Unplugged K-12 AI Learning: Exploring Representation and Reasoning with a Facial Recognition Game

Hansol Lim, Wookhee Min, Jessica Vandenberg, Veronica Cateté, Bradford Mott

Department of Computer Science, North Carolina State University
{hlim5, wmin, jvanden2, vmcatete, bwmott}@ncsu.edu

Abstract

With the growing prevalence of AI, the need for K-12 AI education is becoming more crucial, which is prompting active research in developing engaging and age-appropriate AI learning activities. Efforts are underway, such as those by the AI4K12 initiative, to establish guidelines for organizing K-12 AI education; however, effective instructional resources are needed by educators. In this paper, we describe our work to design, develop, and implement an unplugged activity centered on facial recognition technology for middle school students. Facial recognition is integrated into a wide range of applications throughout daily life, which makes it a familiar and engaging tool for students and an effective medium for conveying AI concepts. Our unplugged activity, "Guess Whose Face," is designed as a board game that focuses on *Representation and Reasoning* from AI4K12's 5 Big Ideas in AI. The game is crafted to enable students to develop AI competencies naturally through physical interaction. In the game, one student uses tracing paper to extract facial features from a familiar face shown on a card, such as a cartoon character or celebrity, and then other students try to guess the identity of the hidden face. We discuss details of the game, its iterative refinement, and initial findings from piloting the activity during a summer camp for rural middle school students.

Introduction

As artificial intelligence (AI) rapidly expands in our daily lives, there is increasing demand for broadening the field of AI education (Touretzky et al. 2019a). Over the past few years, a growing consensus has formed on the importance of introducing AI education to K-12 students (Maslej et al. 2023; Touretzky et al. 2019b; Wang and Lester 2023). In light of this, efforts have been made by the AI4K12 initiative in devising the "5 Big Ideas in AI" and developing national K-12 AI education guidelines organized around them (Touretzky et al. 2019b). Building on these efforts, a number of learning activities have been developed to enable K-12 students to learn AI concepts (Giannakos et al. 2020; Ho et al. 2019). Among these innovations, game-based learning, which allows K-12 students to learn through playing games, has provided access to AI education for a wide range of students (Lee et al. 2021; Vandenberg et al. 2023; Zhan et al. 2022).

There is a growing collection of K-12 AI instructional resources, such as digital learning environments, card and board games, and video content (Giannakos et al. 2020; Touretzky et al. 2019a). Digital content can be effective for teaching advanced technologies like AI; however, research suggests that unplugged activities are also promising for developing AI competencies in K-12 students (Lindner, Seegerer, and Romeike 2019; Virtue 2021). Unplugged activities not only induce interest and active participation from students when learning new concepts, but they can also support introducing complex concepts found in computer science and AI through physical manipulation (Aggarwal, Gardner-McCune, and Touretzky 2017; Lindner, Seegerer, and Romeike 2019). Additionally, because unplugged activities do not require computers, they have the significant advantage of providing engaging and effective educational opportunities in classrooms or learning spaces that lack access to computing hardware (Chen et al. 2023). Given these benefits, there have been increasing efforts focused on designing and developing unplugged activities for K-12 AI education (Ali, Kumar, and Breazeal 2023; Ho et al. 2019; Ma et al. 2023). Many of these unplugged activities are designed to align with the "5 Big Ideas in AI," are aimed at offering a curriculum for a wide range of different learners, and have shown promising results in promoting AI education.

This paper presents the design, development, and implementation of an unplugged activity in the form of a board game focused on facial recognition to teach students concepts aligned with *Representation and Reasoning*—one of AI4K12's 5 Big Ideas in AI. Facial recognition offers significant convenience to individuals and is found in a broad range of applications, including unlocking mobile phones and automatically tagging people in social media posts. Its widespread use provides a familiar and captivating tool for students, offering promise for serving as an effective means for introducing AI concepts to them. Furthermore, we describe the iterative refinement of the game through play testing as well as investigate the efficacy of the game through a pilot study conducted during a summer camp for rural middle school students. We discuss findings from the pilot study, which suggest that our unplugged activity provides an effective learning opportunity for students and holds significant potential for advancing engagement in AI education for K-12 students.

