Attitudes towards and expectations on the role of artificial intelligence in the classroom among digitally skilled Finnish K-12 mathematics teachers

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The growing impact and importance of artificial intelligence in society has led to an increasing interest for the potential of artificial intelligence as an educational tool in schools to aid both students and teachers. In this study we investigate digitally skilled K-12 mathematics teachers' (N=85) attitudes towards and expectations on the role of artificial intelligence in the classroom. The study was done by conducting and analyzing the results of a web-based survey among Swedish and Finnish speaking mathematics teachers using a mixed methods strategy. The Will, Skill and Tool framework was used for the analysis. The survey was done before the introduction of ChatGPT-3. The results indicate that the teachers' attitudes toward AI tools in school are characterized by interest, openness, and awareness. Teachers have a balanced view on the possibilities and risks of AI use in school. However, the teachers also stress that there is a risk that AI tools will shift the focus from learning key mathematical skills towards learning and interaction with the AI tools themselves. The research concluded that the K-12 mathematics teachers surveyed have broad experience with digital tools and will likely become early adopters of AI tools in the classroom.

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1 Introduction

Digital technologies have become a major part of our everyday lives. They change the way we search for and collect information, how we communicate, interact, and socialize (Vuorikari et al., 2022). The parallel advances in digitalization, computing power and data availability, have also made artificial intelligence (AI) a transformative technology in both industry, commerce, and society (Holmes et al., 2019). As for the field of education, Artificial Intelligence in Education (AIED) has become an active research field (Zawacki-Richter et al., 2019). Zawacki-Richter et al. (2019) identify four areas where, within an educational setting, AI could have a large impact: student profiling and predicting student achievement, student assessment and evaluation, adaptive systems and personalization, and intelligent tutoring systems. However, the authors also point to the lack of critical reflection with regards to the challenges and risks of AIED, the rather weak connection to theoretical pedagogical perspectives, and the absence of deeper ethical considerations in connections to AI. These risks and challenges have become even more apparent with the launch of user-friendly large language models, such as ChatGPT, that has stirred multiple sectors of society, not least education (Kasneci et al., 2023; Rudolph et al., 2023). Instead of AI only providing potential useful features, such as individualized learning, more troublesome aspects of AI suddenly seem much more plausible to the public, like job market disruptions and the efficient spreading of misinformation (Farrokhnia et al., 2023). Although the teacher survey in this study was done before the introduction of ChatGPT-3 in 2022, our findings and results have only gained in urgency with this powerful new AI technology.

In 2019 Finland published their national AI strategy with the vision to be a leading country in AI. According to the strategy Finland will utilize AI to increase the competitiveness of its industry, increase the efficiency of its public sector and ensure a well-functioning society and in this strategy knowledge of AI and its use is highlighted as a new civic skill (Ministry of Economic Affairs and Employment, 2019). These ambitions, as well as the speed of technological change, create a pressure to transform educational practices, institutions, and policies. To this end Finland has launched several educational initiatives, among them *Elements of AI*, with the goal of raising AI-literacy among the Finnish population (*Elements of AI*, n.d.). On a European level, the rising importance of AI has resulted in a revision of the EU digital competence framework (DigiComp 2.2) to also include AI literacy and AI skills (Vuorikari et al., 2022).

AI has, so far, only had a limited impact on the day-to-day primary and secondary education. Educators and researchers are only beginning to explore how AI could best be applied to have an impact on classroom teaching and learning (Hwang et al., 2020; Kay, 2012; Luckin et al., 2022). From a mathematics teacher's perspective AI has, for example, the potential of addressing the challenges shared by all K-12 mathematics teachers facing a classroom full of students needing individualized feedback and support. By utilizing AI to identify a given students' challenges during problem solving and provide him or her with step-by-step guidance as needed, while recognizing multiple student strategies and maintaining multiple interpretations of student behavior, AI could potentially serve the role of an intelligent, personalized tutor (Aleven et al., 2009).

As teachers and schools play a key role in how widely the use of AI technology will spread in society and who will stand to benefit, it is important to better understand how teachers view the possibilities and threats of AI. If teachers are hesitant to adopt new AI tools or teach AI related subjects, the full potential of AI will likely not be realized or, which is perhaps the greater danger, will become a powerful tool whose use is restricted to only a selected few within our society. However, a challenge with research trying to probe the attitudes and expectations that teachers have on the role of AI for them and their teaching, is that few teachers in Finland have yet had any direct experience with using decision-supportive AI tools in the classroom (although this situation is changing fast with the introduction of ChatGPT-3). To circumvent the problem of teachers' lack of experience using AI tools, we will use a teacher's current use and attitudes towards digital tools as a proxy for the AI tools they have not yet used. As mathematics teachers have historically been early adopters of new digital technologies, such as calculators with symbolic algebraic capabilities and software to help visualize function graphs and manipulate geometric objects, it is our hypothesis that Finnish K-12 mathematics teachers are in general digitally skilled and early adopters of new, digital technology. Their mathematical knowledge and active use of digital curriculum resources are also expected to inform and deepen how they view the real and potential impact of AI in their classrooms. Mathematics teachers thus represent an interesting group of teachers to query and analyze. To this end we pose and seek to answer the following research question:

> RQ: What are digitally skilled Finnish K-12 teachers' expectations of and attitudes towards the role of AI in mathematics education?

2 Theoretical frameworks and related research

The growing importance of AI systems in daily life has led to an increasing demand for including AI as a topic in schools. Different ideas and frameworks have been proposed for what should be the focus of such a K-12 AI curriculum. For example, a key goal of those promoting the concept of *AI literacy*, is teaching students a critical approach to AI, where the focus is not only on the technical and mathematical aspects of AI, but also on how students can use the new technology to solve (for them) meaningful problems and to be able to evaluate the impact of AI on society (Zimmerman, 2018). The AI4K12 research community has published a list of what they call *Five Big AI Ideas,* which they think the K-12 curriculum should cover, ranging from how machines learn from data to the societal impacts of AI (Touretzky et al., 2019). As a response to the push for AI in schools, countries and organizations have developed various AI curricula and curriculum resources for both teachers and students. To just mention one such resource, *ReadyAI* provides K-12 teaching and learning resources aimed at teachers, students, and parents (*ReadyAI*, n.d.).

As teachers play a critical role in bringing any new pedagogical innovations into the classroom, a successful introduction of AI concepts and ideas into the existing K-12 education requires, besides an AI-focused curriculum and the appropriate teaching resources, a proper preparation of teachers (Lindner & Berges, 2020). The *Technological Pedagogical Content Knowledge* (*TPACK*) is a widely used framework for identifying important skills and competencies for teachers to be able to incorporate information and communication technology (ICT) into their teaching (Chai et al., 2011). The *TPACK* framework has also been expanded to include AI competencies relevant for K-12 teachers (Kim et al., 2021). The expanded *TPACK* competencies and skills, relevant for K-12 AI education, include both pedagogical, technical, mathematical, and ethical aspects. Lindner & Romeike (2019) points out that the emphasis on K-12 education is important, as the skills and competencies necessary for teaching AI and machine learning at the university level are not directly transferable to K-12 teaching, as the underlying learning goals are not comparable. In addition, another extension, dubbed *Intelligent-TPACK*, also include competencies and skills relating to the ethical aspects of AI (Celik, 2023). *Intelligent-TPACK* highlights the interplay of the various *TPACK* components and ethics.

