Designing a Visual Interface for Elementary Students to Formulate AI Planning Tasks

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***Abstract*—Recent years have seen the rapid adoption of artificial intelligence (AI) in every facet of society. The ubiquity of AI has led to an increasing demand to integrate AI learning experiences into K-12 education. Early learning experiences incorporating AI concepts and practices are critical for students to better understand, evaluate, and utilize AI technologies. AI planning is an important class of AI technologies in which an AI-driven agent utilizes the structure of a problem to construct plans of actions to perform a task. Although a growing number of efforts have explored promoting AI education for K-12 learners, limited work has investigated effective and engaging approaches for delivering AI learning experiences to elementary students. In this paper, we propose a visual interface to enable upper elementary students (grades 3-5, ages 8-11) to formulate AI planning tasks within a game-based learning environment. We present our approach to designing the visual interface as well as how the AI planning tasks are embedded within narrative-centered gameplay structured around a Use-Modify-Create scaffolding progression. Further, we present results from a qualitative study of upper elementary students using the visual interface. We discuss how the Use-Modify-Create approach supported student learning as well as discuss the misconceptions and usability issues students encountered while using the visual interface to formulate AI planning tasks.**

Index Terms—Artificial intelligence education for K-12, Visual interface, Game-based learning

I. Introduction

Advances in artificial intelligence (AI) are transforming society and the workplace of the future [1]. With a wide array of capabilities ranging from automated reasoning to machine learning and natural language processing to computer vision, AI is becoming a fundamental tool that people depend on to perform their work and carry out their daily lives [2], [3]. Nations around the world are recognizing the importance of AI and taking steps to develop strategies for creating and sustaining their AI research and development workforce (e.g., [4]-[6]). This has generated a vital need to foster AI literacy among K-12 students to enable them to successfully navigate the future where AI will be ubiquitous [7].

AI literacy centers on enabling individuals to understand and evaluate AI, communicate and collaborate with AI, and effectively use AI [8]. Recognizing that AI literacy is a critical competency for all students, efforts are underway to incorporate AI learning opportunities within K-12 education [9], [10], as well as to develop guidelines for K-12 AI education [11]. For example, a working group on AI K-12 education sponsored by the Association for the Advancement of Artificial Intelligence (AAAI) and the Computer Science Teachers Association (CSTA) has identified a set of big ideas in AI that all students should understand through a collaboration between AI experts and K-12 teachers. These big ideas include *Perception*, *Representation & Reasoning*, *Learning*, *Natural Interaction*, and *Societal Impact* [11]. Given the importance of early learning experiences for fostering students' perceptions and dispositions toward STEM, creating engaging and effective AI learning activities for elementary school students is an important endeavor.

Responding to the growing need to provide elementary students with AI learning opportunities, we are designing and developing PRIMARYAI, a game-based learning environment that enables students to gain experience with AI-infused problem solving [12]. Leveraging the benefits of game-based learning [13], PRIMARYAI aims to create effective and engaging AI learning experiences. Prior work has shown that well-designed game-based learning environments enable students to develop problem-solving skills, communicate and collaborate with other students, and actively participate in rich virtual contexts [14], [15]. Gameplay in PRIMARYAI is structured around overarching quests consisting of a set of missions for students to complete. The first quest in PRIMARYAI focuses on one of the big ideas in AI, *Representation & Reasoning*, by introducing students to AI planning in the context of using a virtual semi-autonomous robot to gather data on an endangered species. Research on AI planning investigates techniques to enable AI-driven agents, such as robots, to utilize the structure of a problem to construct plans of actions to perform a task [16]. Well-designed visual interfaces, languages, and tools tailored to specific users are critical to support learning and enable users to effectively express complex computational tasks [17]-[19]. In this paper, we present our work to design a visual interface for PRIMARYAI to enable upper elementary students (grades 3-5, ages 8-11) to formulate AI planning tasks during gameplay that leverages a Use-Modify-Create scaffolding progression [20]. We investigate three key research questions focused on introducing AI planning to upper elementary students using a visual interface:

RQ1: How does the proposed visual interface in concert with the Use-Modify-Create scaffolding progression help students express AI planning tasks?

RQ2: What misconceptions do students have while formulating AI planning task using the proposed visual interface?

RQ3: What hurdles do students encounter while using the proposed visual interface?

We conducted a study using PRIMARYAI along with the proposed visual interface with twenty-one upper elementary students to explore these questions. Qualitative analysis of video recordings of the students using the visual interface and interview responses from the students suggest that the proposed visual interface along with the Use-Modify-Create scaffolding progression hold significant potential for effectively supporting students to learn AI planning concepts.

