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In-service teachers' (mis)conceptions of artificial intelligence in K-12 science education

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ABSTRACT

Society's future depends on informed perspectives of Artificial Intelligence (AI) and AI related skills, a prognosis that greatly impacts K-12 education. To best prepare students to be AI savvy, there is a need to integrate AI tools, skills, and lessons into the K-12 curriculum. In order for teachers to develop the knowledge and skills, and have the self-efficacy for using AI in instruction, they must be well prepared and informed of what AI is (and what it is not) and its potential role in K-12 education. This study explored teachers' (mis)conceptions relative to their intentional and informal learning. Our research provides important implications for teacher preparation and in-service professional development regarding AI in our society and implementation of AI tools and processes in K-12 education.

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Introduction

"Artificial intelligence" (AI) is a term that dates back to 1956, an era of the seminal research and development of neural networks, expert systems, and symbolic modeling (McCarthy et al., 2006). As the advancements in information and communication technologies allowed us to generate more data (big data) and new insights into computing and its consequences regarding human-computer interaction, scholars across domains have resumed efforts to develop more robust AI methodologies (supervised and unsupervised machine learning, deep neural networks etc.), extend the applications of AI in our society, discuss the ethical implications of developing and using AI models, and, in many ways, redefine AI given its role in the 21st century (Emmert-Streib et al., 2020).

Society's future depends on informed perspectives of AI and AI-related skills (Frank et al., 2019), a prognosis that greatly impacts K-12 education. AI includes four processes that include how a system perceives data, analyzes data, uses data, and improves its intelligence based on the data. Machine learning focuses on how the received data is utilized to improve the intelligence of the machine without human assistance. By doing so, machine learning assists in finding patterns and making decisions – processes that are important in many aspects of our daily lives, education, and work. Whether we acknowledge this or not, humankind is already immersed in AI applications as AI is used to augment much of what we do and how we live our lives. For example, machine learning optimizes a driver's route on Google Maps, sorts emails into a user's junk mail folder, suggests products you may like, and even supports automated driving.

The role of AI in K-12 education is highlighted in such recent publications as "K-8 STEM career competencies: Developing foundational skills for the future of work" (Malyn-Smith et al., 2021) and AI4K12 5 Big Ideas in Artificial Intelligence (AI4K12,12, 2022). As students learn about AI in the

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classroom, they understand that AI is about data and models that are trained using those data. When students use accessible AI tools such as Google's Teachable Machine, they learn that to build AI they must a) collect data, b) prepare data, c) choose an appropriate ML model, d) train the model, e) evaluate the model, f) tune model parameters, and g) test model predictions. Understanding and demonstrating scientific processes such as the ML process described above aligns well with Bloom's taxonomy of learning objectives (Krathwohl, 2002) and is an important component of meaningful and active learning in the STEM classroom (Aluvalu et al., 2017). Integration of AI as a Machine Learning (ML) or Deep Learning (DL) process has the benefits of dispelling students' misconceptions about AI and reinforcing their understanding of scientific inquiry.

As we consider AI skills in relation to K-12 students' future careers, we may look to scientists who demonstrate a wide variety of uses of AI. Ornithologists will be able to use large datasets of pictures and sounds of birds, and train machines to identify patterns among the data to explore a habitat's biodiversity and support conservation efforts. The AI technology is so advanced that it can predict bird migration patterns which can inform people how best to adjust wind turbines or where to construct buildings to avoid impacting any wildlife (Lin et al., 2019). Similarly, agronomists use machine learning to study plant structural roots relative to the amount of moisture and fertilizer they have been exposed to. Such AI-enhanced visualizations of plant roots inform agronomists' decision making regarding how much water or fertilizer a plant has or may need based on the plant root architecture (Peeples et al., 2021). These are just two examples, but they illustrate the benefits AI is already producing in our lives and the importance of integrating AI knowledge and skills in K-12 education. To best prepare students to be AI savvy, policymakers, researchers, and educators must develop strategies to infuse AI tools, skills, and processes into the K-12 curriculum. But before any of this work can be implemented in any meaningful way, it is imperative to explore what K-12 teachers already know about AI so that their existing conceptions and, importantly, misconceptions, can be addressed in the design of the curricula that introduce K-12 students to AI and ML.