A teacher's knowledge and skills are two major factors when it comes to transforming curricular intentions to classroom actions. However, there is a non-trivial interplay between a teacher's knowledge and skills and his or her attitudes towards and expectations of AI (i.e., what drives what?). In our context, attitudes include beliefs, opinions, values, and emotions regarding education, teaching, learning and use of technology in the classroom and expectations refer to a teacher's anticipations or beliefs regarding future outcomes of implementing a new technology. The *Will*, *Skill*, *Tool* (*WST*) framework (Knezek et al., 2013; Petko, 2012), is a model used to frame and understand the conditions influencing a teacher's adoption of digital tools into the classroom. More recently the *WST*-model has been extended to also include a teacher's pedagogical preferences, i.e., if they prefer teaching with old or new technology, as a model construct (Knezek & Christensen, 2016). The *Will* component of the *WST*-framework relates to teachers' attitudes towards computers and information technology and if they think that it will impact their teaching and their students learning in a positive, neutral, or negative way. The *Will* component includes a teacher's motivations, values and beliefs concerning the new technology. The *Skill* component relates to a teacher's own perceived level of digital competence, that is how proficient they think they are at applying and using digital technology in their teaching. According to Petko (2012), the *Skill* element has the largest explanatory power among the three factors of the *WST*-framework. Lastly the *Tool* component of the framework relates to whether the teacher has actual access to the tools needed, i.e., are there enough computers in the classroom, is the software available, are needed learning platforms supported. Here, the main barriers are found to be outdated software and an insufficient IT architecture (Latifah et al., 2022). Ignoring any one of the three components of the *WST*-framework will, according to the models' proponents, result in a low impact on actual classroom practice and the unused new tools gathering dust.

Recently, the *WST*-framework has been used as theoretical lens to study K-12 teachers' perspectives on AI education (Polak et al., 2022). While teachers possessing the necessary skills and tools for teaching AI topics are critical, less focus has been placed on the *Will* component. According to the psychological theory of planned behavior (*TPB*), a teacher's attitudes, subjective norms, and perceived behavioral control, all shape a teacher's behavioral intentions (Ajzen, 1991). Thus, according to *TPB*, a teacher's attitudes toward and perceived readiness to teach AI topics will drive his or her intentions and in extension the actual successful (or not) implementation of the AI curriculum. Ayanwale et al. (2022) have shown that variables such as "AI anxiety", "Perceived relevance of AI", and "Attitudes towards using AI", as identified using an online questionnaire among K-12 teachers, predicts the behavioral intentions of the teachers. Investigating K-12 teachers' existing attitudes towards and expectations of AI, therefore forms a crucial first step in a successful implementation of an AI curriculum.

Although AI is highly relevant outside the STEM subjects, and embedding AI concepts into various non-STEM subjects provides both new possibilities and challenges (Lin & Van Brummelen, 2021), K-12 mathematics teachers form an especially interesting group of teachers to survey. We argue that these teachers will be among the early adopters and implementers of AI in schools. However, as we will apply the *WST*-framework to analyze our survey results, we are faced with the challenge that very few mathematics teachers out there have a direct experience with using advanced AI tools in their classrooms (however, this situation is likely to change). To be clear, when we speak of, “AI tools”, we refer to tools for profiling and predicting student achievement, tools for assessment and evaluation, adaptive systems for personalization, and intelligent tutoring systems (Zawacki-Richter et al., 2019). Waiting for these AI tools to become more widely available, we will use a teacher’s skills and experiences with existing digital tools as a proxy for the AI tools not yet used. The *Skill* and *Tool* components of the *WST*-framework will thus be related to a teacher’s experience with existing digital tools, while the *Will* component relates to a teacher’s motivations, values and beliefs concerning AI and AI technology. Teachers with extensive experience using digital tools in their classrooms have been dubbed as “digitally skilled” in our research.

3 Materials and methods

3.1 Context and educational setting

The Finnish school system consists of nine-year-long compulsory basic comprehensive schooling, starting at age 7 and ending at age 16, that is common for all students. After that it is possible to attend the upper secondary school for three years. Teachers in grades 1–6 (primary school) have a master’s degree in education, while teachers in grades 7–9 (lower secondary school) and grades 10-12 (upper secondary school) often have a master’s degree in a specific school subject. It is common for science and mathematics teachers in lower secondary schools to have a minor subject that they also teach. The combination of a major in mathematics and a minor in physics or chemistry is common. In 2016, programming was introduced as part of the revised National Core Curriculum for Basic Education in Finland. As programming is not thought as a separate subject in K-12 education in Finnish schools, few K-12 teachers have a computer science degree nor any formal knowledge of programming. It is therefore very common that computer science topics, such as algorithms and programming, are thought of as part of the mathematics curriculum.

Finnish (mathematics) teachers have high degree autonomy in deciding what type of digital curriculum resources they use and how they want to utilize them in their mathematics classrooms (Hemmi et al., 2018). This includes everything from the selection of digital pedagogical resources, tools, and aid for student assessment.

Finland has two official languages, Finnish (88.7 %) and Swedish (5.3 %). According to existing legislation, education is organized separately for both language groups in parallel monolingual schools that follow the same national core curricula.

Approximately 5 % of students in compulsory education attend a school where Swedish is the language of instruction.

3.2 Structure of survey and informants

The data for this study was collected using a web-based online survey. The online survey was open for about 8 weeks in Spring 2020 (survey in Swedish) and Autumn 2020 (survey in Finnish). This coincided with the outbreak and beginning of the COVID-19 pandemic. The surveys were advertised through various channels, such as social media, university and teacher networks and in-service training and resource organizations. Participation was the teacher's own choice and relied on their own initiative. The survey consisted of 20 questions that were of different types: single choice, multiple choice, Likert attitude scale statements and open-ended questions. The complete translated questionnaire can be found in Appendix A. The web-based questionnaire started by three introductory pages containing general information on its purpose and goals and explaining central key concepts in AI and AI in education (Appendix B, survey in Swedish).

The time required to complete the survey was on average 22 minutes. The total number of completed responses was N=85, divided into 52 responses from the survey in Swedish and 33 responses from the survey in Finnish. The data material is divided into background data and research data. The background material consists of general information about the respondents. The research data is connected to questions regarding the teachers' current use and experience with digital resources and their views and expectations on the role of AI in mathematics education.

Survey questions 1-7 provide background data on the respondents (Table 1). Survey questions 8-11 collect information on the teachers' current use and experience of digital curriculum resources. The alternatives listed in question 8 captures the current state of digital resources typically found in Finnish schools. The alternatives in question 9 are inspired by the digital technology framework of mathematical practices (Hoyles, 2018). Questions 12-19 probe AI related discussions, awareness, and potential future use in school. Question 20 contains 19 Likert scale statements (1=strongly disagree, 5=strongly agree) on respondents' attitude towards the use of AI in and out of school. The formulation of these 19 statements is based on the computer programming attitude scale (Cetin & Ozden, 2015). That scale includes statements probing affection, cognition, and behavior as the three dimensions of attitude.

