Using Augmented Reality Technology to Support Young Students' Embodied Learning Experience in Computational Tasks

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Abstract: This study introduces an Augmented-Reality-based learning system that aims to support young students' embodied learning in block-based programming activities where they learn computational concepts and create meaningful chunks of codes. Students are going to perform episode-embedded path-finding tasks, which are designed to practice their capacities of applying computational thinking in a reasonable manner to solve problems within different scenarios. Grounded on an embodied cognition approach, the AR integration creates a concrete and tangible environment for young students to understand abstract conceptual knowledge in an engaging and interactive way, with a close connection built between the real and virtual worlds.
Keywords: Keywords: Augmented Reality (AR), Computational Thinking (CT), Embodied Learning, Path-Finding Tasks, K-12

Introduction and Context

Recently, augmented reality (AR) has become a flourishing field that is intensively integrated into applications across various disciplines, by virtue of the interactive environment it creates (Garzón & Acevedo, 2019). Some essential yet abstract conceptual knowledge gets to be enacted and practiced through vivid visualization and situated scaffolds, leading AR to be increasingly used in numerous educational interventions (Bower et al., 2014; Wu et al., 2013). We believe such an advantage could be leveraged in the practice of embodied learning on fundamental computational thinking content for K-12 students, the applications of which are still a relatively sparse area. Therefore, this study integrates AR technology to introduce young students to computational concepts of symbol and sequence and emphasize the use of whole-body movements for the problem-solving process in block-based programming activities. As situated in an environment of hybrid realities, students will gain deeper understandings on the two concepts through some front-loaded interaction and the exposure to vivid representation of scenarios. Next, learners need to apply them to create algorithms for the paths to be physically enacted on the map, upon which virtual objects are superimposed by the AR technology.

Literature Review

AR supplements realities by laying 3D objects over or combining them with physical objects, which enables interwoven experiences that seamlessly connect the virtual and real worlds (Azuma, 1997; Wu et al., 2013).

Some science education studies have detected that the adoption of mixed realities could effectively reinforce the benefits of embodied learning - deepening conceptual understandings through bodily experienced learning - by building intuitions and strengthening spatial reasoning under the facilitation of real-time feedback (Lindgren et al., 2016; Peppler et al., 2020). With respect to learners' attitudes towards educational activities, AR applications are found with evidence on cultivating positive perspectives towards the content to be learnt and retaining deep engagements in the learning process (Kerawalla, 2006; Delello, 2014). Moreover, it contributes to learning effectiveness through a close examination on 3D objects (Sahin & Yilmaz, 2020). In computer science education, some emerging studies help participants practice programming grammars and logics by integrating AR to make concepts tangible, which report significant results on learning achievements (Fidan & Tuncel, 2019; Kao et al., 2022; Lin & Chen, 2020). Participants who accepted instruction with the higher AR interaction mode obtained higher programming achievements, compared to the lower AR interaction mode and traditional learning (unplugged activities) (Kao et al., 2022). Generally, AR-based programs help apply learned codes to appropriately solve specific problems by positioning participants to the context the problem is situated in (Lin & Chen, 2020).

Learning Design Based on AR

This study targets 2nd graders with limited experience in block-based programming activities. Five episode-based path-finding tasks are designed as a trial version with two main purposes regarding the later optimization of AR system: 1) detecting any technical deficiencies arising from the process of students' interaction with the system and making any necessary updates on both fundamental technologies and surface features; 2) getting insights of how students learn and apply computational concepts in this AR-based learning environment and reviewing the current pedagogical considerations on technology integration as well as the implementations of embodied learning in blended realities.

The desirable learning outcome is that students would be able to represent symbols' meaning with their body movements and, meanwhile, apply appropriate symbol codes in different circumstances. In the end of this learning, students are expected to create algorithms for at least one feasible path that fits the situational requirements, which could be seen as the rules to apply embodied programming in different scenarios. In the hybrid environment enabled by AR, virtual models for elements "missions" and "obstacles" are overlaid on the physical chessboard-like mat. Seeing the panoramic view of blended realities, students will gradually generate their path and finally complete them as more objects come into consideration about any potential impacts of their path constructs. Algorithms will be executed on the AR-enabled mats when students move towards or departing away from the objects being considered. Confronted with the incremental learning difficulties as more tasks proceed, students will be obligated to reflect upon their experience in the last path constructs and adapt into the new challenges, which are equipped with more complex configurations, and the accompanying requirements on the longer programming paragraphs and more comprehensive algorithms.

1) *Task 1: Knowing about Symbols and Sequences*. Students will move on a 2-by-2 grid mat step by step, according to the commands of directional symbols delivered by the AR system, through audio broadcast and the visual displays of symbols on the tablet screen. This task is designed to load students with conceptual knowledge of directional symbols and scaffold them to relate those concepts with concrete body languages.
2) *Task 2 & 3: Constructing Paths within Scenarios*. Students will perform a "house-building" task on the 2-by-2 grid mat and then perform a "rocket-assembling" task on a 3-by-3 mat. They will follow situational requirements to make movements to collect designated 3D mission objects placed on some grids and bring them to the destination. In these two tasks, learners will be prompted to make reasoning of the general configuration and conduct simple logical analysis on possible sequences to form at least one path that fits scenarios.
3) *Task 4 & 5: Delving into more complex paths*. Students will perform "Escaping from the Jurassic World" tasks. Prior to the actual learning moments on the 3D mat, students will first make plans on the paths to be performed by entering directional symbols, which will be recorded by the AR system as received commands, and then observe how a virtual character moves on the 2D map according to the algorithms they develop. Further, like what they will do in task 2 and 3, they are going to collect designated mission objects and bring them to the destination while avoiding obstacles halfway on a 4-by-4 or 5-by-5 grid mat. Noteworthily, the order of collecting certain objects is emphasized in task 5, to reflect the importance of logical steps to be orderly carried out in programming activities.