There are reasons to believe that society in general and K-12 teachers, in particular, hold certain misconceptions about AI and AI in education. Kikas (2004) identified a lack of AI concepts in the current teacher education curriculum (in the US) as the key cause of the transfer and propagation of misconceptions in K-12 schools. It is likely that most K-12 teachers in today's schools have not participated in formal AI training in any capacity, although it is also important to note potential cultural differences across nations and their systems of education. Yet, AI has been pervasive in the news and popular media. As a result, K-12 teachers, similar to other members of our society, are informed primarily by non-experts' notions about AI and its applications and may have developed their own "naïve theories" of AI and its functions in our lives (Savion, 2009). Every interaction with popular media, including but not limited to television, radio, film, and social media that a teacher has may, in some way, influence their perception of AI. This phenomenon is typically referred to as incidental learning (Greene et al., 2021), compared to the notion of intentional learning such as a professional development seminar for K-12 teachers. Further, when individuals repeatedly visit the same media sources and are unchallenged on their conceptions, the learned misconceptions are further reinforced and strengthened (Gooding & Metz, 2011). Following an interaction on a new topic (e.g., AI), people reconcile the new information on the topic with what they already know via the processes of assimilation or accommodation of schemata followed by cognitive equilibration (Piaget, 1972). In other words, the teacher's mind will only make sense of the new information (e.g., how AI works) in light of what is already known about the concept or what is perceived to be related concepts (e.g., how human brain works). However, this process may lead to or perpetuate misconceptions (Gooding & Metz, 2011). By nature, humans are actively trying to understand their surroundings to feel comfortable about their understandings of the reality and advantageous in their environment. This inevitably perpetuates naïve theories and misconceptions that are informed by limited access to information and existing knowledge that may or may not be relevant to enhancing the understanding of a new concept (Sinatra et al., 2014). While significant research has addressed the issue of student misconceptions, less attention has been paid to exploring teacher misconceptions (Burgoon et al., 2011). This is problematic because the teacher is responsible for

educating students and their conceptions about the world inevitably influence students' developing understandings. Conceptual change scholars point out that "…adults, too, harbor misconceptions, including many well-meaning teachers who unknowingly pass these inaccuracies on to students—misinformation that may never be caught, challenged, or changed" (Gooding & Metz, 2011, p.35). This is clearly an important but under-explored issue within K-12 education. Similar to individuals in most other professions, teachers hold a number of misconceptions about a variety of aspects of human activity and the environment we live in. For example, Lombardi and Sinatra (2013) note that teachers are often as confused about the difference between climate and weather, or the causes of climate change as their students. Other common teacher misconceptions addressed in educational research literature include neuromyths. For example, Tardif and colleagues (2015) revealed a number of teacher neuromyths regarding hemispheric dominance, modality dominance, and the Brain Gym© method. The outcomes of holding misconceptions about how our brains work and learn have been so-called "brain-based educational approaches" that have been heavily criticized by both education and neuroscience experts (e.g., critique of "right-brain teaching", Lindell and Kidd, 2011). Educator held misconceptions are problematic, especially as teachers prepare their students for the workforce. For example, students may believe they are developing knowledge and skills but upon employment find out that the position does not utilize the skills as much as they once thought. Conversely, employers may have expectations recent graduates have prior knowledge as it relates to AI but ultimately find them to be unprepared for the role (Denning et al., 2017).

Understanding of how conceptions and misconceptions are formed is informed by theories of mental models and theories of naïve beliefs, that is, theories that people develop based on the access to information and data on the subject in question and media coverage of the phenomenon (Savion, 2009). An important aspect of a science teacher's role is to make every effort to make sure these student-formed misconceptions are rectified. Teachers should have the content understanding and expertise to be able to distinguish between accurate conceptions and misconceptions within their curriculum. This is not always the case as recent studies have shown teachers often teach misconceptions to their students (Dack, 2019; Hodkinson, 2005; Larkin, 2012). Concerning the origins of student misconceptions, Yip (1998) writes that for more niche or complex areas of curricular content, misconceptions are more likely associated with how the teacher disseminates information. When the educator holds a misconception, there are much more profound implications for the learning environment than when a student or even groups of students hold misconceptions. Burgoon and colleagues (2009) stressed that teachers will find it especially difficult to correct or reconstruct student knowledge when they too hold science misconceptions. Thus, it is crucial to both study teacher misconceptions regarding important societal topics such as AI and to provide professional development to dispel myths and correct misconceptions so that students benefit from the learning process and become more information and prepared members of our society.

Methodology

Given a lack of scholarship on K-12 teachers' misconceptions in general, and existing conceptions and misconceptions of AI in particular, this study addressed the following research questions:

1. What are the prevalent conceptions and misconceptions about AI in a sample of US K-12 science teachers?
2. What is the relationship between a) science teachers' AI conceptions and misconceptions and b) teachers' intent to integrate AI applications in their instructional practice?
3. What types of intentional and incidental learning are associated with the development of accurate conceptions and misconceptions about AI in a sample of US K-12 science teachers?
4. What are US K-12 science teachers' perceptions regarding the role of AI in K-12 education?