Table 1 contains the gender, age, work experience, school level distributions as well as the distribution of self-perceived level of technological interest. The reason for the higher number of responses for school level is that several teachers work on multiple levels. In general, technological interest was high among the participating teachers.

Table 1. Background information on respondents to the survey. (- = no response, ps = primary school (grades 1-6), ls = lower secondary school (grades 7-9), us = upper secondary school (grades=10-12), M = average response)

Gender			Age				Work experience				School level			Technological interest					
female	male	-	20-29	30-39	40-49	50+	0-9	10-19	20-29	30+	ps	ls	us	1	2	3	4	5	M
55	24	6	11	18	33	23	30	24	20	11	25	42	27	0	9	15	33	28	4.0

3.3 Methods for data analysis

The survey consisted of a combination of open-ended and closed-ended questions. The analysis of teachers' answers requires the use of a mixed-methods methodology. The responses to the open-ended questions are analyzed using an iterative data-driven approach with no pre-defined categories (Bryman, 2016). The categories are identified from the data material, through several cycles of analysis. The answers (in Swedish/Finnish) were read several times, iteratively, by the first two authors and during this step similarities in the answers were identified and categorized. The identified categories were the result of this analysis. The categories arise naturally from the data, but a few answers are harder to categorize and do not match any one, single category.

The responses to the closed-ended questions were analyzed with standard statistical techniques. Descriptive statistical measures (frequency, mean, median, mode, standard deviation) were used to present the teachers' responses to the closed-ended questions.

The responses to the Likert scale statements were considered interval data and Pearsons's correlation coefficient was used. We use parametric methods since the statistical results are rather robust against violations of the ordinality assumption when analyzing Likert scale data (Norman, 2010). The exploratory multivariate data analysis of attitude questions probes the teachers' views and attitudes towards AI in school and society. The method applied is standard principal component analysis and the purpose of this part was to explore the data to find internal structure (Jolliffe & Cadima, 2016).

4 Results

4.1 How digital resources are used by mathematics teachers

This part describes how the responding teachers use digital resources in their teaching. Table 2 shows the result of survey question 8. Many of the teachers use a broad set of digital resources in their daily work, with "Digital response tools" and "On-line math resources" as most common and "Tools for digital documentation" and "Interactive whiteboard" as the least common. Digital response tools and on-line resources are usually free of charge and interactive whiteboards come with a significant economic cost. There is a variation of usage of different resources across school levels. Digital tests are very common in grades 10-12 (almost compulsory) and programming tools are much more widely used in grades 1-9.

Table 2. Types of digital resources used by the teachers.

Type of digital resource used	n (% of 85)
Digital teaching materials	66 (78 %)
Digital calculator	56 (66 %)
Other mathematical calculation tools	62 (73 %)
Programming tools	50 (59 %)
Tools for digital documentation	34 (40 %)
Digital tests	39 (46 %)
Digital response tools	70 (82 %)
On-line math resources	68 (80 %)
Interactive whiteboard	37 (44 %)
Other	2 (2 %)

The responses to question 9 are summarized in Table 3. The focus here is on the pedagogical aspect of the tool. Also, in this question there is a notable variation of pedagogical aspects for different tools across school levels. For example, to perform calculations is a crucial aspect in upper and lower secondary, but not in primary school. According to the teachers, the most common pedagogical aspects that the tool offers is feedback to the teacher on student progress and possibilities for variation in teaching and learning.

Table 3. Pedagogical aspects of digital resources used by the teachers.

Pedagogical aspect	n (% of 85)
1. Perform calculations	58 (68 %)
2. Produce graphs and diagrams	60 (71 %)
3. Give opportunities for differentiation	49 (58 %)
4. Provide formative assessment	51 (60 %)
5. Give feedback for teacher	66 (78 %)
6. Support understanding of concepts and connections	54 (64 %)
7. Add variation to teaching and learning	65 (76 %)
8. Increase motivation and interest	60 (71 %)
9. Other	2 (2 %)

To complement the descriptive data about different aspects of digital tools in mathematics education, the teachers also responded to the open-ended question 10: "What added value do the tools provide? Give examples and relate to those tools that you use often". A total of 61 of the teachers responded to this question and some answers were extensive and rich in nature. Categories of responses were identified from the data using an iterative process of content analysis. Added pedagogical values of digital tools are: The tool offers flexibility and variation in usage (cat1), provides personalization (cat2), aids in assessment (cat3), promotes collaboration (cat4) and enables visualization and outsourcing of calculations (cat5). Representative excerpts from teacher responses are:

> The tool gives the students direct feedback, they can proceed according to their skill level and needs, the teacher can unlock exercises, the exercises give rise to discussion and cooperation between the students. (T25), cat2&4
>
> It is easy for me to follow the students' way of progress, thinking, their motivation and to get in personal contact with them [...] (T44), cat3
>
> The students get new channels for perceiving information and expressing themselves [...] (T48), cat2
>
> [...] It is much more efficient to use a tool for analyzing properties of an object and connections. By using advanced CAS-calculators it allows us to focus on problem solving and analysis instead of tedious calculations. (T50), cat5

Question 11 deals with possible drawbacks, problems, and risks of working with, interacting with, and utilizing digital tools. A total of 65 open responses were given. The major drawbacks and risks with digital tools according to the teachers belonged to four different groups. Four broad categories were identified from the data. Digital tools may have technical and connectivity problems (cat1), shift focus from learning mathematics to learning or interacting with the tool (cat2), may have a negative impact on students' concentration and persistence (cat3) and do not reward mathematical reasoning nor problem solving (cat4). Representative excerpts from teacher responses are:

> [...] It takes time to learn the devices, the students trust them blindly and the justification that "speeding up the calculations gives you more time to think" does not work [...] (T59), cat2

> [...] To some extent, I think that the use of digital aids impairs students' patience with longer and more demanding tasks. They expect to arrive at the answer so quickly [...] (T20), cat3

> Some tasks are too close to gaming, in which case the student advances with game strategies using trial/error, without even trying reasoning [...] (T62), cat4

4.2 Teacher's expectations on the role of AI

AI-tools are emerging as a complement to or being integrated into existing digital resources. This section presents the results of the teachers' view on potential use, benefits, and detriments of AI-based tools in their work. Responses to questions 12-14 provide some background on the teachers' thoughts and discussions at school that have been connected to this topic. Figure 1 shows that AI discussions take place in schools and that some teachers think about and discuss, at least occasionally, the potential use of AI-tools in education.