II. RELATED WORK

A. K-12 AI Education

As AI has grown in prevalence, it has become increasingly important to educate students to learn and think critically about AI [21], [22]. A number of recent efforts have started to explore how to integrate AI into the K-12 curriculum and foster AI literacy among K-12 students. The AI4K12 initiative proposed the Five Big Ideas of what K-12 students should learn about AI [11]. Similarly, researchers at MIT have developed K-12 AI literacy resources that include a wide range of hands-on online AI learning activities for K-12 students to learn about AI [1]. ReadyAI[2] is creating pre-configured toolkits, such as AI-in-a-Box, that includes both hardware and software to teach AI courses to K-12 students. Additionally, Curiosity Machine[3] and AI with MIT App Inventor[4] [23], [24] are also available online to teach AI concepts and the basics of machine learning to K-12 students. Work is also underway to develop modules for K-12 students to learn about AI and how to use it responsibly [25]. For instance, researchers at MIT created the *AI and Ethics for Middle School* curriculum to teach middle school students about ethical issues in AI, such as bias in machine learning algorithms and ethical design principles [10], [26]. Our work on PRIMARYAI fills a gap in the ongoing work by investigating how game-based learning can be used to integrate AI education into upper elementary classrooms.

B. Visual Interfaces for K-12 Computer Science Education

Providing a simple and intuitive visual interface for K-12 students who are not familiar with expressing computational tasks is a challenging endeavor. Although there are many text-based programming tools for K-12 students (e.g., Gidget [27], CodeCombat [28]), researchers are increasingly exploring visual interfaces such as block-based programming languages to help novices learn to program. This is especially appealing for young learners. There are a variety of block-based programming languages, such as Blockly [29], Scratch [30], Snap! [31], and MIT App Inventor that have been developed and utilized in K-12 classrooms. Smith et al. [32] developed an approach to use block-based programming for interactive storytelling to engage upper elementary students in computational thinking. Bradbury et al. [33] investigated how to effectively design collaborative programming environments for elementary students, where students used a block-based programming language called *NetsBlox* [34]. Hill et al. [35] introduced *LaPlaya*, a block-based programming language designed specifically for 4^{th}-6^{th} grade students. They analyzed the benefits of different block-based programming constructs for students and curriculum developers. Our efforts build upon this prior work to design a visual interface for upper elementary students to enable students to formulate AI planning tasks in a game-based learning environment.

C. Visual Interfaces for K-12 AI Education

Efforts are underway to develop visual interfaces, tools, and curricula to support K-12 students to engage with AI tools and learn AI concepts and practices. These visual tools enable students to explore machine learning, computer vision, and other AI technologies by creating opportunities for students to explore and learn about AI on their own. For example, Google's Teachable Machine [5] [36] uses a web-based interface that enables students to train and test machine learning models to classify images, poses, and sounds. AI Programming for eCraft2Learn[6] is an extension to Snap! [31] that enables students to build their own AI program to recognize images and speech. Cognimates [37] is an open-source platform for AI literacy for students between 7-14 years old, and it has an integrated extension for Scratch [30]. Cognimates allows students to participate in creative programming activities that includes building their own AI models to perform image classification, speech recognition, and sentiment analysis. Similarly, other tools also extend block-based programming languages to support building machine learning applications for students unfamiliar with programming. Machine Learning for Kids (ML4Kids) is an extension to Scratch and helps students build simple AI programs by leveraging AI models powered by IBM Watson [38]. PoseBlocks [39] provides a custom block-based programming interface developed on top of Scratch, supporting body, hand, face, and emotion recognitions to help middle school students explore AI concepts. Scratch Text Classifier

[1] https://raise.mit.edu
[2] https://www.readyai.org
[3] https://www.curiositymachine.org
[4] https://appinventor.mit.edu/
[5] https://teachablemachine.withgoogle.com/
[6] https://project.ecraft2learn.eu/

[40] helps middle school students become more knowledgeable about how classifiers work, allowing students to create their own project using a custom created text classifier. The AI Snap! blocks [41] is an extension to Snap!, allowing students to create machine learning applications by utilizing a set of predefined machine learning blocks.

Researchers have begun to systematically create AI curriculum and tools for K-12 students to learn AI. However, most of the prior work has focused on teaching machine learning with either middle or high school students. Little work has investigated effective and engaging approaches for promoting upper elementary students to learn AI concepts. Unlike most previous work that has focused on machine learning in upper K-12 grades, the work presented in this paper explores a visual interface that allows upper elementary students to formulate AI planning tasks within a game-based learning environment.

