Digital transformation with Training 4.0

The commercialization of generative Artificial Intelligence (AI) through systems such as ChatGPT has ushered in a new era in Industry 4.0. The automatic creation of new content with generative AI is particularly important for the development of AI-based tutoring systems (AITS) that promote digital learning in the context of Education 4.0. However, these systems must first be categorized according to learning methods, areas of application and their respective technologies.

Keywords
intelligent tutoring systems, ITS, Education 4.0, Artificial Intelligence, Industry 4.0, adaptive learning, personalized learning

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Further Training in Industry 4.0 with AI Tutoring Systems

State of technology

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The rapid development of Artificial Intelligence (AI) is constantly opening new opportunities, particularly in training for the factory of the future. For employees, this not only means a significant advantage in the actual manufacturing process, but also in the field of continuing education. This paper provides an overview of AI tutoring systems continuing education in the context of Industry 4.0 by presenting a categorization that discusses different approaches of AI tutoring systems by learning methods, application areas and their respective technologies. In addition, an outlook on the disruptive effect of generative AI on AI tutoring systems in Industry 4.0 is given.

The commercialization of generative Artificial Intelligence (generative AI) through systems such as OpenAI's ChatGPT has introduced a new generation of AI for use in all areas of life, but also in industry [1, 2]. Generative AI not only allows existing information to be processed, but also new information to be generated either automatically or with the help of prompts in a humanized way. This technological leap opens up new possibilities in Industry 4.0, including tutoring systems [3, 4]. Artificial Intelligence Tutoring Systems (AITS) or Intelligent Tutoring Systems (ITS) describes software that consists of a total of four main components, known as models. Each of these models represents a specific part of the AITS, for example the domain (also known as knowledge or expert) model contains the subject knowledge that is to be taught. The learner (also known as student) model records how successfully the learner works with the AITS and whether the learner really understands the content to be learned. The tutor (also called pedagogical) model represents the virtual teacher of the AITS, which for example addresses and reacts to problems or questions with the help of feedback and learning content. The learner interacts with the software through the interface (the fourth model), which can be in a variety of multimedia formats [5, 6]. Typical and widespread types of AITS are chatbots [7, 8, 9, 10], virtual agents [10, 11] or social robots [6, 10], which all make use of Artificial Intelligence.

Due to the increasing advancement and market maturity of tools such as various AITS, but also the use of IoT systems, the term Education 4.0 is also used in reference to the further development of digital learning, corresponding to Industry 4.0 [12, 13]. If Education 4.0 is viewed as a supply chain in terms of continuing education, it is recognized that basic knowledge is taught in school education and specialized knowledge is taught in academic education or training, then consolidated in the workplace in Industry 4.0 and constantly expanded in the sense of lifelong learning [14].

When talking about Education 4.0 involving the use of AITS in Industry 4.0, learning basically involves the creation and fostering of competencies of employees in Industry 4.0 [15, 16]. Competencies can be differentiated into:

- Technical or domain competencies: equipment operation, process understanding, understanding of technology
- Methodical or action competencies: creativity, problem solving, decision-making, analytical skills, research skills
- Social competencies: communication, teamwork, networking, leadership skills, knowledge transfer
- Personal competencies: autonomous work, sense of responsibility, organizational skills, flexibility, motivation

Related to this is the acquisition and transfer of knowledge. A distinction may be drawn here between explicit knowledge (documented knowledge) and tacit knowledge (employee experience) [17]. There are a number of roles within an organization that require different skills to a varying degree. For example, there are the technical workers who need skills, e.g. regarding machine operation, or production engineers who need skills, e.g. for production planning, or executives who need in-depth skills across all areas in order to make the right decisions [15, 16]. Digital teaching and learning in general can be put into a classification like the one from [18] (**Fig. 1**). AI influences all of these elements in the model.