Participants

Fifty-three teachers from Southeastern US agreed to participate in the study and fully completed the (Mis)conceptions of AI Survey (MAIS). Our sample represented educators across the K-12 grade levels. Twenty-one of the participants indicated they taught science at the elementary school level, fourteen were middle school science teachers, and 18 participants taught science subjects in high school (i.e., Physics, Marine Science, Forensic Science, Ecology, Zoology, Experimental Science, Biology, Chemistry etc.). Most participants were Biology and Environmental Science teachers. Our sample included primarily white, non-Hispanic females who identify as not Hispanic (n = 40) and the teachers in our sample taught mostly in non-charter public schools (n = 50). Most teachers were between 30 and 59 years old (n = 44) and had between 6 and 29 years of teaching experience (n = 38). Twenty participants indicated that they taught primarily white students, and twenty teachers shared that they taught primarily US ethnic minorities. Sixty percent of the teacher participants ($n = 32$) explained that they most of the students they taught qualified for free or reduced lunch. Important to this study, 31 teacher participants indicated that they had adequate access to educational technologies (e.g., 1:1 access, equipped classrooms), 4 participants had more than adequate access to educational technologies (e.g., 360 cameras, VR headsets), whereas 18 participants shared they had limited access to educational technologies in their classroom.

Instrument

Participants completed the MAIS (Appendix A), a survey consisting of 36 Likert-scale items and seven open-ended items. The Likert-scale items included 18 statements that reflected accurate conceptions of AI (e.g., "AI is always biased") and 18 items reflecting AI misconceptions (e.g., "AI works like the human brain"). These statements were drawn from prior research on AI (mis) conceptions (e.g., Donia & Shaw, 2021; Emmert-Streib et al., 2020; Long & Magerko, 2020) and reviewed by a team of three Science, Technology. Engineering, and Mathematics (STEM) researchers who use AI. Additionally, one question focused on the types of incidental and intentional learning that informed participants' understandings of AI. This item began with the following stem: "Do you use any education related resources and if so, what is the impact of those on your professional development as an educator?" Responses included "educational research publications", "popular science publications", "online videos" and so on. Finally, four open-ended questions focused on the role of AI in science education and the ethics of AI.

Procedure

Survey data were collected during Fall of 2021 and analyzed during Spring 2022. To address the research questions, ordinal data were analyzed using descriptive statistics (measures of central tendency and dispersion) and Spearman Rho correlation matrices. As common in survey research (Fowler, 2013), aggregates of participants' survey responses on subscales were treated as continuous variables and analyzed using linear regression analyses. Open-ended data were examined using thematic analysis (Braun & Clarke, 2006; Patton, 1990). This multi-phased process of data analysis began with examining the data through the lens of each of the study's constructs, that is, AI (mis)conceptions, professional development, intent to use AI in teaching practice. To improve trustworthiness of the results (Lincoln & Guba, 1985), the researchers engaged in collaborative interpretation.

Results

Science teachers' (mis)conceptions of AI

Analysis of the teachers' responses on the 36 items that dealt with AI (mis)conceptions revealed that teachers had both accurate conceptions of AI and some important misconceptions. Table 1 outlines the top five correctly identified (mis)conceptions and top five misidentified (mis)

conceptions about AI. Participants in the sample generally correctly believed that AI is not just a fad, that AI algorithms can differ in purpose, structure, and accuracy, that AI is not really a new phenomenon and so on. At the same time, they held the misconceptions that AI is expensive, that AI can learn on its own, and AI is not biased among other things.

Interestingly, Spearman Rho correlational analyses showed that older science teachers were more likely to hold a misconception that "AI is dangerous" (r_s = .31, p = .02). The more years of teaching experience, the more likely participants were to correctly believe that "AI cannot function independently of humans" (r_s = .30, p = .03). Table 2 provides a summary of the measures of central tendency and dispersion for all AI (mis)conception items.

Overall, participants leaned toward implementing such AI applications as Google's Teachable Machine in their practice (M = 3.79, SD = .9). In fact, only one participant reported that they

Table 1. Top 5 correctly identified AI (mis)conceptions and top 5 misidentified AI (mis)conceptions based on the traditional Likert scale (from 1 = Strongly Disagree to 5 = Strongly Agree).

Accurately identified AI (Mis)Conception	M	SD	Misidentified AI (Mis)conception	M	SD
AI is just a fad[a]	4.26	.84	AI is expensive[a]	2.19	1
AI algorithms can differ in purpose, structure, and accuracy	4.26	.81	Anyone can afford AI technology	2.36	1.1
AI is new[a]	4.15	1	AI can learn on its own[a]	2.49	.93
All AI is created equal[a]	4.19	1	AI is always biased	2.53	1.1
AI is for tech giants only[a]	4.09	.95	AI algorithms have trouble with complex data	2.55	.92

[a]Misconception.