Background

K-12 AI Education

K-12 AI education is of great concern and importance, especially as AI technologies are rapidly evolving. It is an essential and urgent need to prepare today's students for the future, where AI will likely be ever present (Wang and Lester 2023). In addition, AI education has many potential benefits, such as fostering creative thinking and motivation in K-12 students, leading to active research to develop effective learning methods (Wang et al. 2022). To this end, the AI4K12 initiative, sponsored by the Association for the Advancement of Artificial Intelligence (AAAI) and the Computer Science Teachers Association (CSTA), proposed national K-12 guidelines organized around the 5 Big Ideas in AI: *Perception*, *Representation & Reasoning*, *Learning*, *Natural Interaction*, and *Societal Impact*. Furthermore, the AI4K12 initiative has encouraged the development of resources to promote K-12 AI education (Touretzky et al. 2019b). Recently, the U.S. Department of Education released insights and recommendations on AI in schools, which also notes the importance of students learning about AI (Cardona et al. 2023). Research is also underway to introduce culturally responsive approaches for contextualizing K-12 AI learning experiences for students (Eguchi, Okada, and Muto 2021). Together, these endeavors underscore the significance of K-12 AI education, highlighting the need for effective, age-appropriate AI education that can foster early interest in and engagement with AI.

Unplugged Activities

Prior research has noted key benefits of utilizing unplugged activities for computer science education (Bell and Vahrenhold 2018). These benefits include:

- **Excitement and engagement**: Unplugged activities involve working with tangible materials and physical manipulatives, which can be more engaging for some students than sitting at a computer.
- **Low cost**: Unplugged activities offer low cost and independence of use since they do not require unique hardware or equipment, thereby facilitating the implementation of activities in a broad range of settings.
- **Learning potential**: Unplugged activities can provide effective learning opportunities for students to develop a high-level understanding of complex concepts before they master finer details.

Several studies have examined effective designs of unplugged activities by harnessing the advantages noted above. Bell et al. (2018) presented an educational method, CS unplugged, to introduce key concepts in computer science without requiring the use of a computer. Their approach was designed to enable students without prior experience in computer science to easily understand intricate concepts by performing simple activities, which make the concepts accessible and easy to understand. In this regard, Nishida et al. (2009) analyzed the activity structure of CS unplugged to determine what core factors contributed to its success. The authors proposed fundamental design structures and patterns that can be used to improve existing activities or design new unplugged activities.

Designing unplugged activities can also be used to inform the design of computer-based activities, such as digital game-based learning environments (Fullerton 2014; Rowe et al. 2017). Unplugged paper prototypes of digital games can help identify potential issues in game designs and facilitate making refinements to game mechanics before proceeding with the time and labor-intensive process of developing a digital learning environment. Creating and piloting unplugged activities can also assist in ensuring that digital learning environments are well-designed, engaging, and achieve their overall learning objectives (Rowe et al. 2017).

There is a growing body of work investigating unplugged activities for computer science education and developing computational thinking skills (Aggarwal, Gardner-McCune, and Touretzky 2017; Bell and Vahrenhold 2018). For example, Wohl et al. (2015) explored three teaching methods, including Scratch, Cubelets, and CS unplugged, for teaching computer science concepts to young children. The authors found that the unplugged approach yielded an improved understanding of key concepts such as algorithms, logical predictions, and debugging. Leveraging the significant benefits of unplugged activities and a growing interest in AI education, there has been an increased focus on developing unplugged AI learning activities.

Unplugged Activities for K-12 AI Education

Recent studies have explored teaching AI concepts using a range of unplugged activities. Ma et al. (2023) presented their experience implementing two unplugged activities, "The Pasta Land-Decision Tree" and "The *k*-NN-Penguin," which incorporate decision tree and *k*-nearest neighbors algorithms tailored for middle school students. Lindner et al. (2019) designed five distinct unplugged activities encompassing a range of AI topics, from a basic "Introduction to AI" to specialized AI concepts like "Classification with Decision Tree," "Image Recognition with Neural Networks," and "Playing Chess with Reinforcement Learning." Scheidt et al. (2019) introduced a prototype toy, "Any-Cubes," designed to teach children about machine learning and the Internet of Things. Ali et al. (2023) designed an "AI Audit" card game focusing on *AI Ethics*. Playing this game helps students learn about potential risks or harm caused by AI systems and encourages them to think critically about the societal effects of AI adoption. Ho et al. (2019) developed an unplugged activity for primary school students centered on facial recognition. The activity leads students to physically act out the process of "feature extraction" by having them tabulate the characteristics found in a set of images, such as hair length, hair color, and glasses, as well as performing a "database search" to identify a person using a similarity score. Our work is inspired by that of Ho et al. (2019), extending aspects of their unplugged facial recognition activity into a board game setting with unique game mechanics for middle school students.

Game-based learning employs an active pedagogical approach, using games to enhance student engagement and promote learning (Hellerstedt and Mozelius 2019; Pho and

Dinscore 2015; Shaffer et al. 2005). These games can be digital or unplugged and are designed to be fun and interactive, involving challenges, quests, and competitions that ask students to use their knowledge and skills to solve problems and achieve learning goals. Unplugged game-based activities allow for the learning of complex concepts—in our case, AI concepts—and enable students to delve into conceptual learning without depending on digital devices (Lindner, Seegerer, and Romeike 2019). To take advantage of these strengths, we adopted a board game as a platform easily accessible to educators and students and as an effective instructional resource for teaching fundamental AI concepts to middle school students.

