AI-Centered Game Design Activities to Foster Middle Grades AI Education for Rural Students

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Abstract. The phenomenal growth of artificial intelligence (AI) has increased the need to educate younger generations about AI. Young children between the ages of 11 and 14 are particularly important to focus on, since this is a critical time for them to build essential knowledge and skills that can provide a solid foundation for future learning. However, children in rural areas may not have access to the same resources as their urban counterparts, making it more challenging to provide them with opportunities to learn about AI. Digital games and game design activities offer engaging ways to introduce children to AI concepts, and they can be designed to resonate with children in rural areas. Using insights gained from conducting interviews and focus groups with both educators and students from rural areas, we have created and tested a collection of game design activities that focus on the five big ideas in artificial intelligence. The hands-on activities follow a use-modify-create scaffolding progression that will support students in learning core AI concepts through designing AI-driven gameplay.

Keywords: artificial intelligence education · digital games · middle grades.

1 Motivation and Background

As the field of artificial intelligence (AI) continues to evolve and impact a broad array of industries, it is becoming increasingly important for students to develop an understanding of AI. This is especially true for children between the ages of 11 and 14, as this is a crucial age range for developing foundational knowledge and skills that can serve as a strong basis for future learning [11]. By introducing children to AI concepts early on, we can help them develop curiosity for and interest in this growing field, which can serve as a foundation for future career opportunities.

Students from rural backgrounds lack technology access and diverse education experiences. Despite serving almost one-fifth of public school students, rural education, classified as such in approximately 30% of all US public schools, remains understudied, and educators in these areas encounter significant obstacles in delivering quality education [4]. These challenges include limited resources, a shortage of qualified teachers, and a lack of funding. Moreover, rural schools have an even greater disadvantage when it comes to STEM education [5]. Our prior research with two rural teachers and nine middle school students in North Carolina revealed limited computer science and AI experience among teachers, leading to unequal student knowledge mostly acquired through recreational coding and YouTube [13]. The students' understanding of AI varied, and they discussed the ways in which AI is applicable in daily life. Furthermore, it was found that students were familiar with gaming and were involved in coding experiences, but mostly outside the classroom. The students also shared their perspectives on the potential applications of AI in games.

Digital games have emerged as a promising platform for providing engaging and accessible learning experiences, and can be an effective tool for introducing AI concepts to children from diverse backgrounds [3]. Katuka et al. [7] developed a summer camp experience to engage middle school learners in AI through the development of conversational AI apps. ARIN-561, an educational game for high school students, incorporates in-game challenges to introduce targeted AI concepts to learners [9]. Studies using ARIN-561 have observed significant learning gains for students who completed at least half the game, suggesting that such games have potential to support AI learning for high school students, especially if students engage with most of the activity [14]. Design of game-based learning environments can influence both student interest and learning outcomes, making it a powerful tool for overcoming barriers to computing education [10]. Digital games can introduce children to AI concepts, foster interest, and create a foundation for future AI career opportunities.

In this paper, we present a set of hands-on game design activities aligned with the five big ideas in AI [12], guided by feedback from both students and teachers [13]. We adopt a use-modify-create (UMC) approach to progressively introduce students to AI concepts through hands-on experience, such as natural language processing, pathfinding, and reinforcement learning [8]. Throughout the hands-on activities, students can design, develop, test, and iteratively refine their artifacts. By making the content relatable through in-game narratives and providing hands-on activities, children from rural areas with diverse backgrounds can develop a solid foundation in AI concepts.

