Exploring Adaptive Scaffolding in a Multifaceted Tangible Learning Environment

Elissa Thomas, Victor Girotto, Alex Abreu, Cecil Lozano, Kasia Muldner, Winslow Burleson, Erin Walker

Computing, Informatics & Decision Systems Engineering, Arizona State University

{eethomas, victor.girotto, alexabreu, cecil.lozano, katarzyna.muldner, winslow.burleson, erin.a.walker}@asu.edu

Abstract. The majority of educational software is designed for traditional computers, which allow little opportunity for physical manipulation of an environment. Tangible Activities for Geometry (TAG) provides students a tangible learning environment. Currently, however, TAG does not employ adaptive scaffolding techniques. Accordingly, we describe how scaffolding techniques and teachable agent behaviors can be integrated into TAG to improve this tangible learning environment.

Keywords: adaptive scaffolding, tangible learning environments, teachable agents

1 Introduction

Open-ended learning environments (OELEs) enable students to actively engage in problem solving, such as generation, testing and revision of a hypothesis [1]. However, most educational systems target personal computers and their typical WIMP (window, icon, menu, pointing device) setup. These systems rarely allow for embodied interaction between the student and the learning environment, despite the fact that students learn a great deal through physically engaging with their environment [2]. The *Tangible Activities for Geometry* system (TAG) aims to fill this gap, by providing a tangible OELE where students can move beyond the boundaries of the virtual world and explore different strategies for solving geometric problems [3].

The current TAG system provides no feedback or adaptation to the user's performance. Therefore, our goal with this paper is to propose ways of integrating adaptive scaffolding techniques into this tangible learning environment (TUI), laying the foundation for studying the effects that they would have in this type of learning environment. The majority of TUIs do not currently possess such capabilities, which allows us to start exploring this intersection. Here, we will review existing frameworks and techniques that can be used for scaffolding the user's learning in an adaptive manner and will describe ways in which they could be applied to our system.

2 Description of Current System

In the current implementation of the TAG system, a student solves geometry problems by instructing a teachable agent on the steps needed to solve the problem. Problems include plotting a point in a given quadrant, translating a point, or rotating a point around a center of origin. While answers are sometimes the same, problems can often be solved in different ways. The system is comprised of three main components [3]. The *problem space* is a Cartesian plane projected on the ground. This is where the teachable agent and the problem objects, such as lines and points, are displayed. The interactions with the problem space occur through a *hanging pointer* that hangs from the ceiling, functioning as a mouse. Hovering the pointer over the problem space moves the cursor. Clicking is performed when the user moves the pointer below a certain height threshold and back up. The feedback for the user's interactions on the problem space is received on the *mobile interface,* displayed on an iPod Touch. In this interface, the user is able to select an action that will be performed by the agent, view the steps already taken, and navigate through problems.

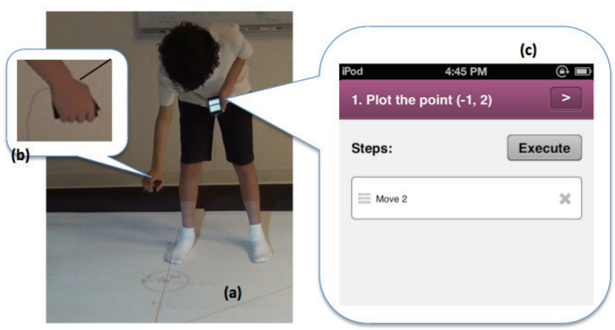

Figure 1: Elements of the TAG system. The problem space (a), where the Cartesian plane is projected, the hanging pointer (b), used by the student to interact with the problem and the mobile interface (c), the iPod interface commands are issued to the agent.

3 Review of Existing Pedagogical Techniques

Prior research has explored how various pedagogical techniques impact student learning. A number of these rely on a teachable agent paradigm, where students learn by tutoring a computerized agent modeled to simulate behaviors of a student tutee. For instance, reflective knowledge building uses questions and explanations generated by a teachable agent to prompt students to reflect on their own understanding of various concepts, and refine their ideas [4]. Agents could also use this technique to introduce new ideas to a student's existing knowledge [5].

Other research has shown that the level of abstraction in the advice provided by a teachable agent can impact a student's perceptions and performance. Students who work with agents that give different kinds of feedback, ranging from high-level advice to concrete, task specific suggestions, performed better than students who interacted with agents that only used task-specific suggestions [6].