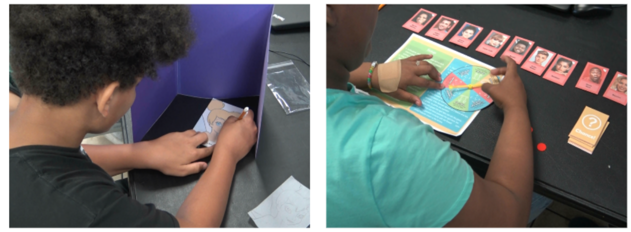

Figure 1: Facial features being extracted onto tracing paper (left). Spinner being used to determine the next action and prompt inferences about the hidden identity (right).

Guess Whose Face

Overview

Guess Whose Face is a board game that introduces students to AI concepts through facial recognition, which many students encounter on a regular basis. One of the most common interactions that middle school students have with facial recognition technology is unlocking their mobile phones. Facial recognition is also widely used in applications such as building access control, tracking boarding records for flights, and banking transactions. *Guess Whose Face* is similar to "Guess Who?," a popular board game where players ask a series of questions to predict the identity of their opponent's character. Both games share a similar objective that fundamentally revolves around predicting the identity of a hidden character. However, in our work, instead of identifying a character's identity through questions, players extract facial features using tracing paper, leveraging those features as clues to guess the identity of a hidden character (Figure 1). Unlike "Guess Who?," which features a one-on-one competition, our game involves teams of two or more players working together to compete against other teams within a classroom or club setting. The team that accurately predicts the identity emerges as the winner. By designing *Guess Whose Face* in a competitive format, students can enjoy playing against each other, promoting their learning experience (Belfield and Levin 2002).

Design Process. Our design process for *Guess Whose Face* took into account major design elements identified in the CS unplugged research for creating successful activities (Nishida et al. 2009). Seven distinctive features were noted: 1) *No computers*, 2) *Games*, 3) *Kinaesthetic*, 4) *Student directed*, 5) *Easy implementation*, 6) *Growing body of ideas*, and 7) *Sense of story*. We also aimed to align the learning objectives of the game with AI4K12's guidelines to ensure key AI concepts are properly represented in the design.

We opted to focus the design of our activity on *"Representation & Reasoning"* from the 5 Big Ideas in AI, which encapsulates key insights in AI concepts around data structures and algorithms. Subsequently, building on the work of Ho et al. (2019), we chose facial recognition as a promising medium for conveying our targeted AI concepts due to students' familiarity with it and its potential to pique their interest. The entire game design process encompassed two primary phases of gameplay and two rounds of pilot studies, each accompanied by refinements to the game.

Target Age Group. *Guess Whose Face* is targeted to middle school students (Grades 6-8).

Player Roles. As noted, the game is designed for teams of two or more students to compete against each other. Each team consists of one *Drawer* and one or more *Guessers*.

- **Drawer** (Figure 1, Left) is given a random face card and is responsible for extracting facial features onto tracing paper without revealing the target character to the Guesser(s).
- **Guesser** (Figure 1, Right) uses a spinner to determine the next action and recognizes the hidden character's identity based on the facial features drawn on the tracing paper.

Targeted AI Concepts. *Guess Whose Face* aligns with *Representation & Reasoning* from AI4K12's 5 Big Ideas in AI, and addresses algorithms for *Reasoning* and data structures for *Representation*, which are key insights covered by this idea. The AI4K12's guidelines outline specific learning objectives (e.g., comparing several algorithms to solve problems) and enduring understandings (e.g., how to choose a reasoning algorithm depending on certain situations) for each age group. These guidelines informed our design choices for *Guess Whose Face*. With respect to *Representation*, the Drawer should look at the facial image presented on the card and consider how individual facial landmarks (i.e., facial features) could be best depicted as points to represent the face. Specifically, the Drawer needs to consider how the connections or combinations of these features signify specific facial structures (e.g., eyes, nose, mouth) focusing on representation. On the other hand, to convey *Reasoning*, the Guessers need to employ diverse mental approaches (i.e., algorithms) to infer the correct face, taking into consideration the facial features that have been extracted (i.e., data structures). For instance, students may adopt a decision tree-like approach operating on facial structures, discard face cards that do not align with salient facial structures captured on the tracing paper, and eventually select the most likely face card that correctly matches the given facial features. By playing the Guesser role, students have the opportunity to experience how to classify data using a systematic approach.

Game Materials

A game of *Guess Whose Face* consists of a collection of materials, including a set of cards (*Face Cards* and *Chance Cards*), a spinner, a trifold screen, a sheet of tracing paper, a pencil, and three guess tokens.