Table 2. Descriptive statistics for the 36 (mis)conceptions items.

Item	M	Med	STD	Min	Max
AI needs time to learn and produce results (C)	3.89	4	0.913	1	5
AI works like the human brain (I)	2.91	3	1.061	1	5
Anyone can use AI (C)	3.64	4	1.178	1	5
All AIs are created equal (I)	4.19	4	1.02	1	5
AI can be 100% objective (I)	3.23	3	1.266	1	5
There is a significant difference between AI and ML (C)	3.19	3	0.761	1	5
AI is dangerous (I)	3.25	3	1.191	1	5
AI is always biased (C)	2.53	2	1.137	1	5
AI can understand and solve new problems the way the human brain can (I)	2.75	2	1.159	1	5
AI cannot be creative (I)	3.49	4	1.067	1	5
AI cannot function independently of humans (C)	2.66	2	0.939	1	5
AI algorithms can figure out any and all your messy data (I)	2.85	3	0.949	1	5
AI cannot learn without human input (C)	3.32	4	1.14	1	5
AI presents no danger to humans (C)	2.68	3	1.015	1	5
AI cannot solve problems the way humans can (C)	3.21	4	1.026	1	5
AI will take your job (I)	3.62	4	1.197	1	5
AI is too difficult for laypeople to understand (I)	3.49	4	0.912	2	5
AI doesn't need humans (I)	3.87	4	0.878	1	5
AI is nothing like the human brain (C)	2.7	2	1.137	1	5
AI is just a fad (I)	4.26	4	0.836	2	5
AI algorithms can differ in purpose, structure, and accuracy (C)	4.26	4	0.812	1	5
AI is expensive (I)	2.19	2	1.02	1	5
AI will not replace human workers (C)	3	3	1.24	1	5
AI and ML are interchangeable terms (I)	3.43	3	0.844	1	5
AI is infallible (I)	3.96	4	1.126	1	5
AI has been around for decades (C)	4.06	4	0.795	1	5
AI yields immediate results (I)	2.96	3	1.037	1	4
Anyone can afford AI technology (C)	2.36	2	1.058	1	5
AI algorithms have trouble with complex data (C)	2.55	2	0.952	1	5
AI can learn on its own (I)	2.49	2	0.933	1	5
Like humans, AI algorithms make mistakes (C)	3.66	4	1.055	1	5
Some AI algorithms can learn to be creative (C)	3.74	4	0.836	2	5
Anyone can understand how AI works (C)	3.19	4	1.057	1	5
AI is new (I)	4.15	4	0.969	1	5
AI holds significant promise for society (C)	3.83	4	0.914	2	5
AI is for tech giants only (I)	4.09	4	0.946	1	5

are extremely unlikely to use AI in their science teaching. Thirty-four participants were either likely or highly likely to start using AI in their practice, 10 participants were undecided, three participants were unlikely, and one participant was highly unlikely to start implementing AI in their instructional practice.

Relationships between science teachers' AI (mis)conceptions and their intent to integrate AI applications in their instructional practice

To explore potential relationships between the (mis)conceptions science teachers have about AI and their behavioral intent to use AI in their practice, we constructed a Spearman Rho correlation matrix. This analysis revealed that both correctly identified (mis)conceptions and the (mis) conceptions that teachers failed to identify as inaccurate contribute to their intent to implement AI in their classrooms. Important to this study, teachers' ability to correctly identify AI (mis) conceptions in the survey did not influence their intent to use AI in their practice (β = .14, t = .98, p = .33). Intent to integrate AI in teaching practice was positively associated with correctly identifying the following common AI misconceptions: a) AI can understand and solve new problems the way the human brain can (r_s = .32, p = .02); b) AI can be 100% objective (r_s = .29, p = .04). Intent to use AI in teaching practice was also positively correlated with the teachers' agreement with the following accurate conceptions about AI: a) AI presents no danger to humans (r_s = .45, p < .001), and b) AI holds significant promise to society (r_s = .43, p = .002). Surprisingly, intent to integrate AI in teaching was also associated with the teachers' inability to identify common AI misconceptions: a) like humans AI, AI algorithms make mistakes (r_s = −.39, p = .007); b) AI is new (r_s = .29, p = .04); and c) AI doesn't need humans (r_s = .35, p = .02).

Teachers' use of professional development resources provided at their school or ones they encounter incidentally (e.g., Twitter posts, online videos) were not positively or negatively related to their intent to use AI in their practice in our sample.

Relationships between intentional and incidental learning and the development of AI (mis)conceptions

The majority of teachers in our sample participated in professional development at their school five or more times a year (n = 33) or two to four times a year (n = 18). Only two participants indicated that they took part in professional development at the school once per year. Most teachers also indicated that they engage in professional development outside of their school two to four times a year (n = 31), five or more times a year (n = 6), or once a year (n = 10).