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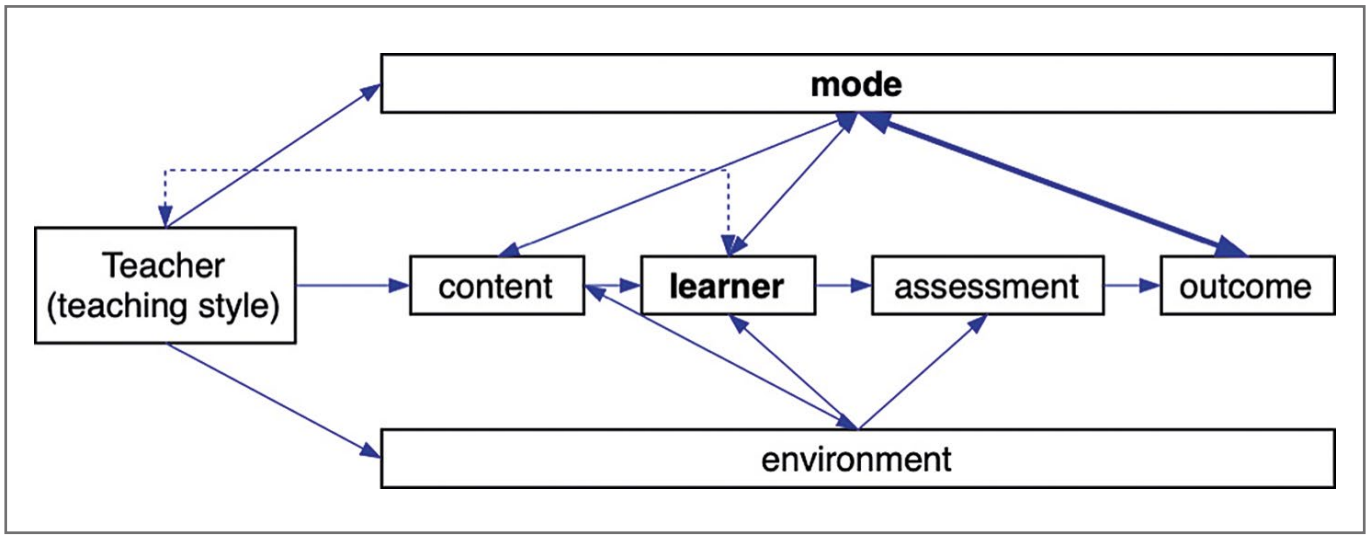

Figure 1: *Teaching and learning in the digital environment-model of the components and their interdependencies [18].*

Categorization of Artificial Intelligence tutoring systems

AITS in Industry 4.0 can be differentiated using various perspectives. On one hand, AITS can be distinguished in terms of the addressed learning approaches [19]. On the other hand, a classification in application, especially regarding work and company organization, might be beneficial [14, 20]. In addition, there are various underlying AI techniques in AITS itself, as well as in conjunction with other technologies that find their use within Industry 4.0 [5, 12, 13, 19]. These differentiations can be combined in a taxonomy to create a framework that can categorize AITS.

Learning approaches

One of the most important tasks of AITS is conveying learning content or supporting both teachers and learners in this process. Various learning approaches or methods can be used in education and training. It is therefore useful to categorize these learning approaches so that both the student and the teacher understand how learning should take place.

Here it is crucial to understand that learning approaches do not have to remain on their own but can be partially combined with other learning approaches. There is a variety of classic learning approaches that can be pursued, some being used particularly frequently, and others being used less frequently [21, 22].

The most common learning approaches, particularly in connection with AITS are shown in **Figure 2**. Firstly, a distinction can be made as to whether the learner learns individually, i.e., alone, or collaboratively in a group with other individuals. A further distinction can be made as to whether the learner learns passively by merely absorbing the learning content or follows the active learning approach, in which the learner participates and actively interacts with the content, e.g., by asking questions. With the project-based or problem-based learning approach, learners are challenged with real or at least authentic problems to solve them and to deal with the solution [22]. Similar to this is the approach of experiential learning, which can also be described as "learning by doing", where practical skills are fostered [23]. Through gamified learning, learning content can be conveyed in a playful way with the help of game design and gamification in order to increase the motivation, interest or commitment of the learner [24, 22]. Transformative learning describes individual learning with a continuously changing overall perspective of the learner on learning content, which is linked to lifelong learning through accumulating experience and self-reflection [21, 25].

