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STEM TEACHER EDUCATION IN THE AGE OF ARTIFICIAL INTELLIGENCE: LESS MEMORIZATION, MORE QUESTIONS

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Artificial intelligence has made its way into education at a remarkable pace. What until recently seemed to be the subject of discussions about the future has now become part of everyday educational reality. Students are using generative AI to search for information, draft texts, solve problems, formulate explanations, and prepare coursework. Meanwhile, teachers are faced with an increasingly difficult question: what exactly should pupils and students know and be able to do when artificial intelligence can provide a seemingly convincing answer in a matter of seconds?

For STEM education, and particularly for the education of future STEM teachers, this issue is of paramount importance. Science education has traditionally been associated with the acquisition of a relatively extensive body of factual and conceptual knowledge. However, the availability of AI does not mean that such knowledge is no longer necessary. Paradoxically, its importance may even increase. A person who knows almost nothing about a particular topic has a limited ability to formulate meaningful questions, assess an AI-generated answer, recognise inaccuracies and, ultimately, take responsibility for the final output. In other words, access to information cannot replace understanding.

It is precisely this distinction that should become one of the central themes of contemporary teacher education. Future teachers should be guided neither towards rejecting AI nor towards uncritically accepting its outputs. They need to gain experience of AI as a tool – and perhaps increasingly also as an environment in which we work – whilst understanding that responsibility for the final product remains with humans. This principle applies to university students, pupils at all school levels and, of course, to teachers themselves (Aberšek, 2025).

The advent of generative AI therefore also calls into question some traditional forms of assessment. Essays, seminar papers and other written assignments do not become meaningless simply because they can be produced with significant assistance from AI. However, the way in which we approach these tasks must change (Šmejkal, 2026). For example, students may be asked to identify the sources on which individual claims are based, explain why they consider these sources to be reliable, compare the AI-generated response with other evidence, correct problematic passages, and defend the resulting work orally. The key question is no longer simply 'Did the student use AI?', but rather 'What did the student do with AI, and what level of understanding does the resulting work demonstrate?'

This brings us to another fundamental question: the relationship between knowledge and rote learning. Certain knowledge must undoubtedly become part of a pupil's or student's cognitive repertoire. Without a conceptual foundation, meaningful thinking is difficult. However, recognising the importance of knowledge need not mean a return to an education system dominated by rote learning.

We often encounter a similar debate in the context of inquiry-based science education. One argument is that pupils must first master the necessary subject matter and only then can they begin to engage in inquiry. However, such a strict separation between the acquisition of knowledge and inquiry does not reflect the nature of scientific work. Scientists do not first learn everything that might be relevant and only then formulate a research question. They encounter a problem,

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ask themselves a question, look for possible explanations, acquire further knowledge as needed, test their hypotheses, and gradually develop a deeper understanding of the phenomenon in question.

So why should learning science always proceed in the opposite direction? Inquiry can begin at a very early age, provided that the questions and methods are appropriate and the teacher provides the necessary support (Lamanauskas, 2025). Children may ask why leaves change colour, why some objects float and others sink, or why certain materials behave differently when heated. The teacher's role is not merely to provide the correct answer as quickly as possible, but to create the conditions in which pupils can seek answers themselves. In this sense, AI can become an interesting ally of inquiry-based learning, rather than its competitor.

If AI can take over some of the routine work involved in searching for information, this may create more scope for questions, interpretation, experimentation and discussion. This possibility is particularly interesting in science education. Here, we can distinguish between three interconnected environments for investigating natural phenomena: direct contact with nature and real-world phenomena (in vivo), laboratory experiments (in vitro), and computer models, simulations, virtual environments, and AI-supported tools (in silico). The future of STEM education should not lie solely in choosing one of these environments at the expense of the others. Their educational potential lies precisely in their combination. Simulations, for example, can help learners explore a particular scientific concept, alter variables, and formulate predictions. A subsequent real-world experiment can then test these predictions against physical reality. The difference between these two experiences is very important from an educational perspective. Real-world experiments are imperfect. Something shifts unexpectedly; the measured value differs from the prediction; the temperature changes faster or more slowly than we expected; and the data do not correspond to the expected pattern. Learners must ask why. Computer simulations, mixed reality, and virtual reality are capable of reproducing increasingly sophisticated situations, including certain types of error and uncertainty; however, digital experiences alone do not provide the same experience of handling materials and apparatus and encountering unexpected results as direct hands-on activity. The natural sciences are not merely something we observe on a screen. We need opportunities to handle materials, encounter unexpected results, and experience the fact that nature does not always behave exactly as our simplified model predicts. This reality has important implications for STEM teacher education. The growing availability of AI should not lead to a reduction in practical science teaching. On the contrary, it should encourage us to rethink how best to use our valuable teaching time. If technology can assist with information retrieval, routine calculations or preliminary explanations, teachers can devote more attention to activities that technology cannot easily replace: asking meaningful questions, designing investigative procedures, discussing evidence, interpreting unexpected results and linking scientific concepts to real-life situations.

