comparable to the evolutionary development of approaches to classifying AI.

It seems advisable to focus more on the core dimensions of TVET ecosystems, their interrelationships, and the links to the employment and labor market when further developing, testing, and implementing competency frameworks for AI in education.

Although all elements of the ecosystem face challenges posed by AI, a particular priority seems to be on addressing new and challenging pedagogical dimensions. Teaching staff in particular face new demands on their competencies regarding their role in the integration of AI into the teaching and learning processes.

In the context of international vocational training cooperation, the following aspects could make valuable contributions:

- Knowledge Sharing Networks with the aim of exchanging
  - Knowledge regarding developed AI tools for specific elements of educational ecosystems and their application
  - Knowledge regarding application of competency frameworks (for teachers and students) and achieved experiences
  - Experiences in pedagogical approaches regarding the application of AI in teaching and learning processes
  - Research and Development Partnerships regarding
  - Standards (and related credit systems) on AI in educational ecosystems
  - Specific AI tools for specific elements of educational ecosystems
  - Development and adjustment of curricula related to the integration of AI in teaching and learning with special focus on branch-specific vocational subjects
- Training Initiatives
  - Development of capacity-building programs regarding AI applications for pre-service and in-service teacher training
  - Implementation of transnational capacity-building programs
  - Establishment of Train-the-Trainer networks

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Artificial intelligence in TVET education: Insights into teacher training and general adaption

F. A. Yamamoto

This study explores the integration of artificial intelligence (AI) into teaching and learning strategies at Senac São Paulo (SP), one of Brazil's leading technical and vocational education and training (TVET) institutions. Using a participant observation approach complemented by detailed field notes, the research investigates the development of AI-enhanced educational methodologies among faculty members. The analysis is grounded in the appreciation of work-based knowledge (Rose, 2007; Barato, 2005) and the application of diverse, creative strategies that align with the distinctive methodologies of vocational education. Preliminary findings reveal a notable generational divide: younger educators demonstrate both proficiency and creativity in adopting AI tools, whereas their senior counterparts initially face challenges and frequently revert to more traditional teaching methods. Despite these differences, the integration of AI has had a broadly positive impact, significantly contributing to the professional development of educators. These findings highlight the importance of designing tailored training programs to address the varying levels of technological competency among faculty members, ultimately enhancing their ability to innovate within the TVET context.

Introduction

Technical and vocational education and training (TVET) plays a pivotal role in preparing young people for the rapidly evolving demands of the labor market and society (see, for example, UNESCO-UNEVOC, 2020). In Brazil, the integration of secondary education (Ensino Médio) and technical education has become increasingly important to foster both academic grounding and professional preparation. The framework provided by the Lei de Diretrizes e Bases da Educação Nacional (LDBE) underscores the relevance of linking general education and vocational training to meet social, economic, and technological needs. In this context, the emergence and proliferation of artificial intelligence (AI) technologies constitute a new frontier for TVET institutions, demanding adaptation in curriculum, pedagogy, and teacher training. At Senac São Paulo (SP), the launch of the new "Ensino Médio Técnico em Inteligência Artificial" program has provided a case for investigating how a TVET institution responds to such a challenge. According to Senac SP's official announcement, the new course offers students the opportunity to develop solutions that integrate data strategies, machine learning, deep learning and ethical AI through modules in the three years of the program.

Half of the seats in each classroom are allocated via full scholarships. The program is organized to award a different professional certification each year: the first year is "Assistente em Gestão de Dados," the second year is "Assistente em Business Intelligence com IA," and the third year is "Assistente em Desenvolvimento e Implementação de IA." The course combines the Base Nacional Comum Curricular (BNCC), technical training, and skills related to artificial intelligence.

The purpose of this manuscript is to examine how teacher training and generational adaptation are taking place in this new AI-oriented TVET environment, with particular attention to the strategies adopted by faculty, the generational differences that emerge, and the implications for capacity development and institutional planning. The narrative begins by placing the relevance of TVET within Senac SP's overall strategy. It then describes current strategies and development trends in the TVET portfolio, addresses the place and range of TVET teachers within the institutional framework, discusses relevant models of capacity development for TVET teacher training, and finally considers the actual challenges faced by the institution in addressing capacity development for TVET teachers. By doing so, the paper intends to contribute to the understanding of how a TVET institution implements AI-enhanced education and what lessons may be drawn for teacher professional development in such contexts.
The remainder of this paper is organized as follows. Section 2 presents the relevance of TVET within the organization's overall current strategies. Section 3 outlines actual strategies and development trends regarding TVET in the organization's portfolio. Section 4 examines the place and range of TVET teachers addressed within the organization's TVET strategy. Section 5 presents relevant models of capacity development for TVET teacher training supported by the organization. Section 6 discusses the actual challenges seen by the organization in addressing capacity development for TVET teachers. Finally, the conclusion summarizes the findings and suggests future directions.

TVET strategies

Within Senac SP's mission of promoting professional development and inclusive education, TVET occupies a central place. The institution emphasizes the connection between professional qualification and social mobility, as reflected in its motto of preparing students "for the profession and for life". The recent introduction of the Ensino Médio Técnico programs – integrating general secondary education and technical qualifications – signals a strategic alignment with national and regional labor demands. For instance, the official website highlights the integrated model: "Students learn by means of a project of the year that brings together the content of secondary education and technical training, with themes that make sense for the class".

In the Brazilian context, TVET has been increasingly recognized as a means to enhance employability and to bridge the gap between education and labor market needs. According to one announcement by Senac SP, data shows that graduates of technical integrated high school programs earn, on average, 32 % more than those who only complete regular high school. This underscores the strategic importance of TVET in institutional planning and resource allocation. Furthermore, the emergence of technological transformations (Industry 4.0, digital economy, and AI) has intensified the demand for institutions such as Senac SP to adapt their portfolios and instructional models to remain relevant and competitive. For example, Senac SP announced the provision of 25,000 complimentary scholarships in the IT domain for 2025, including a thousand dedicated to AI pathways.

Hence, TVET is not a peripheral activity but rather a core strategic axis for the institution: it addresses socio-economic inclusion, technological change, workforce preparedness, and institutional differentiation. The integration of an innovative AI technical high school course reflects how the institution is leveraging TVET to advance its broader goals of relevance, innovation, and social impact.

SENAC'S Portfolio

Senac SP's portfolio demonstrates several trends in terms of strategy and development within its TVET offering. First, the move to integrate technical qualifications with the Ensino Médio (high school) indicates an evolution from stand-alone technical courses toward more integrated pathways. As the website explains, the Ensino Médio Técnico is "dynamic and collaborative" and oriented toward projects that mirror real-world work challenges.

Second, the focus on cutting-edge areas such as artificial intelligence signals the institution's responsiveness to technological change. The launch of the Ensino Médio Técnico em Inteligência Artificial program exemplifies this trend. According to media reports, the new course allows students to develop and apply data collection strategies, design and train models in machine learning and deep learning, and ensure ethical application of AI systems.

Moreover, this program is offered across multiple units (capital city and countryside/interior regions) and has significant scholarship capacity (50 % of places are free) to promote access and inclusion.

Third, there is evidence of institutional efforts to foster teacher professional development and student experience aligned with digital and active methodologies. Senac SP's technology area emphasizes that "the use of artificial intelligence already forms part of the world of work, and here you count on this experience that prepares you for professions of the future."

Additionally, the institution organizes events such as "Artificial Intelligence Experience 2025" to engage students and staff in contemporary issues of generative AI and responsible use. Finally, the development trend shows a commitment to equity and access: for example, the technical high school program offers 50 % of its places as fully free scholarships for families with income up to two federal minimum wages. This indicates that TVET strategy is not only technological but also socially oriented.

These strategic and developmental features demonstrate how Senac SP is positioning TVET not just as a training offer but as a transformative pathway for both students and educators, responsive to the era of AI and future work.

TVET teachers' strategy

Teachers are at the heart of any TVET strategy, and within Senac SP's model, their role is framed in multiple dimensions: as subject-matter experts, mediators of project-based learning, and facilitators of technology-rich, industry-connected practice. The website states that the teaching team has "experience both in the labor market and with youth mediation, group work, and project-based approaches".

In the specific context of the AI technical high school program, educators are required to move beyond conventional content delivery and engage with new methodologies such as designing AI models, guiding student projects, implementing ethical frameworks, and integrating data science practices. The description of the program states that students will learn to "develop solutions that think data, considering social context and impact on society", "propose and use data collection strategies", "create and train deep-learning models", "define and implement AI strategies in business intelligence", and "integrate and automate AI models in existing software systems".

Given these ambitious aims, the range of TVET teachers includes those familiar with technical AI content (algorithms, machine learning, deep learning, data structures), pedagogical skills (project-based pedagogy, blended learning, assessment of competence), and ethical/social dimensions (AI ethics, digital citizenship, data governance). The generational divide observed in the participant-observation setting reflects that younger teachers often exhibit more comfort with AI tools, whereas more senior teachers may rely more on prior methods and may require different forms of support for adaptation. The teacher professional development pathway must therefore cater for this heterogeneity.

Within the organization's TVET strategy the role of teachers is not only to deliver curriculum but to co-design innovation in learning environments, contribute to institutional capacity for AI integration, and collaborate in continuous improvement of offerings aligned with future work. In this sense, the teachers themselves become agents of change, rather than mere implementers of pre-defined modules.

Professional Development for TVET Teachers

The capacity development of TVET teachers at Senac SP involves multiple models and stages. One relevant model is the "train-the-trainer" or cascading model, in which a core group of educators receives advanced training in AI tools, pedagogical innovation, and project-based methods, and then disseminates this knowledge to their peers. This model allows for scalability and contextual adaptation within different units and campuses.

Another relevant model is professional learning communities (PLCs), wherein teachers engage collaboratively in enquiry, reflection, and shared practice around AI integration. Through regular meetings, peer observation, and joint development of teaching resources and student projects, teachers collectively build capacity. Empirical research supports the effectiveness of PLCs in teacher professional development in vocational contexts (Day, 1999; Shulman, 1986; Hargreaves & Fullan, 2012).

Additionally, an action research model is evident in the participant-observation methodology of this study; teachers design and implement small-scale innovations (e. g., using AI tools for student feedback or automated data analytics), observe outcomes, reflect, and refine practice. This model fosters teacher agency and continuous improvement.

Within the institution, continuous professional development workshops on AI, ethics, data-driven pedagogy, and the use of corporate AI tools (e. g., Microsoft Copilot) are integrated as part of teacher training. The AI domain website states that students and presumably teachers have access to Copilot as an assistant, and the methodology emphasizes practical, dynamic learning in labs.

Finally, differentiated training pathways cater for varying levels of technological competency and prior pedagogical experience: novice teachers receive foundational modules in digital literacy and AI concepts, while more advanced teachers engage in specialized workshops on deep-learning project supervision or AI ethics governance. This differentiated model reflects the generational variation observed in the field work and underscores the need for tailored capacity development.

Despite the strong strategic orientation and well-designed models of capacity development, several real-world challenges emerge in the implementation. First, the generational divide among faculty poses a significant barrier. Younger teachers tend to adopt AI tools more readily and innovate their teaching practices, whereas more senior teachers often revert to traditional teaching methods and express discomfort with rapid technological change. This disparity can create varying student experiences and organizational tensions. The participant-observation data shows that some senior faculty require more time and support to become comfortable with AI-rich pedagogy.