Through the communication bridged by the tablet with the AR system, students could easily navigate among pages, get informed of rules and scenario settings from the entry guidance in each task, and receive warning or celebration on their performance within tasks. Illustrative functions are embedded to the system to streamline the learning process, including symbols corresponding to body movements that pop up on the tablet screen, audio and visual instructions on objectives to achieve, real-time feedback on students' body movements to strengthen impressions for appropriate actions or prompt another attempt, and interactive animation effects on certain objects to inspire interests and the sense of achievements. Besides, with tracking records kept being demonstrated during path construction, students could modify or reconstruct paths anytime during the embodied movements by simply modifying inappropriate symbols with their body movements.

Findings

We conducted a preliminary pilot test with a 2nd grader. The participant easily identified the task objective in each scenario through the navigation and explanation from the AR system. Making good use of the real-time location detection, she quickly figured out her relative positions to virtual objects she needed to move towards or avoid. Besides, based on our observation, the participant modified paths several times by referring to the immediate feedback she received on her movements. Through this test, we successfully updated the AR system with improvements on three aspects: 1) offering a clearer instruction that is more friendly and accessible to young children's understanding levels, 2) improving the accuracy of offered feedback to avoid wrong confirmations on incorrect embodied movements or wrong warning signals on correct movements, 3) adding more detailed guidance on regarding which aspects they should modify their movements. More importantly, to tackle some fundamental technical problems such as unstable anchoring issues and the accuracy of the detection on movements and locations, we made several adjustments on our physical environmental settings, including the way we placed the physical mats and the scale of hand-held tablets. These improvements make strides toward a more user-friendly system that benefits the learning process with more accurate and stable feedback on students' embodied programming actions.

Discussion and Implications

Based on the preliminary pilot-test and researchers' close observation on developers' continuous experiments on the system, the AR-based learning environment could be a promising means of helping deepen understanding of computational concepts, which students apply to solve problems while exploring the virtual scenario settings around them with body movements. It is also expected to decrease students' cognitive overload by visualizing the cause-and-effect relationship of embodied programming in the participatory space. As students immerse in the interaction with the hybrid realities enabled by the AR system, the depth, and duration of engagement in the learning process could be significantly improved. Furthermore, the integration of AR is believed to promote young students' acceptance and adaptability to any newly emerging technologies in the future classrooms. With respect to the learning task design, since they are mainly developed to use in the pilot test that aims to improve the AR system, there are some deficiencies, admittedly, such as the disconnect of storylines among the five tasks. In the near future, a set of more culturally inclusive and playable tasks will be finalized with a consistent theme to string all the discrete scenarios together. More advancements on the current AR system will be made based on new tasks and examined in the formal pilot test to be conducted in a local elementary school in Indiana state.

Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant No.2048989.

References

Azuma, R. T. (1997). A survey of augmented reality. Presence: teleoperators & virtual environments, 6(4), 355-385. https://doi.org/10.1162/pres.1997.6.4.355

Bower, M., Howe, C., McCredie, N., Robinson, A., & Grover, D. (2014). Augmented Reality in education–cases, places, and potentials. Educational Media International, 51(1), 1-15. https://doi.org/10.1080/09523987.2014.889400

Delello, J. A. (2014). Insights from pre-service teachers using science-based augmented reality. Journal of computers in education, 1(4), 295-311. https://doi.org/10.1007/s40692-014-0021-y

Fidan, M., & Tuncel, M. (2019). Integrating augmented reality into problem-based learning: The effects on learning achievement and attitude in physics education. Computers & Education, 142, 103635. https://doi.org/10.1016/j.compedu.2019.103635

Garzón, J., & Acevedo, J. (2019). Meta-analysis of the impact of Augmented Reality on students' learning gains. Educational Research Review, 27, 244-260. https://doi.org/10.1016/j.edurev.2019.04.001

Kao, G. Y. M., & Ruan, C. A. (2022). Designing and evaluating a high interactive augmented reality system for programming learning. Computers in Human Behavior, 132, 107245. https://doi.org/10.1016/j.chb.2022.107245

Kerawalla, L., Luckin, R., Seljeflot, S., & Woolard, A. (2006). "Making it real": exploring the potential of augmented reality for teaching primary school science. Virtual reality, 10(3), 163-174. https://doi.org/10.1007/s10055-006-0036-4

Lin, P. H., & Chen, S. Y. (2020). Design and evaluation of a deep learning recommendation-based augmented reality system for teaching programming and computational thinking. IEEE Access, 8, 45689-45699. http://doi.org/10.1109/ACCESS.2020.2977679

Lindgren, R., Tscholl, M., Wang, S., & Johnson, E. (2016). Enhancing learning and engagement through embodied interaction within a mixed reality simulation. Computers & Education, 95, 174-187. https://doi.org/10.1016/j.compedu.2016.01.001

Peppler, K., Rowsell, J., & Keune, A. (2020). Advancing posthumanist perspectives on technology-rich learning. British journal of educational technology, (4), 1240-1245. http://doi.org/10.1111/bjet.12979

Sahin, D., & Yilmaz, R. M. (2020). The effect of Augmented Reality Technology on middle school students' achievements and attitudes towards science education. Computers & Education, 144, 103710. https://doi.org/10.1016/j.compedu.2019.103710

Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities, and challenges of augmented reality in education. Computers & Education, 62, 41-49. https://doi.org/10.1016/j.compedu.2012.10.024