Face Cards. In the game, face cards are a collection of cards that act as the dataset of target faces that Guessers try to recognize. Each deck of face cards consists of 10 cards that come in two sizes: a larger deck, sized 4 inches x 6 inches, for the Drawer and a smaller deck, sized 2 inches x 3 inches, for the Guessers. The character images on the larger deck and the smaller deck are matched. We specifically provide bigger cards to the Drawer to enhance visibility and facilitate the drawing of features on tracing paper. The smaller cards adhere to standard board game dimensions, making them ideal for laying out on the Guessers' side for comparison. In our pilot testing, to engage students and maximize their interest, we selected popular celebrities and cartoon characters known to middle school students as target characters for the face cards. We organized our sets of face cards into three levels of difficulty, *Easy* (Green), *Medium* (Blue), *Hard* (Red), depending on the distinctiveness of the character's facial features (Figure 2).

To support local adaptation, we provide a template for the face cards so that educators can customize the set of face cards based on their students' preferences. Playing with identical face cards repeatedly may reduce student interest over time. The template enables educators to modify the face cards by downloading a desired set of images and arranging them, helping to ensure continued high student engagement.

Chance Cards. In the game, chance cards are a set of cards that influence how the game unfolds. Guessers draw a chance card whenever they land on "Chance!" using the spinner. Chance cards are categorized as follows:

- *Discover a facial landmark*: Draw dots around the specified landmark (e.g., eyes, lips, nose, face outline) to reveal those facial features.
- *Free Guess*: Make a guess about the face without consuming one of the available guess tokens.
- *Double / Triple*: Double or triple the number of feature or noise dots the Drawer utilizes during their next turn.
- *Skip*: Pass the turn and move to the next player.

Spinner. The game utilizes a spinner to introduce a layer of unpredictability into the gameplay (Figure 3). The spinner uses a variety of colors and designs to captivate and engage students visually. During each turn, Guessers use the spinner to make progress in the game, which helps to streamline the rules of the game.

- *Feature Extraction* $+\alpha$: Drawer draws α dots (3, 5, or 7) that outline a facial feature.
- *Add Noise* $+\alpha$: Drawer draws α dots (3 or 5) randomly around the face.
- *Guess Face*: Guesser takes a guess at identifying the face being drawn.

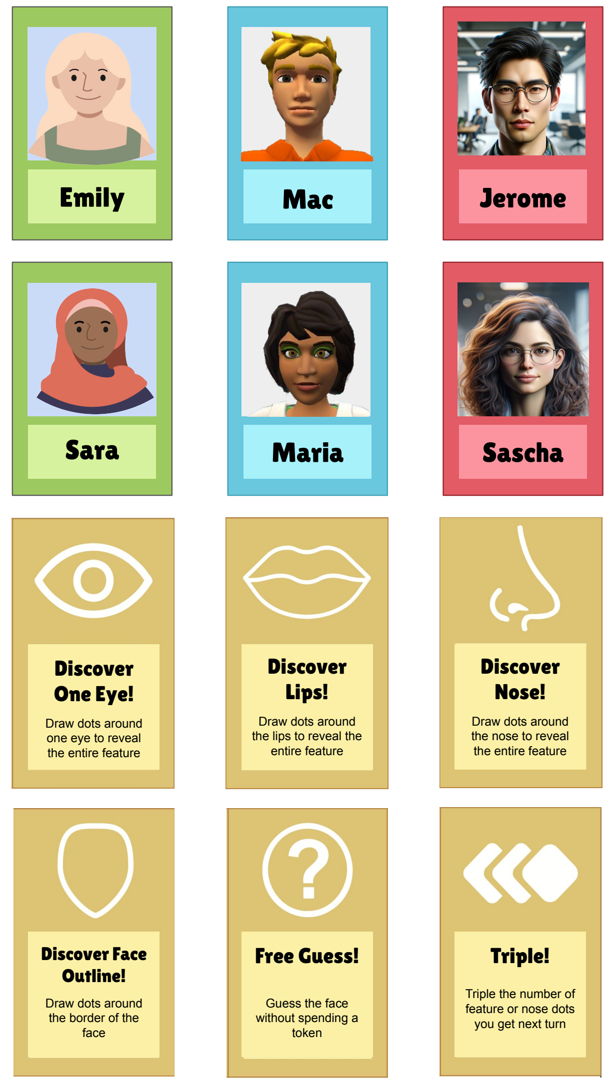

Figure 2: Top two rows show sample "Face Cards," while the bottom two rows illustrate example "Chance Cards." Face Cards can be divided into three difficulty levels using colors (Green for Easy, Blue for Medium, and Red for Hard).

- *Chance*: Guesser draws the top chance card and follows its instructions.

