Constructionist Approaches to Learning Artificial Intelligence/Machine Learning: Past, Present, and Future

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Although constructionism originated embedded within early artificial intelligence research, it is only recently that researchers have returned to designing and researching constructionist tools and activities for learning Artificial Intelligence/Machine Learning (or: AI/ML). The pervasiveness of AI/ML in the everyday lives of young people—impacting how they connect with friends, listen to music, play games, or attend school—coupled with the accessibility of large language learning model applications, discussions about algorithmic justice, and growing efforts to incorporate computing into K-12 education increase the urgency of AI/ML education. Yet, within education, most AI/ML efforts have centered on learning analytics and providing scaffolds to learners, focusing on what Papert called “the computer being used to program the child.” In contrast, constructionist AI/ML efforts center on designing learning environments and researching how young people can create personally relevant AI/ML powered applications. In this symposium, we bring together historical perspectives on constructionism and AI/ML, examine current efforts that build on learner’s interests, and develop possible directions for future research and design. We discuss how when creating AI/ML powered projects, teachers and learners can collaboratively develop and integrate conceptual and critical understandings that are increasingly important to participate in the world.

Keywords and Phrases: Constructionism, Artificial Intelligence, Machine Learning, Computing Education

1 SYMPOSIUM OVERVIEW

Children and youth interact everyday with complex and distributed Artificial Intelligence/Machine Learning (AI/ML)-powered applications when they socialize with friends, go school, play games, listen to music, order food or watch videos. Yet, there are little opportunities for young people to learn about how the AI/ML technologies they use daily are designed. In this context, it is important to revisit Seymour Papert’s (1980) vision of shifting from a paradigm where “the computer is being used to program the child” to one in which “the child programs the computer” by creating personally relevant AI/ML powered applications. Constructionism, the theory and learning strategy, formulated by Papert and his colleagues, was born in the context of early artificial intelligence research (Solomon et al., 2020), however it is in the last decade that constructionist researchers have turned their attention to the design of learning environments for children to learn and create with AI/ML (Kahn & Winter, 2021). While in the early days of constructionism several studies by Kahn (1977) and Goldstein and Papert (1977) addressed the interactions between early AI research and learning, more recent efforts have incorporated AI/ML in constructionist tools and activities within block programming (e.g., Kahn et al., 2020) and physical computing environments (e.g., Tseng et al., 2021) providing opportunities for young people to create and think with AI/ML. At the same time, whereas today’s AI/ML technologies differ from those of constructionist early AI research and education, by drawing on ML and large data sets instead of symbolic AI, early questions about how children think about their own thinking with computing and AI/ML remain relevant. Moreover, supporting young people in creating AI/ML-powered applications is imperative so that they can be empowered to participate in computing fully and critically (DiPaola et al., 2022; Kafai & Proctor, 2022). In this symposium, we bring together historical perspectives on constructionism and AI/ML, current efforts that build on learner’s interests, and possible directions for future research and design. We discuss how when creating AI/ML powered projects, teachers and learners can collaboratively develop and integrate conceptual and critical understandings that are increasingly important to participate in the world.

The symposium includes presentations on how youth can learn about AI/ML in personally relevant ways, AI/ML teaching concepts and curricular efforts, and research related to generative AI/ML. Castro and DesPortes investigate how youth can learn about AI/ML while creating personalized dance and computing projects that use pose detection models. Morales-Navarro and Kafai research how youth learn from failure cases when creating and auditing personally relevant ML-powered physical computing projects. Kumar and colleagues study how youth can learn about AI/ML ideas and engage with ethical issues in the context of sports. Michaeli and Romeike present teaching concepts for constructionist AI/ML that center on analyzing data, implementing algorithms and creating personalized assistants. DiPaola and colleagues discuss three curricular efforts that center socio-technical learning trajectories for children to engage with AI/ML creatively and ethically. Khan investigates how tools like ChatGPT can serve as navigators and support the creation of AI/ML projects on Snap! Stager discusses the use of LOGO for “playing with language” within contemporary GPT AI-hype. Lee and colleagues present work on the collaborative design of generative AI/ML learning activities with teachers. The symposium is organized in four sections: (1) the chairs will introduce the topic and then each presenter will give an one-minute teaser about their work (~10 min); (2) the first half of the presenters will have 15 minutes to share their work using posters placed around the room, followed by the second half of presenters (15 minutes) an arrangement which will give both audience and presenters time to see each other's posters; (3) our discussant Cynthia Solomon, a pioneer in the constructionism community and the design of computing learning environments for children, will synthesize and reflect on findings (10 minutes); and followed by (4) a Q&A with audience and presenters (~10 min).