Second, the pace of technological change in AI means that teacher training must be continual and responsive; tools, frameworks, and industry practices evolve quickly, and there is a risk of obsolescence if professional development is not sustained. Related to this is the challenge of infrastructure: ensuring that all units across the state network have up-to-date laboratories, software licenses, computational resources, and access to real-world datasets is a logistical and financial issue. While Senac SP's units such as the Nações Unidas campus provide robust infrastructure (e. g., Informatics labs with Macs, PCs, and gaming PCs exist) but some smaller regional units lag behind, leading to inconsistencies in teacher training.

Third, aligning teacher training with teachers' workloads and time constraints is a practical challenge. Teachers often juggle teaching, student support, curriculum design, and administrative tasks; finding dedicated time for capacity development, experimentation, and reflection can be difficult.

The study's field notes indicate that some teachers deferred participation in training during busy semesters.

Fourth, the cultural shift required for integrating AI into TVET pedagogy entails more than technological skills: it involves change in beliefs about teaching, student-teacher relationships, assessment modalities (moving from content recall to project-based outcomes), and institutional reward structures. Some teachers resist change or feel unsupported in the transition. This socio-cultural dimension is often underestimated in capacity-building design.

Fifth, measuring the impact of teacher capacity development on student learning outcomes and institutional innovation remains challenging. While the strategic data point to higher employability and wages for graduates of technical programs isolating the effect of AI-integration and teacher training requires longitudinal data that is still emerging for the new AI program at Senac SP. Moreover, professional development cost-effectiveness and scalability across campuses require clear metrics and sustained evaluation.

These challenges imply that despite promising frameworks and strategic alignment, the practical implementation of capacity development for TVET teachers in an AI-infused environment remains complex and multifaceted.

Conclusion

This study has examined the integration of artificial intelligence into a TVET institution, specifically through the lens of teacher training and generational adaptation at Senac SP. The analysis shows that TVET holds a central strategic role in the institution's mission of linking education, work and innovation. Strategies and development trends indicate a forward-looking portfolio that blends technical qualification, project-based pedagogy, and AI specialization. Teachers within this framework fulfil an expanded role, requiring both technical and pedagogical competencies, and capacity development models must address generational variation, technological evolution, and institutional context.

At the same time, practical challenges such as generational divides, infrastructure disparities, time constraints for teachers, cultural change management, and the measurement of outcomes remain salient.

Looking ahead, several future directions are suggested. First, research should track longitudinally the impact of teacher training on student outcomes and institutional innovation in AI-oriented TVET programs. Second, capacity development programs should incorporate adaptive, modular, and micro-learning formats to accommodate busy teacher schedules and rapid technological change. Third, institutions may benefit from stronger peer-mentoring and cross-campus collaborative networks to diffuse innovative practices and reduce isolation of teachers in less-resourced units. Fourth, policy dialogue should emphasize support for equitable infrastructure across TVET networks to ensure all educators have access to AI labs, datasets, and software tools. Finally, further inquiry into the socio-cultural dimensions of teacher adaptation – especially how generational attitudes, institutional culture, and teacher identity affect adoption of AI-rich pedagogy – would deepen understanding of how to sustain innovation in TVET.

In conclusion, as TVET institutions embrace AI, the professional development of teachers emerges as the critical fulcrum of success: when educators are effectively prepared and supported, they can lead the transformation of teaching and learning, thereby enabling students to engage meaningfully in the professions of the future.

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Integration and Utilization of AI Tools in Teacher Training at BBPPMPV BMTI

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This paper presents a comprehensive overview of the integration of artificial intelligence (AI) utilized in vocational teacher training at UNESCO's Center for Quality Assurance Development of Vocational Education in Mechanical and Industrial Engineering BBPPMPV BMTI from 2020 to 2023 across various fields of expertise. The study highlights three AI-based innovation projects: a ship navigation simulator (2020–2021), educational games for software development (2021–2022), and an augmented reality (AR)-based welding simulator (2022–2023). These innovation projects utilized AI for features such as automatic ship navigation, adaptive gameplay, and error detection in welding training. By integrating AI into these training tools, BBPPMPV BMTI aims to enhance vocational teacher competence and prepare them for delivering more interactive and effective teaching. Findings indicate that AI integration fosters improved instructional strategies and supports Indonesia's technical and vocational education and training (TVET) transformation. The paper offers practical insights for other institutions planning to adopt AI in vocational education.

1 Introduction

Artificial intelligence (AI) has rapidly become an essential component in the transformation of education and training systems, especially in technical and vocational education and training (TVET). As reported by UNESCO [1], the adoption of AI technologies in education enhances personalization, increases access, and optimizes learning outcomes. Indonesia, recognizing the strategic value of vocational education, has initiated multiple innovations in integrating AI into teacher training on a national level. This paper explores the implementation of AI tools in teacher training activities conducted by UNESCO's Center for Quality Assurance Development of Vocational Education in Mechanical and Industrial Engineering BBPPMPV BMTI from 2020 to 2023.

BBPPMPV BMTI plays a strategic role in Indonesia's national effort to improve the quality and relevance of vocational education. Aligned with the Ministry of Education's roadmap for the revitalization of vocational education, BMTI's approach emphasizes the integration of digital technologies to improve teacher competencies. AI tools are viewed not merely as enhancements but as essential components for ensuring vocational education keeps pace with industrial advancements. These innovations align with Indonesia's commitment to preparing a future-ready workforce [2].

BMTI adopts a blended learning approach in its capacity development efforts, combining face-to-face workshops, online modules, and AI-based tools. Each AI-integrated project follows a competency-based training model aligned with national standards. The AI-integrated projects adopt the Competency-Based Training (CBT) framework mandated by Indonesia's vocational training standards (SKKNI–KKNI), while the development of the digital learning tools – such as simulators, augmented reality (AR) modules, and educational games – follows established instructional design models, particularly Dick and Carey, which guide the formulation of learning objectives, assessment instruments, and competency-aligned learning experiences [18]. The Dick and Carey model conceptualizes instruction as a systematic and linear process [18]. It begins with identifying instructional goals, followed by conducting an instructional analysis and examining learner characteristics. Based on these findings, performance objectives are formulated and appropriate assessment instruments are developed. The model then guides the development of instructional strategies and the selection or creation of relevant instructional materials. After implementation, the instruction process undergoes formative evaluation, revisions based on the evaluation results, and finally, a summative evaluation to measure overall effectiveness.

The use of AR and virtual reality (VR) simulations, for instance, allows for experiential learning that is both scalable and adaptable. Additionally, the learning management system (LMS)-supported tools enable personalized feedback and performance tracking, which are crucial for effective competency assessment. These models reflect international best practices while being contextualized for Indonesian vocational education. Relevant frameworks from the Ministry of Education, Culture, Research, and Technology (Kemdikbudristek) and the National Professional Certification Agency (BNSP) are also utilized to ensure certification alignment [3].

The study highlights three main innovation projects developed within this timeframe: a ship navigation simulator integrated with AI features, educational games designed for vocational software teachers, and an augmented reality welding simulator. Although these inventions represent the major technological outputs, the research extends beyond technology application by investigating how these tools have been deployed, assessed, and integrated in vocational teacher-training contexts. Each project was rolled out across a range of training cohorts to gather quantitative and qualitative data on teachers' performance, engagement, and preparation for AI-supported learning tools. This study was mixed-methods in that quantitative data consisted of pre- and post-test scores from a professional competencies exam and task analysis data from the simulators, as well as performance logs generated by the LMS; with qualitative insights obtained through facilitator observations, teacher semi-structured interviews, reflective learning, and also from the evaluation of the training program implementation. These projects aimed to provide immersive and practical learning experiences for vocational teachers while preparing them to implement similar technologies in their classroom environments.

2 Project-Based AI Integration at BBPPMPV BMTI

The period between 2020 and 2023 witnessed a surge in the implementation of AI-based tools within BMTI's training programs. Three major initiatives demonstrate this trend:

2.1 Ship Navigation Simulator (2020–2021)

The first AI-based innovation project is a ship simulator developed to train vocational teachers and students in maritime schools. The simulator includes autopilot systems and automatic radar plotting aid (ARPA), enabling users to experience real-time ship navigation while analyzing positional data, speed, collision avoidance, and distance measurement [4]. The RADAR ARPA system in the BMTI ship simulator includes several key functions, such as:

1. Radar Motion Modes
   - Relative Motion (RM): Ship's position as origin, targets calculated relative to it.
   - True Motion (TM): Fixed origin based on last ship position before moving out of range, resetting upon re-entry.
2. Radar Orientation Modes
   - North Up: Default ship orientation (facing north).
   - Head Up: Rotated based on the ship's yaw (heading).
   - Course Up: Rotated according to the ship's velocity vector angle.
3. Gain control: Rendering only targets with echo strength above a set threshold (0.1–1.0).
   Sea clutter suppression: Removing targets within a defined radius around the ship.
4. Rain clutter suppression: Filtering out low-echo targets beyond a certain distance.
5. Target alarm: Highlighting nearby targets and displaying their names.

The simulator's autopilot system provides automatic heading and speed control, allowing the user to switch between manual and automatic steering to understand the role of navigational aid systems in the practice of piloting a ship. From a learning perspective, the inclusion of these technical activities serves to align the simulation with the vocational competencies in the ship's nautical skills program, specifically situational decision-making, collision avoidance, and radar interpretation. The integration of the autopilot and ARPA SYSTEM RADAR functions allows trainees to engage in authentic navigation tasks and develop competencies that are directly transferable to the real-world ship-handling environment. This tool simulates authentic maritime conditions, allowing trainees to make decisions in dynamic virtual environments [5].

2.2 Educational Game Development (2021–2022)

The second innovation project involves the creation of 2D, 3D, and VR-based educational games adapted for teaching various vocational subjects. AI was integrated into these games to adjust gameplay difficulty, provide adaptive feedback, and align with pedagogical goals [6]. In the development of educational games for this project, AI is integrated at the gameplay level through machine learning and rule-based systems. For example, in matching game mechanics, the AI module is used to classify and match various visual objects. Meanwhile, in platformer gameplay, AI controls score calculations, enemy behavior, and the handling of various events such as collision detection and item collection. The AI component functions as an embedded logic system that responds dynamically to player actions so that each game level can provide consistent automatic feedback and support the achievement of targeted learning objectives. Specifically for AR games, there is an AI system that can convert text into speech, so it can be used by students with special needs who cannot see, these students can hear the audio in the AR game system. These tools are designed not only to enhance engagement but also to help vocational teachers develop gamification strategies within TVET contexts [7].

2.3 AR-Based Welding Simulator (2022–2023)

The third innovation project is an augmented reality welding simulator equipped with AI-powered error detection. In this developed welding simulator, AI elements are specifically used to present participants' welding results based on technical parameters recorded during the welding process. After participants select a specific welding module, for example gas metal arc welding (GMAW), and determine the initial parameters available in the Welding Simulator system. Next, participants practice GMAW welding in AR mode, the system will scan and analyze various key parameters such as torch angle, travel speed, torch distance to the work material (standoff distance), bead consistency and thickness, motion stability, and deviation from the usual welding path. AI then compares these parameter values with the thresholds according to the standards specified in the SKKNI welding. Based on the results of this analysis, the system automatically classifies the welding quality into poor, moderate, or good categories, and presents a performance graph of the participant's welding results, as well as showing the welding areas on the plate that need improvement, as well as welding aspects that are already in accordance. Thus, AI functions as an objective automatic evaluation mechanism and can provide real-time feedback to participants. Integrated with a LMS, the simulator provides real-time feedback, video recording of the welding process, and analytical tools to support formative assessment [8]. This simulator offers a safe and cost-effective alternative to traditional hands-on welding training, making it a significant step forward in vocational pedagogy.

