Leveraging Game Design Activities for Middle Grades AI Education in Rural Communities

Jessica Vandenberg
jvanden2@ncsu.edu
North Carolina State University
Raleigh, North Carolina, USA

Wookhee Min
wmin@ncsu.edu
North Carolina State University
Raleigh, North Carolina, USA

Veronica Cateté
vmcatete@ncsu.edu
North Carolina State University
Raleigh, North Carolina, USA

Danielle Boulden
dmboulde@ncsu.edu
North Carolina State University
Raleigh, North Carolina, USA

Bradford Mott
bwmott@ncsu.edu
North Carolina State University
Raleigh, North Carolina, USA

ABSTRACT

The ever pervasive nature of artificial intelligence (AI) in our world necessitates a focus on fostering an AI literate society. Young children, those aged 11 to 14, are at a critical point in developing their dispositions toward and perceptions of science, technology, engineering, and mathematics (STEM), which influences their future education and career interests. Youth in rural areas are in particular need of access to AI learning opportunities to prepare them for the future workforce; digital games may be one way to attract young, rural students to STEM education and careers. In this paper, we explore how to introduce rural middle grades students to foundational AI concepts through digital game design activities. To inform our efforts and to establish an understanding of what these student populations as well as their teachers know about AI and games, we conducted a set of interviews and focus groups. In brief, students' awareness and understanding of AI varied significantly, whereas teachers had limited knowledge of AI. Moreover, students shared great interest in playing and designing games. In support of our findings, we are developing a set of game design activities around five core AI concepts and ensuring the activities are of interest to our rural students.

CCS CONCEPTS

• Social and professional topics → K-12 education; • Computing methodologies → Artificial intelligence.

KEYWORDS

artificial intelligence, digital games, middle grades students

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1 INTRODUCTION

Artificial intelligence (AI) literacy is a critical competency for all students to be successful in their ever-changing world and in the computationally-intensive workplace of the future where AI will be pervasive [12, 18]. Of primary importance is creating engaging AI learning opportunities for middle grades students (ages 11 to 14) as this is a critical time for developing their perceptions and dispositions toward STEM [15].

Rural areas—those located geographically removed from urban centers and often with reduced access to technology, high-paying jobs, and wide ranging educational experiences—are particularly in need of access to engaging AI learning opportunities. Rural education remains understudied [14] despite approximately 30% of all public schools in the United States deemed as rural [10]. Rural schools, being smaller and more isolated than their urban and suburban counterparts, tend to struggle with attracting and retaining high-quality teachers [10], leading to significant disparities between rural and urban areas in access to advanced coursework in STEM [10, 17]. Colleges, industry, and science organizations tend not to offer educational opportunities to rural student populations [14], further contributing to the challenges for rural youth to access innovative computing opportunities and careers. Rural counties comprise 80% of North Carolina, where, despite having world-renowned research and development facilities in a central urban area, it still ranks as a top priority state regarding rural education issues in the United States [17].

Digital games, ubiquitous in many youths' lives, offer an exceptionally promising context for engaging students from diverse backgrounds in AI. Game design has the power to encourage student interest and knowledge in computing [4, 5, 19]. Building on this line of research, we present our initial work toward creating engaging AI learning experiences for middle grades students through game design activities.

2 BACKGROUND

Research suggests that game design can augment student interest and knowledge in computer science [4, 5, 19]. As such, many researchers have begun to utilize game design as a strategy to broaden

participation in computer science, especially students from traditionally underserved and underrepresented groups in STEM [16]. Students often find digital game design personally relevant as they become empowered through creative expression while mastering computer science practices [16]. Although games have traditionally been considered more appealing to males than females, a significant demographic shift has occurred. A study published by the Entertainment Software Association revealed that, in 2018, nearly half of all gamers were female [1]. Likewise, research on digital game design with middle school girls demonstrates positive cognitive and affective outcomes [4]. Thus, game design can be a particularly effective strategy for addressing barriers to computing practices [9].

Game designers and developers are widely adopting AI to create engaging gameplay experiences. The digital games research community has investigated a broad range of AI technologies and applications, including human-like pathfinding [3], automated testing [2], player modeling [7], and building simulated players [6], that aim to promote player engagement and improve gameplay experiences. While traditional approaches to AI in digital games has relied on simple methods such as scripts, triggers, and state machines for reacting to players [21], recent work is grounded in advanced machine learning techniques [13]. Digital games offer a wide range of possibilities for engaging middle grades students in exploring AI concepts and technologies through designing and developing gameplay experiences.

3 RESEARCH OBJECTIVES

The goal of our work is to introduce rural middle grades students and teachers to foundational AI concepts through the engaging work of digital game design. For students, it is essential that this work be developmentally appropriate and, for both teachers and students, that we have an understanding of their background with AI, digital games, and coding. As such, the research objectives for this paper are to explore the range of background experiences students and teachers have in these areas in service of developing co-design sessions with students in which they will create their own AI-driven gameplay experiences.