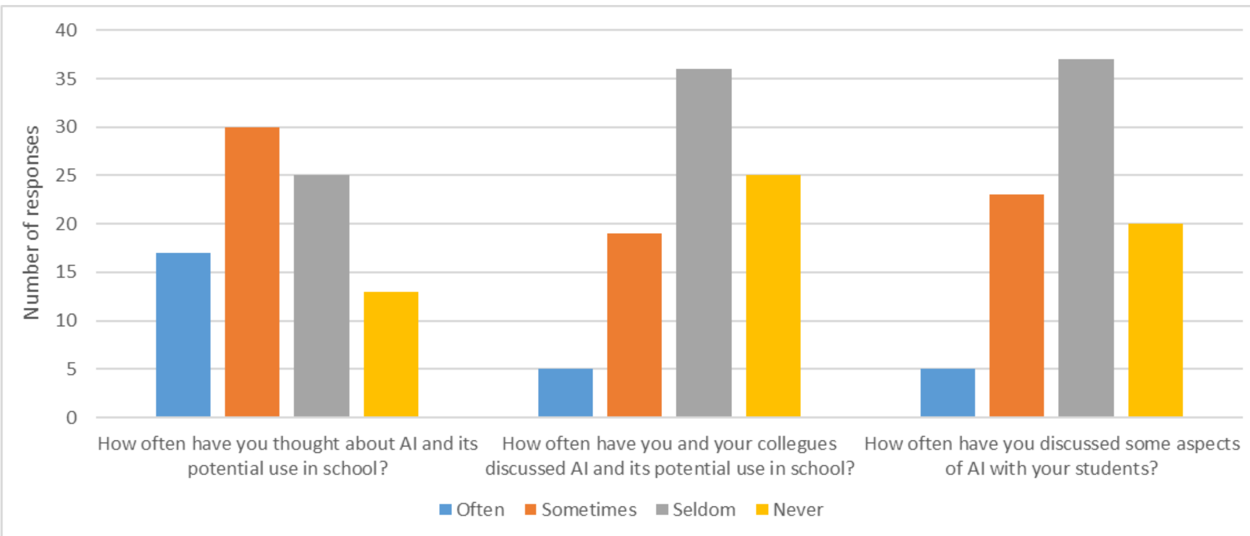

Figure 1. AI discussions at school (N=85).

There were only a few responses to question 16 on the teacher's early experience with AI-based tools, possibly reflecting the absence or lack of proper AI tools in schools. The most common example was that the tool provides individual exercise suggestion for students (based on student knowledge level and progress), basic assessment assistance for the teacher (automatic summary statistics and analytics) and automatic exercise generation (using a single exercise the tool generates several exercises of the same type). One teacher highlights the possibility for cheating using a tool that generates a solution to an exercise based on the photograph of the problem description. All these examples can in a broad sense be viewed as AI tools. In table 5 below the results of responses from question 17 are presented.

Table 4. Potential pedagogical use of AI-tools in mathematics learning.

Potential for AI-tools	**n (% of 85)**
1. Create individual learning path	66 (78 %)
2. Support in homework	51 (60 %)
3. Offer help in school for students in need of support	52 (61 %)
4. Offer challenges in school for interested students	69 (81 %)
5. Make it easier for teacher to follow-up and assess students	56 (66 %)
6. Increase the motivation for and interest in mathematics	56 (66 %)
7. Other	1 (1 %)

The distribution of responses is rather even for question 17. The teachers see benefits, both from a teacher as well as a student perspective, by using different types of AI-based tools. This was a multiple-choice question with no restrictions on the number of selected choices. The distribution of the number of selected choices is given in Figure 2. Two teachers saw no potential for AI-tools in the classroom and 24 teachers identified potential in all six proposed areas.

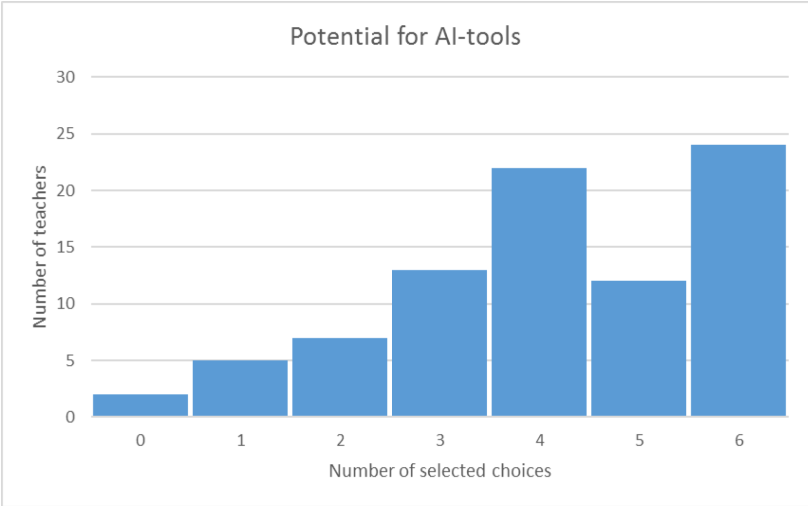

Figure 2. Distribution of the number of selected choices by teachers.

Question 18 allowed open-ended comments on risks, problematic issues and drawbacks connected to AI presence in school. Three different categories were identified from the data. The most common problematic issue was related to the data collection, data handling and data security connected to efficient AI usage (cat1). For an AI-tool to work properly a lot of data is required. Data is continuously collected, stored, and analyzed. It is used in, for example, dashboards for presenting analytics and for improving internal AI models in the tools. This data can indeed be sensitive and must be stored properly and ethically according to jurisdiction and laws. Another negative aspect highlighted by some teachers was that AI might have a negative impact on collaboration between students and social aspects in the classroom (cat2). Continuous interaction with an AI might also have negative emotional consequences for some students according to the responses. The third negative aspect was that teachers and students may have an over-belief and trust to AI-tool blindly, for example in connection to assessment and personalization aid (cat3).

> Artificial intelligence requires the use of data, which is a huge risk for students' information security [...] (T79), cat1

> Teaching can become impersonal and more machine-like. Many students already found this spring's distance education unpleasant and missed classroom teaching with its social contacts and interaction with other people [...] (T61), cat2

> [...] Another risk is that teachers and students blindly trust the algorithm and its statements about the student's development. (T20), cat3

4.3 Teachers' attitudes towards AI

In this section we describe and explore the results of the 19 statements related to attitude towards AI in school and society (see Appendix A, Q20). The Likert scale data are interpreted as interval data. The analysis is conducted using Matlab 2020b and the toolbox for Statistics and Machine Learning (MathWorks - MATLAB & Simulink). In Figure 2 descriptive statistics of the responses of the 19 attitude statements are presented. In Figure 2a the responses for each statement are summarized with the mean, median, mode and standard deviation. Statements 5 and 18 had the lowest mean (1.47, 1.65) and median (1) and statements 6 and 11 had the highest mean (3.61, 3.48) and median (4).