These tools represent BMTI's commitment to aligning its teacher development programs with emerging technological trends and the evolving demands of the labor market.

3 Discussion

These three AI-integrated tools developed at BBPPMPV BMTI exemplify the transformative potential of digital technologies in vocational teacher training. The tools address key challenges in TVET, such as limited access to real equipment, safety risks, and the need for updated pedagogical methods [9, 10]. Teachers involved in these programs reportedly developed increased confidence and competence in applying digital learning strategies, as observed by BMTI facilitators and program evaluations.

BMTI's strategy targets both pre-service and in-service TVET teachers across multiple technical disciplines. The training programs are tailored for teachers in maritime, information technology, and manufacturing sectors. By utilizing AI tools, BMTI aims to enhance not only technical competencies but also digital literacy and pedagogical adaptability. The innovations cater to a broad spectrum of teacher needs, from basic instructional support to advanced skill simulations, ensuring comprehensive professional development [11].

Furthermore, AI's capacity to personalize learning through data-driven insights aligns with international trends in TVET modernization [12]. According to the World Bank, such innovations are essential in preparing the workforce for Industry 4.0 [13]. Recent studies also emphasize the importance of ethical and inclusive use of AI in vocational contexts [14, 15]. In line with Zhao et al. [14], institutions must consider not only technical but also socio-emotional implications of AI in the classroom. Moreover, a global review by Tan and Morgan [15] suggests that AI in TVET must promote inclusion, access, and equity, especially in underserved communities.

Despite these advantages, the integration of AI into teacher training faces several challenges. These include limited digital infrastructure in remote areas, varying levels of digital literacy among teachers, and a lack of standardized frameworks for AI-based instructional design. Resistance to change and the need for continuous professional development further complicate the implementation process. Furthermore, ensuring data privacy and ethical AI use remains a growing concern [17, 18]. These issues demand sustained investment, collaboration between stakeholders, and robust policy frameworks to ensure long-term success. Future studies could focus on comparative implementation models or teacher readiness frameworks in different regions.

4 Conclusion

The case of BMTI demonstrates that AI integration in TVET teacher training is both feasible and transformative when grounded in project-based, collaborative, and locally contextualized strategies. Rather than replacing the teacher's role, AI amplifies pedagogical impact, fosters industrial alignment, and supports a more interactive and effective learning environment.

Capacity development should remain the cornerstone of these innovations. As global TVET systems continue to adapt to digital disruption, the BMTI model offers a replicable and scalable pathway for empowering teachers, enhancing instructional quality, and driving institutional resilience. Sustained investment in digital infrastructure, cross-sector partnerships, and continuous upskilling of teachers will be essential to ensuring long-term success.

Looking ahead, institutions must view AI not as a challenge to overcome but as a tool to strategically embrace for inclusive and future-ready vocational education.

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AI-Enhanced Learning Material Development in TVET for In-Service Trainers

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As of 2025, the integration of artificial intelligence (AI) into technical and vocational education and training (TVET) remains under-researched in the Caucasus region, specifically in Georgia. This study evaluates the efficacy of a three-day workshop, designed to upskill 20 Georgian TVET professionals in the development of AI-enhanced learning materials. Utilizing a mixed-methods research design comprising participant questionnaires and semi-structured participant interviews, the study applies Guskey's five levels of professional development evaluation to interpret the intervention's impact. Findings indicate that the workshop was highly effective in demystifying AI and imparting technical skills, with participants successfully utilizing AI bots to create relevant learning material. However, the study indicates significant systemic barriers to widespread adoption, including a digital skills gap, psychological resistance among educators, and a need for improved institutionalized knowledge-sharing structures. The article concludes that while short-term training can initiate individual competency, achieving sustainable system-wide innovation requires a strategic shift to continuous coaching models, supported by policy frameworks and further incentives for adoption.

1 Introduction: The Need to Evaluate AI Integration in TVET

The rapid advancement of artificial intelligence (AI) has presented both challenges and opportunities for the technical and vocational education and training (TVET) sector worldwide, like other technological watersheds before (e. g., the integration of computer technology, internet search engines, websites, etc.) [1]. As of 2025, there remains a notable dearth of research and documented best practices for the effective integration of AI into TVET, particularly in the Caucasus region and, more specifically, in Georgia [2, 3] due to a limited research infrastructure and a small or non-existent academic TVET community. While a significant body of research exists on AI's potential in broader educational contexts, its application to the unique, practice-oriented pedagogy of TVET remains largely uncharted when it comes to the day-to-day application of technical teachers who have not been trained in the age of AI and may need to adopt a culture of AI-based innovation [4, 5].

For example, studies have explored how AI can be used for better planning, personalized learning, and supporting intelligent tutoring systems, as well as to assist in grading and provide dynamic feedback [6, 7]. The need to upskill in-service TVET teachers is paramount to tap into such great potential. To address skills gaps in this field in the country of Georgia, a three-day workshop was conducted for the German development organization (GIZ) from November 19–21, 2024, upon the request of the Georgian government to support the up-to-date development of learning material in TVET. The workshop aimed to equip 20 Georgian TVET professionals, directly involved in TVET teaching and learning as well as management processes, with sufficient English and the skills to use AI to create modern, stimulating, captivating, and practice-relevant learning materials. A follow-up study was initiated to evaluate the workshop's impact. The primary research question guiding this inquiry was to what extent TVET practitioners have integrated AI tools into their professional practice and what factors have facilitated or hindered the adoption and dissemination of these skills. This article details the research design and presents the findings, applying a well-established evaluation model to interpret the results and providing recommendations for a strategic path forward.

2 Workshop Design for Enhanced Learning Material Design

The three-day workshop focused on enhancing and streamlining the task of creating high-quality learning materials using AI [8]. The agenda was structured to progressively build skills, moving from foundational pedagogical concepts to advanced application of AI tools. On Day 1, participants were introduced to the basics of modern learning material development and a selection of free AI tools. They immediately applied these skills to create a practice-relevant case study for their respective technical fields (especially IT, hospitality, and logistics), a presentation, and a student-engaging task. Day 2 focused on team-based development of an entire curriculum component, including learning situations, content, and engaging group tasks. The use of AI in developing competence-based assessment tasks, both formative and summative in nature were also introduced the second day. The final day, Day 3, was dedicated to optimizing educational material for "higher order" contexts and exploring alternative assessment methods like learning rubrics and portfolio criteria, which could be generated by AI. The workshop was highly interactive, using both traditional and up-to-date AI-powered media, alongside emotional warm-up and "caesura" phases, to encourage continuous reflection and participation [8].

3 Research Design and Methodology of the Study

To provide a comprehensive evaluation of the workshop's impact, a mixed-method research design was employed, utilizing two distinct data collection tools: a questionnaire for workshop participants and a semi-structured interview guide for key stakeholders.

This approach allowed for the collection of both quantitative data on AI adoption rates and qualitative data on the lived experiences and perceptions of AI integration. The results of this study were effectively interpreted using Thomas Guskey's "Five Levels of Professional Development Evaluation" [9], which draws explicitly on Donald Kirkpatrick's seminal work on training evaluation in industry and expands it into educators' training. The levels will be introduced later as a framework for interpretation (see chapter 4).

However, it has to be mentioned that the subject numbers are small and the results potentially mirror this first workshop; the data may nonetheless indicate a way ahead for future large-scale support and how to disseminate skills in AI-driven TVET.

3.1 The Data-Collection Instruments

3.1.1 The Questionnaire for Participants

The questionnaire was designed for the 14 participants who attended all three days of the workshop and was based on a validated questionnaire assessing teacher agency, especially regarding the use of the domain information and communication technology (ICT) in teaching [10]. The items were adapted with respect to the use of AI instead of general ICT in education. Nine participants completed and returned the questionnaire within the specified timeframe. The questionnaire was divided into distinct sections to capture different aspects of the participants' experiences. Section A, "Demographic Information," gathered data on age, gender, current role, and years of experience. The purpose of this section was to identify potential correlations between demographic factors and AI adoption patterns.

Section B, "AI Tool Adoption and Integration," was the core of the questionnaire. It used a combination of closed- and open-ended items to measure the extent and nature of AI tool use. The closed-ended questions, such as items B1, B3, B4, B5, and B6, used a five-point Likert scale (e. g., "Never" to "Very Often" or "Strongly Disagree" to "Strongly Agree") to measure frequency of use, perceived quality improvement, efficiency gains, and confidence in using AI. The open-ended question, B7, asked participants to describe the most valuable AI tool or technique they were currently using, providing deeper qualitative insights.

3.1.2 The Semi-Structured Interview Guide

A separate interview guide was created for a series of semi-structured video interviews with three key stakeholders: the senior GIZ workshop organizer, a senior TVET expert, and a high-level official from the Georgian Ministry of Education. The interviews were designed to last 25 to 30 minutes and provide a rich, multi-perspectival view of the workshop's impact. The guide included a series of open-ended questions across six sections covering: general reflection on the workshop, practical implementation of AI, perceived usefulness and challenges, knowledge dissemination, future support needs, and a final reflection. This interview-based approach allowed for a deeper exploration of systemic issues, attitudinal barriers, and policy-level perspectives that could not be captured by the participant questionnaire.

3.2 Overview of Results

3.2.1 Questionnaire Findings

The analysis of the nine completed questionnaires provides a statistical snapshot of participants' post-workshop AI use, highlighting entries that appear multiple times and descriptive peculiarities:

(a) Post-Workshop AI Use:
Out of the nine respondents, only three reported using AI "regularly" since the workshop, while one used it "a few times". The remaining six questionnaires did not indicate an answer to this question. One participant who responded "Yes, regularly" and another who responded "Yes, a few times" also did not check a box for this question on a separate document.

(b) Specific AI Tools Used:
All nine participants mentioned using Gemini, Claude, and ChatGPT occasionally, as they were covered in the workshop. Other popular tools included Canva AI (five participants), Bing Copilot (four participants), and DALL-E (four participants). One participant also mentioned Gamma for presentations, one mentioned Deep Seek as well as Grog, and one mentioned Presentations.ai. Other AI tools were not specified.

(c) Purpose of AI Use:
The primary applications of AI were for creating lesson plans (four participants), developing quizzes and tests (two participants), and writing texts like case studies and practice-relevant simulations (two participants). One participant used it for generating images/media, and one for "all purpose".

(d) Knowledge Sharing:
Only three participants reported sharing their new AI knowledge with colleagues, while one explicitly reported not sharing. The majority of respondents did not provide an answer to this item.

(e) Challenges:
The open-ended responses identified several challenges, including balancing AI use with academic integrity and the promotion of critical thinking, ensuring the authenticity and accuracy of information, technical and skill-based hurdles (such as not knowing how to generate texts properly), and adapting teaching methods to integrate AI meaningfully. Language barriers were also mentioned as a difficulty, as English was perceived as the primary medium of prompt creation, even though Georgian was already partly available and two automatic translation tools were applied during the workshop.

3.2.2 Qualitative Interview Findings

The thematic analysis carried out for the three stakeholder interviews revealed a more nuanced picture, highlighting both the workshop's "wow" (quote from the interview with the senior expert) factor and the systemic barriers to scaling its impact.