Game Setup

1. Determine who will be the Drawer on the team.
2. Choose a difficulty level: Green cards (easy), blue cards (medium), red cards (hard).
3. Randomly select a large face card from the chosen difficulty level and place it, the trifold board, a sheet of tracing paper, and a pencil in front of the Drawer.
4. Place the 10 small face cards from the chosen difficulty level, shuffled chance cards, spinner, and 3 tokens in front of the Guessers.

Figure 3: Spinner consists of various sections that determine the next action in the game.

How To Play

1. During their turn, each Guesser spins the spinner
2. Based on where the spinner lands, the player takes the corresponding action:
   (a) *Feature Extraction and Add Noise*: Drawer adds dots as indicated by the spinner to the tracing paper and shows them to the Guessers. [1]
   (b) *Make a Guess*: Guessers may choose to spend one guess token to identify the face or pass their turn.
   (c) *Chance*: Guesser draws the top card from the 'Chance Card' deck and follows its instructions.
3. Players iterate through steps 1 and 2 until Guessers have a sufficient level of facial features to make a guess.
4. Teams who guess the identity before using all of their guess tokens win the game. If more than one team guesses correctly, the team who guesses using the fewest number of features wins.

The gameplay can be divided into two phases: the *feature extraction phase*, corresponding to *Representation*, and the *database search phase*, corresponding to *Reasoning*. During the feature extraction phase, the Drawer overlays the tracing paper with the target character, observes the reflected face, and extracts primary facial features centering on the eyes, nose, mouth, and face outline. The Drawer is assumed to focus on highlighting the most distinct facial features to assist the Guesser with making the correct guess. This Drawer's task is related to how an AI system stores and organizes information through this process.

[1] Before playing the game, students are informed about how to extract facial features and add noise using an instructional slide.

Moreover, during the feature extraction phase, not only do the students extract facial features, but they at times also introduce noise depending on where the spinner lands. Our unplugged activity aims to teach students that data can contain noise, and learning how to handle it is crucial to developing robust AI systems. This noise appears as random dots on the tracing paper, mirroring potential disturbances in real-world data that hinder the accuracy of AI systems.

In the database search phase, the Guessers speculate which face in the face card set corresponds to the target character by sifting through the given face cards and comparing them to the features drawn on the tracing paper. This Guessers' task is related to how AI systems make decisions or generate new information based on given data.

Implementations

To refine and evaluate *Guess Whose Face*, we conducted a play test of an initial version of the game with four university graduate students to gain input on the design of the game, and to test if the game was playable as intended. After refinements were made based on findings from the play test, we conducted a pilot study using the updated game with ten students attending a summer camp for rural middle school students.

Play Test: Refining Game Design

The initial play test of the game involved a group of four adults who were graduate students studying Computer Engineering or Art and Design. They had a good general understanding of facial recognition technologies and one had previous experience designing games. The initial version of the game involved identifying faces by collecting facial features as players moved around a board, similar to "Monopoly" using dice (Figure 4). Our initial design utilized a Monopoly-style board because we thought students' familiarity with this board game would make it easier for them to grasp the rules of the game. Moreover, the concept of gathering money to purchase properties in Monopoly could be seamlessly transitioned to collecting facial features to make inferences in our game about faces.

This initial play test aimed to (1) determine if the game smoothly operates as planned, (2) assess the suitability of the placement and setup of different game elements like features and noise, and (3) evaluate if the game aids in enhancing the understanding of facial recognition and AI concepts before it was fully implemented at a larger scale. Findings from the play test suggested the following. First, the Monopoly-style board configuration had the advantage that students were somewhat familiar with our game design based on their prior experience with similar games, but it required rather labor-intensive efforts to construct the board game materials. This was in stark contrast to one of the key characteristics that unplugged activities should have in being easy to implement (Nishida et al. 2009). On the other hand, using a spinner allowed us to implement similar gameplay with fewer components. This efficiency influenced our decision to select the spinner for the current design of the game. Second, during gameplay, we noticed that one group consistently failed to

Figure 4: Play test conducted using an initial version of the game with four graduate students.

extract facial features and kept acquiring only noise, suggesting the need to better balance the chance of players having to inject noise into their drawings. Lastly, although the play test participants were not in our target age group, they believed our game held potential for improving students' understanding of facial recognition technologies and AI concepts.

Pilot Study: Summer Camp Implementation

Building on refinements made to the game after the play test, we conducted a pilot study using the game as part of a week-long summer camp focused on AI education with ten rural middle school students. The camp was held at a community-based center that offers afterschool and summer services to local youth. During the pilot, students were grouped into five teams consisting of two students each. The ten participants consisted of four girls and six boys, with 90%, identifying as Black or African American and 10% identifying as Hispanic or Latino. This study aimed to (1) see if the game could spark interest and engagement among rural middle school students, and to (2) determine if the game effectively conveyed AI concepts from an educational standpoint.