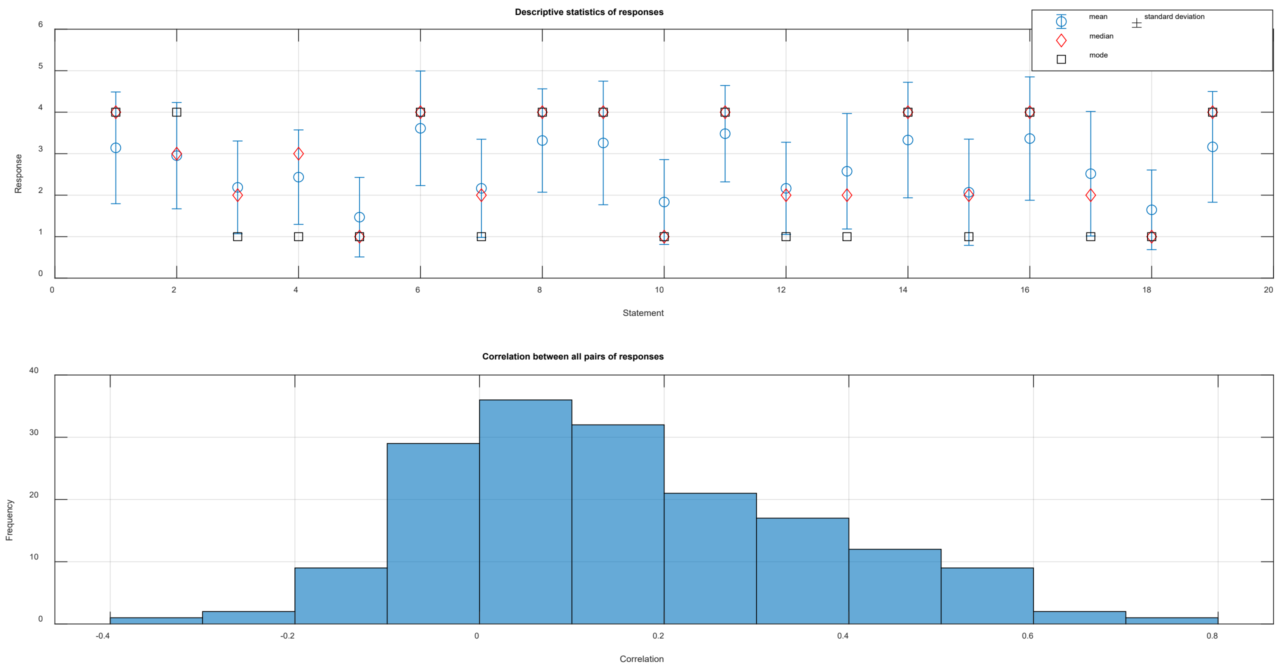

Figure 3. a) Descriptive statistics of responses to attitude statements (Likert scale 1-5), b) Histogram of pairwise correlations between variables (attitude statements)

In Figure 3b the correlations (Pearson's correlation coefficient *r*) between every possible pair of statements are illustrated as a histogram. There is a total of 171 possible pairs of statements. The maximum correlation is 0.75 (between statements 16 and 19) and the minimum correlation is -0.33 (between statements 2 and 18). A total of 41 pairs have a negative correlation, and 130 pairs have a positive correlation. The mean correlation of all pairs of statements is 0.15. Most of the correlations were relatively low and reflect that the statements measure different aspects of the teachers' attitude towards AI and perceived role of AI in education.

An explorative data analysis is performed as a standard principal component analysis of the data (Jolliffe & Cadima, 2016). The variables (responses to statements) are standardized prior to analysis. In social and educational sciences, a variable may be considered to contribute to a specific principal component if it has an absolute loading of at least 0.3 or greater (Peterson, 2000). Thus, in this analysis we set the threshold of 0.3 for a variable loading to consider it significant.

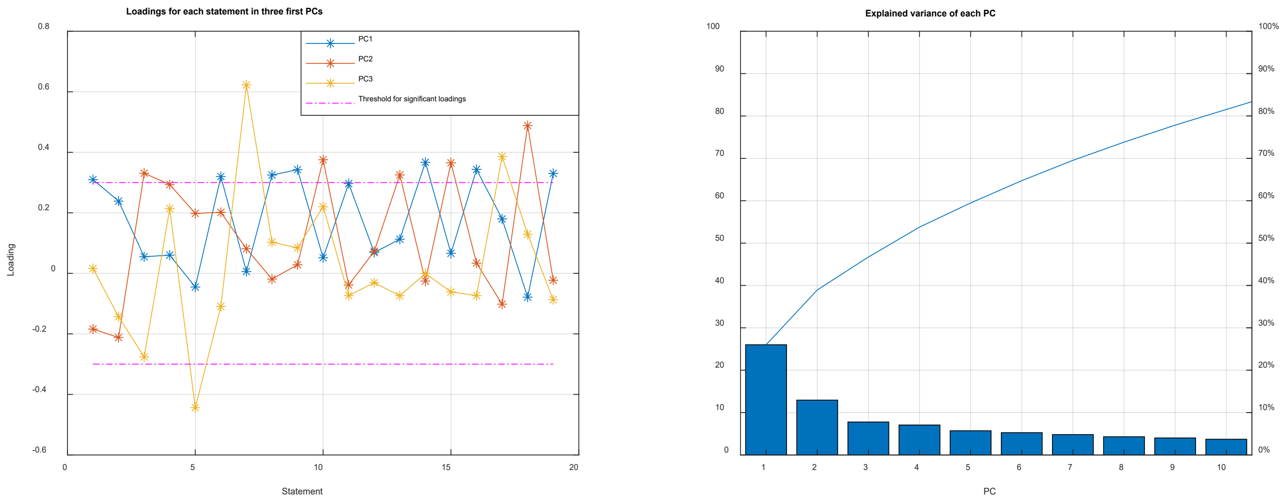

Figure 4. a) Loadings of the first three principal components, b) Explained variance of principal components

The first three principal components explain 47% of the total variance of the data (Figure 4b). All loadings higher than the threshold 0.3 has statistically significant correlation with the corresponding original variable ($p<.01$). Inspecting the loadings of the three first principal components suggests the following interpretations.

PC1 (27%): Variables (statements) 1, 6, 8, 9, 11, 14, 16 and 19 all have high positive loadings on the first principal component. All these statements are connected to a positive mindset towards AI in mathematics education and PC1 can be interpreted as general "AI-openness". A respondent that scores high on PC1 can be described as one who is interested in and curious of AI, sees clear possibilities in AI and is looking forward to applying such tools in her or his educational work.

PC2 (12%): Variables 3, 4, 10, 13, 15 and 18 represent statements that are associated with negative feelings, such as scariness, inequality, resistance or uninterest of AI in general and of AI tools. All these variables have high positive loadings on the second principal component. Thus, PC2 can be interpreted as a kind of "AI-ambivalence" and a respondent that scores high on PC2 is likely to be skeptical of and sees clear risks in using of AI tools in the classroom.

PC3 (9%): The third principal component has high positive loadings on variables 7 and 17 and a large negative loading on variable 5. Statement 7 claims that all talk about AI is exaggerated and statement 17 is about the respondent's own usage of AI tools outside of school. Statement 5 claims that AI will make teachers unemployed. A person that scores high on PC3 is not impressed with AI tools and is not afraid that AI will lead to unemployed teachers. Thus, PC3 may be interpreted as a type of "AI-exaggeration".

The structure of the responses to these 19 AI attitude statements can be divided into three dimensions: "AI-openness", "AI-ambivalence", and "AI-exaggeration". We also explored the data by grouping teacher responses with respect to gender, age, work experience, school level and language, but no clear clusters or structure could be identified.

4.4 Summary of results

This section summarizes the results from the survey. The first part collected information on what digital tools the teachers use and how (for what purpose) the teachers interacted with different digital resources in their mathematics teaching. The responding teachers seemed to use a broad palette of digital tools in their teaching, and they highlighted many aspects where the digital tools served a clear pedagogical purpose. They also identified several challenges and problem areas, both pedagogical and technological ones, when classrooms are becoming more digitalized. From the background data the responding teachers also have a high self-perceived technological interest (4/5). Therefore, we claim that the respondents are digitally skilled and likely to be early adopters also regarding AI-tools in education.