(a) Perceptions and Practical Utility:
The interviews confirmed that the workshop successfully demystified AI, with participants discovering "how easy and handy it can be" to use these tools and that many useful tools are free of charge. Participants found AI "really useful" for creating complex pedagogical materials, such as "practical cases" for teaching and assessment alike. A key learning outcome was the realization that specific and detailed prompts are necessary for high-quality results, suggesting that AI acts as a tool for refining one's own thinking, not just a replacement for it, maybe even for sharpening and condensing one's thoughts for the prompt-generation, as pointed out by two interviewees.

(b) Systemic and Attitudinal Barriers:
A significant barrier seems to be the psychological resistance from educators who may fear AI as a threat to their job necessity. With regard to that, one interviewee described having a "fear that something new had come along that would take something away from me". A "foundational digital gap" also exists, with many educators having "very low modern computer skills". A linguistic barrier further complicates this, as many AI platforms are primarily in English, which many older Georgian educators do not speak, creating a "lingual and generational divide", no matter what translation bots may be available. A major finding was the disconnect between policy and practice, where a key institution in TVET in Georgia, the so-called Skills Agency, was mentioned as not yet taking on a "leading role" in disseminating relevant AI knowledge, despite the Ministry's high-level policy vision.

(c) The Potential Path Ahead:
Interviewees agreed that a single workshop might not be enough, no matter how well organized and implemented; a shift from "training" to continuous "coaching" is pointed out as needed to embed AI into daily practice. There is a call for AI literacy to be an "obligatory" part of a new TVET teacher model, something Georgia aspires to implement, and a need for an incentivized structure where paid "AI coaches" can replicate the knowledge on a large scale, maybe supervised by some international TVET senior expert counselling these coaches.

All in all, the data from the questionnaires reveal both the successes of the training with respect to the participants and the AI-generated learning material developed for the respective fields of technical expertise as well as the challenges of integrating AI into their specific institutions and the wider Georgian TVET system.

4 Interpreting Results through Guskey's Five Levels of Evaluation

Using Thomas Guskey's "Five Levels of Professional Development Evaluation" [9], the impact of the training program was effectively interpreted, to provide insights into future AI training for trainers by exploring five particularly relevant aspects of training:

Level 1 (Participants' Reactions): Based on the interviews, participants' reactions were overwhelmingly positive. The workshop was seen as an "eye-opening" and "very good discovery" that explained AI in detail, thereby "lifting the veil on the mystery" and "revealing its practical utility", according to the thematic interview analysis. This suggests a high degree of participant satisfaction with the training itself. The hands-on nature and focus on free tools addressed initial psychological and financial barriers, making the experience more accessible and engaging.

Level 2 (Participants' Learning): The data confirms that participants learned new skills. The questionnaire responses elucidate that a variety of AI tools were used post-workshop, and interviews highlight the new understanding of the importance of prompt engineering and AI's time-saving benefits. This level was a resounding success, with participants gaining both technical skills and a more nuanced understanding of how to interact with AI effectively to produce quality results as well as a shift in attitudes toward AI, as evidenced by the open-ended survey questions and interviews.

Level 3 (Organizational Support and Change): This is where the evaluation reveals a significant gap. While a high-level policy vision exists from the Ministry of Education in Georgia, the interviews indicate a lack of proactive "organizational support" from key partners like the Skills Agency in the TVET sector or the Quality Agency, which were noted to be "passive" regarding the integration of AI. The absence of a formal structure for knowledge dissemination and the low number of participants who shared their skills with colleagues (only three out of nine), even though one of the selection criteria was the expected integration into the scheme of further training in their home institution and beyond, point to systemic inertia. This suggests that the environment for applying new skills was not consistently supportive, and no follow-up activity supporting the dissemination was carried out.

Level 4 (Participants' Use of New Knowledge and Skills): The results here are mixed and point to a lower rate of sustained use. While some participants reported using AI regularly, the majority of questionnaires did not provide an answer in that regard. The low rate of knowledge sharing also suggests that the use of new skills has been limited to a few proactive individuals, failing to achieve a system-wide spread. This is a critical finding, indicating that the new skills did not translate into widespread, institutionalized practice and point to a future need for action.

Level 5 (Student Learning Outcomes): This study did not directly measure the impact on student learning outcomes as the final "customers" of teacher education. However, the qualitative data suggests that the use of AI to create more "stimulating" and "captivating" learning materials could, in the long term, improve student engagement and learning tremendously and that the workshop has enabled at least the participants to provide for such AI-enhanced TVET classrooms and workshops. However, future research is needed to confirm this.

In summary, the workshop was highly successful at Guskey's Levels 1 and 2, sparking a positive reaction and imparting new skills to the participants. However, it faced significant challenges at Levels 3 and 4, where systemic barriers prevented the widespread use and dissemination of these skills, which points to further focus and support being needed in these areas. Consequently, level 5 (student outcomes) success can only be limited in scope.

5 From Developing Learning Materials to Broader AI Integration in TVET

The findings from this workshop, while focused on learning material development and limited in scope as to the number of participants and subjects researched, may still have broader implications for the integration of AI into other facets of TVET. The challenges observed – namely, the foundational digital skills gap, attitudinal resistance, and systemic inertia – are presumably not unique to this single use case of implementation AI into TVET practice.

They are rather likely to apply with equal or greater force to other areas of AI integration, such as:

(a) AI Integration into the Planning of TVET:
The use of AI for time-consuming and sometimes even "piecemeal" tasks, such as data collection for educational standards, demonstrates its potential for TVET planning. AI could be used to analyze labor market data, identify emerging skills gaps, and assist in designing curricula and, in due course, lesson plans that are responsive to industry needs [7]. However, the same challenges of low digital literacy and a need for an incentivized structure would apply.

(b) AI Integration into the Conducting of TVET:
AI offers potential for personalized learning experiences and automated feedback [11]. As Boehner notes in a 2025 paper [12], it is important to empower learners to find their own solutions rather than simply giving them tasks with predetermined answers. AI can support this by creating individualized learning paths. However, the psychological fear of AI "taking something away" from the TVET teacher, as described by one interviewee, would be a major barrier to this type of integration.

(c) AI Integration into Grading in TVET:
The workshop specifically included a session on using AI for grading, such as designing rubrics and other competence-based instruments. While AI can automate parts of this process, the issue of "authenticity and accuracy of information" provided by students, remains a major concern, as highlighted in particular by the qualitative data. The need to maintain "agency over their pedagogical choices" and ensure "authentic human learning" might be critical in this domain. This

would require a clear policy framework for academic integrity in assessment (and beyond), which is currently a significant challenge mentioned by participants.

The World Bank and UNEVOC have both emphasized the critical role of AI in TVET transformation, focusing on its potential for personalized learning, skill forecasting, and curriculum development [13, 14]. Yet, they also highlight the significant need for investment in digital infrastructure and teacher training, particularly in developing economies [7, 13]. The findings from the Georgian context echo these concerns, highlighting that without addressing foundational digital skills and creating a supportive, incentivized ecosystem, even well-designed AI interventions will struggle to achieve system-wide change. The paper “Status Quo of TVET System and TVET Strategy in Georgia” by Hennige, Bünning, and Grzelidze notes that despite initial successes in modernizing TVET institutions and developing vocational qualifications, vocational education remains a second option only for the majority of young people and economic stakeholders show little confidence in the qualifications of graduates in the country [15], as confirmed by the interviewees in this study. This suggests a persistent quality and perception gap that AI could help address, but only if its integration is managed regularly and strategically as well as communicated to the wider public.

6 TVET-Specific AI Literacy and Future Development

To achieve sustainable integration, the focus must shift from basic AI tool training and usage to a comprehensive AI literacy framework for TVET teachers and students. The UNESCO AI competency framework for teachers, for example, emphasizes the need for teachers to understand not only the technological aspects of AI but also its importance, potential, and socio-ethical implications, such as bias and privacy [16]. This aligns with the qualitative findings from the survey of going beyond one particular AI training and continuously grasping deeper aspects of a fundamental change by receiving counselling support as well as the highlighted concerns about academic integrity and the authenticity of AI-generated content.

A key insight from the Magdeburg Expert Meeting on AI and TVET is that “the AI revolution will not result in the massive job destruction predicted about a decade ago. For most jobs in … labor markets AI means the transformation of tasks and skills” [17]. This understanding is crucial for TVET and the training instructors to obtain and be counselled on, as the goal is to equip workers with the skills to work effectively in hybrid environments where humans and AI-powered machines collaborate. This requires a new approach to training that moves beyond a simple outcome-oriented pedagogy and toward one that values the learning process itself while applying AI and enhancing that process accordingly [17].

As Spöttl also noted in his presentation at the Magdeburg conference, “New concepts for the interaction of people, ’smart’ technology, and AI are needed to ensure that the society of the future is still in control and remains humane” [17]. This perspective suggests that future TVET curricula and lesson plans should be designed to prepare individuals for a world of increasing AI-driven automation and autonomy, in which a skilled worker's competence lies not only in their vocational tasks but in their ability to manage, assess, and understand technology within a human-centered framework. This aligns with the findings from the survey that comprehensive and enduring support is needed and particularly resonates with requests from the qualitative interviews for a new teacher education model in which AI becomes an "obligatory" part of the framework, ensuring that future TVET teachers are equipped with these new, broad competencies, capable of dramatically changing the teaching profession in the technological arena.

7 Conclusions

According to the evaluation results, the GIZ workshop was a highly effective and impactful initiative, particularly in its ability to demystify AI and overcome the initial psychological barriers to its use. It successfully demonstrated the practical utility of these tools for a select group of motivated individuals. However, the analysis reveals that the full, system-wide impact is limited by significant systemic and attitudinal barriers, including a potentially foundational digital skills gap, linguistic challenges in non-English-speaking countries, and a potential disconnect between high-level policy and on-the-ground implementation.

The future of AI, at least in the Georgian TVET context, is not necessarily a question of technology skills only, but also of policy, systemic support, continuous professional development, and cultural change in the teacher education and teaching culture. The findings from this small-scale study indicate nonetheless a strategic roadmap for addressing these challenges. By shifting from a one-off training model to a continuous coaching framework, institutionalizing AI literacy in the new teacher preparation program, and creating an incentivized support structure, stakeholders can transform the workshop's initial success into a lasting impact of AI-driven innovation in the TVET sector.

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AI and the Transfer of Expert Knowledge – Implications for TVET

T. Haase, P. Stürzebecher

Implicit knowledge is a relevant source of knowledge in technical vocational education and training. It provides the basis for effective problem-solving strategies. Experienced professionals have a deep understanding of complex systems and can rely on a wide range of proven solutions. These strategies are acquired on the job and those with experience are often unaware of their specific knowledge. Methods are therefore needed to identify and transfer implicit knowledge in order to make it usable for vocational education and training.

The use of artificial intelligence enables in-depth access to a repository of explicit and implicit knowledge and has the potential to support employees directly in the workplace in the future, e. g., through the utilization of chatbots. The design and implementation of such AI-based knowledge management is a proactive process that requires, on the one hand, the teaching of technological skills and, on the other, prevention of de-qualification in order to enable future professionals to become critical thinkers. The article reflects on fields of engagement in the design and implementation processes and provides guidelines for a human-centered design approach.

Introduction

In technical and vocational education and training (TVET), tacit knowledge (TK) represents a key resource of implicit, experience-based understanding. Deeply embedded in practical work contexts, it forms the foundation for effective problem-solving strategies in complex professional situations. TK is highly personal and deeply rooted in individual action, experience, and involvement in a specific context. It encompasses insights, intuitions, and hunches that are hard to communicate or share, forming the basis for innovation and learning within organizations. Experienced professionals possess a broad repertoire of TK – that is, implicit knowledge (IK) acquired through workplace practice, which, in contrast to explicit knowledge, is rarely documented systematically or consciously reflected upon. As a result, this knowledge often remains inaccessible – both to colleagues and to subsequent generations [1].