A multiple regression model was used to determine whether participants' intentional and incidental learning about AI predicted their ability to correctly identify AI (mis)conceptions. The model was significant at $F_{9,38}$ = 2.31, p < .03, R^2 = .35. The adjusted R^2 value suggested that the intentional and incidental learning predictors in this model explained about 35% of the variance in the outcome variable "ability to correctly identify AI (mis)conceptions." Specifically, this multiple regression analysis demonstrated that the ability to correctly identify AI (mis) conceptions was positively predicted by participants' use of online videos (β = .35, t = 2.38, p < .02) and by reading popular science publications (β = .55, t = 2.2, p < .05) for professional development. It was negatively predicted by reading publications in educational practice magazines (β = −.81, t = −2.03, p < .05).

Reading popular science publications was positively associated with correctly identifying that "AI has been around for decades" (r_s = .39, p = .006). Watching online videos was positively associated with correctly identifying the common misconception that "AI doesn't need humans."

Reading educational research publications was positively associated with correctly identifying that "anyone can use AI", that "AI has been around for decades" (r_s = .38, p = .009), and with

correctly identifying the following misconceptions: "AI yields immediate results" (r_s = .33, p = .02), "AI algorithms have trouble with complex data" (r_s = .35, p = .01), and "AI can learn on its own" (r_s = .32, p = .02).

Reading educational practice publications was positively associated with correctly identifying that "AI algorithms can differ in purpose, structure, and accuracy" (r_s = .34, p = .02), "AI has been around for decades" (r_s = .43, p = .002), and that "some AI algorithms can learn to be creative" (r_s = .33, p = .02). Interestingly, reading educational practice publications was also negatively associated with the ability to correctly identify misconceptions, specifically that "AI can learn on its own" (r_s = −.52, p < .0001) and that "AI can be 100% objective" (r_s = −.32, p = .03).

Teachers' perceptions about the role of AI in K-12 education

Participating teachers provided a wealth of insights in their open-ended responses to the survey. Three themes emerged as a result of the thematic analysis: 1) teachers are overall enthusiastic about the potential of AI for K-12 education; 2) teachers believe it's important for their students to understand the basics of AI; and 3) teachers are overall not concerned or unsure about the ethics of AI in K-12 education.

Theme 1: Teachers are overall enthusiastic about the potential of AI for K-12 education

Forty-six of the participants shared that they are excited about the potential of AI to improve their instructional practices and the learning experiences of their students. Twenty-seven teachers felt that AI can help them teach science in terms of engaging students, saving time, and providing new opportunities. For example, one of the teachers focused primarily on the use of AI in educational assessment:

> "… AI is already involved in our educational system. Through the use of online assessments, many AI programs cater their questions/activities based on previously answered questions. I don't have strong feelings either way about the influence of AI on science education because of my lack of knowledge about it."

Others discussed new opportunities for experiencing the world that cannot be provided using the traditional instructional means:

> "I think AI can bring the extended world into the classroom to teach science. It can help students experience or see things they could only find in lectures or textbooks before. I think it could be very useful and provide opportunities to the students that they may not otherwise have."

Similarly, a teacher from a rural area expressed

> "I am open to almost anything that will help me to expose my students to the world around them. We are in a RURAL area so access to cultural or scientific institutions is limited, therefore they have a narrower view of the world than most."

One of the teachers made an important point about the dynamic nature of science and how it is important for science educators to vary their instructional methods and include new tools such as AI: "Science is always changing and so too should how we educate our students that can include the use of AI."

Another participant emphasized the role AI could play in provided differentiated for students with an Individualized Education Plan (IEP):

> "I prefer using hands-on activities and hard copies of interactive notebooks with active processing of notes, but I believe AI can enhance student understanding of concepts. This could also increase the comprehension for my IEP and 504 students." One of the teachers also shared that "AI has potential in education to meet the needs of individual students. In science, this could potentially provide deeper understanding of topics based on each students' personal needs and desires."

Interestingly, one of the teachers highlighted the potential importance of AI to help correct students' misconceptions about STEM:

> "There are many different potential uses of AI in education, from flagging student misconceptions to making the research process easier. It should also be a part of the STEM/CS curriculum to understand how various AI applications are created and how they function."

Teachers also expressed enthusiasm about AI and the development of students' research and experimentation skills: "I think the ability for students to interact with an AI will assist in computer and research-based skills - e.g., refining search terms, approaching a problem from multiple directions, etc." Another teacher indicated that "… since science is inquiry-based, AI can facilitate in research and final outcomes of projects and claims." Another participant believed AI could help implement more robust simulations to help teach science:

> "I think there is a potential for AI to teach science even if it is only about the scientific method and the processes that go along with it. Students could create scenarios that they could test against the AI system and other humans."