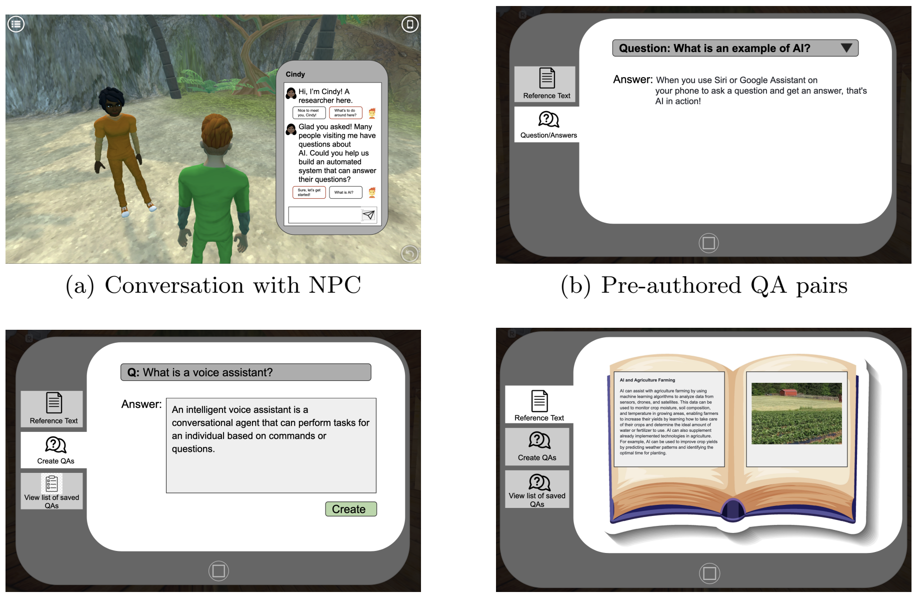
2 Game Design Activities

Our prior research has shown that students exhibit a wide range of awareness and understanding when it comes to AI [13]. It was noted that all students expressed an interest in games and were intrigued by the idea of studying AI through them. In fact, a few students desired to enhance games using AI techniques, with one student expressing her wish to interact with non-player characters (NPCs) in a more dynamic manner, acknowledging that triggered responses by NPCs are often repetitive and "old." Guided by this feedback, we have been prototyping and developing hands-on game design activities to introduce middle grade students in rural areas to the five big ideas in AI, including *Perception*, *Representation* *and Reasoning*, *Learning*, *Natural Interaction*, and *Societal Impacts* [12]. One major goal is to design engaging learning experiences that maximizes students' learning outcomes. To this end, our work to date includes three hands-on game activities that students can explore, centering on natural language processing for NPC's dialogue capabilities, search algorithms for NPC's pathfinding, and reinforcement learning for training NPC's decision making. The activities follow a use-modify-create progression, which is a popular scaffolding approach for introducing computer science concepts to students [8]. In this approach, the *Use* phase involves running pre-made programs, *Modify* phase requires making modifications to existing programs, and *Create* phase focuses on developing new programs.

2.1 Question Answering for NPC Dialogue

The activity described here targets Natural Interaction, Representation and Reasoning, and Machine Learning, and was developed based on feedback from students who suggested using AI to enhance the intelligence of NPCs in games. The goal of the activity is to help students enrich the conversation capabilities of an NPC based on reference text and questions that the NPC should be able to answer. As noted, a use-modify-create progression is used to ease students into the activity and help them gain a solid understanding of the inherent concepts (Figure 1).

In the Use phase of the activity, an NPC introduces students to the challenge of automated question answering. Their character is handed a book about AI and shown some examples of pre-authored question-answer pairs (Figure 1(b)). Students can then interact with the NPC by asking variations of the pre-authored questions (Natural Interaction). The system looks up the closest match to their question from the set of pre-authored questions, which is determined by comparing the cosine similarity between sentence-level embeddings (Representations) for the questions. The NPC then answers the question with the pre-authored answer paired with the most similar question (Reasoning). After a few such interactions with the NPC, the NPC introduces the students to the concept of embeddings in natural language processing (Machine Learning) and explains how the system discovers the closest match to their question. In the Modify phase, students are handed a book on voice assistants and asked to author answers to pre-authored questions (Figure 1(c)). Students can then try asking the NPC questions that are similar to the pre-authored questions, and the NPC replies with the answer to the most similar question. Finally, in the Create stage, students are asked to author their own text titled "AI and Agriculture" and create custom question-answer pairs based on the text (Figure 1(d)). This topic has been guided by our interviews with rural middle school students who showed interest in the use of AI in farming, and the text can include descriptions on how AI can be used to improve crop yields by predicting weather patterns and identifying the optimal time for planting and harvesting. The students can then interact with the NPC and ask questions similar to the authored questions for their custom passage, and the NPC responds with the answer to the most similar question.