In practice, clear structures for systematically capturing and documenting IK are often lacking. Moreover, this knowledge is closely tied to the individual, which significantly complicates its transfer to other employees. According to Reisach et al. [2], the challenge therefore lies in developing suitable methods that enable the identification, structuring, and utilization of this valuable knowledge for learning and work processes.

Artificial intelligence (AI) offers new potential in this context. It enables access to diverse knowledge sources and can support employees directly in their work environments – for example, through the use of chatbots that provide context-specific information [3]. However, the design and implementation of such AI-based knowledge systems requires more than just a technological solution. A responsible design approach is needed – one that enhances users' technological competence while also counteracting potential de-skilling due to technological overload [4].

The aim of this paper is to explore the opportunities and challenges associated with AI-supported transfer of implicit knowledge in the TVET context. Following an introduction to the background and objectives, the significance of TK for professional competence and its relevance to TVET will be discussed (Section 2). Section 3 outlines established methods for capturing and transferring TK, along with their limitations. Building on this, Section 4 examines the potential of AI as a tool for knowledge application, both in general and specifically through knowledge-based chatbots. Finally, Section 5 addresses key design principles for AI-supported knowledge tools, followed by a conclusion and outlook in Section 6.

The Relevance of Tacit Knowledge for TVET

Tacit knowledge constitutes a fundamental element of workplace education – particularly in the context of complex, non-standardized work processes. In contrast to explicit knowledge, which is codified and can be conveyed through manuals or formal training, it is difficult to verbalize. While implicit knowledge denotes forms of understanding that are not consciously articulated but can be made explicit through reflection, explanation, or systematic analysis, TK refers to personal, experience-based familiarity that is deeply rooted in action, commitment, and involvement within a specific context. It encompasses intuitive skills, perceptions, and know-how that individuals possess but cannot easily articulate or formalize [1]. It enables individuals to navigate uncertainty, deviations, and contextual demands in everyday work situations – precisely where theoretical knowledge reaches its limits.

In TVET, implicit knowledge plays a pivotal role in bridging the gap between theoretical instruction and practical application. Learners must not only understand rules and procedures but also learn when and how to adapt them. In this sense, as Rauner [5] points out, IK contributes significantly to the development of occupational competence.

The practical relevance of TK can be illustrated through the following example: An experienced industrial mechanic notices a slight but unusual vibration when starting a production machine. Without hesitation, she reduces the rotational speed and inspects the system. She immediately recognizes the sign of an imbalance – possibly caused by a loosening drive component or a misaligned workpiece. A novice, by contrast, might not have noticed the vibration at all or might have dismissed it as harmless. Here, the mechanic's IK enables a prompt, context-appropriate, and damage-preventing decision.

TK is also highly individualized: Two skilled workers may solve the same task using different yet equally effective strategies. Access to standardized curricula alone is therefore insufficient. Learners must be exposed to diverse tacit perspectives in order to develop the ability to apply knowledge flexibly across varying contexts.

Specific methods of knowledge transfer are essential to preserve and pass on this valuable form of knowledge. Digital transformation offers significant opportunities in this regard: Modern documentation systems, knowledge networking, and intelligent assistance technologies can facilitate more efficient documentation, structuring, and dissemination of IK. In particular, AI-powered chatbots hold potential to establish new pathways for knowledge transfer in vocational education – although their effectiveness largely depends on the quality of the underlying knowledge base and the specific use case.

Future professionals must therefore be empowered not only to interact with AI systems but also to use them proactively for documenting and applying knowledge. AI is becoming an integral part of the work environment – whether through the retrieval of experience-based decision support or the continuous refinement of work processes. This gives rise to a new learning domain within TVET: AI competency in the workplace. Learners must be equipped to engage with AI in a reflective and responsible manner, including an understanding of its potential, limitations, and ethical implications.

Methods for Capturing and Transferring Tacit Knowledge

Despite the inherent challenges, specific methods can be employed to make implicit knowledge accessible and usable for learning processes in TVET contexts.

Didactically, formats such as peer learning [6], mentoring [7], and workplace-integrated learning [8] have proved effective in the past. These approaches enable experienced professionals to pass on their knowledge through direct interaction. The focus lies not only on factual information or procedural instructions but also on reflective experiences, situational problem-solving, and strategic action in professional contexts. Empirical studies, such as those by Mulder [9], show that learners benefit from these methods not only in terms of technical skills but also in social and personal competencies such as teamwork, autonomy, and a sense of responsibility.

Traditional research methods such as workplace observations, experience reports, and semi-structured interviews with experienced people are suitable for capturing IK. Narrative approaches with a storytelling component – such as storytelling itself [10] or triadic conversations [11] – are particularly well suited for verbalizing tacit knowledge and making it comprehensible to others. Case-based learning, for instance through the collaborative resolution of real-world problems, also supports the targeted transfer of professional experiences within a team setting [12].

At the same time, these conventional approaches face limitations: They are often time-consuming, person-dependent, and heavily reliant on the willingness and ability of experienced people to reflect and communicate. Moreover, as Mohajan [13] emphasizes, the implicit dimensions of TK are difficult to fully formalize or standardize, as they include both expressible and inexpressible elements.

Here, AI-supported technologies can offer valuable contributions. They are intended to assist in the documentation and pedagogically effective preparation of professionals' implicit knowledge. By systematically capturing, structuring, and making this knowledge accessible (e. g., through the analysis of work processes, user feedback, or targeted knowledge elicitation) AI systems can enhance and extend existing methods for sharing knowledge.

AI as a Tool for Knowledge Utilization

Within the framework of digital transformation, technologies such as digital assistance systems, AI-powered chatbots, and automated process documentation tools open up new possibilities for making tacit knowledge accessible and usable in organizational contexts [4, 13]. AI is capable of analyzing and structuring both explicit knowledge (e. g., training materials or protocols) and implicit knowledge, such as experience-based behavioral patterns, and integrating them into learning processes [3].

In the context of TVET in particular, AI enables the analysis of extensive data sources, including logs, experience reports, and informal notes, and can extract relevant content from them. Through semantic methods, typical error patterns, proven solution strategies, and context-sensitive recommendations can be automatically identified and delivered in a situationally appropriate manner [4]. Applications range from the classification of root causes of errors to dialog-based assistance systems that guide employees in their work processes. These approaches offer significant advantages in terms of scalability, availability, and personalization of learning content – users receive tailored information precisely when it is needed [4].

However, many AI models operate as black boxes, making their functioning difficult to understand for users. They also carry risks such as hallucinations, bias, inaccurate recommendations, or data privacy concerns [14]. Furthermore, AI may be perceived by employees as a potential replacement for human expertise, which can lead to uncertainty. These concerns must be taken seriously and addressed through a responsible design approach [4, 5].

In practice, AI technologies can support the transfer of experience through automated transcription, text analysis, and structured capture of process data. This enables relevant content from experience reports to be systematically extracted and integrated into digital learning and assistance systems – for example, through adaptive learning modules, context-based prompts, or interactive follow-up questions [3].

As highlighted by Wildemann [15], by combining analog methods with AI-supported technologies, a powerful infrastructure for continuous organizational learning can be established. In this way, TK – which has traditionally been difficult to access – can be systematically documented, updated, and incorporated into both learning and work processes.

Practice Example: Chatbots as Digital Learning Companions in Industrial Vocational Training

Digital assistance systems are gaining importance in vocational education and training, particularly when they can provide context-sensitive and work-integrated access to TK [3, 4]. A practical example of this is the use of a chatbot in the training of industrial mechanics at a medium-sized manufacturing company:

A trainee is working on a CNC milling machine and encounters uncertainty while setting up the clamping device. The theoretical training took place several weeks earlier, and no expert is currently available for consultation. Instead of interrupting the workflow or waiting for a response, the trainee turns to the company's chatbot and asks, "What should I do if the workpiece shifts during milling?"

The chatbot analyzes the inquiry based on the available knowledge base, identifies the problem area, and points to the frequent root cause of uneven contact due to a dirty machine table. It then provides a step-by-step guide for inspecting the clamping elements and offers an experience report in which an expert describes the proper procedure using a real-life case. If desired, the chatbot also provides safety-related notes and links to the relevant operating instructions.

The trainee receives real-time support – low-threshold, context-relevant, and conducive to learning [8]. This allows them to independently analyze the issue, reflect on it, and implement a solution. In this moment, implicit knowledge – knowledge he is not consciously aware of – is made accessible through digital assistance [13].

This scenario illustrates how chatbots can support the transfer of TK without replacing the role of instructors. They serve as digital companions that enhance training, particularly in the domain of informal learning between formal instructional units. However, the effective use of such systems depends on subject-matter-validated content, intuitive usability, and an established enablement framework that fosters learner trust [4].

Design Requirements for AI-Supported Knowledge Tools

The development and application of AI-supported knowledge management systems require a holistic design approach that systematically considers both technical and pedagogical requirements [4, 14]. As Papagiannidis et al. [16] stresses, such an approach must be rooted in the principles of responsible AI, including transparency, fairness, data protection, accountability, and security.

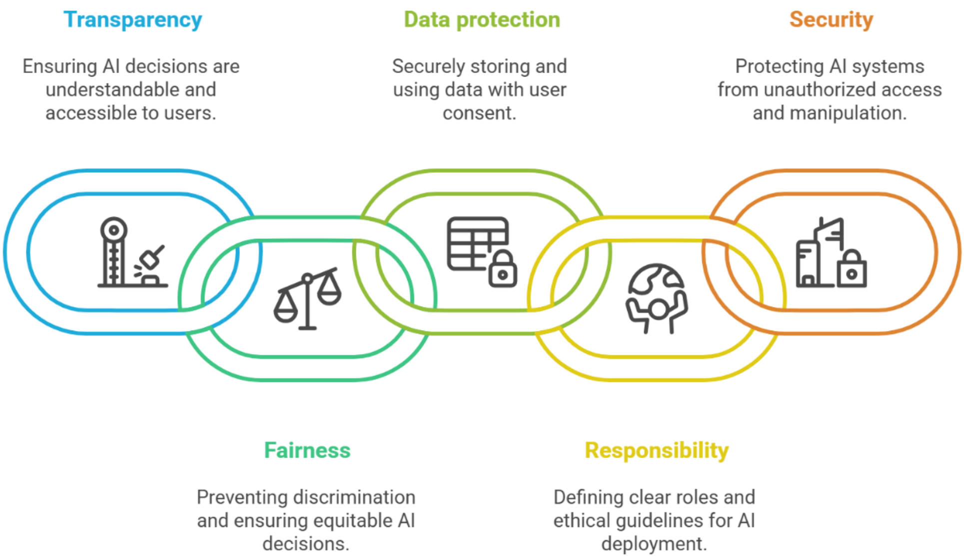

Figure 1: Design criteria for responsible AI systems in knowledge management

1. Transparency in AI-based systems means that their decision-making processes and operations must be comprehensible and accessible to users. This includes explainable models, clear documentation, and instructional design that fosters critical thinking and discloses knowledge sources. For successful implementation of AI tools such as chatbots, complementary enablement strategies are essential. Users should understand how chatbot responses are generated, what data sources they rely on, and whether a given recommendation is transferable to their own problem context. A didactically informed design should, therefore, encourage critical reflection and provide access to underlying sources, such as manuals or operational logs. In practice, this could involve integrating introductory training that explains the chatbot's operational logic, data usage, and how users can assess the relevance and validity of recommendations.
2. *Fairness* implies that AI systems do not discriminate against individuals or groups and that decisions are made in a transparent and equitable manner. This requires the mitigation of data bias and hallucinations, the inclusion of diverse perspectives, and the implementation of transparent selection processes. A chatbot, for instance, should be equally accessible to all employees, regardless of experience level, gender, age, language, or religious background. This raises important questions: What counts as expert knowledge when curating the system's content? Should all experiences be weighted equally? Additionally, solution recommendations must be presented objectively to avoid privileging any particular user group. In workplace practice, this could mean that a chatbot integrates both the strategies of seasoned professionals and the insights of newer employees to reflect a diverse body of knowledge.