III. PRIMARYAI GAME-BASED LEARNING ENVIRONMENT

In this section we provide a brief overview of the PRIMARYAI game-based learning environment as well as discuss the design of the visual interface integrated within the game to support upper elementary students in formulating AI planning tasks during gameplay.

A. *Game Design*

PRIMARYAI is a game-based learning environment that is being designed to enable AI learning for upper elementary students (Figure 1). The learning environment enables students to learn about AI by engaging in a rich storyworld in which they address life science problems using AI tools. In the game, students play the role of an ecologist to investigate the recent declining population of yellow-eyed penguins on New Zealand's South Island. Throughout their exploration in the game, students complete a series of AI-centric quests that help them gather data and evaluate hypotheses regarding the interactions among wildlife on the island. The learning environment's curricular content is driven by the Next Generation Science Standards [42] as well as concepts and practices from the K-12 Computer Science Framework [43] oriented towards age-appropriate AI concepts.

PRIMARYAI gameplay incorporates three quests that cover key AI concepts: *AI planning*, *Machine Learning*, and *Computer Vision*. In the first quest, students learn that the yellow-eyed penguins are very shy around humans and are asked to collect data using a robot disguised as a penguin—playfully referred to as RoboPenguin in the game. Students learn to formulate AI planning tasks using our proposed visual interface to control the robot to collect photos of wildlife from designated areas on the island (e.g., beach or nest). In the second quest, students are asked to review the collected photos and apply labels to each photo, so that they can train the robot to learn how to correctly classify wildlife photos as either penguins, weasels, or other wildlife. This quest introduces students to supervised machine learning concepts. In the final quest, students are asked to learn about and use computer vision techniques to further enhance the robot's capabilities. For example, providing the robot with the ability to accurately recognize predators of the penguins, which

Fig. 1. PRIMARYAI Game-Based Learning Environment.

might be contributing to the recent decline in the penguin population. The version of PRIMARYAI used in the study described in this paper focuses on the first quest, which introduces AI planning concepts, the other two quests are under development.

To help students gain a deeper understanding of the AI concepts and practices being covered in PRIMARYAI, the quests are organized using a Use-Modify-Create (UMC) scaffolding progression, which has shown promise for promoting the acquisition and development of computational thinking skills [20]. For example, PRIMARYAI's first quest on AI planning uses a UMC scaffolding progression consisting of three missions: 1) *Use*: students are initially provided a fully formulated AI planning task in the visual interface in order to support them in becoming familiar with the interface and the planning tasks being addressed, 2) *Modify*: students are asked to manipulate blocks in a partially formulated AI planning task using the visual interface, 3) *Create*: students are asked to formulate a new AI planning task from scratch using the visual interface. We expect that this UMC approach will help scaffold student learning during the quest.

B. *Visual Interface for Formulating AI Planning Tasks*

The visual interface for formulating AI planning tasks in PRIMARYAI is shown in Figure 2. This interface enables upper elementary students to specify AI planning tasks through initial states, possible actions, and goal states. The design of the interface was refined through several rounds of iterative feedback and refinement with the goal of delivering a clear concept of AI planning while interacting with the visual interface. Students can observe how each component in AI planning contributes to the generated plan and how different AI planning problem constructions affect the AI robot's action in the game. The visual interface consists of three main functional areas: *Control Panel*, *Block Panel*, and *AI Planning Panel*. The Control Panel along the top of the interface enables students to deploy the robot in the virtual storyworld using their formulated AI planning task, revisit the mission briefing describing the task that needs to accomplished using the robot, and reset the AI