4 METHOD

4.1 Participants

Our participants included two teachers and nine students from rural middle grades schools in North Carolina. The teachers, one male and one female, taught at low-income, rural schools. Participating students attended a rural after school club that serves mostly ethnic and racial minorities. All participants consented to the interviews, which were conducted under an approved institutional review board protocol.

4.2 Procedure

Two researchers open-coded the interviews, highlighting important words and concepts, then met to compare codes. A third researcher facilitated with collapsing codes into broader themes. Below, we present our thematic findings on students' and teachers' knowledge and understanding of AI and games, in support of creating co-design sessions wherein students will learn about AI concepts.

5 FINDINGS

5.1 Student Focus Group Interview Results

To ground our findings of what students know about AI in games, we first asked them to explain what AI is and for examples of AI. Responses from students to this question ranged from a conflation with technology in general (i.e., "I press a button and it'll automatically connect to the game.") to a beginning awareness (i.e., "robots") to a more advanced understanding (i.e., "a computer program that can think for itself" and "self-driving cars."). When asked to share if certain careers benefit from using AI, students acknowledged that farmers (i.e., "drones can water crops" and "to fertilize and get their plants to harvest") and truck drivers (i.e., "helping with sharp turns... and GPS") could use AI to help perform their jobs.

We then asked the students about their interest in and time spent playing digital games. All students indicated that they often play games and that their games of choice include Minecraft, Roblox, Fortnite, Dying Light, and Ib. Students' coding experiences only occurred outside of a classroom, with participants sharing that they learned from a parent, YouTube videos, or free playing on coding websites. Students were queried on how AI may be used in games. One student noted that AI can trigger character dialogue, sharing that "the [speech] bubbles are automatically triggered... those are probably like old. And what if you're trying to ask [the NPC] ques-tions?" Her hope was to engage with the NPC in more natural and interactive dialogue. This was mirrored by another student who said "especially if the NPC would say something different every time, so you won't have to be reading the same thing over and over and over again." Another student indicated that AI in games
appears as "smart NPCs." He further shared that a smart NPC would "dodge my hits and predict my moves."

5.2 Teacher Interview Results

Using a similar structure to the student focus group interviews, individual teachers were asked to explain what AI is or to provide an example. Neither teacher was able to provide a definition, with one saying "I don't really know what it is" and the other stating "I do not know anything, like nothing, like zero comes [to mind] when I think of artificial intelligence." Both teachers indicated they do not directly teach coding, with one noting that students have self-selected coding activities in class and the other saying that activities on sites like code.org are used as incentive for early finishers or to fill up time before a holiday break. Teachers reported on their students' interest in gaming, and indicated they enjoy competition driven games with sports and racing, and shooters. Additionally, they noted that although they are not currently confident in teaching AI to their students using digital games, they enthusiastically welcomed the idea of professional development sessions and co-teaching with more experienced teachers.

6 DISCUSSION

Our analysis of the student focus group interviews indicates that students vary significantly in their awareness and understanding of AI. It is likely that this diversity of understanding stems from students' exposure to technology and computing in school and at home. Noted previously, neither of our teacher participants taught

Table 1: Targeted AI Concepts and Example Activities

Targeted AI Concepts	Example Activities
Representation & Reasoning * Knowledge Representation * Search-based Problem Solving * Reasoning Processes	* Create representations of game levels using various formalisms (e.g., textual, image) to support reasoning by non-player characters * Explore search-based pathfinding algorithms to enable non-player characters to navigate game levels * Design non-player characters to take actions in the game world using decision trees and planners
Perception * Sensing * Processing Sensory Data	* Investigate how non-player characters can sense information from multiple modalities (e.g., visual, auditory) within the game world * Design non-player characters that interpret sensory data from the game world to inform their decisions
Machine Learning * Nature of Machine Learning (ML) * Decision Trees * Neural Networks	* Explore how the ML pipeline, including loading datasets, preprocessing data, training models, and evaluating models, can be used to create decision trees and neural networks for enhancing games * Apply ML techniques to enrich non-player character behaviors, so characters can respond to predictions about player actions
Natural Interaction * Natural Language Processing (NLP) * Affective Computing	* Explore how NLP and affective computing (e.g., natural language dialogue management, affective expression) can be utilized to create lifelike non-player characters * Apply NLP and affective computing techniques to design interactive non-player characters' verbal and non-verbal behaviors
AI Ethics * Fairness * Transparency	* Explore consequences of encoded bias in machine learning models used for creating game worlds * Understand the importance of algorithmic fairness and transparency for machine learning models

coding in class nor could provide an example of AI; both used external district-supported vendors for curricular support and materials. Moreover, students' home use of technology largely centered gaming devices. All of the students we interviewed stated that they played digital games, indicating a likely interest in learning about AI through games. In fact, some students already had some awareness of how AI is used in games and seemed excited by the idea of learning to create their own.

