Evidence-based advancement of teaching AI in K-12: an action research approach

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ABSTRACT

AI is omnipresent in our daily lives. It is, therefore, crucial that students acquire necessary competencies as part of their CS education in order to be able to use and develop this technology responsibly. However, this growing need has hit the educational landscape mostly unprepared. Curricula are only gradually adapted, and there is a lack of empirical evidence on how the topic can be implemented in K-12 education. The study presented in this article uses the cyclical and participatory approach of action research to address this gap. This ensures that theories found about teaching and learning processes can be implemented directly into practice to develop AI teaching on an empirical basis. The initial cycle focuses on content-specific difficulties experienced by learners. First findings indicate that, besides general barriers such as required mathematical and programming skills, students encounter problems when applying or transferring the concepts they have studied.

CCS CONCEPTS

• **Social and professional topics → K-12 education**.

KEYWORDS

artificial intelligence, action research, K-12, computing education

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1 INTRODUCTION

In recent years, AI has evolved from a trendy topic to an integral part of our daily lives. Consequently, students frequently interact with AI systems, such as content generation tools. In light of this, various stakeholders from politics (both international [16] and national [6]) and the science community [13] have called for integrating AI into the curricula in order to prepare students for a reflected and responsible use and design of this technology. As a result, curricula are being modified, and the topic is also becoming increasingly relevant in research on K-12 computing education.

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A considerable number of publications document the development of teaching materials and the testing of pedagogical approaches to teaching AI in schools [14]. However, these are usually experience reports in specific contexts with a small sample size. Grover, like others, therefore emphasises a fundamental lack of evidence concerning AI as a learning subject in K-12 education [5].

This article presents a study that aims to address this gap in order to enhance the lessons about AI on an empirical basis. Conventional research methods often face the challenge of findings not making their way into school practice due to, for example, insufficient external validity. To overcome this, the participatory action research approach was chosen to ensure that the resulting theories could be directly implemented into practice.

2 RELATED WORK

Most research on teaching AI has focused on higher education, but recently, there has been an increasing amount of research on AI education in K-12 [18]. While efforts to identify learning objectives (e.g. [9, 15]) or proposals for curriculum development (e.g. [19]) provide insights into the question of *what to teach*, the existing approaches to identifying students' (mis)conceptions of AI [1] may be regarded as a foundation for answering *how to teach* AI. However, many of these tend to focus more on capturing students' attitudes (e.g. [2]) rather than perceptions in the sense of mental models (like [8]). If this is the case, they primarily capture static actual states; the change of models (as in [10]) is rarely subjected to analysis. The question of whether and how perceptions influence or hinder learning has hardly been investigated so far. Sulmont et al. identify barriers to teaching AI, but only in higher education [12].

The large number of publications on exploratory approaches to teaching specific AI topics offers further insights into how to teach. They present many materials and tools [14] but tend to be experience reports in most cases. Although some studies measure the efficiency of learning opportunities, they usually focus on a specific tool or pedagogical approach (e.g. [17, 20]). Furthermore, Rizvi et al. point out that these studies often have a small sample size and are carried out in extracurricular programmes [11].

In light of the presented previous work, a study was developed to address the lack of systematic research with an adequate sample size. It aims to investigate teaching and learning processes in the context of AI education in K-12 using an action research approach.

3 PARTICIPATORY ACTION RESEARCH

All forms of action research (AR) share certain specific characteristics. AR is always action- and problem-oriented and aims to bridge the gap between science and practice by cooperation. In contrast to conventional methods, AR is a cyclical process [3]. The project presented here is based on the concept of participatory AR, as described by Eilks and Ralle, who define the cycle as follows: (1) developing teaching strategies and materials, (2) testing in practice, (3) evaluation, (4) reflection and revision [4]. Eilks and Ralle's approach is more research- than practitioner-driven, which can be seen in the fact that the researchers (rather than practitioners) formulate the research questions to achieve generalised results [4].

4 IMPLEMENTATION OF THE FIRST CYCLE

The initial action research cycle is exploratory and focuses on learners' difficulties. It is currently being conducted as part of compulsory computer science lessons in German high schools in the state of Bavaria. There, the topic of AI is firmly anchored in the 11th-grade curriculum. Within a sequence of about 16 lessons, fundamental concepts, like the definition of AI, basic ML algorithms, the structure of neural networks, and ethical aspects, are covered (c.f. [7]).

Participants

A total of 14 K-12 computer science teachers (two of them female) were recruited for the project based on personal contact. Most of them (11) have undergone the regular teacher education programme in computer science, while three of them have completed an in-service qualification programme in computer science. Currently, the participants are teaching 26 Year 11 classes within the first cycle.

Research questions

The following research questions guide the first cycle.
RQ 1: Which content-specific difficulties can teachers identify among their students after they have been taught AI?
RQ 2: How do teachers modify their teaching in order to address these difficulties?

Procedure and Instruments

At the *beginning of the cycle*, the participating teachers designed their lessons independently without specific training regarding the research project. This approach was chosen to ensure a high degree of diversity in lesson planning. During the *second phase* (testing in practice), which is currently being carried out, the teachers are asked to reflect on each lesson using a specially developed protocol. These brief reflections provide initial indicators of content-specific learning difficulties and help to answer RQ 1. In the *third phase* of the AR (evaluation), a semi-structured interview will be conducted with each teacher after they have taught the sequence. In addition, a test was designed to determine how well the students have internalised the content. This survey can provide information about difficulties by identifying systematic errors.

To address RQ 2, the teachers will be invited to a joint two-day workshop in the *final phase*. The evaluation results will be presented and discussed during the workshop, and the teachers will engage in a dialogue with the researchers on how the teaching can be appropriately developed in response to potential learner issues.

5 FIRST FINDINGS

By now, only one teacher has taught the entire sequence. The interview was conducted with him, and the survey results are available. In addition, three other teachers have provided the brief reflections on the lessons held up to this point. Based on this data, initial indications of possible results can be formulated, but a comprehensive evaluation can only be carried out once all data has been received.

So far, the feedback indicates that students are highly motivated to learn about AI and that teachers can often use the available teaching materials with benefit in their lessons.

There are indications of non-topic-specific difficulties with mathematical or programming skills due to a lack of prior knowledge.

Regarding content-specific difficulties, there are various indications that the application and transfer of concepts are challenging for learners. For example, two teachers have documented in their brief reflections that students have problems applying the concept of reinforcement learning to a specific context. Furthermore, the interview indicates that learners have difficulties transferring concepts such as overfitting and underfitting from one algorithm (k-nearest neighbours) to another (decision tree learning).

While problems in mathematics and programming could confirm the general barriers identified by Sulmont et al. [12], difficulties in the application and the transfer of concepts into different contexts are the crucial skills required for the responsible use of AI technology. These findings need to be reviewed as part of the further data collection and analysis of the first cycle.

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