The focus of the second part was on teachers' expectations on the potential role of AI in the mathematics classroom. At the time for the data collection (spring-autumn 2020) some of the teachers had begun to think about the potential use of AI in school and there were already teacher-teacher and teacher-student discussions on the concept of AI present in schools. The teachers also saw clear possibilities for AI to assist in their work, mainly for personalization and assessment tasks. However, they also expressed distrust in AI tools being able to correctly assist the teacher or student in personalization and assessment tasks and considered it a clear risk to trust an AI too blindly. In addition, several teachers also expressed their concern on ethical and data integrity issues that are connected to the use of AI tools.

The final part of the result was connected to teachers' attitudes toward AI. Three dimensions of attitude could be found from the 19 attitude statements. The first principal component was interpreted as general AI-openness and captures interest and curiosity of AI and willingness to apply AI-tools in the classroom. The second dimension was identified as AI-ambivalence and it expresses worries and skepticism with AI as a tool in school. The third component was labelled AI-exaggeration and is connected to a general overestimation of the capabilities of AI.

5 Discussion

A clear majority of the mathematics teachers sampled are experienced users of online teaching resources and digital teaching materials (Table 1 & 2). Most teachers also use formative response tools to probe their students' understanding and get feedback. The possibility of direct, individualized feedback is also what some of the teachers see as the main advantage of using digital tools. Although many of the current digital tools used by teachers are not AI tools per se, the teachers are clearly aware of the value of personalized student assessment and evaluation. This realization is in line with one of the four areas where AI is expected to have the largest impact within an educational setting according to Zawacki-Richter et al. (2019). The teachers that responded to our survey did not only see the possibilities, but also the dangers of relying too much on digital technology. One such area of concern is at the very core of teaching and learning mathematics. By concentrating on learning a tool, their fear is that less focus is placed on conceptual learning, mathematical reasoning and problem solving. Although much effort has been put into making AI able to reason and problem solve creatively, there remain huge challenges before these types of AI tools are available in the K-12 classroom.

Based on our results we have identified most of our respondents as aware and digitally skilled users of current digital tools and resources. As we use this as our AI proxy for the *Skill* and *Tools* dimensions in the *WST*-framework, our main focus is on the teachers' expectations and attitudes towards AI, or the *Will* dimension of *WST*. This choice is motivated by previous research on teachers' attitudes on AI education, where the *WST*-model has been used as a theoretical lens, that has shown that a positive attitude towards and motivation for AI in education translates to a positive *Will* factor (Polak et al., 2022). As a reminder, the *Will* dimension includes factors such as a teacher's motivations, values and beliefs concerning the new technology (Knezek & Christensen, 2016). Many teachers in our survey, although they have no extensive experience using AI tools themselves, have mostly positive expectations on and see the potential of AI in schools (Table 4 and Figure 2). However, although they list the potential uses in areas of individualization and scaffolding, almost 81 % of respondents see AI as offering challenges in school for interested students. In our opinion this reflects that many teachers still partly see AI as something that is reserved for a selected few students. With regards to the risks of AI, privacy issues and concerns top the list. These concerns reflect, we think, the general conversation surrounding AI and media headlines focused on leaked and hijacked accounts. On the pedagogical side, teachers see a risk of a blind trust in tools and a further decrease in the collaboration among students. In summary, the teachers' expectations on the future role of AI in schools are balanced, they realize the potential but are also aware of some of the risks.

A teacher's expectation is only one component making up the *Will* factor. Another important component is a teacher's attitudes towards AI. Analyzing the respondents' answers to the 19 questions probing teachers attitudes towards AI, the main results show a positive mindset towards AI in mathematics education, what we identify as an openness to the positive potential of AI ("AI-openness"). Although the positive attitude towards AI dominates our results, there is also a second, weaker component associated with negative feelings (e.g., scariness, inequality, resistance). This component overlaps somewhat with what Ayanwale et al. (2022) in their research among in-service teachers call "AI anxiety". However, as the strength of the negative statements are too weak in our results to warrant the use of the word "anxiety", we have identified this component as an ambivalence towards AI ("AI-ambivalence"). The third, and weakest component in our results, is related to the potential overselling of AI ("AI-exaggeration"). Teachers measuring high on this component don't see AI threatening their future work as teachers. One interpretation of this result could be that they do not see any potential for AI in schools. However, it could also be argued based on the results discussed above that the teachers realize the complex nature of their work and see no indications that this could be automated in the near future.

6 Conclusions and further research

Putting together the three factors of the *WST*-framework, we conclude that the K-12 mathematics teachers surveyed have both the experience and will to become early adopters of AI tools in the classroom. It should be emphasized that this does not imply that AI curriculum material, in-service teacher training and easy-to-use AI tools are also not critical. However, a good starting point for any curriculum reform is an insight among teachers on the usefulness of change and an openness towards change. Regarding possible future research, it would be interesting to redo our questionnaire after the introduction of ChatGPT-3. It is our general feeling that the introduction of ChatGPT-3 in late autumn 2022 served for many teachers as a wakeup call concerning the potential of AI in schools. This would also provide insights into the important *Skill* and *Tools* components of the WST framework as a result of the rapidly emerging new AI tools used in schools and society. Finally, we stress the importance of finding a balance between teaching and learning key mathematical concepts and skills and the reliance on AI tools, not letting the tool dictate our didactical ambitions in mathematics education.

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References

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Aleven, V., McLaren, B. M., & Sewall, J. (2009). Scaling Up Programming by Demonstration for Intelligent Tutoring Systems Development: An Open-Access Web Site for Middle School Mathematics Learning. *IEEE Transactions on Learning Technologies*, *2*(2), 64–78. https://doi.org/10.1109/TLT.2009.22

Ayanwale, M. A., Sanusi, I. T., Adelana, O. P., Aruleba, K. D., & Oyelere, S. S. (2022). Teachers' readiness and intention to teach artificial intelligence in schools. *Computers and Education: Artificial Intelligence*, *3*. https://doi.org/10.1016/j.caeai.2022.100099

Bryman, A. (2016). *Social Research Methods* (Fifth edition). Oxford University Press.

Celik, I. (2023). Towards Intelligent-TPACK: An empirical study on teachers' professional knowledge to ethically integrate artificial intelligence (AI)-based tools into education. *Computers in Human Behavior*, *138*, 107468. https://doi.org/10.1016/j.chb.2022.107468

Cetin, I., & Ozden, M. Y. (2015). Development of computer programming attitude scale for university students. *Computer Applications in Engineering Education*, *23*(5), 667–672. https://doi.org/10.1002/cae.21639

Chai, C. S., Ling Koh, J. H., Tsai, C.-C., & Lee Wee Tan, L. (2011). Modeling primary school preservice teachers' Technological Pedagogical Content Knowledge (TPACK) for meaningful learning with information and communication technology (ICT). *Computers & Education*, *57*(1), 1184–1193. https://doi.org/10.1016/j.compedu.2011.01.007

Elements of AI. (n.d.). Retrieved June 19, 2023, from https://www.elementsofai.com/

Farrokhnia, M., Banihashem, S. K., Noroozi, O., & Wals, A. (2023). A SWOT analysis of ChatGPT: Implications for educational practice and research. *Innovations in Education and Teaching International*, 1–15. https://doi.org/10.1080/14703297.2023.2195846

Hemmi, K., Krzywacki, H., & Koljonen, T. (2018). Investigating Finnish Teacher Guides as a Resource for Mathematics Teaching. *Scandinavian Journal of Educational Research*, *62*(6), 911–928. https://doi.org/10.1080/00313831.2017.1307278

Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education – Promises and implications for teaching and learning*. The Center for Curriculum Redesign.