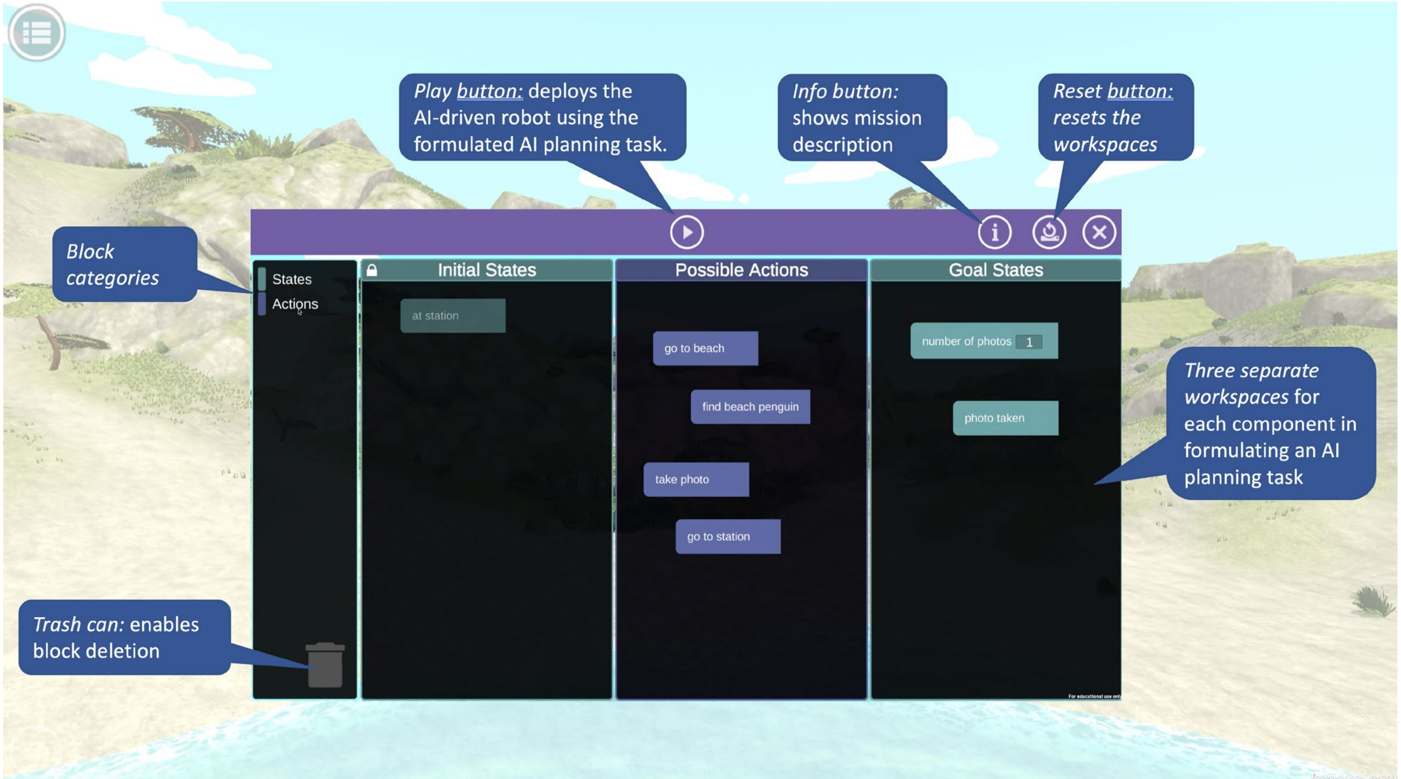

Fig. 2. Proposed visual interface for formulating AI planning tasks.

Planning Panel to its original configuration for the mission in case the student would like to start over.

The Block Panel along the left side of the interface allows students to select blocks from two different categories: States and Actions. The blocks are color coded based on the part of the AI planning task specification that they correspond with and can only be dropped in the appropriate columns of the AI Planning Panel. For example, students can only move blocks under the *Actions* category into the *Possible Actions* workspace of the AI Planning Panel. The Block Panel also includes a trash can icon, which allows students to delete unwanted blocks from the workspaces by dropping the block onto the icon.

The AI Planning Panel, which occupies most of the interface, consists of three vertically-divided workspaces that represent the key components of the AI planning task specification. The *Initial States* workspace is pre-populated by the game based on the context of the mission (e.g., robot is currently located at the research station on the island), which allows students to understand the starting state for the robot and think about which actions and goals are appropriate for achieving the objective of the mission. The *Possible Actions* workspace allows students to specify which actions should be considered, while creating a plan for achieving the mission objective. Finally, the *Goal States* workspace is used to specify the goals that need to be achieved in order for the mission to be successfully completed. As students drag blocks from the Block Panel to the workspaces, they are highlighted in yellow when the block is over a valid workspace, otherwise the blocks are highlighted in red. When a block is dropped onto an invalid workspace (i.e., highlighted in red), the block snaps back to its original location to help ensure students learn to place blocks correctly.

Using the visual interface, students specify AI planning tasks for the robotic penguin. Students drag blocks from the States and Actions block categories to specify the AI planning task based on the mission's scenario (e.g., "Take three pictures of penguins at the beach and come back to the station"). After specifying the AI planning task using the visual interface, students can watch the robotic penguin plan and execute actions to achieve the goals based on their formulated AI planning task. Figure 3 shows the view of the robotic penguin students see as it executes the plan. The AI Dashboard on the left side of the screen shows students aspects of the plan as the robot executes the plan (e.g., goals, current actions). The current action is also presented in a thought bubble above the robotic penguin's head to help students follow what action is currently being executed. This indicator is also used to notify whether a goal is being achieved by the robot, or if it is unable to create a plan based on the student's AI planning task formulation.