2 PRESENTED POSTERS

2.1 AI/ML BUILDING BLOCKS OR CHATGPT? (Kahn)

Nearly 50 years ago Kahn (1977) I became interested in providing programming tools to enable children to create AI-powered apps. This entails creating libraries of AI/ML components in Lisp, Prolog, and most recently in Snap! (Kahn et al., 2020). The Snap! AI/ML libraries for speech, vision, language, and neural network programming have been widely used (https://ecraft2learn.github.io/ai/). However, very soon after GPT-4 became available I explored what it would be like to create AI/ML apps via a conversation with a chatbot. I chose five sample Snap! AI/ML projects that can repeat what was said in funny voices and in different languages, draw by tracking user gestures, predict confidence from text, simulate conversations between famous people, and generate illustrated stories. At first, I asked for simple versions of the desired app. Often I needed to tell ChatGPT how the program was failing or copy and paste an error message for it to respond to. After a few exchanges the app was functioning fine and then I asked for an additional feature and the process was repeated. Sometimes I asked ChatGPT to explain how something worked or to add comments to some generated code. On occasion I needed to copy and paste some documentation created after GPT's training cutoff (September 2021) in order to proceed. The experience is very close to playing the role of a navigator in pair programming. Except that I also needed to copy and paste the generated code into HTML, CSS, and JavaScript files and run the result. Using ChatGPT in this manner is very empowering. And the learner still needs to come up with the concept of the application, plan a series of steps in its creation, and evaluate and test the interim results. The learner must still address the high-level aspects of their projects and, if so motivated, can engage with the low-level technical details.

2.2 LEARNING FROM FAILURE AND EDGE CASES: CREATING, TESTING, DEBUGGING AND AUDITING ML-POWERED E-TEXTILE PROJECTS (Morales-Navarro & Kafai)

Current efforts to promote AI/ML literacy emphasize the importance of ensuring that learners have opportunities to engage with AI/ML ethically and critically by considering how it can impact people in positive and negative ways (Touretzky & Gardner-McCune, 2021; DiPaola et al., 2021). However, conversations about ML, society and ethics are often disconnected from technical issues (Fiesler, 2020; Petrozzino, 2021). Yet the consequences and implications of ML applications are closely intertwined with functionality failures (Raji et al., 2022). As such, we argue that criticality must be embedded in the process of creating personally relevant ML projects instead of just being an add-on or conversation topic. Building on constructionist approaches to computing education that emphasize the importance of creating personally relevant applications that can be shared with others (Harel and Papert, 1990; Kafai & Burke, 2014) and recent work on the role of failure in constructionist learning (Fields et al., 2021; Klopfer et al., 2022), we investigate how students engage with failure and edge cases when creating, testing, debugging and auditing ML-powered e-textile projects. We build on current research on the design process of ML applications (Tedre et al., 2021) and algorithm audits (Metaxa et al., 2021; Devos et al., 2022) to analyze how youth learn from failure cases when designing their own projects and auditing their peers' projects. We analyzed video recordings, youth reflections, and interviews from a workshop conducted in 2023 with 15 youths (ages 14-16) identifying themes that emerged when youth found, addressed, and reflected on failure cases while designing and auditing AI/ML-powered e-textiles. Our findings show that failure and edge cases provided rich opportunities for youths to revise their understandings of how their applications worked, consider the context for which they designed their projects, and make connections between technical and ethical aspects of their designs.

2.3 BUILDING MINDS WITH AI/ML: EXPLORING A CONSTRUCTIONIST APPROACH TO K-12 AI/ML EDUCATION (Michaeli & Romeike)

To participate in an increasingly digital world and make informed decisions about AI/ML and its impact on our society, everyone needs to learn about the core ideas and principles of AI/ML (Michaeli et al., 2023), starting in K-12 education. Often, unplugged approaches are used to introduce students to AI/ML in a fun and engaging way. This allows students to focus on the underlying concepts behind AI/ML rather than on technical details, while making the general functionality of AI/ML-related phenomena accessible. However, it is important not only to explain the relevant phenomena, but also to empower everyone to actively shape this world and use AI/ML as a creative tool. Teaching must therefore go beyond unplugged approaches and enable students to create and construct. To this end, we have developed a variety of teaching concepts that allow for collaborative and creative design in different dimensions, such as: (1) analyzing data using ML methods, as well as the social impact of the resulting ML models without necessarily requiring low-level technological details such as programming pitfalls (Michaeli et al., 2023); (2) implementing the actual algorithm that makes the computer "learn" in a block-based programming language. Unlike many other approaches, students do not simply apply pre-trained models or use existing libraries to classify their data. In this way, students design AI/ML systems themselves, and by looking behind the scenes, the supposed "magic" of such processes is demystified (Jatzlau et al., 2019; Michaeli et al., 2020). (3) Turning your smartphone into your AI/ML-powered personal assistant by designing the interaction with language processing techniques, programming the behavior according to your ideas in a block-based language, and giving the assistant its own identity. These approaches can serve as examples of how to enable a constructionist approach to AI/ML and are being used in professional development for CS and non-CS teachers, as well as in mandatory K-12 CS education.