Hoyles, C. (2018). Transforming the mathematical practices of learners and teachers through digital technology. *Research in Mathematics Education*, *20*(3), 209–228. https://doi.org/10.1080/14794802.2018.1484799

Hwang, G.-J., Xie, H., Wah, B. W., & Gašević, D. (2020). Vision, challenges, roles and research issues of Artificial Intelligence in Education. *Computers and Education: Artificial Intelligence*, *1*, 100001. https://doi.org/10.1016/j.caeai.2020.100001

Jolliffe, I. T., & Cadima, J. (2016). Principal component analysis: a review and recent developments. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *374*(2065), 20150202. https://doi.org/10.1098/rsta.2015.0202

Kasneci, E., Sessler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., Gasser, U., Groh, G., Günnemann, S., Hüllermeier, E., Krusche, S., Kutyniok, G., Michaeli, T., Nerdel, C., Pfeffer, J., Poquet, O., Sailer, M., Schmidt, A., Seidel, T., … Kasneci, G. (2023). ChatGPT for good? On opportunities and challenges of large language models for education. *Learning and Individual Differences*, *103*, 102274. https://doi.org/10.1016/j.lindif.2023.102274

Kay, J. (2012). AI and Education: Grand Challenges. *IEEE Intelligent Systems*, *27*(5), 66–69. https://doi.org/10.1109/MIS.2012.92

Kim, S., Jang, Y., Choi, S., Kim, W., Jung, H., Kim, S., & Kim, H. (2021). Analyzing Teacher Competency with TPACK for K-12 AI Education. *KI - Künstliche Intelligenz*, *35*(2), 139–151. https://doi.org/10.1007/s13218-021-00731-9

Knezek, G., & Christensen, R. (2016). Extending the will, skill, tool model of technology integration: adding pedagogy as a new model construct. *Journal of Computing in Higher Education*, *28*(3), 307–325. https://doi.org/10.1007/s12528-016-9120-2

Knezek, G., Christensen, R., & Fluke, R. (2013). Testing a will, skill, tool model of technology integration. *Annual Meeting of the American Educational Research Association (AERA)*.

Latifah, R., Budiyanto, C. W., & Saputro, H. (2022). Digital Transformation Readiness in Education: A Review. *International Journal of Information and Education Technology*, *12*(8), 809–815. https://doi.org/10.18178/ijiet.2022.12.8.1688

Lin, P., & Van Brummelen, J. (2021). Engaging Teachers to Co-Design Integrated AI Curriculum for K-12 Classrooms. *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, 1–12. https://doi.org/10.1145/3411764.3445377

Lindner, A., & Berges, M. (2020). Can you explain AI to me? Teachers' pre-concepts about Artificial Intelligence. *2020 IEEE Frontiers in Education Conference (FIE)*, 1–9. https://doi.org/10.1109/FIE44824.2020.9274136

Lindner, A., & Romeike, R. (2019). Teachers' perspectives on artificial intelligence. *12th International Conference on Informatics*.

Luckin, R., George, K., & Cukurova, M. (2022). *AI for School Teachers*. CRC Press. https://doi.org/10.1201/9781003193173

MathWorks - Makers of MATLAB and Simulink - MATLAB & Simulink. (n.d.). Retrieved January 13, 2023, from https://se.mathworks.com/

Ministry of Economic Affairs and Employment. (2019). *Leading the way into the age of artificial intelligence: Final report of Finland's Artificial Intelligence Programme 2019*. http://urn.fi/URN:ISBN:978-952-327-437-2

Norman, G. (2010). Likert scales, levels of measurement and the "laws" of statistics. *Advances in Health Sciences Education*, *15*(5), 625–632. https://doi.org/10.1007/s10459-010-9222-y

Petko, D. (2012). Teachers' pedagogical beliefs and their use of digital media in classrooms: Sharpening the focus of the 'will, skill, tool' model and integrating teachers' constructivist orientations. *Computers & Education*, *58*(4), 1351–1359. https://doi.org/10.1016/j.compedu.2011.12.013

Peterson, R. A. (2000). A Meta-Analysis of Variance Accounted for and Factor Loadings in Exploratory Factor Analysis. *Marketing Letters*, *11*(3), 261–275. https://doi.org/10.1023/A:1008191211004

Polak, S., Schiavo, G., & Zancanaro, M. (2022). Teachers' Perspective on Artificial Intelligence Education: an Initial Investigation. *CHI Conference on Human Factors in Computing Systems Extended Abstracts*, 1–7. https://doi.org/10.1145/3491101.3519866

ReadyAI. (n.d.). Retrieved June 19, 2023, from https://medium.com/readyai-org

Rudolph, J., Tan, S., & Tan, S. (2023). ChatGPT: Bullshit spewer or the end of traditional assessments in higher education? *Journal of Applied Learning & Teaching*, *6*(1). https://doi.org/10.37074/jalt.2023.6.1.9

Touretzky, D., Gardner-McCune, C., Martin, F., & Seehorn, D. (2019). Envisioning AI for K-12: What Should Every Child Know about AI? *Proceedings of the AAAI Conference on Artificial Intelligence*, *33*(01), 9795–9799. https://doi.org/10.1609/aaai.v33i01.33019795

Vuorikari, R., Kluzer, S., & Punie, Y. (2022). *DigComp 2.2 - The Digital Competence Framework for Citizens*. https://doi.org/10.2760/115376

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education – where are the educators? *International Journal of Educational Technology in Higher Education*, *16*(1), 39. https://doi.org/10.1186/s41239-019-0171-0

Zimmerman, M. (2018). *Teaching AI: Exploring new frontiers for learning*. International Society for Technology in Education.