To develop the visual interface for specifying AI planning tasks, we iteratively evaluated different design alternatives with elementary school teachers who have been co-designing PRIMARYAI with the research team over the last year. Early mockups of the interface were created using the Blockly developer toolkit to support design discussions with the teachers (Figure 4). The first mockup we worked on with teachers is shown in Figure 4a where a nested block was utilized to represent the AI planning task specification (i.e., initial state,

Fig. 3. In-game screenshot of the plan being executed by the robotic penguin based on a formulated AI planning task.

possible actions, and goals) where state and action blocks could be attached to it. This approach had several advantages: 1) students would likely find it easy to manipulate, since it is similar to other block-based programming environments, and 2) we could leverage an existing block-based programming toolkit based on Blockly that was designed specifically to integrate with game-based learning environments [44], which would speed up development. However, after discussing the approach with our partner elementary school teachers, several concerns were identified: 1) stacking the state and action blocks vertically might inadvertently suggest to students that the states and actions are sequential in nature, and 2) using a more traditional block-based programming design might give students the impression that they can program the AI agent directly.

After working on the first mockup, additional design alternatives were explored (Figure 4b and Figure 4c). Figure 4b attempts to address the sequential order concerns by explicitly showing that states and actions are contained in a "set" block where students can manipulate the number of possible actions or states using the "+" and "-" signs on the block; however, this design raised concerns of being overly complex for upper elementary students. Figure 4c explores another approach at resolving the sequential ordering concern, while providing students with an easier approach using checkboxes to modify and test their AI planning task formulation; however, this design raised concerns of not being scalable to larger AI planning tasks that incorporate a variety of actions and states. After reflecting on all of the alternatives we concluded that although we could probably resolve the sequential ordering issues within the individual components, the outer nested block still presented challenges by implying a sequential relationship between initial states, possible actions, and goals. Unlike traditional programming tasks upper elementary students are familiar with, the specification of an AI planning task is less sequential in nature. The AI planning agent considers each of the components in an AI planning task formulation to come up with a plan (i.e., sequence of actions that can achieve the goals). Thus, in the final version of the interface as described above (Figure 2), we aimed to make the interface as easy to understand as possible for upper elementary students, while addressing the concerns raised by our partner teachers.

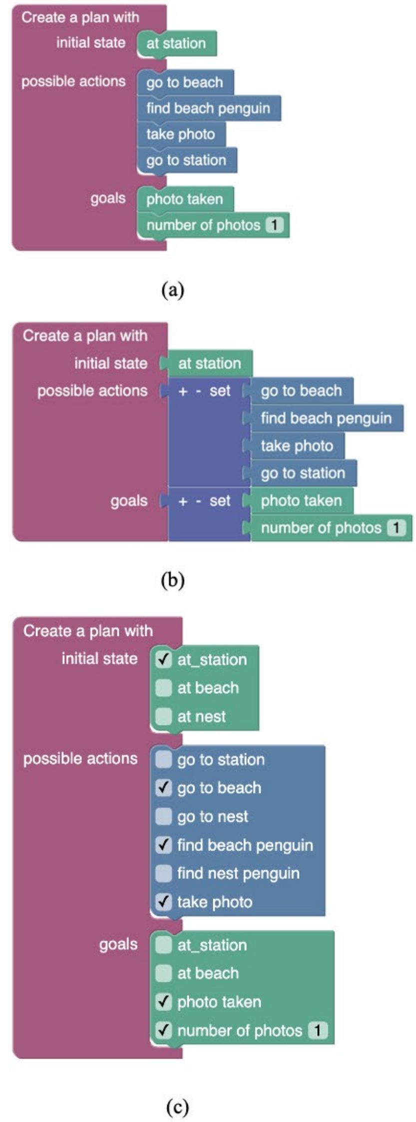

Fig. 4. Three mockup designs for AI planning task formulation from early design iterations.

IV. Method

A. Study Design

In order to test our visual interface to support upper elementary students in expressing AI planning tasks, we conducted a qualitative study, which consisted of data collections at two sites in Spring 2021, with twenty-one students (Figure 5). There were 14 male and 7 female students (12 third grade, 2 fourth grade, and 7 fifth grade students). All students were native English speakers. Prior to playing the game, students were engaged in pre-survey and unplugged activities to gauge their prior knowledge as well as introduce the basic concepts around AI planning. During gameplay, students were encouraged to ask questions if they needed any help proceeding through the game. As described in Section 3, we adopted a Use-Modify-Create approach to present the AI planning tasks to the students in the game. The mission scenarios we used were as follows:

- *Use*: A non-player character (NPC) in the game, who narrates the missions, adds the appropriate actions and states to the workspaces to specify the AI planning task for the students. Using this formulated AI planning task, the robotic penguin will take a picture of a penguin at the beach and then return to the research station. Students are asked to review the formulated AI planning tasks in the visual interface and deploy the robotic penguin.