For use in the pilot study, we created face cards in three levels of difficulty using cartoon characters and celebrities. In assembling these cards, we ensured a diverse distribution of characters across gender, race, and age.

- Green Cards (Easy): The easiest level includes cartoon characters with distinct facial features, such as SpongeBob SquarePants and Homer Simpson.
- Blue Cards (Medium): The medium level utilized Disney characters such as Ariel and Jasmine, whose facial features are less pronounced.
- Red Cards (Hard): The most challenging level features widely recognized celebrities among middle school students, such as Taylor Swift and Dwayne Johnson. This level requires players to discern subtle differences to guess accurately.

During gameplay (Figure 5), the majority of students grasped the game mechanics with ease. However, one team required guidance from a camp instructor for smooth gameplay. Each game round lasted approximately 10 to 15 minutes, allowing for over three rounds within an hour. Analysis of the students' drawings revealed that approximately 46 facial features were needed for accurate prediction. We judged the number to be small because the students learned how to extract key facial features, which allowed for more effective reasoning about the faces through repeated gameplay. We also identified several challenges during gameplay. Some students depicted facial features not as points but as lines outlining facial contours. This deviation required intervention from camp instructors. A few students consistently landed on "noise" using the spinner, outnumbering the facial features they obtained. This adversely affected their inference accuracy. Even though the spinner was designed with a balanced content distribution, it was evident that controlling the odds of landing on either facial features or noise was challenging and needs additional refinement.

At the end of the activity, students were asked to complete an exit ticket consisting of three questions. (1) When asked, 'On a scale of 1 to 5, how much did you enjoy the activity?', the average score given by the students was 4.625. This high score suggests that the majority of the students were engaged and actively enjoyed the game. The format of having two students team up to compete against other pairs seemed to promote active participation. (2) In response to the question, 'On a scale of 1 to 5, how much do you think you learned from this activity?', the average score was 4.375. This indicates that most students felt they gained substantial knowledge from the experience. (3) As for the ability to explain how AI models recognize faces, responses like "AI scans the face to recognize it and captures 80 dots around the face

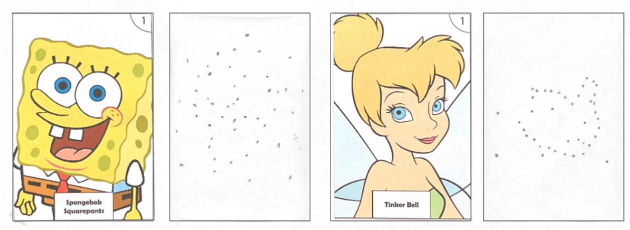

Figure 5: Gameplay results showing extracted features on tracing paper from students for SpongeBob SquarePants (left) and Tinker Bell (right).

for identification" and "They use scanners to detect facial structures and rely on a database" suggest that the objective of helping students grasp the concept of facial recognition by AI was largely achieved.

Discussion

The exit ticket survey results suggested that the game helped students learn about facial recognition and AI concepts. In particular, the creation of the face cards, considering the age and likely interests of the students, was effective. In each face card, gender and race were equally represented, and characters that are well-known to middle school students were selected. According to the camp instructor's observations, it was found that the students showed great enthusiasm when they found a character card they liked or were familiar with. This underscored the importance of personalizing the face cards according to student preferences.

As noted, facial recognition, which can be intricate for middle school students, was segmented into two phases: feature extraction and database searching, to facilitate students' comprehension of the technology and the related concepts on *Representation and Reasoning*. Specifically, by assigning the task of extracting features and searching the database to the Drawer and Guesser roles, respectively, students could learn to understand different AI concepts by switching roles in the game.

On the other hand, there are several limitations we identified during the implementations. First, each student prioritized different facial features when determining the significance of a face. Consequently, their strategies for extracting facial features (extracting one part intensively or extracting the entire face) were different, which substantially affected the accuracy of the face recognition task. Because of this, some teams could not make definitive guesses even with 30 to 40 features, while others could accurately recognize target faces using only with the character's 3 most salient features. For example, during one session, the winning team accurately identified its target with three features representing Beyoncé's narrow nose.

Second, one aim of the game is to help students understand how an AI system can perform facial recognition, but there is a gap in knowledge on how it works. Because AI does not have see like humans, these systems judge objects by encoded numeric values rather than visually recognizing them. In our game, the Guesser is different from actual AI systems in that the Guesser compares the extracted facial features with the database as visual data rather than reasoning based on specific values. However, for middle school students to understand this in-depth *Representation* concept, foundational knowledge or prior learning in computer vision would likely be required, so we left this part out of the game design, helping to ensure our unplugged activity is age-appropriate.

