Designing Meaningful AI Learning Activities in Pre-Service Teacher Education

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Abstract: This article examines how artificial intelligence can be meaningfully integrated into pre-service teacher education through a case study approach. Rather than treating AI as a general technological innovation or a universal tool for increasing efficiency, the article focuses on three concrete teaching interventions in the subject didactics of Czech language, mathematics, and biology. Each case was designed and implemented in university courses for future teachers and illustrates a different way in which AI can support students in professionally demanding areas where they often experience uncertainty, anxiety, or lower self-efficacy. The study is grounded in the assumption that the educational value of AI does not lie in the mere use of a digital tool, but in its integration into subject-specific and pedagogically meaningful activities. In Czech language education, AI supports work with authentic language data, particularly when formulating corpus queries, interpreting corpus results, and didactically transforming language material for school use. In mathematics, AI functions as a consulting partner in the design of empirical investigations and the statistical processing of data in students' final theses, helping students understand the relationship between research questions, data, methods of analysis, and interpretation. In biology, AI-based applications facilitate the identification of plants and animals using visual and audio inputs, thereby allowing students to focus not only on correct species naming but also on observation, comparison, verification, and argumentation. Across the three cases, the analysis shows that AI can serve as didactic scaffolding. It lowers the entry barrier to complex activities that student teachers might otherwise avoid, while still requiring them to check, refine, interpret, and critically evaluate AI outputs. The aim is therefore not to replace expert judgement, but to make it more visible and to support its development. The cases also show that AI-supported activities become educationally meaningful only when they are clearly connected to future classroom practice and when students are guided to reflect on the limits and responsible use of AI. The article formulates common principles for designing AI-supported activities in teacher education: subject-didactic anchoring, orientation toward professionally demanding areas, critical work with AI outputs, explicit links to future work with pupils, development of AI literacy, and support for students' professional confidence. In this sense, AI can contribute not only to technological competence but also to subject reasoning, pedagogical judgement, and the didactic transformation of knowledge.

Keywords: Artificial Intelligence, Teacher Education, Self-Efficacy, Subject Didactics, AI literacy, Pedagogical Design

1. Introduction

The growing availability of artificial intelligence tools opens up new questions for pre-service teacher education (Bae et al., 2024). In both academic and public debate, AI has often been presented as a technological means to make information retrieval, the creation of teaching materials, or data analysis more efficient (Xiaoyu et al., 2025; Yadav et al., 2026). Attention is increasingly shifting, however, to how AI-based learning activities should be designed to genuinely support pedagogical goals and the professional competences of future teachers (Blonder et al., 2025). One of the approaches discussed is AI-supported scaffolding in lesson planning, that is, the use of AI as a supportive tool for designing, refining and reflecting on learning activities (Cai et al., 2025), as well as for developing critical thinking (Oliveira et al., 2025).

This article assumes that AI is meaningful in teacher education if it is understood not merely as an isolated technological innovation, but as part of a concrete subject-didactic activity. This assumption follows the TPACK framework, according to which meaningful integration of technology into teaching emerges only through the interconnection of teachers' technological, pedagogical and content knowledge (Mishra & Koehler, 2006). The article focuses primarily on technological content knowledge, which is subsequently linked to pedagogical content knowledge, thereby creating space for the development of TPACK. A future teacher thus learns not only to use a new tool within a subject, but also to interpret its outputs and transform them into work with pupils.

The article presents three practical examples from the preparation of Czech language, mathematics and biology teachers. All three cases share the fact that AI enters areas where students often experience uncertainty, anxiety, or low confidence in their own abilities. AI is understood here as a means of helping to bridge the gap between theoretical knowledge and its practical use in teaching.