AITS can pursue all these learning approaches in different ways with the help of their respective design. All these learning approaches often require learners to be guided by a teacher, the tutor. However, in many learning scenarios, a tutor cannot respond to the individual needs of each learner. Learning content is often standardized. However, AITS can close the gap of exactly that problem, so that a large number of learners can benefit simultaneously from both the learning approaches of personalized learning and adaptive learning [23, 12, 19, 26]. The AITS adapts to the learner and creates its own AI model (Learner's Model), which continues to refine itself and therefore improves as it is progressively used [20]. With personalized learning, individual needs, preferences, and abilities can be addressed.

Learning approach	Explanation
Individual learning	Learning alone
Collaborative learning	Learning in groups
Passive learning	Learning by absorbing learning content
Active learning	Learning through interaction with learning content and participation
Project-based learning / problem-based learning	Learning by working on authentic problems or challenges
Experiential learning	Learning by doing
Gamified learning	Learning with game elements
Transformative learning	Learning with individual and continuously changing perspectives through self-reflection
Personalized learning	Learning with an individualized structure
Adaptive learning	Learning with real-time adjusted learning content

Figure 2: *Common learning approaches of AITS.*

This leads to a more effective development of skills and acquisition of knowledge. Learners can dedicate themselves to new content at their own pace or focus particularly carefully on areas that need improvement. The learning process is thus individually structured [12, 23, 27]. This is closely linked to adaptive learning, in which the AITS, including its learning materials, adapts to the learner's learning progress. The level of difficulty is dynamically controlled, and the learner is given real-time feedback based on their performance. In this way, the AITS can provide the right level of difficulty and support and increase the effectiveness of the overall learning process [23, 12, 28]. Therefore, the goal of an AITS is to allow the learner a strong personalization and interactivity in the learning process

Figure 3: *Common areas of AI usage in AITS.*

AI-usage	Purpose
Adaptive guidance	• Adaptive feedback generation • Adaptive hint generation • Adaptive recommendation generation
Adaptive instruction	• Presenting adaptive learning material • Adaptive learning path navigation • Presenting adaptive tests and exercises
Evaluation of the learner and grade assistance	• Knowledge evaluation • Performance evaluation • Skill evaluation
Definition and improvement of the learner's model based on	• Learning style • Knowledge level
Classification if the learner based on	• Effect • Intelligence • Learning style • Learning needs • Characteristics
Others	• Communication • Calculation of level of difficulty of exercises • Classification of learning materials

AI technique	Short explanation
Reinforcement Learning (RL)	Agent that learns to make optimal decisions through rewards and punishments (trial and error)
Fuzzy Logic	A decision-making approach that uses uncertain (non-binary) values of true, false, and any value in between, to model and solve complex and imprecise problems
Bayesian Network	Graphical model that represents the probability dependencies and underlying conditional relationships of a set of variables.
Clustering	Unsupervised method that divides data points into groups so that similar data points form the same group.
Artificial Neural Networks (ANN)	Models that are used for pattern recognition and data processing inspired by the principles of the human brain.
Generative AI	Combination of advanced generative machine learning algorithms to create new content or data in a human-like manner.

Figure 4: *Common AI techniques used in AITS.*

[26]. It should also be emphasized that AITS meets every learner with none or the same social and emotional bias, which can be seen as both an advantage and, under certain circumstances, a disadvantage, as human factors of a human tutor disappear [19].