Conclusion

We introduced an unplugged board game tailored to middle school students to learn about AI, featuring facial recognition technology. This game integrates content aligned with *Representation and Reasoning* from AI4K12's 5 Big Ideas in AI, emphasizing the phases of 'feature extraction' and 'database searching.' During gameplay, each of the players—the Drawer and the Guessers—embodies each phase, collaboratively working to recognize the correct face. The game was designed to not only serve as an age-appropriate introduction to AI concepts but also give students an opportunity to understand the processes behind facial recognition systems.

During our piloting of the game with rural middle school students, the students showed significant interest in the cartoon characters and celebrity faces we adopted for the implementation. While playing the game, it seemed that students grasped how an AI system could make inferences utilizing the information given by sensors. The pilot also confirmed that the game is age-appropriate and that team competition can promote participation in our unplugged AI learning activity. Furthermore, through a post-survey, we gathered evidence on the educational effectiveness of the game, confirming that the students could explain facial recognition technology in their own words.

For future directions, it will be important to continue refinements to the game based on feedback and observations collected during the pilot study to improve the overall player experience. For example, adjusting the balance between adding noise and extracting features will be important. In addition, introducing a simpler version of the spinner (Figure 3) that utilizes two six-sided dice to pick the player's next action could enhance the scalability of our unplugged activity dispensing with the need to create the spinner. We anticipate that a dice chart, which visually correlates actions with corresponding dice numbers, will serve the same purpose as the spinner. Also, building upon our face card template, exploring a 'game construction toolkit' to enable teachers and students to design customized versions of the game is a promising avenue for future work (Beça et al. 2020). To support this, a web-based application could be developed that allows students to design their own face cards using characters of their choice. Lastly, given the potential for the misuse of facial recognition technology, it will be important to also explore how to incorporate AI ethics in our unplugged activity. Facilitating a post-gameplay discussion on AI ethics (e.g., how AI tools might impact and harm certain communities) could offer an opportunity for students to explore potential ethical issues and considerations that we must keep in mind when developing AI systems.

Acknowledgements

This research was supported by the National Science Foundation (NSF) under Grant DRL-2148680. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NSF.

References

Aggarwal, A.; Gardner-McCune, C.; and Touretzky, D. S. 2017. Evaluating the Effect of Using Physical Manipulatives to Foster Computational Thinking in Elementary School. In *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education*, 9–14.

Ali, S.; Kumar, V.; and Breazeal, C. 2023. AI Audit: A Card Game to Reflect on Everyday AI Systems. *arXiv preprint arXiv:2305.17910*.

Beça, P.; Aresta, M.; Ortet, C.; Santos, R.; Veloso, A. I.; and Ribeiro, S. 2020. Promoting Student Engagement in the Design of Digital Games: The Creation of Games Using a Toolkit to Game Design. In *2020 IEEE 20th international conference on Advanced Learning Technologies (ICALT)*, 98–102. IEEE.

Belfield, C. R.; and Levin, H. M. 2002. The Effects of Competition Between Schools on Educational Outcomes: A Review for the United States. *Review of Educational Research*, 72(2): 279–341.

Bell, T.; and Vahrenhold, J. 2018. CS Unplugged—How Is It Used, and Does It Work? *Adventures between Lower Bounds and Higher Altitudes: Essays Dedicated to Juraj Hromkovič on the Occasion of His 60th Birthday*, 497–521.

Cardona, M. A.; Rodríguez, R. J.; Ishmael, K.; et al. 2023. Artificial Intelligence and the Future of Teaching and Learning: Insights and Recommendations.

Chen, P.; Yang, D.; Metwally, A. H. S.; Lavonen, J.; and Wang, X. 2023. Fostering Computational Thinking Through Unplugged Activities: A Systematic Literature Review and Meta-Analysis. *International Journal of STEM Education*, 10(1): 1–25.

Eguchi, A.; Okada, H.; and Muto, Y. 2021. Contextualizing AI Education for K-12 Students to Enhance Their Learning of AI Literacy Through Culturally Responsive Approaches. *KI-Künstliche Intelligenz*, 35(2): 153–161.

Fullerton, T. 2014. *Game Design Workshop: A Playcentric Approach to Creating Innovative Games*. CRC press.

Giannakos, M.; Voulgari, I.; Papavlasopoulou, S.; Papamitsiou, Z.; and Yannakakis, G. 2020. Games for Artificial Intelligence and Machine Learning Education: Review and Perspectives. *Non-formal and Informal Science Learning in the ICT Era*, 117–133.

Hellerstedt, A.; and Mozelius, P. 2019. Game-Based Learning: A Long History. In *Irish Conference on Game-based Learning 2019, Cork, Ireland, June 26-28, 2019*, volume 1.