As noted earlier, we aim to create engaging learning activities that enables middle grades students to design and co-create digital game experiences using AI techniques, with which students explore and master foundational AI concepts. To ensure our learning activities are developmentally appropriate while simultaneously aligning with rural middle grades students' interest and diverse backgrounds, we take a hybrid method of combining a top-down approach (i.e., how to provide students with effective AI learning experiences guided by previous K-12 AI education research) and a bottom-up approach (i.e., how to take into account rural students' feedback in designing and developing our learning activities and software platform).

As a top-down approach, we are targeting five AI concepts, including (1) representation and reasoning, (2) perception, (3) machine learning, (4) natural interaction, and (5) AI ethics, informed by Touretzky and colleagues' work on five big ideas in AI [18]. For each AI concept, the project team has iteratively designed a set of activities grounded in digital game development to introduce the AI concepts (Table 1).

On the other hand, as a bottom-up approach, we created two key requirements, including (1) the learning activities should be of interest to rural middle grade students and (2) the software platform should be developed for web-based deployments, since Chromebooks are quickly becoming the platform of choice in schools throughout the United States. In addressing Requirement 1, the project team is exploring a variety of platforms including Minecraft Education (e.g., Unit 9: AI), Fortnite Creative Mode, and computer science-focused game-based learning environments [8, 11, 20]. To support Requirement 2, we are leveraging a client-server architecture, in which students (i.e., client side) use Chromebooks to interact with the game design software implemented in WebGL using the Unity game engine, while computationally-intensive tasks (e.g., machine learning and natural language processing) are handled on the server side (e.g., cloud services).

Intertwining the top-down and bottom-up approaches, we are designing and developing a set of NPC interaction design activities focusing on natural interaction and machine learning, where AI ethics underlies all of the learning activities. In particular, students can use, modify, and create NPC dialogues and learn how customized training data can impact the verbal behaviors of NPCs. Current storyboarding activities include soliciting feedback on NPC's appearance and the contextual environment in which the games are set (e.g., a warehouse, a farm, a sporting event, a long-haul drive; see Figure 1). We are also preparing to conduct professional development sessions to enhance teachers' understanding of AI and promote their confidence in teaching AI using game design activities. Together, it is anticipated that students will learn core AI concepts with engaging game design activities, while effective supports will be provided by teachers as well as in-software scaffolding.

7 CONCLUSIONS AND FUTURE WORK

Engaging digital game design activities, centered on foundational AI concepts, has great potential to support young students' understanding of AI, perhaps even influencing their educational and career trajectories. By harnessing students' interest in digital games, this work can promote deep, meaningful interest in and understanding of AI. Rural populations are often not given access to industry- or university-sponsored learning opportunities, yet a significant

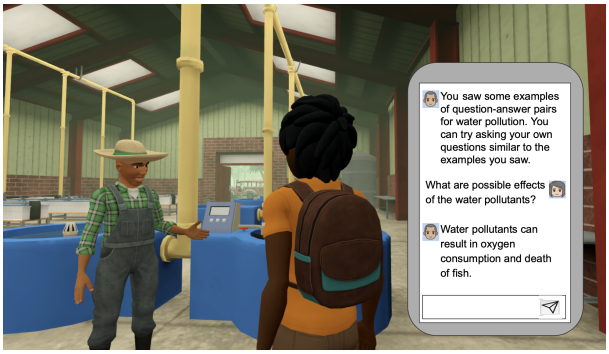

Figure 1: AI Play NPC Conversation Activity

percentage of students in the United States, and our state in particular, live in rural areas. This disparity contributes to a lack of diversity in STEM fields. Our work aims to address this directly. To more pointedly design our learning activities for this rural population, we gathered interview data from both students and teachers. The results suggest that students have some background with AI, little experience with coding, and a good amount of digital gaming experience, with knowledge of or interest in how AI is used in farming, long-haul truck driving, and other careers such as firefighting. Teachers, however, need additional professional development support and background knowledge to reinforce their and their students' abilities to work with core AI concepts and technologies. To assist with these efforts, we have outlined a game-centric AI concept framework, building on the work of Touretzky et al. [18] that aims to ensure the activities are of interest to our rural students.

Although our sample size is small, we feel the teachers and students we interviewed are representative of the rural education experience in our area. We plan to continue recruiting and interviewing rural middle grades teachers and students in service of refining our understanding of their needs, background experiences, and interests. In future work, it will be important to incorporate all the targeted AI concepts covered in our game design activities. It will be interesting to implement AI agents who can dynamically analyze students' interactions and provide adaptive feedback to effectively facilitate learning, by which the learning technology can achieve improved scalability and outreach capability. We also anticipate designing teacher professional development in ways that supports teachers' current knowledge and comfort with teaching AI, recognizing that internet connectivity and access to devices may be limited. Finally, it will be important to evaluate the impact of our learning technology on rural middle grades students' learning outcomes, including knowledge of AI concepts, attitudes toward AI, and interest in AI careers, as well as teacher practices for K-12 AI education.

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