(a) Conversation with NPC (b) Pre-authored QA pairs

(c) Authoring answers (d) Authoring context

Fig. 1. Use-Modify-Create Progression for Automated Question-Answering.

The last phase of this activity introduces students to potential ethical concerns in such automated NLP systems. They are presented with question-answer pairs based on text that has inherent gender bias, thus making the answers to questions about gender roles biased. This serves as a reminder of the importance of considering ethical issues when developing AI systems, and highlights the potential impact of biased systems in decision making processes. This hands-on activity holds potential for being generalizable to introduce diverse AI concepts by changing the context and question-answer pairs.

2.2 Pathfinding for NPC Navigation

This hands-on activity is designed to target the AI concept of Representation and Reasoning, with the goal of helping middle school students learn about the significance of automated pathfinding and how NPCs can navigate to a destination in a virtual world following a path identified by a search algorithm (Figure 2). In the Use phase of the activity, students are introduced to four different search algorithms: greedy, breadth first, depth first, and A*. This is done with guidance from Leitner et al.'s work on ARIN-561, which has been shown to be effective in teaching these concepts to high school students [9]. This activity also follows a use-modify-create progression to introduce students to the core concepts of AI for search.

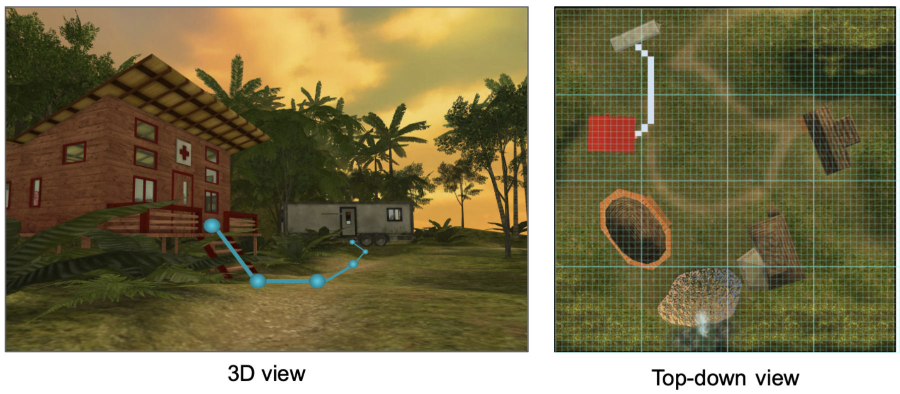


Fig. 2. Computing Shortest Path for NPC Pathfinding.

In the Use phase of this activity, students compare the effectiveness of each algorithm in terms of the search time and optimality of the path. To support this activity, the project team has been creating an interactive interface building on two public projects, the "Path Finding Algorithms" Unity project [2] and the Unity NavMesh project [1]. By customizing these two projects to be relevant to middle school students, this hands-on activity incorporates a Modify phase, which enables students to generate maps with randomized starting and destination points. This allows them to explore how each search algorithm performs pathfinding differently and understand the effectiveness of each algorithm.

During the Create phase of this activity, students are presented with different search problems, and they are required to map the most efficient algorithm for each problem. For instance, a pathfinding problem where there are no obstacles between the starting position and the destination may be best solved using the greedy algorithm. Alternatively, if the goal is to find the shortest path to the destination while collecting the most number of coins along the way, students can choose A* algorithm.

As students progress through the activity, they will gain a better understanding of the A* algorithm and how it can be used to find the optimal path from the starting point to the destination. By allowing them to switch between different heuristic options, they can explore the influence of their choices on the pathfinding process. For example, one heuristic option could be the Manhattan distance, which measures the distance between two points by adding the horizontal and vertical distances together, whereas another heuristic option could be the Euclidean distance, which measures the straight-line distance between two points. Students can be introduced to multiple problems, and they can explore different heuristics to decide which is more applicable for each problem. Through this exploration, students can gain a deeper understanding of how the choice of heuristic affects the performance of the A* algorithm. They may discover that certain heuristic options are better suited to certain pathfinding problems, and others may not be as effective. By providing opportunities for students to experiment with different heuristics, they can develop their intuition about the differences between these options and how they impact the pathfinding process.