2. Theoretical Background

The article's starting point is a conception of teacher education as a process in which content, pedagogical, and technological knowledge are mutually interconnected. This approach aligns with the TPACK framework, which builds on Shulman's concept of pedagogical content knowledge and emphasises that meaningful use of technology in teaching cannot be separated from knowledge of content and pedagogical intention (Shulman, 1986; Mishra & Koehler, 2006). For this article, the connection between technological content knowledge and pedagogical content knowledge is especially important: AI first supports students in working with subject-specific procedures, such as formulating a corpus query, designing statistical processing or recognising biological species, and then creates space for their didactic transformation into work with pupils. This emphasis aligns with current research on generative AI in teacher education, which shows that working with AI to design learning activities can reveal and develop pre-service teachers' pedagogical content knowledge (Blonder et al., 2025; Wen & Wen, 2024).

In the case of AI, this connection is particularly important. The mere ability to generate a text, propose a statistical procedure or recognise the species of an organism does not in itself mean that the output has educational value. Such value emerges only when the student can assess the quality of the output, relate it to subject knowledge, adapt it to pupils' needs, and reflect on its limitations. This ability to handle AI critically and knowledgeably corresponds to a broader understanding of AI literacy, which includes not only technical understanding of AI tools but also the ability to interpret their outputs, understand their limitations and use them responsibly in specific situations (Long & Magerko, 2020). AI is therefore not understood as a substitute for expert or pedagogical judgement, but as a tool that can activate and make such judgement visible (Blonder et al., 2025; Celik et al., 2026).

The second starting point of the article is the concept of self-efficacy. Bandura defines self-efficacy as an individual's belief in their own ability to perform a particular activity successfully; this belief affects whether a person begins the activity, how much effort they invest in it and whether they persist when obstacles arise (Bandura, 1977). In teacher education, this concept is developed as teacher self-efficacy, that is, teachers' belief in their own ability to support pupils' learning and manage the demands of teaching (Tschannen-Moran et al., 1998). In teacher preparation, students often encounter areas where they are unsure of their competence. These may include working with the formal language of corpus queries, statistical evaluation of data or identifying natural objects in the field. Such areas are not marginal; on the contrary, they are important components of a teacher's professional equipment. Low self-efficacy, however, may lead students to avoid them, replace them with simpler procedures, or omit them from their future practice (Bandura, 1977; Tschannen-Moran et al., 1998).

In such situations, AI can serve as a supportive tool or a form of scaffolding. It does not take over responsibility for expert decisions, but it lowers the entry barrier, provides working drafts, enables iteration and supports the student's active reflection. Research on AI-supported scaffolding in teacher education shows that ChatGPT can support the development of lesson-planning skills, especially when structured through targeted questions, proposal critique, and lesson-plan revisions (Cai et al., 2025). From the perspective of teacher education, it is therefore essential that work with AI does not end with accepting or rejecting its output, but continues through its interpretation, subject-based justification and didactic transformation into a teaching situation (Celik et al., 2026; Wen & Wen, 2024).

3. Research Design and Methodology

The study is designed as a practice-oriented multiple-case study. It presents three teaching interventions implemented in university-based teacher preparation. Each intervention comes from different subject didactics and was designed by a different university teacher. The aim is to identify common principles that enable the meaningful use of AI in teacher education.

The analysed cases are:

1. The use of AI when working with authentic language data in Czech language didactics.

2. The use of AI when designing and statistically processing empirical investigations in mathematics didactics.
3. The use of AI when identifying plants and animals in biology didactics.

Attention is paid to three questions:

1. What area of insufficient knowledge, skills or low self-efficacy does AI help students overcome?
2. How does AI support subject-specific thinking?
3. How is the AI output transformed into subsequent work with pupils?

4. Case Studies

4.1 Czech Language: AI, Corpus Data and Text-Centred Teaching

In language didactics, including Czech, one important challenge is how to work with authentic language data and transform them into material suitable for school teaching. The current communicative conception of Czech language teaching emphasises text-centredness and situationality: language phenomena should be explored in relation to texts and communicative situations, not only through isolated model sentences (Šebesta, 2005; Štěpáník, 2020).

Language corpora support this approach because they provide authentic data, frequency counts, collocations, and real contexts of use (Boulton & Cobb, 2017; Curry & McEnery, 2025). This is usually discussed as data-driven learning (DDL), in which learners investigate language data themselves (Lusta et al., 2023). In the Czech context, the educational use of corpora has been addressed, for example, by Šmejkalová and Kopřivová (2019) and Lukešová and Lukeš (2021).