3. *Data protection* is critical when working with AI systems that process personal or organization-specific information. Sensitive data must be stored securely, processed responsibly, and used only to the extent necessary – always in compliance with applicable data protection regulations and based on transparent user consent. When working with experience-based content, it is important to consider how much personal information is truly necessary for a meaningful narrative. In practice, the origin of an experience may influence whether a recommendation is trusted, yet it must also be determined whether stories need to remain intact or may be synthesized across multiple sources. Furthermore, organizational data must remain within the company. In the context of a chatbot, this means ensuring that personal data in the training set is anonymized and that access to sensitive project-related content is restricted to authorized user groups.
4. *Accountability* is essential across all phases of AI deployment to ensure that ethical, legal, and practical implications are addressed effectively. Clear responsibilities must be defined to guide the development, implementation, and ongoing operation of the system. To ensure that employees continue to critically reflect on their actions when interacting with AI, the system must be didactically designed to promote critical thinking. A responsible implementation process must be accompanied by a comprehensive enablement strategy. Decision-making authority should remain with the users, who must be able to understand the context of AI-generated recommendations and assess their applicability to specific situations. This requires validated content and clearly defined governance structures: Who approves system content? Who is responsible for adaptations? How is user feedback incorporated into further development? Only through such measures can AI use remain controlled and accountable.
5. *Security* is a fundamental requirement for AI systems, particularly when handling sensitive or organization-specific information. These systems must be protected against unauthorized access, manipulation, and malfunction. Implicit knowledge is regarded as a valuable and proprietary asset and must therefore be safeguarded accordingly. Only authorized content should be entered into the system, and access to sensitive information must be restricted to designated user groups. In the case of a chatbot, for example, which may process confidential maintenance protocols, experience reports, or production-specific procedures, it must be ensured that no external access is possible and that only users with defined roles – such as service personnel or trainers – can retrieve or manage the data.

From these criteria for responsible AI design, key didactic principles can be derived for developing AI-supported knowledge management systems in the TVET context [3]. AI-based tools such as chatbots should:

- Be designed to support learning processes [17];
- Promote learner autonomy and self-regulation [18];
- Connect to learners' professional and implicit knowledge;

- Be adaptive, supporting diverse learning paths and providing personalized feedback;
- Empower learners to critically assess AI-generated content and validate its relevance [19];
- Transparently explain how content and recommendations are generated (e. g., by referencing source experiences) [20];
- Foster critical thinking to enable reflective and responsible use of the system [21].

Particular emphasis should be placed on integration into workplace learning. AI systems should not be implemented in isolation but as part of hybrid learning environments – in combination with practical training, peer learning, and facilitated reflection. In such contexts, instructors no longer act solely as transmitters of knowledge but increasingly take on the role of learning environment designers and facilitators of learning processes [5].

This shift in instructional roles highlights the need for a new competency profile for TVET educators. In addition to technical literacy, educators must possess pedagogical and didactic skills in working with AI. They need to be able to curate meaningful learning experiences, critically reflect on digital content, and support learners in interacting with AI systems. Only then can AI-supported tools be designed not only to be technologically powerful but also to be pedagogically effective and contextually relevant to real-world practice, as emphasized by Yun et al. [4].

Conclusions and Outlook

This paper has shown that tacit knowledge represents a key resource in the context of technical and vocational education and training. As implicit, action-based knowledge, it forms the foundation of employees' situational problem-solving abilities and occupational competence. However, its transfer remains challenging due to the lack of systematic documentation and structured dissemination.

The analysis of traditional knowledge management methods – such as peer learning, mentoring, and workplace-integrated learning – demonstrates that interaction with experienced professionals continues to play a vital role. Nevertheless, analog approaches reach their limits, particularly in terms of availability, scalability, and documentation capabilities.

AI-supported knowledge management systems offer new potential in this regard. These systems can structure, contextualize, and deliver information on demand. Rather than replacing TK, they support its activation and transmission within work processes [22]. The example of a chatbot in vocational training illustrated how digital assistance systems can make implicit knowledge situationally accessible.

Successful implementation, however, requires several conditions to be met. From a technical perspective, this includes adequate IT infrastructure, structured data sources, and compatible interfaces. Equally important is targeted user enablement –

through training, awareness-raising measures, and continuous support. Teachers and trainers should be involved early in the development process, assuming new roles as curators, prompt engineers, or learning facilitators.

A phased rollout via pilot projects is recommended, with iterative refinement and ongoing evaluation. Monitoring and feedback mechanisms are essential to ensure system quality and promote continuous improvement. The involvement of key stakeholders – such as IT departments, workers' councils, and management – fosters acceptance and supports sustainable integration into the educational system.

With the growing use of AI systems in vocational education, a new learning domain is emerging: AI competency in the workplace. This field demands both technological and pedagogical innovation. Future professionals must be empowered not only to use AI tools but also to understand their functionality, limitations, and risks – and to reflect on them critically. Likewise, instructors require new competencies to integrate AI systems into learning processes in a pedagogically sound manner. The development of corresponding competency frameworks and the investigation of long-term effectiveness are therefore central tasks for both research and practice.

Future developments may move toward adaptive, interactive systems that respond more precisely to individual learning needs and dynamically adjust to users' levels of experience. Only through a balanced interplay of technology, pedagogy, and organizational development can AI be implemented in TVET in a sustainable, effective, and responsible manner.

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Fostering AI Competencies in Higher Education: The Digital Skills to Succeed Approach in Asia

E. Antohi

The digital transformation of Asian economies has created a pressing demand for artificial intelligence (AI) skills among university graduates. The Digital Skills to Succeed in Asia project (DS2S), commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by the German Agency for International Cooperation (GIZ), addresses this challenge by fostering AI competencies in higher education institutions in Bangladesh, India, and Vietnam. Through co-created micro-credentials, faculty development programmes, and industry-linked learning environments, DS2S equips students with practical, ethical, and employable AI skills. The project emphasises interdisciplinary learning, gender mainstreaming, and applied problem solving via Living Labs, hackathons, and capstone projects, ensuring alignment with local labour market needs while adhering to international standards. By strengthening employability, promoting inclusive digital education, and facilitating cross-border academic and industrial collaboration, DS2S establishes a model for responsible AI skills development. The initiative highlights how context-sensitive higher education interventions can contribute to regional innovation, sustainable AI adoption, and EU–Asia digital partnerships. Insights from DS2S offer guidance for policymakers, educators, and development actors seeking to build scalable, inclusive, and future-oriented AI skills ecosystems in emerging markets.

1 Introduction: Rationale and Context

The Digital Skills to Succeed in Asia project (DS2S), commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by the German Agency for International Cooperation (GIZ), seeks to strengthen digital competencies among university students – particularly young women – in Bangladesh, India, and Vietnam. Anchored in a collaborative model involving universities, private sector partners, and government agencies, the project focuses on three core pillars: establishing a regional digital skills network for knowledge exchange; enhancing faculty capacities through targeted professional development; and co-designing micro-credential courses in artificial intelligence (AI), data, and digital entrepreneurship with German higher education institutions and industry partners. While DS2S covers a wide spectrum of digital skill areas, this article concentrates specifically on the measures that contribute to AI skill development, given their growing strategic relevance in all three partner countries.

1.1 Rationale of the Project

Across Asia, labour markets are undergoing profound digital transformation, positioning AI and digital technologies as foundational drivers of economic competitiveness and job creation. Recent regional analysis highlights that the rapid evolution of technology increases the demand for new skills and shapes labour markets, with digital jobs and skills now central to employment growth across the region [1]. Governments in India, Viet Nam, and Bangladesh have invested in national digital strategies explicitly targeting digital transformation and workforce readiness to harness productivity gains from emerging technologies [1].

However, the rapid pace of technological change has intensified skills mismatches between graduates and industry needs. Regional labour market outlooks note persistent "labor market imbalances" and the need for stronger skills development responses to ensure workers can participate fully in the digital economy, especially as automation and digitalisation reshape work patterns and labour demand [2]. This mismatch is compounded by gaps in foundational and applied digital competencies, which restrict graduates' employability in high-growth, technology-driven sectors.

Findings from the project's Rapid Country Assessments (RCAs) confirm this mismatch. Across all three countries, universities face systemic barriers to providing future-oriented AI training, including outdated curricula, limited access to applied learning environments, insufficient faculty competencies in emerging technologies, and weak linkages between academia and industry. These supply-side constraints coexist with strong demand: employers in finance, manufacturing, services, and the public sector consistently report shortages in AI-related skill profiles – particularly in areas such as machine learning literacy, data-driven problem solving, and responsible technology deployment.

The gender dimension adds another layer of urgency. In Asia-Pacific labour markets, young women are disproportionately excluded from employment and skills pathways: the International Labour Organisation reports that "young women [in the region] are almost three times more likely not to be in employment, education, or training (NEET) than young men" [2]. This exclusion reflects broader gender inequalities that inhibit women's participation in digital and technology-intensive sectors, exacerbating skills gaps and barriers to meaningful work. Beyond labour force participation, gender disparities in digital skills and advanced technological learning further entrench inequality; women in low- and middle-income countries are 15 percent less likely than men to use mobile internet, a critical access point for acquiring digital and AI-related competencies [9].

Underrepresentation of women in STEM and AI-linked fields risks reproducing structural inequalities and reinforcing gendered biases in algorithmic systems. UNESCO's 2024 Gender Report highlights persistent gaps in access to technology and digital skills acquisition, noting that gender divides in digital competencies start early and continue throughout educational and professional pathways [4]. Addressing this imbalance is therefore not only a matter of inclusion but also of technological integrity and social justice, as ensuring women's equitable participation in digital ecosystems strengthens innovation, fairness, and economic outcomes for entire societies.

1.2 Country-Specific Contexts

Although united by a shared trajectory of digitalization, the three partner countries exhibit distinct challenges and opportunities:

- **India** has a rapidly expanding digital economy and a leading global IT sector, yet significant regional disparities and uneven institutional capacities hinder inclusive AI adoption [3]. Universities frequently highlight gaps in practice-oriented AI training and access to industry-grade tools.
- **Viet Nam** is experiencing strong governmental momentum toward AI innovation, supported by its National Digital Transformation Roadmap [7]. However, higher education institutions face constraints in modernising curricula and in fostering pedagogical approaches that emphasise applied problem solving.
- **Bangladesh** is one of the fastest digitalizing economies in the region but encounters acute shortages in AI-competent graduates [1]. Many universities lack faculty with up-to-date expertise in data science and AI, making capacity development a prerequisite for any meaningful curricular reform.