Advantages of AI usage in AITS

In addition to classifying which learning approaches can be addressed by AITS, it should also be asked where the learner, and the teacher, can benefit from AI using AITS. AITS can help to provide every learner with a personalized and adaptive learning environment. However, a major benefit is that AITS can help in the assessment of both learning content and the learner's skills and knowledge [19]. Furthermore, AI can be used to classify the learners and create individual AI learner models to track the learning progress of individuals as well as entire groups. This also makes it easier to adapt learning content, both in terms of content and difficulty. Specific AI benefits and their purposes are listed in **Figure 3** based on [20], who conducted a systematic review of AITS. With the help of this table, AITS can be classified according to which benefits they pursue and how they do so. An AITS can fulfill several purposes.

AI techniques

In addition to the classification of AITS into the addressed learning approaches and areas of AI usage, the differentiation of the underlying AI techniques is also crucial. This allows an even more in-depth determination of which AITS are used and how, and which capabilities can be used to address tasks of AITS and how well they can be fulfilled. It also helps, for example, to further develop an AITS. Furthermore, it can also be used to determine whether the AI of an AITS can be classified as weak or strong [29]. **Figure 4** summarizes the most common AI techniques and how they work to build AITS, based on [5]. These include reinforcement learning, fuzzy logic, Bayesian networks, clustering and artificial neural networks. Moreover, these techniques have been complemented by the combination of several advanced techniques under generative AI [20, 30, 31]. An AITS can be built using one AI technique or can combine several techniques, depending on the desired complexity of the tasks.

Categorization

AITS can be viewed from different perspectives: the learning approach, the usage of AI and the technique of AI. Combining these three perspectives from **Figures 2-4**, a taxonomy (**Figure 5**) can be established. This taxonomy allows AITS to be categorized from these perspectives. When applying the taxonomy, each AITS can be examined from each perspective, with each AITS addressing one or more categories for each perspective.

Conclusion and future research

The categorization can help to understand how an embedded AITS works or how it should be designed. In addition, it can be better understood how AITS can be

Perspective	Learning approach	AI usage	AI technique
Categories	Individual learning	Adaptive guidance	Reinforcement learning
	Collaborative learning	Adaptive instruction	Fuzzy Logic
	Passive learning		
	Active learning	Evaluation of the learner	Bayesian Network
	Project-based/problem-based learning		
	Experiential learning	Definition and improvement on learner's model	Clustering
	Gamified learning		
	Transformative learning	Classification of the learner	Artificial Neural Networks
	Personalized learning	Others	Generative AI
	Adaptive learning		

Figure 5: *Taxonomy of AITS.*

more effectively integrated into other cross-sectional technologies of Industry 4.0, such as augmented reality, virtual reality, Internet-of-Things, assistance systems, robotics, additive manufacturing, simulation, big data, CPSs, wearables, among others, from the educational perspective of Education 4.0. AITS also support more autonomous, consistent or even automated learning in such an environment [13, 14, 32]. The disruptive character of generative AI can lead to even greater effectiveness in use, as it can be used to respond even more strongly and quickly to the learner [30, 31]. For practitioners of operational transformation, this categorization will help in the selection of existing AITS, in which the categories shown can be used to evaluate the available AITS and thus allow them to be better compared with each other. Here, the perspective of learning approaches is particularly advantageous. This allows a better understanding and classification of how a learner learns with the help of AITS in the first instance.

The categorization may not yet be complete and could be expanded to include further perspectives in the future. Furthermore, the individual categories are not necessarily exhaustive, as they only represent the most common categories in the context of AITS in Industry 4.0. Additional categories could emerge in the future. Moreover, the question could arise as to how both explicit and tacit knowledge can be transferred in terms of knowledge management with a wide variety of AITS, including with the help of new types of AITS using generative AI, for example. AITS that are based on generative AI still need to be developed and, above all, become mature enough for the market, in which the adaptivity and personalization of the systems can be used to a much greater extent. This also raises the question of how robust the underlying data constructs need to be. Lastly, the tutor perspective should be discussed in more detail, to what extent the tutor becomes replaceable and must adapt to the AITS, and how this is dealt with ideally, especially regarding gaining acceptance within organizations.

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