For student teachers, however, corpus work is demanding. The Czech National Corpus (Český národní korpus, n.d.) offers extensive language material, but effective use requires the ability to formulate queries, navigate the corpus interface and interpret results. AI can therefore serve as a mediator between a naturally formulated teaching intention and the formal language of a corpus query. Its outputs must still be checked, refined and didactically interpreted.

The intervention included several AI-supported activities with language data, authentic or AI-generated communicative texts, and syntactic reasoning. Three of them are presented here to show how AI can support lesson preparation without turning student teachers into corpus linguists. The common aim was to help students use language data and AI outputs critically when preparing Czech language lessons.

The first activity focused on Czech spelling, specifically on the so-called “listed words” (*vyjmenovaná slova*). These are traditional sets of Czech words in which pupils memorise the use of the letter *y* after certain consonants, although contemporary pronunciation no longer distinguishes it from *i*. Student teachers used AI to translate a natural-language teaching question into a workable corpus search strategy. They first asked AI how to search for the occurrences and contexts of selected words in the Czech National Corpus, then checked the suggested procedure or query in the corpus interface and interpreted the results didactically.

For example, they examined the pair *dmýchat* and *rozdmýchat*. Both words are relatively archaic: *dmýchat* means “to blow air into a fire”, while *rozdmýchat* means “to fan into flame” and is now more often used figuratively, for example, to “stir up” a conflict or emotion. The aim was not merely to count occurrences, but to decide whether such words are suitable for younger pupils, in which contexts they appear, and whether they are meaningful for teaching. Corpus data thus support professional decision-making by showing which words are common in contemporary Czech, which are peripheral, and which may be didactically difficult or poorly motivating.

The second activity examined the possibilities and limits of generative AI in creating short communicative texts for school use. With frequent words, AI can produce plausible texts appropriate to pupils’ age; with infrequent or archaic words, it often creates unnatural contexts, historicising situations or linguistically problematic formulations. This failure is didactically useful because it shows student teachers that AI outputs must be evaluated against authentic language use, pupils’ age and teaching aims.

The third activity focused on syntactic competence and metalinguistic reasoning. In work with attributes, AI or an image generator can visualise the difference between a text without attributes and one supplemented with them. Pupils compare the texts and visual outputs, identify the attributes and discuss how they refine meaning.

Other examples involve false syntactic pairings or attachment ambiguity, such as *Filé pro děti bez kostí* ("fillet for children without bones") or *Šampon na vlasy s chmelovým extraktem* ("shampoo for hair with hop extract"). Such cases show that AI may misinterpret Czech syntactic structures, often under the influence of English or general syntactic categories. The learner therefore becomes an active corrector of the model: they identify the inaccuracy, reformulate the prompt and explain why the construction sounds comic or ambiguous.