- *Modify*: The NPC asks students to revise the formulated AI planning task using the visual interface so that the robotic penguin will take 3 photos of penguins at the beach and then return to the research station.

- *Create*: The NPC informs the student that someone accidentally deleted all the possible actions and states from the formulated AI planning task, so students are asked to specify a new AI planning task to control the robotic penguin using the visual interface.

In this study, we collected video recordings of students' screens along with voice recordings during their gameplay. Collecting the video recordings allows us to carefully examine the students' behavior during the gameplay, and is helpful in capturing students' micro-interactions with the learning environment [45]. After 45 minutes of playing the game, some of the students participated in interviews where they were asked questions about the game, the visual interface, and what they learned about AI.

B. *Qualitative Analysis*

To analyze the collected recordings, we leveraged Ramey et al.'s approach to qualitative analysis of video data, which focuses on three themes of video analysis; transcription tensions, defining the unit of analysis, and representing context [46]. First, we defined the specific things we were interested in exploring using the collected data based on our research questions: 1) Using the proposed visual interface, are students becoming familiar with the AI planning task formulations by going through the missions? 2) What are the misconceptions students present while formulating the AI planning tasks? 3) What hurdles do students encounter while using the visual interface (i.e., usability issues)?. Second, based on the defined unit of analysis, we transcribed our recordings iteratively to capture both verbal and non-verbal interactions (i.e., screen-based activity) during gameplay. Lastly, we extracted general patterns from the observations from multiple students in our study.

V. RESULT AND DISCUSSION

In this section, we discuss the student behavior and reactions we observed from the recordings, interview responses from the students, and design implications from the study observations.

A. *Observation*

Overall, students were very active while playing the game. The recorded data contained many examples of students' verbal reactions of excitement about the game-based learning environment. Also, students seemed to be deeply engaged in the overarching narrative of the game. Considering our target students are upper elementary students, seeing them engaged in the learning environment was a positive step in delivering the desired learning outcomes. The following excerpts from the recordings demonstrate some of the reactions to the visuals and problem solving tasks in the game-based learning environment:

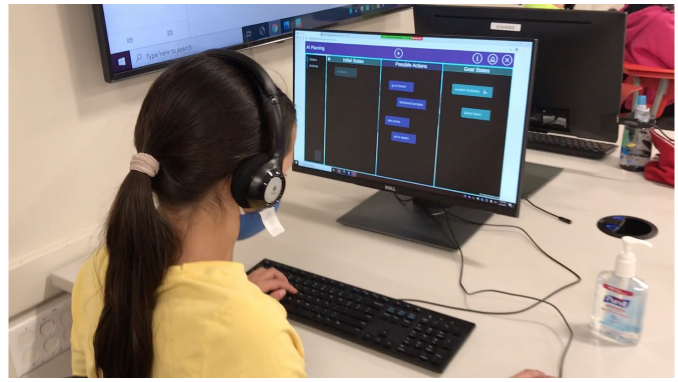

Fig. 5. Student playing PRIMARYAI in the study. The student is formulating an AI planning task using the in-game visual interface.

- *"Penguins are adorable!"* (While seeing the penguins in the game)
- *"Oh, he came through a bush!"* (Pointing at a penguin)
- *"Go RoboPenguin, go!"* (While seeing the robotic penguin approaching a group of penguins)
- *"Why Ted… why?"* (Reacting in the third mission to one of the engineers, Ted, who accidentally erased the possible actions from the AI planning task formulation)
- *"I want to see the baby penguins in the nest!"* (While dragging action blocks related to taking photos of the penguins)

Related to our visual interface for expressing AI planning tasks, all students successfully formulated the tasks using the proposed visual interface and most of them completed all provided missions (*RQ1*). First, none of the students seemed to have difficulties with dragging and dropping blocks. We believe this is one of the advantages our visual interface gets from adopting a look-and-feel similar to block-based programming, since many students will have some familiarity with block-based programming. Also, students seemed to understand that the robotic penguin executes actions that are listed in the Possible Actions workspace. Students did not appear to have any issue with understanding the language used in the blocks, which suggests that our visual interface is intuitive for upper elementary students; however, since our participants were all native English speakers, additional study is needed to confirm this with a broader population of upper elementary students.