Several of the elementary teachers shared that they have limited time for explicit science instruction and that AI could be helpful to address this need: "I think the potential of AI relative to science education is interesting. Teachers, especially primary teachers, have limited time for explicit science instruction, so if an AI program could help with supplemental science education, that would be great."

Finally, seven teachers raised concerns about the potential costs involved, a need for professional development and time to learn more about the applications of AI. For example, one of them noted "It would be great to get this technology into the hands of my students; however, I am weary about all of the extra training I would have to go through to learn how to operate AI." Another participant shared the following comment: "Like everything else, time, money, accessibility. I don't think we will be any better or worse for it [AI]." The motif of the cost was present in several other teachers' responses: "I like the idea of using AI in science education. I am not sure the price point is low enough yet to make widely available."

Theme 2: Teachers believe it's important for their students to understand the basics of AI

Two-thirds of the teachers responded that they felt it is important for students to learn about the topic since it will be part of their future career or lifestyle. Participants sentiments can be summed up using the following quote: "I think AI is very much part of the future. Learning about it may benefit their future careers."

Many of the participants spoke about the role AI is already playing in today's jobs and careers. For example, one of them shared "AI is becoming more integrated into career fields across the spectrum." Another teacher was quite categorical sharing that

> "AI and ML is coming, regardless of anyone's personal viewpoint. Understanding how it truly works will be essential. AI is here to stay and will be integrated more and more into our communities. If students are aware of this, then they will be better equipped to interact with it."

Several important points were made by teachers regarding how AI could provide students with more options regarding their learning, careers and other future activities. For instance, one teacher shared "It [AI] gives them choice and will hopefully expand their learning opportunities." Another participant expressed "My students are very much underprivileged, so if it would give them the opportunity to make connections and gain background knowledge on certain subjects that they wouldn't otherwise get, so yes." "Understanding AI is important as the future is growing stronger toward AI intervention and application. The human element can assist in maintenance and future advancements, but knowledge of the product would be necessary."

Finally, some of the sentiments shared by our participants focused on how learning more about AI will help students become better consumers (and in the future producers) of

technology: "I believe students should understand computers including smart computers, as this is part of STEM and this is part of their future. Students will need computers to do their future work." Similarly, another teacher commented "I foresee AI technology being the future of computers, and it's important for my students to see that so they can make career decisions that will stay current or be adaptable to the changing technological environment." The following quote provides a good summary for this theme:

> "Students should understand the implications and benefits of the technology- as it is the direction that society is moving towards. Responsible use of technology must be taught. AI systems are learning computers and are the future of technology. Students should be exposed to them so they are familiar with those systems as they become more and more common."

Theme 3: Teachers are overall not concerned or unsure about the ethics of AI in K-12 education

When considering the ethics of AI, most teachers stated that they did not know enough about the potential effects or unintended consequences of AI to comment: "I do not know the benefits and setbacks of the use of AI in an educational setting, so I don't feel I can comment on the ethics of it." A few participants felt that ethics were not of concern to them: "AI will be a fact in their [students'] adult lives so regardless of what the ethics are, current learners need to gain a full understanding of both AI and machine learning in order to compete in tomorrow's workforce." Someone even joked about what we mean by AI when we discussed the ethics of its use: "Are we talking about Alexa/Google or are we talking about Skynet? AI is another tool to be used. I don't see why it would be unethical."

Those teachers who did express concerns regarding the ethics of AI in K-12 education, shared they had hesitations about its implementation (i.e., AI needs clear rules, teachers need implementation guidelines, instruction needs to be balanced between teacher and AI): "I have a healthy fear of the likelihood of AI becoming a danger if precautions are not taken." One of the teachers shared concerns about potentially increasing the digital divide and exacerbating existing inequities in the K-12 education system:

> "I don't know enough about it to state a knowledgeable response but I do worry about the inequities already at hand for lower income and learners of color. If nothing else, the pandemic has shined a glaring light on the haves and have nots. AI will be one more area that affluent students will be given resources and access that others will not."

One of the participants commented that AI has great potential for enhancing learning and teaching as long as it is "programmed correctly." Another teacher commented that "It [AI] could be beneficial if used in the right way." An interesting point was made by another participant who reported the following: "AI will become more prevalent. I am very concerned that we not move to a society like China with their social credit score determined by AI."

Discussion

Our research on identifying in-service teachers' (mis)conceptions of AI provides important implications for teacher preparation and in-service professional development regarding AI in our society and implementation of AI tools and processes in K-12 education. Our data show that educators within our sample of K-12 science teachers mostly held accurate conceptions of AI (e.g., AI algorithms can differ in purpose, structure and accuracy; AI needs time to learn and produce results) and correctly identified many of the common misconceptions of Ai such as "AI is just a fad", "AI is new", "All AI is created equal", or "AI is for tech giants only."

