Machine Learning and Education in the Human Age: A Review of Emerging Technologies

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Abstract. Today's emerging technologies are moving in the direction of the human age. As technologies emerge in the educational setting, humans can evolve in the way they learn because of technology; and machines can evolve in the way they learn because of humans. Technology can be used to effectively observe and assesses human behaviors to better understand and respond to them. Whether the behaviors need to be adjusted or the behaviors are worth modeling, technology can provide support such as tools to track and collect data, assess performance, and provide meaningful feedback to the learner. In the human age of machine learning, the focus is less on technology and more on being human. To adapt to changing educational contexts, more effective applications of emerging technologies are needed. This paper explores the following novel applications of human-centered approaches to using technology in education: the quantified self, affective computing, emotional design, and pedagogical agents.

Keywords: Emerging technologies · Education · e-Learning ·
Artificial intelligence · Quantified self · Affective computing ·
Pedagogical agents

1 Introduction

In *Ex Machina* [1], a film about a humanoid robot with a sophisticated artificial intelligence system, the main character tells the robot a story that describes how machines are different from humans. A reference to Plato's Allegory of the Cave [2], the story explains that while machines are locked in a room and can only see in black and white, humans are on the outside and can see in color. Like the people imprisoned in Plato's Cave who can only see shadows, machines can only see a manufactured reality. To escape this constraint, machines need to become more human.

In recent years, machines have become more human in appearance and behavior by modeling the way humans think, act, and learn. The emergence of technologies designed to look and act in more human-like ways are changing the way people interact with machines and each other. For example, motion capture systems have been used recently to record and model human body movements to create more human-like avatars and ecologically valid social interactions in virtual training environments [3, 4]. Such realistic contexts provide new opportunities for human connection through

authentic experiences. These experiences can also provide machines new opportunities to understand humans in settings where more realistic interactions are observable. The more human machines become, the more they will be able to adapt to change. An important function of early human development, adaptation is adjusting to the demands of the environment [5]. Humans are equipped with tools to analyze data from their environment, and the results of their analyses inform their behavior. When their environment changes, humans adapt. Like humans, machines can learn to recognize and interpret data to adapt to new contexts.

In the educational context, humans and machines will need to adapt to unforeseen changes created by the integration of emerging technologies. A defining characteristic of emerging technologies is that they are unpredictable and uncertain [6]. This uncertainty associated with emerging technologies makes it difficult to study their effect on human psychology. As technologies become more human-centered and ubiquitous, they will be used with greater frequency and in more creative ways [7]. To adapt to today's unprecedented rate of technological change, people need to use their imagination and creativity to explore more effective applications of emerging technologies. The following novel applications of human-centered approaches to using technology in education are explored: the quantified self, affective computing, emotional design, and pedagogical agents.

2   Characteristics of Emerging Technologies

Before considering the applications of emerging technologies, it is helpful to frame the discussion with a definition of emerging technologies. Whether a technology is considered emerging depends on its place, domain, and application [8]. In the information and communication technology (ICT) domain, a characteristic of an emerging technology is that it does not need to have a limited or fixed life; and even when the technology has been used for a considerable length of time, it can begin to emerge when it is used in novel ways to serve individuals as a means of accomplishing their goals. Like the ICT domain, other fields have also developed definitions to guide research. For example, policy researchers have operationalized emerging technologies with the following attributes: (a) radical novelty, (b) relatively fast growth, (c) coherence, (d) prominent impact, and (e) uncertainty and ambiguity [9].

In the education field, technology has been defined broadly as "tools and resources that are used to improve teaching, learning, and creative inquiry" [11]. Research in this domain has defined emerging technologies with the following characteristics: (a) not necessarily new, (b) still evolving, (c) not yet fully understood or researched, and (d) unfulfilled but promising potential [10]. In addition to exhibiting these characteristics, whether a technology is emergent depends on its context. Defining the characteristics of emerging technologies in educational contexts can help improve technology integration models (e.g., technology acceptance model, the substitution augmentation modification redefinition model, and the technological pedagogical and content knowledge model), which can help understand how technology is adopted. According to 15 years of research on emerging technology trends, several developing technologies are expected to be adopted over the next 5 years, including enabling

technologies (i.e., technologies that make tools more useful by expanding their reach) such as affective computing, artificial intelligence, and virtual assistants [11]. These emerging technologies have the potential to change the way people teach and learn as they adapt to changes in technology and education.