Furthermore, we observed that most students were able to specify the complete AI planning task in the final mission suggesting that the Use-Modify-Create scaffolding progression is supporting student learning of AI planning concepts. However, we also observed that some students complained about the tasks being too repetitive. This might have been because the planning tasks were too easy for the students or because there needs to be more variation between the tasks in each mission. This will require additional investigation to identify the appropriate balance between "not too difficult" and

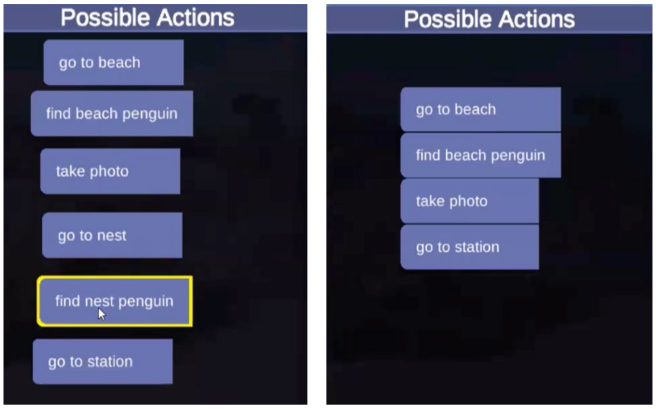

Fig. 6. Observed student misconception about the sequential order of blocks in formulating an AI planning task. The student is inserting a new block before the "Go to station" block that is always executed at the end of the plan (Left). The students made all blocks left-aligned and attached to one another (Right).

"not too easy" when considering the task variations, or possibly developing several sets of tasks that are adaptable for individual students' knowledge competencies.

We observed a key misconception held by many students as they formulated their AI planning tasks (*RQ2*). Although the possible actions and states in the task formulation are not sequential, it was clear from reviewing the videos that many students tried to align the blocks sequentially as they do in other block-based programming environments. In an attempt to prevent this misconception, we intentionally laid out the pre-populated blocks in the workspaces during the Use and Modify missions so they were not aligned; however, that scaffolding was insufficient since students still seemed to view the blocks as being sequential actions from top to bottom. Although some of the actions (e.g., "Find beach penguin", "Take photo") are iteratively executed in the generated plan multiple times, the current design can still lead to this misconception. We also observed students trying to organize all of the other possible actions on the workspace before the "Go to station" action, which is always executed at the end of a successful plan but does not need to be necessarily at the end of the AI planning task specification (Figure 6, Left), or trying to attach blocks to each other by aligning them (Figure 6, Right).

Lastly, we observed some usability issues with the visual interface that could generate frustration, and lead to students disengaging from the learning activities (*RQ3*). As shown in the lower-left corner of Figure 2, the trash can icon is available to allow the deletion of blocks from the workspaces. This is similar to the functionality found in block-based programming languages such as Blocky, but since we have three workspaces for each component in the AI planning task formulation some of the blocks on the workspaces are rather far away from the trash can icon. This was not an issue for students who used a mouse; however, for some students who used a trackpad or touch screen on their computer, we observed it was difficult for them to drag the blocks to the trash can at times. Also, in the current version of the interface blocks have to be properly aligned over the trash can icon to allow block deletion (i.e., when it is highlighted in yellow) (Figure 7). Since we expect students will need to iteratively test formulating their AI planning tasks to develop

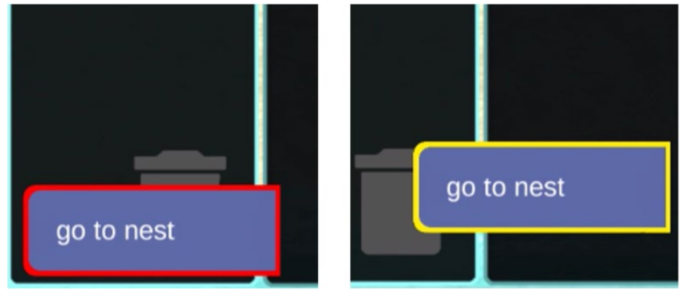

Fig. 7. Observed usability issue when deleting blocks. A block cannot be deleted when it is highlighted in red (Left), and it can only be deleted when highlighted in yellow (Right).

complete solutions, by manipulating the blocks it is critical to enhance the usability of block deletion in our visual interface.

B. *Interviews*

After playing the game, we conducted interviews with a subset of the students to get their feedback on the learning environment as well as to understand how the visual interface was being received. The questions along with a set of representative responses from the students are listed below

What did you think of the game?

- *"It was pretty fun, I liked it."*
- *"I liked the animations."*
- *"I thought it was great. It was really well programmed for people to use the environment. It was pretty impressive."*
- *"It was pretty interesting and it taught me a lot about AI that how simple it can be. I always thought AI is the super complex thing, and it still can be, but also it can be super simple just like planners."*

What did you like about the visual interface for specifying AI planning tasks?