Ho, J.; Scadding, M.; Kong, S.; Andone, D.; Biswas, G.; Hoppe, H.; and Hsu, T. 2019. Classroom Activities for Teaching Artificial Intelligence to Primary School Students. In *Proceedings of International Conference on Computational Thinking Education*, 157–159. The Education University of Hong Kong.

Lee, S.; Mott, B.; Ottenbreit-Leftwich, A.; Scribner, A.; Taylor, S.; Park, K.; Rowe, J.; Glazewski, K.; Hmelo-Silver, C. E.; and Lester, J. 2021. AI-Infused Collaborative Inquiry in Upper Elementary School: A Game-Based Learning Approach. In *Proceedings of the AAAI Conference on Artificial Intelligence*, volume 35, 15591–15599.

Lindner, A.; Seegerer, S.; and Romeike, R. 2019. Unplugged Activities in the Context of AI. In *Informatics in Schools. New Ideas in School Informatics: 12th International Conference on Informatics in Schools: Situation, Evolution, and Perspectives, ISSEP 2019, Larnaca, Cyprus, November 18–20, 2019, Proceedings 12*, 123–135. Springer.

Ma, R.; Sanusi, I. T.; Mahipal, V.; Gonzales, J. E.; and Martin, F. G. 2023. Developing Machine Learning Algorithm Literacy with Novel Plugged and Unplugged Approaches. In *Proceedings of the 54th ACM Technical Symposium on Computer Science Education V. 1*, 298–304.

Maslej, N.; Fattorini, L.; Brynjolfsson, E.; Etchemendy, J.; Ligett, K.; Lyons, T.; Manyika, J.; Ngo, H.; Niebles, J. C.; Parli, V.; et al. 2023. The AI Index 2023 Annual Report. *AI Index Steering Committee, Institute for Human-Centered AI, Stanford University, Stanford, CA*.

Nishida, T.; Kanemune, S.; Idosaka, Y.; Namiki, M.; Bell, T.; and Kuno, Y. 2009. A CS Unplugged Design Pattern. *ACM Sigcse Bulletin*, 41(1): 231–235.

Pho, A.; and Dinscore, A. 2015. Game-Based Learning. *Tips and Trends*, 2.

Rowe, J. P.; Lobene, E. V.; Mott, B. W.; and Lester, J. C. 2017. Play in the Museum: Design and Development of a Game-Based Learning Exhibit for Informal Science Education. *International Journal of Gaming and Computer-Mediated Simulations (IJGCMS)*, 9(3): 96–113.

Scheidt, A.; and Pulver, T. 2019. Any-Cubes: A Children's Toy for Learning AI: Enhanced Play with Deep Learning and MQTT. In *Proceedings of Mensch und Computer 2019*, 893–895.

Shaffer, D. W.; Squire, K. R.; Halverson, R.; and Gee, J. P. 2005. Video Games and the Future of Learning. *Phi Delta Kappan*, 87(2): 105–111.

Touretzky, D.; Gardner-McCune, C.; Breazeal, C.; Martin, F.; and Seehorn, D. 2019a. A Year in K–12 AI Education. *AI Magazine*, 40(4): 88–90.

Touretzky, D.; Gardner-McCune, C.; Martin, F.; and Seehorn, D. 2019b. Envisioning AI for K-12: What Should Every Child Know about AI? In *Proceedings of the AAAI Conference on Artificial Intelligence*, volume 33, 9795–9799.

Vandenberg, J.; Min, W.; Catete, V.; Boulden, D.; and Mott, B. 2023. Leveraging Game Design Activities for Middle Grades AI Education in Rural Communities. In *Proceedings of the 18th International Conference on the Foundations of Digital Games*, 1–4.

Virtue, P. 2021. GANs Unplugged. In *Proceedings of the AAAI Conference on Artificial Intelligence*, volume 35, 15664–15668.

Wang, N.; and Lester, J. 2023. K-12 Education in the Age of AI: A Call to Action for K-12 AI Literacy. *International Journal of Artificial Intelligence in Education*, 1–5.

Wang, N.; Tonko, P.; Ragav, N.; Chungyoun, M.; and Plucker, J. 2022. A Perspective on K-12 AI Education. *Technology & Innovation*.

Wohl, B.; Porter, B.; and Clinch, S. 2015. Teaching Computer Science to 5-7 Year-Olds: An Initial Study With Scratch, Cubelets and Unplugged Computing. In *Proceedings of the Workshop in Primary and Secondary Computing Education*, 55–60.

Zhan, Z.; Tong, Y.; Lan, X.; and Zhong, B. 2022. A Systematic Literature Review of Game-Based Learning in Artificial Intelligence Education. *Interactive Learning Environments*, 1–22.