Techniques used in cognitive tutors can also be useful for extending TAG. Cognitive tutors provide the user with feedback on a step-by-step basis, in response to common errors and with on-demand instructional hints, and adapt the selection of problems based on user-performance [7]. The challenge is to adapt these techniques to an open-ended system such as TAG while still encouraging open-ended exploration.

4 Proposed Extensions on the Current System

We propose expanding TAG to employ adaptive scaffolding as a way to increase the system's effectiveness. Techniques such as reflective knowledge building could be integrated into our system to improve student learning while also enhancing unique tangible aspects of our system. For example, if the student is attempting to plot a point in quadrant II, but moved the agent into quadrant IV, a question from the agent might prompt the student to recognize that their actions are not leading them to the correct solution. As another example, after a student solves a problem, the TAG agent could propose an alternate solution, helping students evolve their ideas, which some students struggle to do in OELEs [8]. As an extension of adaptive scaffolding in a traditional learning environment, students could also be encouraged to try additional tangible interactions that may not have been incorporated into their original solution.

Scaffolding could also be employed through hints given by the agent while a student is working on a problem. In this scenario, the agent uses cues that a student might be confused, such as a long pause without any activity, and provides a hint to guide the student in the right direction. Are there unique cues within TUIs that could be detected to improve an adaptive scaffolding model? To study this, our system could monitor embodied behaviors exhibited by the student, such as pacing back and forth or kneeling down on the projected Cartesian plane. Following standard convention, the agent's hints should vary in detail based on the student's performance within a given problem. Students would initially be provided with high-level feedback from the teachable agent, allowing them to apply the information given to them by the agent to the problem domain. If the student continues having trouble, the system can adaptively adjust the agent's hints to be more direct, allowing students to discover the correct approach, albeit, with less reflection on the metacognitive process. By providing feedback in this manner, we can foster an atmosphere of discovery, which should help students feel more engaged [2]. Since previous work has shown that increasing the sociability of an agent improves student perceptions of the system and student performance [9], hints from the agent could be provided textually through a pop up on the iPod interface while also being spoken by the agent.

On a less localized scale, adaptive scaffolding could also be applied based on a student's performance throughout an entire session. Indicators that could be used to measure student performance include the amount of time taken to solve a problem, the number of correct and incorrect solutions a student has produced, and the number of steps a student uses as compared to an optimal solution with a minimal number of steps. Applying this type of adaptive scaffolding in a TUI introduces some unique challenges. For example, how do we differentiate between students that are struggling with the problem domain and students that are having trouble understanding how to use the unique tangible interactions of our system?

5 Conclusion

By proposing a novel set of techniques to augment the TAG system, we aim to provide the appropriate level of scaffolding needed to improve student learning, while maintaining student engagement when faced with difficulties and failure. The ultimate goal is to ensure that students receive help when it is needed, but are not hindered during open-ended exploration. We also hope to learn more about how this scaffolding should be presented to the student on the different dimensions that a TUI provides, exploring the advantages and drawbacks of each type of scaffolding.

References

1. Land S. Cognitive requirements for learning with open-ended learning environments. Educational Technology Research and Development. 2000, Volume 48, Issue 3, pp 61-78.
2. Walker, E, and Burleson, W. User-Centered design of a teachable robot. Intelligent Tutoring Systems, 2012.
3. Mulder, K., Lozano, C., Girotto, V., Burleson, W., and Walker, E. Designing a Tangible Learning Environment with a Teachable Agent. Artificial Intelligence in Education, 2013.
4. Roscoe, D., Wagster, J., and Biswas, G., Using Teachable Agent Feedback to Support Effective Learning by Teaching, In Proceedings of the 30th Annual Meeting of the Cognitive Science Society, Washington, DC, 2008.
5. Blair, K., Schwartz, D., Biswas, G., and Leelawong, K. Pedagogical Agents for Learning by Teaching: Teachable Agents. In Educational Technology & Society: Special Issue on Pedagogical Agents, 2006.
6. Lester, J. C., Converse, S. A., Kahler, S. E., Barlow, S. T., Stone, B. A., and Bhogal, R. S. The Persona Effect: Affective Impact of Animated Pedagogical Agents. In Proceedings of CHI '97, 1997.
7. Koedinger, K., Aleven, V. Exploring the Assistance Dilemma in Experiments with Cognitive Tutors. 2007.
8. Land, S. M. Cognitive Requirements for Learning with Open-Ended Learning Environments. Educational Technology Research and Development 48.3, 2000.
9. Hershey D. K., Mishra P., and Altermatt, E. All or nothing: Levels of sociability of a pedagogical software agent and its impact on student perceptions and learning. Journal of Educational Multimedia and Hypermedia 14.2, 2005.