- *"I thought [it was] more interactive because if you didn't exactly create [the AI planning task formulations], it would be just you pressing play and watching everything [...] so I thought [the visual interface] made [the game] a little bit more fun."*
- *"I felt [the visual interface] was very customizable. There were so many things you could do."*
- *"I loved it. I felt like [the game] was very interactive. I really liked the coding part because [the visual interface] puts into initial states, possible actions, and goal states, which I thought it was actually pretty cool."*

How could we make the visual interface for specifying AI planning tasks better?

- *"I would make it a little more detailed, so under [the AI Planning Panel], it tells you [more] about possible actions."*
- *"For the number of photos, you could say how many photos you want to have taken in the end, so that kids*

know actually what [the block] means. I feel like a lot of kids don't exactly understand and [might] interpret it in a wrong way and something could go wrong."

- *"I think [a] pop up [with a detailed description] when you hovering over [the components in the interface] would be nice."*
- *"For some students with blurry vision, it might be really hard for them [to read the text in the blocks], so maybe we could increase [the text size] a bit."*
- *"Having a slider that can change the text size would be helpful."*
- *"Initial state color can be a different color [than] the goal states."*

What did you learn about AI?

- *"I learned how simple AI is and how AI can be used to help study endangered species."*
- *"I learned AI can be used to help people and animals."*

What did you think about using an AI-driven robotic penguin to save the yellow-eyed penguins?

- *"It was a pretty smart idea because it combines science and ingenuity all in one."*
- *"I thought it was really cool how someone engineered up robot penguins to take pictures of real ones."*

Overall, students' responses show that they were engaged in the game and the ability of manipulating the robotic penguin using our visual interface made the game more interactive. Students' suggestions on the visual interface point to potential improvements to make to the visual interface. Lastly, students were interested in the game's approach of connecting life-science problems with AI learning, and started to see AI as a useful tool that is not as complex as one might imagine.

C. Design Implications

From the study observations, we identified a set of design implications for supporting student learning. First, the representations used in visual interfaces for the components of an AI planning task are very important in supporting student learning. Although we carefully designed the proposed visual interface to reduce potential misconceptions, additional refinement of our representations are still needed so that we can clearly deliver the fact that the actions as laid out in the interface are not necessarily sequential, and they do not need to be connected together for the AI-driven agent to successfully create a plan. A few ideas we are exploring to address this issue include: 1) better arrangement of the pre-populated blocks so they are distributed both horizontally and vertically, in the Use and Modify missions, to show that the blocks do not need to be sequentially aligned, 2) providing immediate feedback to students whenever they are trying to connect two blocks together in a workspace. Secondly, given that elementary classrooms utilize a wide array of computing platforms, we need to refine the design of our visual interface so that it better supports a range of input devices (e.g., trackpads). As mentioned earlier, one of the main usability issues identified during the study was with using the trash can icon to delete unwanted blocks. Potential approaches to resolving this issue, include: 1) exploring other deletion schemes (e.g., right-click and remove), or 2) placing a trash can icon in each workspace so they are closer to the blocks being deleted. Lastly, based on students' suggestions on the visual interface, we should explore a few areas for improving the usability of the interface: 1) supporting a tooltip-mode where students can click or hover over components in the visual interface (e.g., blocks, icons, terms) and see details on it, 2) introducing a revised color scheme for each of the three components in formulating an AI planning task, and 3) introducing accessibility functions such as resizable text or customizable color schemes.

VI. Conclusion

Accelerating advances in artificial intelligence have introduced the need to introduce AI education to K-12 students. In this work, we proposed a visual interface for elementary students to formulate AI planning tasks within a game-based learning environment. The qualitative analysis of recordings and student interviews showed how our visual interface and a Use-Modify-Create scaffolding progression helped students learn about AI planning. The analysis also identified student misconceptions while using the visual interface as well as usability issues with the current version of the interface. As we continue to develop PRIMARYAI, it will be important to refine the visual interface and conduct additional rounds of testing. Adopting rigorous qualitative data analysis will be important as we iteratively modify-and-test our environment. As AI education continues to expand into K-12 settings, it will be important for future work to explore age-appropriate visual interfaces across a wide range of grade levels and AI concepts, including machine learning and computer vision. Co-designing these visual interfaces and tools with elementary school teachers and students will help ensure they are designed to meet the needs of K-12 classrooms. Another promising area of future work is to explore how AI-driven adaptive learning techniques can tailor the AI problem solving tasks for individual students as well as the feedback provided by visual interfaces supporting student learning to assist a broader population of upper elementary students.

Acknowledgment

This work is supported by the National Science Foundation through grants DRL-1934153 and DRL-1934128. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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