1.3 A Strategic Response

The DS2S project is positioned as a systemic intervention addressing these multi-layered challenges. By aligning its measures with national strategies, labour market needs, and international frameworks – including UNESCO's AI competency guidance [5, 6], and the DigComp [8] digital skills taxonomy – the project operationalises a context-sensitive yet globally informed approach. Its emphasis on co-creation with local universities and industry ensures that AI-related micro-credentials, faculty development programmes, and gender-mainstreaming measures are not abstract add-ons but embedded responses to concrete institutional and societal needs.

Furthermore, DS2S contributes to broader geopolitical and policy agendas, including EU–Asia digital cooperation and Germany's efforts to foster responsible and inclusive AI partnerships under the Global Gateway Initiative. In this sense, the project serves both developmental and strategic objectives: strengthening employability and innovation ecosystems in partner countries while advancing shared values in the governance and use of emerging technologies.

2 Developing the DS2S Learning Offer: From Needs to Co-Created AI Capacity Building

The development of the DS2S learning offer – comprising micro-credentials for students and faculty development programmes for teaching staff – followed a structured yet highly adaptive process. While international digital and AI competence frameworks provided orientation, the decisive drivers were the needs identified through rapid assessments, consultations with partner universities, the respective ministries of education, and feedback from industry actors. The resulting courses reflect a deliberate balance between global standards and contextual relevance across Bangladesh, India, and Viet Nam.

2.1 Foundations: Needs Assessments and Framework Mapping

The design process began with the Rapid Country Assessments (RCAs) conducted in 2023, which examined the digital skills landscape in each partner country. These assessments highlighted a consistent pattern:

- growing demand for AI and data-related competencies across sectors,
- insufficient applied learning opportunities in higher education institutions (HEIs),
- limited exposure of non-technical students to emerging technologies, and
- strong institutional interest in integrating digital innovation and entrepreneurship into curricula.

In parallel, the team reviewed leading international frameworks, including the EU's DigComp and the UN Digital Literacy Frameworks. These frameworks supported the structuring of competencies and ensured that the emerging learning pathways adhered to internationally recognised standards. However, they were not treated as prescriptive templates; rather, they served as analytical tools that helped clarify the landscape of digital and AI skills relevant to the project.

2.2 Identifying Priority Areas: Convergence of Needs and Strategic Relevance

The decision to focus on **artificial intelligence**, **data literacy**, and **digital entrepreneurship** emerged from the convergence of three factors:

1. **Empirical evidence from the RCAs**, which identified AI and data skills as growing labour market requirements in all three partner countries.
2. **Institutional mandates and priorities** of partner universities, particularly in India and Viet Nam, where digital transformation and innovation figure prominently in academic development strategies.
3. **The thematic scope of DS2S**, which aims to enable young people – especially women – to participate in digitally transforming economies and access new employment pathways.

During design workshops with partners it was collectively recognised that the project should not replicate foundational digital literacy training. Such content was either already available or not aligned with the capabilities and ambitions of HEIs. Instead, the project would promote applied, interdisciplinary AI literacy, enabling non-tech students to use AI tools, understand data-driven decision-making, and integrate digital innovation into field-specific contexts.

2.3 Co-Creation and Content of the Micro-Credentials and Faculty Development Programmes

A defining feature of the DS2S approach was its co-creation methodology. Rather than importing pre-defined curricula, the project worked closely with partner universities in Bangladesh, India, and Viet Nam to jointly design micro-credentials and faculty development programmes. This process was supported by collaboration with German academic partners – Leipzig University and the Humboldt Institute for Internet and Society (HIIG) – which contributed methodological expertise, quality assurance, and perspectives on responsible AI use and digital pedagogy.

Co-creation unfolded through iterative steps, including mapping institutional priorities and skills gaps, developing and refining learning outcomes and course outlines, and integrating locally relevant case studies and practical assignments. Draft modules were reviewed collaboratively with academic staff and validated through consultations with students and industry representatives. This collaborative design model ensured academic rigour, pedagogical soundness, strong institutional ownership, and close alignment with the needs of local higher education ecosystems, thereby enhancing both contextual relevance and long-term sustainability.

The first output of this process was the micro-credential **"Unpacking AI: Practical Foundations for Non-Technical Students"** and introduces undergraduate students to the technical, social, and ethical foundations of artificial intelligence. The course moves deliberately beyond technical definitions to highlight AI's societal implications – covering topics such as algorithmic bias, discrimination, misinformation, and the governance of AI systems. Modules on basic technical principles and machine-learning logic are complemented with content on inequality and the political economy of data, enabling non-technical learners to build critical AI literacy rather than only functional skills. The micro-credential thus supports learners in understanding *how* AI works, *where* it is applied, and *why* responsible and inclusive use matters.

Another micro-credential, **"Digital Fashion"**, was developed in response to the textile and garment sector's digital transformation in South Asia. Tailored to textile engineers, technologists, and fashion designers, the blended-format course introduces students to digitalisation trends in manufacturing workflows, blockchain for supply-chain transparency, big data applications, AI in fashion design, and emerging models around digital goods. The course also integrates sustainability and ethics, preparing future professionals to navigate a sector where digital tools increasingly shape creative processes, logistics, and labour relations. This specialised micro-credential demonstrates how AI-related skills can be embedded in sector-specific learning pathways that reflect local industry relevance.

The micro-credential **"AI for Social Good Projects"** targets undergraduate and graduate learners who already possess a basic understanding of AI concepts and have occasional experience using AI tools in their studies or work. The course is designed to guide students in applying AI directly to project management tasks, enabling them to connect core concepts of artificial intelligence, social good, and project management, and to use AI tools effectively across all phases of the project cycle.

By the end of the hybrid course, learners will be able to apply AI in project initiation, planning, execution, monitoring, and impact evaluation; analyse project outcomes using AI-supported methods; identify sources of bias in AI systems and understand their implications for project decisions; and evaluate approaches that enhance transparency and long-term sustainability in AI-supported project environments.

By combining methodological rigour with a strongly application-oriented perspective, the course equips students with practical skills to manage projects more efficiently and responsibly using AI tools. This empowers them to develop AI-enabled project solutions that address societal challenges effectively and ethically within their local and regional contexts.

The **Industry Challenge Micro-Credential** forms the applied cornerstone of the DS2S learning portfolio, bridging foundational AI competencies with real-world problem solving through experiential learning formats jointly implemented with industry partners such as Cisco, IBM, and HP. Designed as a blended, modular learning pathway, the micro-credential requires students to first complete DS2S-developed foundational micro-credentials in AI, data, or digital entrepreneurship, after which they transition into hands-on experiential learning environments supported by global industry platforms. Within the experiential learning formats, students engage in challenge-based hackathons, industry-linked innovation sprints, and cross-country collaboration formats, applying AI tools and methods to concrete societal and business problems. A second pathway focuses on project-based learning in game development and esports, where participants – guided by HP and specialised micro-credentials – translate AI and creative tech skills into capstone projects presented to industry experts. To ensure long-term sustainability, universities integrate these pathways into their credit systems, curriculum structures, and faculty development processes, making the industry challenge micro-credential a deeply institutionalised mechanism for fostering job-relevant, practice-oriented AI capabilities among diverse groups of learners.

Complementing the student-focused interventions, the project developed a comprehensive **Faculty Development Programme (FDP) on "AI for Teaching and Research"**. Co-designed with Leipzig University, the FDP equips lecturers with both the pedagogical and technical competencies needed to integrate AI – particularly generative AI – into their teaching, research, and administrative practices. Structured into four modules, the programme supports lecturers in designing AI-enabled curricula, creating multimedia teaching materials with AI tools, applying AI to research workflows, analysing quantitative and qualitative data, and developing AI-powered teaching assistants. A dedicated module on responsible and ethical AI use guides faculty in implementing institutional policies on academic integrity, transparency, and data governance. Through this programme, universities strengthen their internal capacities to embed AI competencies sustainably within their teaching ecosystem.

Taken together, the micro-credentials and faculty development programmes developed under DS2S reflect a curricular architecture that is:

1. **co-created** with local and international academic partners,
2. **grounded in contextual needs** rather than prescriptive global frameworks,
3. aligned with interdisciplinary and industry-relevant applications of AI, and
4. **designed for long-term institutional embedding** through faculty training and credit recognition.

This approach ensures that AI skills development in partner universities is both structurally anchored and responsive to societal needs – laying the foundation for sustainable impact beyond the project's duration.

2.4 Balancing Global Frameworks with Local Context: A Pragmatic Design Logic

While international frameworks such as EU DigComp and the UN Digital Literacy Framework provided a valuable conceptual orientation, they were never applied as rigid templates. Instead, they served as reference points for structuring competencies and ensuring alignment with international standards, while the actual design choices reflected the needs and realities of partner universities and their socio-economic environments.

Early needs assessments – conducted with faculty, students, industry partners, and university leadership – revealed a clear demand for competencies in AI, data literacy, and digital innovation. These findings were further reinforced by the project's rapid assessment report, which identified AI and data-related skills as critical growth areas for learners in Bangladesh, India, and Viet Nam. This evidence shaped the thematic direction more strongly than any predefined competency catalogue.

In practice, the project adopted a context-first interpretation of these global frameworks. Discussions during the co-creation workshop in Bangkok helped clarify that the focus would not be on foundational computer literacy – already largely covered in the partner universities – but on applied, interdisciplinary AI literacy aligned with digital entrepreneurship, industry relevance, and employability. The strong emphasis on AI also reflected the strategic priorities of the participating universities, many of which hold mandates or institutional strategies centred on digitalisation and innovation.

By carefully comparing framework requirements with institutional needs, DS2S identified areas where its interventions could create the greatest added value:

- strengthening AI literacy among non-technical learners,
- promoting responsible and ethical use of AI technologies,
- embedding AI skills within sector-specific domains such as fashion, manufacturing, and sustainability, and
- supporting faculty in adopting AI tools for teaching, curriculum design, and research.

This led to a design logic where frameworks provided structure and legitimacy, but local needs and contextual realities determined the learning outcomes, course focus, and teaching methodologies.

In essence, while global digital and AI competence frameworks informed the architecture of the learning pathways, the decisive factor was always the bottom-up articulation of needs from partner institutions. This ensured that the resulting courses were not only aligned with international standards, but also relevant, feasible, and meaningful within their institutional and societal contexts.

3 Collaboration with Industry as a Driver of Applied AI Skills Development

The integration of industry expertise has been a defining feature of the DS2S approach, ensuring that the project's micro-credentials and learning pathways respond directly to evolving labour market demands. While Section 2 highlighted how industry actors shaped the content and application-oriented design of several micro-credentials – including the Industry Challenge pathway – this section elaborates on the broader structures, partnerships, and mechanisms that underpin these collaborations.

3.1 Industry Co-Creation for Labour-Market Relevance

From the outset, DS2S adopted a systematic consultation process with industry actors across India, Viet Nam, and Bangladesh. Rather than relying solely on the perspectives of large multinational technology companies, the project engaged a diverse ecosystem of organisations ranging from global industry leaders (IBM, Cisco, HP) to small and medium enterprises working at the intersection of AI, data literacy, digital innovation, and social sciences. Partners such as CivicDataLab, for example, contributed grounded insights regarding the application of AI and data skills for public-interest technology and civic innovation – ensuring that the resulting micro-credentials would prepare students not only for the private sector, but also for broader societal challenges.