This activity is particularly suited to rural middle school settings where students may not necessarily be exposed to coding in the classroom and have varying levels of coding expertise. By providing a hands-on, simulation-driven interactive learning experience, this activity aims to induce a fundamental understanding of common pathfinding algorithms without delving into algorithmic complexities or the need to use or modify code. Additionally, it encourages critical thinking and problem-solving skills, which are essential for a career in the STEM industry. Additionally, this activity serves as a gateway for students to learn about controlling NPCs and establishes the groundwork for more advanced NPC control activities, including natural language interactions and intelligent responses to environmental changes.

2.3 Reinforcement Learning for NPC Behavior

This activity provides an opportunity for students to explore two additional fundamental AI concepts—Machine Learning and Perception—through the use of reinforcement learning (RL). The idea of creating smarter NPCs that can learn a policy by interacting with the environment and can take actions based on observations of the game world could be particularly appealing to many students, as it adds a new level of challenge to the game design activities. During our focus group interviews, several students proposed utilizing AI to enhance the intelligence of NPCs, while one student suggested the idea of a smart NPC capable of predicting their moves and avoiding attacks. Using reinforcement learning, NPCs can be trained to exhibit desired behavior over time by observing and reacting to perceptions of the environment. A reward system can be used to reinforce desirable behavior, allowing the NPC to learn and adapt to its surroundings. This activity is designed using the Unity ML-Agents Toolkit [6] that will enable students to experience how to train policies for NPCs, deploy pre-trained models to the NPCs, and explore how NPCs behave differently depending on the learned policies for the same task. Similar to the previous activities, this activity too follows a use-modify-create progression to familiarize students with the concepts of reinforcement learning.

In the Use phase of this activity, students load a pre-trained behavior model for an NPC in a game environment. They can then play the game to see how the NPC behaves in reaction to environmental percepts using the pre-trained behavior model. The system introduces students to the concept of reinforcement learning and describes the reward system that was used for training the pre-trained model. In the Modify phase, students can modify reward parameters and re-train the models to observe changes in behavior patterns for the NPC. Finally, in the Create phase of the activity, students are introduced to a new reinforcement learning problem where they can act as the reward system to help train the agent's behavior. For instance, a farming game where a virtual farmer needs to harvest their crops efficiently. However, there are pests and weeds in the field that the farmer needs to deal with, and they have limited resources to do so. Students can act as the reward system and give positive rewards for efficiently harvesting crops and negative rewards for leaving crops unharvested or failing to deal with pests and weeds. A machine learning backend can be used to train behavior for such a robot based on reward feedback from the student using techniques like Q-learning [15]. The student can then observe the resulting behavior for the reinforcement learning using a trained policy based on their custom feedback. This RL hands-on experience will provide students with an intuition of how reinforcement learning can be applied in games to automate NPC behaviors and understanding of Perception and Machine Learning to create intelligent NPCs.

By incorporating a farming-focused application of RL in the Create phase of the activity, students from rural farming areas can imagine the practical applications of RL in their own communities. This relatability can help promote interest and understanding of how AI can be used as a tool to advance rural communities, and encourage students to consider careers in technology that can benefit their home communities.

3 Conclusions and Future Work

Digital game design shows great potential for fostering AI education among middle school students residing in rural areas. Leveraging students' interest in games can help foster the development of a deeper understanding of AI and cultivate an interest in AI and its applications in game development as well as other real-world scenarios. Building on our prior findings from focus groups and interviews with rural students and teachers, we presented the design of a set of learning activities that introduce students to core AI concepts. Students are encouraged to explore and engage with AI in these hands-on activities, including NPC dialogue design, pathfinding, and reinforcement learning, that follow a use-modify-create scaffolding progression. This approach will not only help students learn fundamental AI concepts but also provide them with opportunities to apply these concepts in real-world contexts. In the future, it will be critical to conduct pilot studies with middle school students to evaluate the effectiveness of these designs for both engagement and learning. By making learning AI more engaging and accessible, we look to bridge the AI education gap in rural communities.

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