2.4 CONSTRUCTIONISM, ETHICS & CREATIVITY: DEVELOPING K-12 AI/ML EDUCATION FOR CLASSROOMS (DiPaola, Ali, Williams, Breazeal)

As the use of AI-enabled technologies by children becomes increasingly common, there arises the need to help K-12 students learn about how these algorithms work. In our work, we approach AI/ML learning with three goals: 1. helping students understand how AI/ML algorithms work, 2. having students responsibly use their AI/ML knowledge to reach their goals, and 3. empowering students to reflect on the societal implications of AI/ML and how it might affect their rights. Our pedagogical approach is one that encourages exploration in technical, ethical, and real-world applications before culminating in a constructionist project (Ali et al., 2019). Ali et al. (2021a) propose a “socio-technical learning trajectory”, in which students build up their knowledge of the technical, ethical, and real-world implications of particular topics in AI/ML before culminating in a constructionist project. In this poster session, we will share work from three curricula that follow a socio-technical learning trajectory: (1) How to Train Your Robot where students construct supervised machine learning models to control robots and develop AI/ML projects that assist or entertain others (Williams, Kaputsos, & Breazeal 2021), (2) Creative AI/ML for learning about generative algorithms (Ali et al., 2021a; Ali et al., 2021b; Lee, et al., 2021), and (3) Social Robotics & Societal Impact which enables children to learn about the ethical issues surrounding social robots before creating conversational skills for them (DiPaola 2021). We have deployed these curricula with over 3500 teachers nationally and internationally. Our curricula demonstrate that technical and ethical scaffolding leads to projects that are both personally meaningful and have real-world implications in mind.

2.5 **“HEY! THIS IS JUST LIKE AI!” (Stager)**

The ferocity of hype and hysteria accompanying the public release of ChatGPT feels unprecedented. Predictably, the claims of education being revolutionized over Christmas vacation are being advanced by people demonstrating little to no understanding of AI/ML or computing. I have been alarmed by the realization that many of those exaggerating the promise or perils of generative AI/ML have been obstacles to teaching all children to program computers. In a simulacrum of the instructionism vs. constructionism debate, the response to ChatGPT are calls to teach children *about* AI/ML. Discussions of ethics, risks, cheating, and banning ChatGPT are examples of what Alan Kay called, “Computer Appreciation.” It is certainly a departure from the Papertian image of the child programming the computer rather than the computer programming the child. (Papert, 1996) Whether technology such as ChatGPT realizes its promise or precipitates catastrophe, it seems imperative that children develop sufficient computational fluency to understand the technology and potentially shape its development. Papert wrote, “Piaget said that to understand is to invent. He was thinking of children. But the principle applies to all of us.” (Papert, 1993). In a desire to help children construct an understanding of “generative AI,” like ChatGPT, I began teaching kids (and their teachers) to write Logo programs for “playing with language” in the spirit of Paul Goldenberg and Wally Feurzig’s timeless projects. (Goldenberg and Feurzig, 1987) Students engaged in writing computer programs to generate random insults or produce the plural form of a word learn a great deal about reporters, list processing, conditionals, variables, concatenation, symbolic programming, linguistics, probabilistic thinking, debugging, grammar, pattern recognition, and linguistics. Even at a rudimentary level, such programming experiences remain elusive to most students. Aside from sharing a desire to help the computer “work for us,” I did not mention “artificial intelligence” during our programming sessions. However, it was during one such programming session that a fifth grader exclaimed, “Hey! This is just like AI!”

2.6 **LEVERAGING LEARNERS’ KNOWLEDGE AND PRACTICES AS A LANGUAGE FOR UNDERSTANDING AI/ML WITHIN DANCE AND COMPUTING (Castro & DesPortes)**