Appendix A

Translated survey. * Indicates obligatory questions

Question 1*: I teach mathematics
(Yes/No)

Question 2*: Gender
(Open answer)

Question 3*: Age
20-29
30-39
40-49
50-59
60-

Question 4*: Where do you work?
Regional choices

Question 5*: Work experience in years
0-4 years
5-9 years
10-19 years
20-29 years
30- years

Question 6*: What grades do you teach?
(Multiple choice)
grade 1-6
grade 7-9
grade 10-12 (upper secondary school)

Question 7*: Rate to what degree you personally are interested in digital technology and its possibilities
(1 = none or very weak interest, 5 = very large interest)

Question 8*: Which different digital resources do you use in teaching mathematics? Some examples are given, but there are of course many other tools that can be included in case
(Multiple choice)

- Digital teaching materials
- Digital calculator
- Other mathematical calculation tools

- Programming tools
- Tools for digital documentation
- Digital tests/exams
- Digital response tools
- On-line math resources
- Interactive whiteboard
- Other

Question 9*: If you consider the digital resources you use, what aspects of mathematical learning, follow-up and assessments do they support? The digital tools are used for...
(Multiple choice)

- Perform calculations
- Produce graphs and diagrams
- Give opportunities for differentiation
- Provide formative assessment for students
- Give feedback to teacher
- Support understanding of mathematical concepts and connections
- Add variation to teaching and/or increase motivation and interest
- Other

Question 10: What added value do the tools provide? Give examples and relate to those tools that you use often.
(Open answer)

Question 11: Are there drawbacks to working digitally in mathematics? Please motivate and highlight which problems, risks and dilemmas you associate with a digital way of working .
(Open answer)

Question 12*: How often have you thought about AI and its potential use in school?
(Often, sometimes, seldom, never)

Question 13*: How often have you and your collegues discussed AI and its potential use in school?
(Often, sometimes, seldom, never)

Question 14*: How often have you discussed some aspects of AI with your students?
(Often, sometimes, seldom, never)

Question 15*: Have you encountered or used in your math teaching a tool that you consider is based on AI?
(Yes/No)

Question 16: Which AI-tools are you thinking about?
(Open answer)

Question 17*: For which purposes do you think AI-tools could have an important function to fill within mathematics learning?
(Open answer)

Question 18: What risks and problems can AI in school bring with it?
(Open answer)

Question 19: Are there elements in a teaching and learning situation that could be enhanced with a social robot? If so, which?
(Open answer)

Question 20*: Please take a stand on the following statements regarding AI in society and in school (Totally disagree = 1, partly disagree = 2, neutral = 3, partly agree = 4, totally agree = 5)

1. I look forward to using AI-tools in my teaching
2. AI gives me hope for the future
3. The use of AI worries me and makes me scared
4. There is a risk that AI will increase inequality in the classroom
5. AI can make future teachers unemployed
6. I think that a good student could get new challenges from using AI-tools
7. I consider all this talk of how AI will change society is exaggerated
8. AI will in the future support and make a teachers work easier
9. Adaptive and individualizing teaching material will be a valuable resource in the classroom
10. AI-tools are not suitable for the formative assessment of student learning
11. It is important for students in school to come into contact with and learn about AI
12. AI and the gathering of data will intrude on the personal integrity of the student
13. I do not follow the discussions concerning AI in society or school
14. I would like to participate in continuing education and projects focusing on AI in school
15. I would not use a social robot in my classroom
16. Students would quickly adapt to a social robot
17. I regularly use AI-tools outside of school (ex. Siri, Google translate,...)
18. It is hard for me to see that I would start using AI-tools in my teaching
19. A social robot can be used to offer differentiated and individualized learning

Appendix B

The three introductory pages of the survey (from the survey in Swedish).

Page 1

INFORMATION OM ENKÄTEN

Denna enkät riktar sig till verksamma lärare som undervisar i matematik (åk 1-9 och gymnasiet). Syftet med enkäten är tvådelat. Det första är att öka kunskapen om och insikter i vilka digitala resurser som lärare använder i sin matematikundervisning och hur de ser på resursernas pedagogiska värde. Det andra syftet är att bidra med kunskap om hur lärare förhåller sig till möjligheterna och riskerna med verktyg som använder sig av artificiell intelligens.

Enkäten består av totalt sju sidor. De tre första sidorna är information om enkäten, om artificiell intelligens och hur den kan användas i skolan. Enkätfrågorna (20 stycken) finns på sidorna fyra till sex och på den sista sidan ges möjlighet att ge respons, sina kontaktuppgifter och samtidigt delta i utlottningen av en iPad. Att svara på enkäten beräknas ta ca 20 minuter. All insamlad data hanteras konfidentiellt och enligt dataskyddslagen.

Enkäten är en del av projektet Artisan som leds av professor Kirsti Hemmi vid fakulteten för pedagogik och välfärdsstudier vid Åbo Akademi i Vasa. Enkäten är öppen till 7 juni 2020.

Tack för att du tar dig tid att besvara enkäten! Ditt svar är värdefullt.

Page 2

VAD ÄR AI?

Med artificiell intelligens (AI) avser man system som uppvisar ett intelligent beteende, genom att automatiskt samla in och analysera data för att uppnå specifika mål. Man kan samla in data om en lyssnares favoritlåtar för att sedan kunna föreslå andra lämpliga låtar och artister som kan vara intressanta. På motsvarande sätt kan man samla in data om elevers prestationer, t.ex. hur väl de klarar av att lösa vissa uppgifter för att sedan kunna skräddarsy vilka typer av uppgifter enskilda elever ska lösa i fortsättningen. Insamlat data fungerar som informationsunderlag och AI-tekniker används för att dra nytta av informationen, för att därefter ge rekommendationer och fatta beslut.

Exempel på områden i samhället där AI används är språkigenkänning (t.ex. assistenten Siri), maskinöversättning (t.ex. Google translate), chattbotar på websidor, ansiktsigenkänning (t.ex. vid passkontroll), självkörande bilar och andra autonoma system.

Page 3

VAD KAN AI I SKOLAN INNEBÄRA?

De nya läroplanerna för den grundläggande utbildningen och gymnasiet föreskriver att digital kompetens ska ingå i undervisningen och ge varje elev och studerande möjlighet att utveckla en förståelse för teknologins användning, möjligheter och risker. AI ingår som en viktig del i detta. Ett krav för att ett verktyg ska kunna kallas AI-baserat är att det är anpassningsbart eller adaptivt. Om en elev lär sig att lösa en viss typ av uppgift snabbt får den eleven automatiskt svårare och mer utmanande uppgifter, medan en elev som inte lyckas lösa en uppgift får öva på flera liknande uppgifter. AI-verktyg för skolbruk kan vara av olika typ:

- Adaptiva läromedel och anpassat innehåll: På basen av hur eleven presterar föreslår systemet lämpliga uppgifter och innehåll.
- Intelligenta tutorer och kognitiva assistenter: Eleven för en dialog (ofta skriftlig) med systemet som ger feedback i form av ledning och tips samt stöttning och beröm. Ett dylikt verktyg kan både användas i skolan och som hjälp vid hemarbete.
- Lärandeanalytik och verktyg för bedömning: Systemet samlar in information om vilka uppgifter som eleven löst och hur hen lyckats. Informationen sammanställs och eleven får feedback på sitt lärande och läraren erhåller en sammanställning av elevens prestationer (svagheter/styrkor).
- Sociala robotar: Sociala robotar kan användas på olika sätt i klassrummet. De kan programmeras, förses med mjukvara, exempelvis för matematiklärande och fungera både som lärare och elev (eleven ska lära roboten något).

Nedan följer tre videor som exempel på hur AI-baserade verktyg kan användas i klassrummet. Notera att alla filmer är reklammaterial.
ALEKS – ett adaptivt verktyg för uppföljning av matematiklärande (3:50)
https://www.youtube.com/watch?v=-1Q4jRbpODQ
PEPPER och NAO - undervisningsrobotar (2:53) och sociala robotar (5:56) i klassrummet
https://www.youtube.com/watch?v=eH11lpxLZ-g
https://vimeo.com/159045118