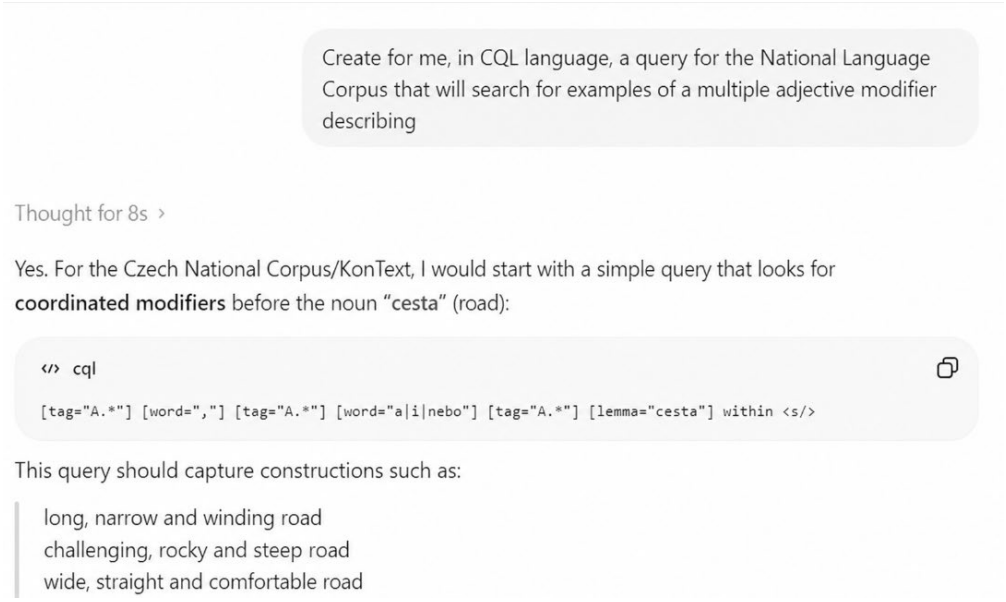


Figure 1: Example of generative AI being used to create a CQL query for the Czech National Corpus / KonText (English translation of the original Czech screenshot).

For advanced students or exceptionally gifted pupils, AI can also support the formulation of corpus queries for different types of attributes. A natural-language request is transformed into CQL queries that must be refined: overly broad queries yield unmanageable results, while syntactically incorrect queries return irrelevant examples. Students must therefore use their own syntactic knowledge, evaluate the retrieved occurrences and decide which examples are didactically useful.

Overall, the Czech language case shows that AI can support work with language data, metalinguistic thinking and the didactic transformation of subject content. Its value lies not in producing ready-made teaching materials, but in helping student teachers enter demanding work with language data while requiring expert checking, interpretation and pedagogical decision-making.

4.2 Mathematics: AI and Statistical Reasoning in Final Theses

In mathematics, the intervention focused on statistical data analysis in student teachers' final theses. Although students complete a theoretically oriented Statistics course, they often use statistical tools only rarely and inefficiently in their own empirical investigations. An analysis of final theses showed that students frequently avoid quantitative analysis, often citing small research samples, even when simple quantitative analysis would be possible.

This problem is not only a matter of statistical knowledge. It is also linked to statistical self-efficacy and statistics anxiety: students may doubt their ability to choose, interpret, and defend statistical procedures correctly (Finney & Schraw, 2003; Perepiczka et al., 2011). For this reason, AI-supported activities were included in the Final Thesis Seminar. They focused not only on evaluating collected data, but also on designing the research investigation itself. Students learned to ask, for example, what data they need, which variables will be observed, whether the expected result can be evaluated quantitatively, what a realistic sample size is, and what conclusions can legitimately be drawn.

In this activity, AI acts as a consulting partner. It can help refine a research question, propose the structure of a questionnaire, distinguish between data types, recommend possible methods of analysis, and formulate results in an appropriate professional style. Recent research suggests that tools such as ChatGPT can support quantitative data analysis, generate code for statistical software and help interpret results, although their outputs require expert checking (Prandner et al., 2025; Xing, 2024).

The student must therefore verify whether the proposed procedure is appropriate to the nature of the data, the sample size and the aims of the thesis. The main benefit is not that AI identifies a statistical test, but that it lowers the entry barrier and helps students understand the purpose of statistical processing and its connection to research design. Teaching thus moves from mechanical test selection to the development of statistical reasoning.

This experience is also relevant for future teaching practice. Student teachers learn to work with data as a means of reflecting on teaching, for example, when evaluating pupils' results, assessing the effectiveness of teaching methods or planning pedagogical interventions. AI does not take over analytical responsibility; rather, it enables students to enter an area they might otherwise avoid.

4.3 Biology: AI, Species Recognition and Field-Oriented Learning

The case study in biology didactics focuses on the use of applications for recognising plants and animals based on visual and audio inputs. In the preparation of future biology teachers, correct species identification is usually associated with uncertainty. Students and beginning teachers may worry that, in the field, they will not be able to identify all plants, animals or their vocalisations correctly. This uncertainty may lead them to avoid field teaching, reduce it to familiar and safe examples, or shift attention away from direct observation of nature toward work with a textbook or pre-prepared materials.