3   The Quantified Self: Self-tracking as an Emerging Technology

As humans become more connected through the mediating experiences afforded by technology, they need to enhance their understanding and use of these technologies, and by extension, enhance themselves. One way in which people can enhance their understanding of themselves and potentially improve their behavior is through technologies that support the quantified self, an individual who engages in the self-tracking of any biological, physical, behavioral, or environmental information [12]. Some examples of this emerging technology are smart watches and fitness trackers that can track and analyze a variety of activities such as exercise and sleep patterns. An example of the quantified self for educational purposes is a web application called Stackup. Called by teachers "the Fitbit of reading," Stackup measures students' level of online reading and engagement through big data metrics [13]. An advantage of the quantified self is its focus not just on the quantified data but the qualitative data as well [12]. The tracking and analysis of both quantitative and qualitative data will offer new avenues of research to better understand human behavior.

As educators consider new uses of technology in new contexts, it is important to align these uses with learning theories and empirical evidence showing the impact of these emerging technologies on teaching and learning [14]. For example, the decision to use a technology may be dependent on how the technology can support instructional design strategies that are effective. Regardless of the medium or technology used to teach, the pedagogical strategy should be an important consideration. This will place the focus on using technology to keep the learner motivated and engaged emotionally and cognitively.

4   Emotions and Technology

4.1   Emotion, Cognition, and Technology

To motivate and engage students, technology-enhanced approaches to instruction need to take into consideration both the learner's cognitive and emotional needs. For example, you might hear a student say, "the more I thought about it, the more I felt confused." Such a statement counters the dichotomized view of human psychology that has separated thinking from feeling. Current research indicates cognition and emotion are not mutually exclusive, but rather, they are inherently interconnected [15].

In the same way that emotion and cognition are linked, humans and computers are not necessarily divided by two separate worlds: the real and the virtual. Instead, they are connected. Technologies can mediate a person's experience of reality. This

experience serves as an extension of the person's self, which is why it makes sense to think of human experience with computers in terms of human psychology [16]. Technology is more than just a tool; it is inextricably connected to the social and psychological lives of the people who use these tools. Technology affects how people see themselves and the world around them.

4.2   Measuring Emotion

The close connection people have with technology makes it an ideal medium for studying, modeling, and responding to human emotion. To understand the important role of user affects in human-computer interactions, the highly complex and multi-modal phenomenon of emotional expression needs to be investigated. Using technology, there are an increasing number of methods for measuring emotional expressions. Although self-report measures are still considered the gold standard for measuring emotion, facial expression coding and physiological measures such as electrodermal activity (ED) are empirically grounded approaches that are showing some promise in the field of emotion research [17]. Other factors that need to be considered when attempting to understand and measure emotion are the individual differences of the users, from their traits to their self-confidence to the ways in which they use the technology [18]. Being able to track and monitor both quantitative and qualitative user information is another reason technology serves as a useful tool to control for and accurately measure the variables associated with studying human emotion. Through technologies such as affective computing, human emotion can be measured, analyzed, and influenced within educational contexts.

4.3   Affective Computing

Affective computing is the use of technology to purposely influence emotions [19]. Emotion is tied to a cognitive, motivational and behavioral process [20]. Since emotion plays a central role in the control of behavior, environments that influence emotion can greatly control user experiences. This means that instructional design can benefit from considering the effect of emotions on learning.

In the educational setting, affective computing can be considered an emerging technology. For example, a novel application of affective computing in learning management systems would be to collect and analyze emotion data to provide relevant and meaningful feedback to the learner. Not considering a students' emotions may explain why students receive less socio-emotional support in online learning environments, which can lead to a loss of motivation and decreased learning comprehension [21]. Affective computing can emerge as a solution to address these deficits.

4.4   Emotional Design

Although affective computing can be used to influence emotion, what is important is not so much that emotions are induced but how they are induced. For example, designing instruction to induce emotion can support cognition and learning when those emotions are positive [22]. When done effectively, positive emotions can strengthen

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motivation. Thus, building a learner's positive affect is an essential first step when designing instruction.

While inducing positive emotions can be beneficial for learning, reducing negative feelings can also provide emotional support, and the technology used to provide this level of support does not have to be new [23]. For example, in a study that used pictures of an agent instead of an embodied agent with voice recognition and response capabilities, the facial expressions and textual statements provided to the user were impactful enough to significantly reduce negative feelings [24].