At the same time, K-12 science teachers in our sample tended to support a number of AI misconceptions such as "AI is expensive" or "AI can learn on its own." K-12 educators in our study also did not believe that "AI is always biased" or that "AI algorithms have trouble with complex data" both of which are actually accurate statements about the current state of AI.

Having too much confidence in AI's ability to remain unbiased is an important concern, especially given recent evaluations of AI algorithm biases and flaws and reports of multiple issues in the large datasets that were used to train key computer vision or natural language processing algorithms that many companies, governments and educational institutions use today to design AI applications. For example, there is evidence of the discrimination that AI tools perpetuate when used with already marginalized groups of people – from AI-augmented college admissions systems, the criminal justice system, to housing and our finances (Akselrod, 2021; UN News, 2020). In their recent commentary in *Nature*, Zou and Schiebinger (2018) provide evidence that current AI systems are often sexist and racist such as when a popular natural language processing based AI algorithm classifies European American names as pleasant and African American ones as unpleasant. More and more observers call for a need for scientists and engineers to work on identifying sources of bias, de-bias the data used to train AI algorithms, and develop AI algorithms that account for skewed data in the training datasets. To be fair, several of our participating teachers shared concerns regarding the unintended consequences of AI potentially promoting digital divide, and commented that AI tools will only be useful in K-12 education if designed with fairness and ethical considerations in mind.

Despite holding certain misconceptions about AI, most teachers in our sample were enthusiastic about integrating AI tools and applications in their own instructional practice (n = 34) and only four participants shared that they were unlikely to implement AI in their classrooms. Our analyses revealed that even though the overall ability of the teachers in our study to correctly identify AI (mis)conceptions in the survey did not influence their intent to use AI in their practice, it was associated with several individual (mis)conceptions regarding AI. Both correctly identified (mis)conceptions and the (mis)conceptions the teachers in this study were not able to identify contributed to their intent to use AI in their teaching. For example, intent to integrate AI in teaching was positively associated with correctly identifying the common misconceptions that "AI can understand and solve new problems the way the human brain can" and "AI can be 100% objective". It was also positively associated with the teachers' agreement with the accurate conceptions about AI such as "AI holds significant promise to society. Surprisingly, intent to integrate AI in teaching was also associated with the teachers' inability to identify several common AI misconceptions: "Like humans, AI algorithms make mistakes", "AI is new", "AI doesn't need humans." The role of teacher preconceptions and misconceptions has been explored in the literature before and empirical data show that intent to use technology in the classroom is often associated with certain misconceptions about that technology. For example, a recent study on pre-service and in-service teachers' misconceptions about making in education was associated with certain pervasive misconceptions such as "making technology implementation involves use of advanced manufacturing tools such as 3D printers" (Cohen et al., 2018). Thus, it is not uncommon to observe certain misconceptions among early adopters of a technology or those who are new to it. It is important to integrate more factual information about new and emerging technologies in teacher preparation courses and professional development opportunities for in-service teachers to ensure adequate and realistic expectations on the part of the teachers and more meaningful implementation of the technology in K-12 classrooms.

The results of our study highlight the need for providing more general education related knowledge in addition to the discipline-specific knowledge and skills that teachers develop in teacher education programs. AI is a concept and a set of practices that cut across multiple domains including mathematics, data science, informatics, statistics, and so on. A need for such general education knowledge is addressed in the literature on preparing STEM education teachers (Lin et al., 2021). Thus, recognizing the importance of disciplinary knowledge in individual domains, it is important to also acknowledge the changing landscape of 21st century occupations that require integration of knowledge and skills from a variety of fields, something teachers should be ready to address in schools.

Finally, our study results also demonstrate that teachers' use of professional development resources provided at their school or ones they encounter incidentally (e.g., Twitter posts,

online videos) was not associated related to their intent to use AI in their practice in our sample. On the other hand, teachers' use of intentional and incidental learning resources predicted the development of certain preconceptions, including misconceptions, about AI. Intentional and incidental learning predictors in our analytic model accounted for a significant amount of variance (35%) in teachers' ability to correctly identify AI (mis)conceptions. Specifically, this multiple regression analysis demonstrated that the ability to correctly identify AI (mis)conceptions was positively predicted by participants' use of online videos and by reading popular science publications for professional development. It was negatively predicted by reading publications in educational practice magazines, which implies that educational practice publications may propagate certain myths and misconceptions about AI. Reading educational practice publications was positively associated with correctly identifying that "AI algorithms can differ in purpose, structure, and accuracy", "AI has been around for decades", and that "some AI algorithms can learn to be creative". However, reading educational practice magazines was also negatively associated with "AI can learn on its own" and "AI can be 100% objective." An important implication for teacher professional development is that one needs to be careful about taking information in some publications for granted, particularly when the article does not provide data or expert insights to support the claims put forward in the article.