In this area, AI tools for image and sound recognition can lower the entry barrier. In the preparation of future teachers, the main applications used were Merlin Bird ID, Seek by iNaturalist and PlantNet/Pl@ntNet. Merlin Bird ID supports identification from photographs or sound recordings; Seek by iNaturalist enables identification of various groups of organisms; and PlantNet/Pl@ntNet is primarily used for identifying plants from image data. These tools enable rapid species identification and allow students or teachers to name species correctly.

The educational value of these applications, however, does not consist only in the fact that they provide the name of an organism. More importantly, they make it possible to shift attention from encyclopaedic identification to the observation of features, comparison of similarities and differences, and formulation of arguments. AI functions here as a supportive means, not as an authoritative identification key. The application's suggestion becomes a prompt for further verification: students and pupils examine which features of the organism the application probably evaluated, which features are actually relevant and how the result can be confirmed or challenged using additional sources.

Teaching of future teachers, therefore, includes an activity in which students work with several similar plants, photographs or sound recordings. First, they themselves describe the observed features and formulate a hypothesis about whether they are dealing with the same species or different species. Only then do they use the application to suggest an identification. They then compare the AI output with their own observation, identification literature or other expert sources. The aim of the activity is not only to arrive at the correct species name, but to learn to recognise similar and different features, work with uncertainty and justify one's own conclusion.

This activity directly overlaps with future teaching practice. The future teacher learns not only to operate an application, but above all to organise a learning situation in which AI supports pupils' inquiry-based and observational activities. Pupils may, for example, compare two similar plants, observe differences in leaf shape, flowers, or habitat, or work with bird sound recordings to identify recurring acoustic features. The application provides a suggestion, but teaching is organised so that pupils must interpret, verify, and justify the result.

Situations in which the application offers an uncertain or incorrect result have special didactic value, for example, when it identifies an animal species that does not occur in the Czech Republic (Figure 2). Such an error is not merely a technical deficiency, but can become a learning opportunity. The teacher can discuss with pupils why the incorrect identification may have occurred: whether the sound recording was of poor quality, whether an important diagnostic feature was missing, whether similar species were involved, or whether the application was working with limited probability, possibly even suggesting a first occurrence in the Czech Republic. Precisely such situations lead pupils to engage in critical thinking, verify results in other sources, develop scientific literacy, work with species distribution ranges, and understand that biological identification is not a mere assignment of a name but an argumentative process. Student teachers thus learn that the AI output is not a final answer, but part of the process of species identification.

For future teachers, this experience is also significant for self-efficacy. AI helps them overcome the fear that they will not know the names of all organisms in the field. At the same time, however, it leads them to a more general

professional competence: guiding pupils toward observation, classification, comparison and argumentation. Species-level identification is therefore not a self-serving goal, but a means of developing biological thinking. The teacher does not have to act as an infallible expert on every organism found around the school; on the contrary, they can model a professionally responsible procedure in which hypotheses are verified, results are compared, and uncertainty becomes part of learning.