These consultations helped refine the scope, technical depth, and pedagogical structure of the micro-credentials. They ensured that skills such as data-enabled decision-making, ethical AI awareness, basic coding for AI-supported problem solving, and cross-disciplinary innovation were directly aligned with current hiring practices and emergent job profiles across sectors. As described in Section 2.4, this collaborative design process fed directly into both the foundational and specialised micro-credentials, including Unpacking AI, AI for Social Good, Digital Fashion, and the Industry Challenge pathway embedded in experiential learning formats.

3.2 Formal Partnerships and the Role of Stackability

The partnership framework was formalised through Memoranda of Understanding (MoUs) with HP, Cisco, and IBM. These agreements serve two critical purposes. First, they guarantee that micro-credentials developed by DS2S are stackable – meaning they can be combined with industry-certified modules on platforms such as the Cisco Networking Academy or HP's digital learning environments. This enhances the portability and recognition of competencies across institutional and national borders. Second, the MoUs institutionalise collaboration on emerging topics such as generative AI in education, industry challenge-based learning, cloud and cybersecurity competencies, and AI applications in creative industries.

In practice, this stackability enables students to transition seamlessly from DS2S-designed foundational modules to industry-provided applied modules, thereby strengthening employability and expanding opportunities for certification in line with international industry standards.

3.3 Experiential Learning Formats: Translating Learning into Practice

As outlined in Section 2.4, the experiential learning model is the central mechanism for translating theoretical learning into authentic problem-solving experiences. Co-developed with Leipzig University and the Maharashtra State Skills University (MSSU), the experiential learning formats establish a physical and digital environment where learners, faculty, and industry practitioners jointly engage in experimentation, simulation, and iterative solution design. This includes:

- **Simulated industry processes**, combining manual workflow simulations with digital video analysis and 3D modelling;
- Real-time testing of AI-enabled process optimisation techniques;
- **Hackathons and Process Optimisation Challenges (POCs)** that involve multidisciplinary student teams engaging with live business cases.

These practical engagement formats have yielded several implementation effects. MSSU, for example, has expanded its industry network by offering process optimisation and digital transformation analyses to local SMEs – demonstrating an emergent model where universities act not merely as learning institutions but as innovation partners for the private sector. Hackathons and challenge-based learning formats, often conducted jointly with Leipzig University and with the support of industry partners, have also become platforms for cross-country learning and for testing student prototypes that leverage AI for societal and business needs.

3.4 Institutional Anchoring for Long-Term Sustainability

An important outcome of the industry collaboration component is the **integration of applied learning formats into university structures**. Partner universities increasingly recognise micro-credentials as electives, stackable learning units, or components of modular degree programmes. Simultaneously, faculty development initiatives ensure that instructors can facilitate project-based learning, mentor students during hackathons, and integrate industry tools into teaching and assessment.

Through this combined approach – industry co-creation, formal partnerships, experiential learning formats, and institutionalisation – DS2S contributes to transforming higher education institutions in Asia from traditional teaching-focused organisations into dynamic ecosystems capable of nurturing AI-ready, practice-oriented, and future-responsive graduates.

The combination of co-created micro-credentials, formal industry partnerships, and applied learning spaces not only addresses immediate skill gaps but also sets the stage for broader systemic change in higher education. The next section will explore gender mainstreaming and inclusion strategies, demonstrating how DS2S embeds equity considerations alongside technical competencies to cultivate an inclusive AI workforce in Asia.

4 Gender Mainstreaming Measures and Their Contribution to Fostering Inclusive AI Skills

Gender mainstreaming was a strategic priority in the DS2S project, reflecting the recognition that women are disproportionately under-represented in AI and digital fields in Asia. Ensuring inclusivity in AI education is critical not only for social equity but also for the development of diverse, ethical, and effective AI solutions, as research shows that homogenous teams risk embedding biases into algorithms and technological applications.

Webinars on Data Feminism and Gender-Transformative Approaches. DS2S, in collaboration with the GIZ Data Lab, organised webinars targeting university administrators, faculty, and students. The sessions introduced concepts of data feminism and gender-transformative approaches, highlighting how AI systems are embedded in societal structures that may reproduce inequalities. These interventions were designed to equip participants with the analytical skills to examine and mitigate bias in AI development. Across the three partner countries, these webinars reached over 150 participants, with post-event surveys indicating a significant increase in participants' confidence to integrate gender perspectives into AI and data curricula.

Gender Mainstreaming Checklist for Digital Courses. Based on research with the Vietnam Women's Academy, the DS2S team developed a structured checklist for lecturers and course designers. The tool addresses gaps in planning, implementation, and evaluation of digital courses, ensuring equitable participation, attention to learner barriers, and integration of inclusive content. Its application has already influenced course design in six partner universities, with documented revisions in syllabi and teaching approaches to better support female students.

Spring School for Empowering Futures: Women, AI, and the Future of Work. The Spring School provided an immersive space for female-identifying learners to explore AI as a socio-technical construct. Combining intersectional feminism, participatory learning, and intercultural dialogue, the programme engaged 40 participants from Bangladesh, India, Viet Nam, and Germany. The school focused on real-world challenges such as bias in AI, equitable technology design, and ethical implications, while equipping participants with both technical and critical thinking skills relevant for digital labour markets. Feedback from participants emphasised enhanced confidence in applying AI tools, awareness of ethical considerations, and increased motivation to pursue careers in technology.

Collectively, these measures demonstrate DS2S's commitment to embedding gender considerations into AI skills development. By fostering awareness, providing practical tools, and creating dedicated learning environments, the project not only enhances female participation in AI education but also contributes to longer-term institutional commitments toward gender equity. Measurable impacts include increased participation rates of women in micro-credentials and faculty development programmes, adoption of gender-inclusive course practices across partner universities, and the establishment of sustained networks for women in AI and digital entrepreneurship.

5 Strategic Relevance for Partner Countries and the EU

The DS2S project extends beyond the development of individual competencies, influencing regional and global collaboration and contributing directly to national digital transformation strategies in Bangladesh, India, and Viet Nam. By equipping graduates with employable, ethical, and innovative digital skills aligned with labour market needs, the project strengthens the long-term economic resilience of universities and builds innovation capacity, which is essential for regional competitiveness in AI-enabled industries.

Importantly, DS2S demonstrates the value of rethinking partnerships in AI skills development. Traditional approaches often prioritise large technology companies and focus predominantly on the developer perspective. However, effective AI adoption requires not only skilled developers but also informed, conscious users who can critically engage with AI technologies and understand their societal, ethical, and organisational implications. Accordingly, the project emphasises interdisciplinary collaboration and engagement with partners beyond the tech sector – including government agencies, multilateral organisations, and civil society actors – to ensure that AI skills development aligns with societal needs, governance standards, and inclusive development objectives. Expanding the definition of partnership in this way fosters a more holistic, socially responsible, and inclusive AI skills ecosystem.

DS2S also serves as a platform for EU–Asia cooperation. Through initiatives such as Global Gateway and EuroStack, the project lays the foundation for knowledge exchange and technology development partnerships between European and Asian institutions. These efforts are complemented by systemic educational reforms, including sustainable adoption of micro-credentials, faculty capacity building, and gender mainstreaming, ensuring that interventions are embedded into national academic structures and can be scaled over time. By demonstrating how targeted, competency-based education interventions can achieve measurable workforce readiness while promoting ethical, inclusive, and interdisciplinary approaches, DS2S provides a model for future EU–Asia digital partnerships and contributes to shaping global standards for responsible AI development.

6 Conclusion: Advancing AI Skills through Strategic Collaboration

The Digital Skills to Succeed (DS2S) project demonstrates that fostering AI competencies in higher education requires more than curriculum development – it necessitates a systemic, context-sensitive approach that integrates empirical needs assessments, stakeholder collaboration, and gender-inclusive strategies. By grounding micro-credentials and faculty development programmes in the realities of partner universities and local labour markets, the project ensures that skills development aligns with societal and economic priorities, while remaining informed by global digital skills frameworks.

Collaboration with industry, ranging from multinational corporations to small and medium enterprises, has enriched the project's practical relevance, enabling experiential learning formats that bridge theory and applied learning. These engagements provide students not only with technical competencies but also with interdisciplinary perspectives on AI as a socio-technical system. Gender mainstreaming initiatives, including targeted webinars, checklists, social media campaigns, and the Spring School, have further enhanced the inclusivity and social impact of the project, equipping learners to navigate AI's ethical and societal dimensions.

At a macro level, DS2S exemplifies how targeted capacity-building efforts in higher education can contribute to broader strategic goals. By fostering workforce readiness, embedding responsible AI practices, and promoting cross-border collaboration, the project supports EU and Germany's Global Gateway and EuroStack initiatives, laying the foundation for sustainable EU–Asia digital partnerships. Beyond immediate educational outcomes, DS2S illustrates a scalable model for integrating technological, societal, and policy dimensions of AI education, offering lessons for governments, universities, and international organisations seeking to build resilient, inclusive, and future-ready digital ecosystems.

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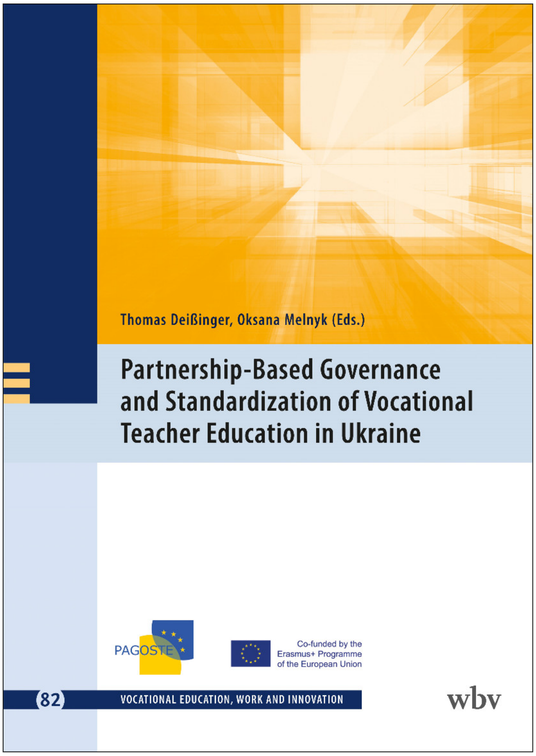

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Thomas Deißinger, Oksana Melnyk (Hg.)

Partnership-Based Governance and Standardization of Vocational Teacher Education in Ukraine

This publication addresses the pressing issues of vocational teacher education (VTE), focusing on institutional, organizational and governance aspects. Firstly, it summarizes the results of the four-year Erasmus+ capacity-building project "New Mechanisms of Partnership-based Governance and Standardization of Vocational Teacher Education in Ukraine" (PAGOSTE), funded by the European Education and Culture Executive Agency. The project's focus has been governance in VTE in Ukraine. Secondly, it goes beyond the narrow project context and explores challenges as well as good practices in VTE systems of other countries in and outside of Europe. Therefore, contributions from England, New Zealand, Australia, Italy, Germany, Austria and Switzerland complement the Ukrainian context and provide readers with a more comprehensive understanding of VTE systems.

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Artificial intelligence is transforming technical and vocational education and training (TVET) and creating new opportunities and challenges for education systems worldwide. This edited volume brings together international perspectives from academia, industry and policymaking to explore current developments in AI and TVET. The contributions focus on human-centred approaches to AI integration, teacher preparation, digital learning environments and practical applications in research and continuing education. Through theoretical reflections and case studies, the volume demonstrates how AI can shape the future of vocational education and skills development.

The **Vocational Education, Work and Innovation** series offers a forum for basic and application-oriented vocational training research. It makes a contribution to the scientific discourse on innovation potentials of vocational education and training.

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