Reciprocal perspectives on AI and human intelligence in education

Our study demonstrates that successful coupling of human and artificial intelligence is not feasible without understanding and accounting for humans' perspectives on AI. In our context, human teachers hold a number of pervasive preconceptions about AI and its use in society and education and their conceptual frameworks of AI include a good amount of misconceptions. The sources of these preconceptions and misconceptions are diverse and include both intentional and incidental learning resources. Just like AI algorithms are trained using large datasets of relevant material, human understanding of the world is informed by the information available to us via the resources we choose or happen to use in our daily lives. And similar to how flawed or biased datasets can result in a flawed or biased AI algorithm, information resources that contain prejudiced or skewed opinions can result in the development of misconceptions in the humans that consume that information.

It seems abundantly clear that just like with most technologies we attempt to integrate into K-12 education, teachers and school administrators must seek and provide adequate time, expertise, funds, and resources to provide in-service teacher professional development on AI and its applications in education. Potential topics may include a) using AI to become more informed about how students' learn (e.g., predictive analytics, Internet of Things), b) adapting the learning environment to the needs, interests, and abilities of learners in the class (e.g., use of personalized and adaptive software), c) exploring what and how to teach when it comes to understanding the processes underlying AI in various fields (e.g., natural language processing, computer vision) and discussing the differences and similarities regarding human vs. AI processing and use of information, and d) considering with students the ethics, equity, and fairness in AI use in our society. As one of the participants in this study shared, "… AI is very much part of the future." We would add that AI is also a significant part of our present, whether we acknowledge its role in our life or not. If we are to address the demands and challenges of today's and future society, we must invest in our teachers and support their important contributions to educating generations that are well-informed about AI and prepared to collaborate with Ai and together solve the problems of the 21st century.

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Appendix A: (mis)conceptions in AI survey

1a. Have you participated in the Scientist in Every Florida School program?
- Yes
- No

1b. How often do you participate in professional development opportunities at your school?
- Less than 1 time per year
- 1 time per year
- 2-4 times per year
- 5 or more times per year

1c. How often do you participate in professional development opportunities outside of your school?
- Less than 1 time per year
- 1 time per year
- 2-4 times per year
- 5 or more times per year

2. Participants were asked to respond to the following prompts using a Likert scale (strongly disagree, somewhat agree, neither agree nor disagree, somewhat agree, and strongly agree).
- AI needs time to learn and produce results
- AI works like the human brain
- Anyone can use AI
- All AIs are created equal
- AI can be 100% objective
- There is a significant difference between AI and ML
- AI is dangerous
- AI is always biased
- AI can understand and solve new problems the way the human brain can
- AI cannot be creative
- AI cannot function independently of humans
- AI algorithms can figure out any and all your messy data
- AI cannot learn without human input
- AI presents no danger to humans
- AI cannot solve problems the way humans can
- AI will take your job
- AI is too difficult for laypeople to understand
- AI doesn't need humans
- AI is nothing like the human brain
- AI is just a fad
- AI algorithms can differ in purpose, structure, and accuracy
- AI is expensive
- AI will not replace human workers
- AI and ML are interchangeable terms
- AI is infallible
- AI has been around for decades
- AI yields immediate results
- Anyone can afford AI technology
- AI algorithms have trouble with complex data
- AI can learn on its own
- Like humans, AI algorithms make mistakes
- Some AI algorithms can learn to be creative
- Anyone can understand how AI works
- AI is new
- AI holds significant promise for society
- AI is for tech giants only

3. Participants were asked to respond to the following questions using a Likert scale (do not use these resources, completely useless, useless, neither useful nor useless, useful, and highly useful).

Do you use any education related resources and if so, what is the impact of those on your professional development as an educator?

- Educational research publications
- Educational practice publications
- Popular science publications
- Repositories of instructional activities
- Online videos (tutorials, TED talks, presentations, etc.)
- Professional learning groups and networks (e.g., listservs, Twitter, etc.)
- National reports (e.g. National Academies Press publications)
- Resources provided by the University (e.g., teach.ufl.edu)
- Resources provided by your College (e.g., instructional support or teaching and learning center)

4. Would you consider employing an AI educational program in your instructional practice? (e.g., Google Teachable Machine)
   - Extremely unlikely
   - Unlikely
   - Neither likely nor unlikely
   - Likely
   - Extremely likely

5. What do you think about the potential of AI to influence science education?
6. Do you think AI could help you teach science? Why?
7. How do you feel about the ethics of AI in science education?
8. Do you think it's important for students to understand AI? Why?