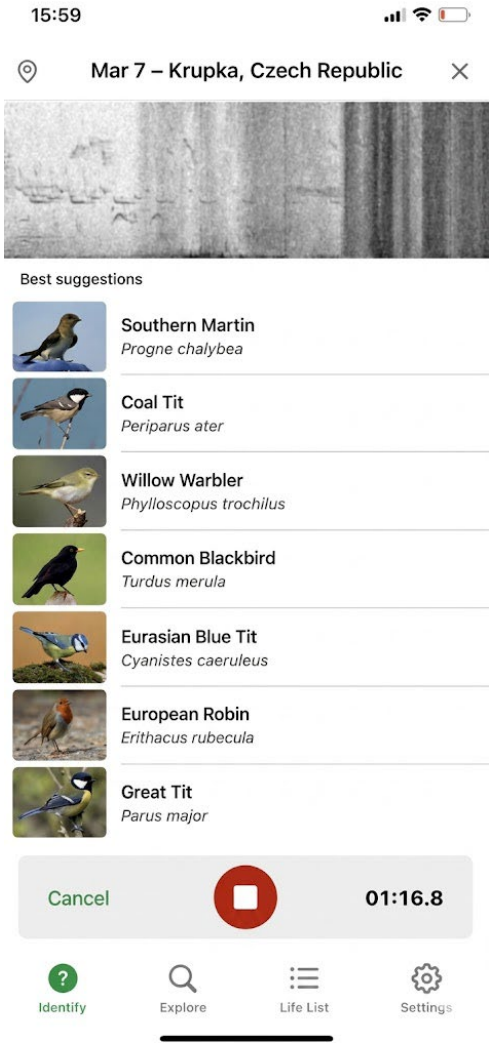


Figure 2: AI misidentification example: a South American bird species, the southern martin, suggested for a recording from the Czech Republic.

The contribution of AI in this activity does not lie in the automation of expert decision-making, but in lowering the entry barrier to an activity that may be associated with uncertainty for future teachers. Applications for organism recognition are therefore not used merely to name species, but as support for teaching based on observation, comparison, verification and justification.

5. Discussion

The three examples differ in subject area, tools used and teaching situation, but they share a common structure. In each case, AI enters an area that is professionally demanding for student teachers and may be associated with uncertainty or lower self-efficacy. In Czech language education, this concerns work with authentic language data and formal corpus queries; in mathematics, the design of empirical investigations and statistical data analysis; and in biology, the identification of organisms and work with natural material.

Across the cases, AI lowers the entry barrier to activities that students might otherwise avoid. It offers initial scaffolding, a working draft, an interpretative guide or the possibility of iteratively refining a procedure. Its educational value, however, does not lie in the output itself, but in what students do with it: checking, refining,

interpreting and transforming it for teaching. Students therefore learn not only to use AI, but also to question it, correct it and decide when expert knowledge, additional sources or teacher judgement are needed.

From the perspective of the TPACK framework, all three cases show that AI first supports work with subject-specific content, but becomes pedagogically meaningful only when this content is transformed for work with pupils. In Czech language education, corpus data and AI-supported queries are used to prepare authentic or didactically adapted language material. In mathematics, AI supports understanding the relationship between a research question, data, an analytical method, and the interpretation of results. In biology, AI-based identification tools support observation, comparison, verification and biological argumentation rather than merely naming species.

Several design principles for integrating AI into teacher education can be derived from these cases:

- The AI activity should be anchored in a specific subject didactics.
- The task should target an area in which students experience uncertainty or lower self-efficacy.
- AI should serve as support for entering a demanding activity, not as a substitute for expert decision-making.
- The AI output should be subject to critical checking, interpretation and possible revision.
- The activity should have a clear overlap with future work with pupils.
- The activity should include reflection on the limits of AI and responsible use of the tool.

These principles suggest that meaningful AI integration in teacher education is not isolated technology training. Its value lies in connecting technological support, subject content and pedagogical decision-making. AI can become a means of professional learning when embedded in carefully designed activities that foster subject understanding, critical reflection and didactic transformation.

6. Conclusion

The case studies show that AI can serve as didactic support in pre-service teacher education, especially in areas that are professionally demanding and often associated with low self-efficacy. Its main benefit is not the automation of teachers' work or the replacement of expert judgement, but the opportunity for students to engage in complex activities safely and learn to evaluate, interpret, and use AI outputs didactically.

Meaningful use of AI, therefore, requires a clear pedagogical intention, subject anchoring, critical work with outputs and a connection to future classroom practice. Under these conditions, AI can support not only technological skills, but also subject reasoning, pedagogical judgement and the professional confidence of future teachers.

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Ethics Declaration

The research is based on an analysis of learning activities implemented as part of regular university teaching. The text does not include students' personal data or individually identifiable statements.

AI Declaration

During the preparation of the working version of the text, ChatGPT was used as support for structuring the argumentation, formulating the language, and compressing the source materials' style. All content was subsequently checked by the authors, who are responsible for the factual accuracy, data interpretation, and the final form of the article.

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