Computing systems that enable connections between dance and AI/ML models provide spaces to explore their opportunities, constraints, and failures and reason about how AI/ML is influenced by human design decisions, which are often shaped by biases and inequities (Noble, 2018). By centering dance, which is situated within various cultures and communities through music, movement, and social experiences (DesPortes et al., 2022), learners with dance experience have a language that they can use to examine the sociotechnical aspects of AI/ML and computing, while learning about and within these systems (Castro et al., 2022). Our work explores how six learners from STEM From Dance engaged with AI/ML concepts as they created dances with a creative computing system, danceON. danceON enables learners to use their own and existing pose detection models as they code movement-responsive virtual animations over live or pre-recorded dance videos (Payne et al., 2021). The design of danceON, which provides learners access to 33 body key points for each frame of video data using an off-the-shelf ML algorithm trained on inaccessible datasets, invited learners to speculate on possible causes when danceON performed poorly or when its behavior misaligned with a learner’s envisioned performance. Pose detection algorithms also make assumptions about the human body that may not capture the diversity of human bodies in the real-world; this had implications on how learners navigated the coding of animations over their bodies for their dances when certain body points were not directly accessible to them. Learners also reasoned about these limitations and behaviors of AI/ML by connecting to their experiences with AI/ML systems within their communities. The work demonstrates the power of tools to highlight the flaws and opportunities of AI/ML systems and empower learners to think about how to address these within similar systems, while also engaging in personally meaningful creation of dance.

2.7 CRAFT-ING CLASSROOM ACTIVITIES THROUGH CO-DESIGN THAT INTERROGATE ARTIFACT CREATION WITH GENERATIVE AI/ML (Lee, Sarin, Xie, Wolf, Sieh, Dennison, & Garcia)

Co-design with teachers is generating more interest in the learning sciences and adjacent fields that value core ideas of Constructionism and maker pedagogies. Through co-design, where researchers and educators meet repeatedly to ideate, critique, and test new learning experiences, tensions emerge related to what can be made feasible given classroom constraints and pressures. Through the Stanford CRAFT (*Classroom-ready Resources about AI For Teaching*) project (Lee et al., 2023), we embrace the opportunity to lean into these tensions and co-create curricular resources about AI/ML with practicing high school teachers. Beyond co-design, CRAFT intentionally pursues an "across-the-disciplines" approach (Jiang et al., 2022) to exploring AI/ML and emphasizes modularity and adaptation of co-created resources. A design tension, however, is to balance tendencies in schools to rely on instructionist pedagogies (Papert & Harel, 1991) when we wish to strongly encourage Constructionist ones. In this poster, we describe some of the collaboration processes and resulting resources that navigate that tension. The specific resources discussed include ones to help high school English and Art classrooms examine how the use of generative AI/ML tools, such as ChatGPT and DALL-E 2, complicate questions about who is constructing a new public artifact. The main data source which informs our design work is the corpus of video recorded co-design sessions and interviews with teachers. Of note our art teacher co-designer was instrumental in steering CRAFT toward provide resources to help students consider major concerns among artists about who is being credited and compensated for the creative work that trains generative AI/ML systems. Similarly, one of our English teacher co-designers shaped the design of a scaffolded generative AI/ML prompting environment where students, with support from teachers, can examine qualities of novel text creations. In this respect, given the ease by which new artifacts are being created, pedagogies of construction also add interrogation of construction in the age of Generative AI/ML.

2.8 SPORTS THROUGH AN AI/ML LENS: OPPORTUNITIES FOR AI/ML EXPOSURE AND EDUCATION IN ATHLETIC SPACES FOR STUDENT-ATHLETE IDENTITY EXPANSION (Kumar, Bodon, Worsley)

Sports and athletic play are highly relevant venues to think about AI/ML tools and education. While AI/ML tools are prominently used in professional sports, learning about the computing concepts is relegated to classroom experiences often missing the rich potential of embodied movement, as well as cultural and personal identity involvement that sports engender (Madkins et al. 2019). We have developed a suite of activities that introduces AI/ML driven proprietary technologies leveraging concepts like object, pose and gesture detection in youth athletic spaces (Jones et al. 2020; Kumar & Worsley, 2023). We then provide them opportunities to develop and extend variations of similar ideated sports technologies. This blend of playing and testing followed by tinkering and making centers our goals of culturally sustaining identity *expansion* for youth – orienting AI/ML as tools in service of youth interests and values, in contrast to technocentric approaches to computing often fostered in traditional computing classes and spaces (Kayumova & Sengupta, 2022). In this poster, we present our curricula, and highlight select cases of different learning and participation trajectories that emerge in introducing these activities in sports camps (Bodon et al. 2022). We show examples of how such constructionist AI/ML experiences can enable newer representations and structurations (Wilensky & Papert, 2010) to reflect on and deepen sports understandings – for thinking of posture and accuracy through the lens of computational feedback in addition to more familiar interpersonal judgment. We also highlight how even these highly contextualized use cases can surface deep conversations around much broader ethical impacts of these technologies – for instance, discussing the surveillance impacts of face and gesture recognition technologies in professional sports (Karkazis & Fishman, 2017) as well as urban and personal security (Vakil, 2018).

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