Video is another technology that is not new but can make an impact on learner affect. When used in a novel way, this everyday technology can be considered an emerging technology. A study that used relationship-building strategies in instructional videos found that the affective features in the video (i.e., the instructor used a friendly and warm tone of voice, included colloquialisms, provided anecdotes about own experience, and used encouraging language toward learners) significantly improved the students' attitude toward the instructor and the learning material compared to video presented without these strategies [25].

Another example of emotional design is the use of a framework that integrates both emotional and cognitive design factors. When designing digital media for learning, the use of this integrative model can have a significant impact on learning [26]. This emotional design approach used design features to influence learner's emotions such as the way information is presented and the way interactions in the environment are structured.

More than just recognizing emotions and adjusting the instruction, the learning system needs to provide students with quality feedback. Instructors have the potential to influence a student's emotions, a goal of affective computing [19], but "misleading affect recognition could result in inadequate emotional feedback, ruining learning" [27]. Therefore, designers of learning environments also must be cognizant of the potential negative effects of delivering affective responses to student learning.

5 Pedagogical Agents

Pedagogical agents are another emerging technology in the education field. Although these types of agents have been in existence for some time, the new applications and context in which they are used make them an emerging technology. As the research indicates, when considering the use of affective embodied agents, it is no longer a question of whether they can influence users' behavior in virtual environments, but the question is how and in what context these agents can be effective in engaging and motivating the learner.

Before using pedagogical agents, it is important to first validate the emotional expressions the agent will be using to make sure they will be perceived by the users as intended [28]. This is not unlike considering the user's emotional type, which could be compared to taking a baseline approach prior to calibrating how the effect of an intervention will be measured. If the user is sensitive to emotional expressions, validating them in advance of instruction will aid in understanding the user's behavior. Such an approach is key when studying human-computer interactions as it places

emphasis on the human side of the interaction by designing from the user's perspective. When agents play the role of a colleague instead of a tutor, the user's perceptions of the affective agent were enhanced, which resulted in improved learning outcomes [28]. Understanding the user's perceptions is an important first step to determining how to influence them.

The decision to use pedagogical agents should depend on the efficacy of the design and behaviors of the agents [29]. In a meta-analysis of studies comparing the presence of affect in embodied pedagogical agents, the findings indicated that to effectively respond to learner affect, agents' expressions needed to be authentic and student affect had to be detected accurately [30]. Without meeting these two requirements, embodied agents cannot be effective.

One of the reasons affective agents are more effective than non-affective agents in supporting interactions, particularly those that yield desirable learning outcomes, is because embodied agents use abstract symbols better than disembodied agents [31]. Social cognitive theory may provide an explanation for this as the role of embodied agents serve as a model to guide users' behaviors [32]. In addition, embodied agents support cooperative learning, which is known to be more effective at promoting interactive learning than individualistic instruction [33].

In the educational context, pedagogical agents can support learning by catering to the needs of the user who may need empathetic support initially until they are confident enough to self-regulate their learning. Users tend to like and trust pedagogical agents when they express empathetic emotion [24]. People respond to being cared about by computer agents, so caring agents have an advantage in motivating users because agents are perceived as trustworthy. In addition, people are likely to be more compliant toward an agent that reciprocates helpful behavior [34]. This suggests a design approach that incorporates reciprocity with a collaborative task between the agent and human would be helpful. Based on social exchange theory, people may even prefer working with computers to humans, especially when they experience a stable pattern of reciprocity, they may exhibit a higher degree of commitment toward a computer than a human [35].

6 Conclusion

An advantage of an emerging technology is that it presents an opportunity to engage with something novel, an experience that may shed light on the mysteries of human behavior. Technologies that are designed to model human-human interactions based on observations of positive human emotions and behaviors can support instructional objectives such as increasing learner motivation and successfully building student-instructor relationships in online environments. Technology can be used to effectively observe and assesses human behaviors to better understand and respond to them. Whether the behaviors need to be adjusted or the behaviors are worth modeling, technology can provide support such as tools to track and collect data, assess performance, and provide meaningful feedback to the learner. Although technology still exists within the realm of the digital and the artificial, the aim of technology is to move toward the natural and the authentic. From natural user interfaces such as wearable

technologies to enabling technologies such as artificial intelligence, today's emerging technologies need to be designed to perform less like a machine and more like a human.

Today's emerging technologies are moving in the direction of the human age. As technologies emerge in the educational context, humans can evolve in the way they learn because of technology; and machines can evolve in the way they learn because of humans. In the human age of machine learning, the focus is less on technology and more on being human.

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