STEM education, as conceived here, does not necessarily require the complete integration of science, technology, engineering and mathematics into a single subject. Chemistry, physics and biology can retain their disciplinary identities. However, traditional subject-specific topics can be approached through technological tools, engineering thinking, modelling, problem-solving and authentic contexts. We do not have to carry out a chemical reaction simply because it illustrates a reaction described in a textbook. It can form part of a meaningful problem: Where do we encounter such a process? Why is it important? How might we investigate it? What evidence would convince us that our explanation is reasonable (Bílek & Pelikánová, 2026)?

At the same time, this approach highlights the broader purpose of science education in schools. The main aim of teaching chemistry at lower secondary level, for example, cannot be to turn every pupil into a chemist, just as the teaching of physics cannot be aimed solely at training future physicists. Science subjects should help young people learn to think about themselves and about the natural and technological world in which they live. Knowledge of science is therefore not merely an end in itself, but also a means of developing the ability to ask questions, reflect and make informed decisions.

All of this inevitably changes the role of the teacher as well. The traditional metaphor of the teacher as a fountain of knowledge is becoming increasingly inadequate in a world where information is constantly available through digital technologies. Teachers remain important; however, the nature of their professional expertise is changing. Teachers must become designers of learning environments and guides to the learning process. They need to know when pupils need an explanation, when it is appropriate to encourage them to search for answers independently, when AI can be used productively, when a real-world experiment is irreplaceable, and when the most valuable pedagogical intervention is simply another carefully chosen question.

That is precisely why subject didactics should occupy an exceptionally prominent position in contemporary teacher education. Future STEM teachers naturally need in-depth subject knowledge. However, knowing the natural sciences and knowing how to create the conditions in which others can learn them are distinct competencies. In our experience, prospective teachers often begin to understand their subject at a whole new level precisely when they are learning how to teach it. Explaining a particular concept, anticipating learners' misconceptions, designing experiments, choos-

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ing appropriate representations and linking abstract knowledge to everyday experience force us to reorganise our own understanding as well.

AI makes this pedagogical expertise even more important. Future teachers will be entering classrooms where students are already using AI – sometimes openly as part of lessons, at other times covertly on their mobile phones. A simple ban is unlikely to be a sustainable educational strategy in the long term. However, the unrestricted use of AI without pedagogical purpose is equally problematic. As with calculators and other technologies that preceded it, the central question should be why and when we use a particular tool. If the aim of a given activity is to practise a specific skill, the use of AI may be inappropriate. However, if the aim is to interpret a complex result, compare different explanations, formulate hypotheses or critically evaluate information, AI can be a very valuable tool.

Teacher education should therefore not merely prepare future teachers to 'use AI', but above all to make pedagogically sound decisions about its use. This involves establishing clear rules together with pupils or students, discussing academic and intellectual responsibility, recognising the limitations of AI-generated information, verifying claims using reliable sources, and developing the ability to ask increasingly productive questions.

This development can be viewed with cautious optimism. It cannot be assumed that AI will automatically make teachers' work easier. In many respects, their work may initially become more demanding. Teachers will have to redesign tasks, rethink assessment, discuss sources and evidence in greater depth, and continually learn how new technologies are influencing their pupils' ways of thinking and learning. However, this extra work may well pay off.

The most promising contribution of AI to STEM education may ultimately not be its ability to provide us with answers. Its greater educational value may lie in the fact that it forces us to rethink the questions we ask: What knowledge is truly important? What should pupils understand, rather than simply reproduce? What experiences cannot be replaced by a screen? How can we link digital models with experiments and the real world? And what kind of teachers do we need when information itself is no longer a scarce resource?

We can therefore view AI as a catalyst rather than the main driver of change in education. Perhaps the age of artificial intelligence will remind us of something that has always been fundamental to high-quality science education: education does not begin with an answer, but with a meaningful question.

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