A design-based research study of teaching non-STEM majors distance sensor in robotics

Word Count: 1604

1. Purpose and Research Questions of the Study

Robotic sensors detect, measure, and collect changes in their physical surroundings, such as temperature, distance, light, and colors (Benitti, 2012). These functions allow students to witness and manipulate the translation from abstract programming to concrete real-world actions or reactions. Therefore, educational robots have been widely used in K-12 science, technology, engineering, and mathematics (STEM) education (Blikstein, 2013). In this design-based research study, we compared two designs of a workshop to teach distance sensors to elementary education students. The first cohort participated in a short lecture and hands-on coding practice with the distance sensor. The embodied design was applied in the second cohort, who interacted more with the sensors through the embodied presentation and sensitivity test. The research question is: How did students' knowledge of distance sensor change as a result of the training in two designs?

2. Perspectives

Embodied design is a design methodology that emphasizes the human body interaction with the environment and its importance in helping us to learn and understand the world (Abrahamson & Lindgren, 2014). Abrahamson and Lindgren (2014) proposed three design principles to apply embodied design in education. The first principle, activities principle, requires students to "use their perceptual senses and kinesthetic coordination" (p. 6) to understand new concepts. The second principle, materials principle, requires an establishment of action-feedback loops between students' physical movements and their learning environment with the aid of tools. The third principle, facilitation principle, requires guidance and instructions, such as physical demonstration and hands-on coaching, to facilitate students' conceptual development.

Kopcha et al. (2020) in their study with fifth graders found that young students used physical movement to explain mathematical concepts or patterns. Sung et al. (2017) compared the full body versus hand-embodied learning activities in elementary students' learning of robotics. They found that students in full-body-embodied learning activities demonstrated better problem-solving skills than those in only hand-embodied activities. The results of these studies suggested that embodied design was promising in improving novice computer science learners' performance.

3. Cohort 1

This study used the design-based research methodology to examine the two designs of robotics sensor training in two semesters. The purpose of design-based research is to improve educational practices through an iterative process of designing, testing, and refining implementations in real classroom settings (Cobb et al., 2003). In this study, we implemented a traditional short lecture plus hands-on practice mode in the workshop for cohort 1. Activities with embodied cognition theory were applied to the cohort 2 workshop. We compared the quantitative and qualitative data collected from two cohorts to detect their differences on students' learning.

3.1 Participants

Cohort 1 included 22 junior undergraduates majoring in elementary education in Spring 2022 from a four-year university at southern U.S.. Most of them were between 22 and 25 years old, with 2 students older than 25 years old. Twenty-one of them were female and one was male students. Eighty-six percent of the students were Caucasian, 14% were Black or African American, and 4.5% were American Indian or Alaska Native. Eighty-six percent of the students took the fundamental training on computational thinking in prior technology courses.

3.2 Interventions

This training aims to improve students' understanding of the distance sensor used on mBot Neo®, an educational robot for upper elementary students. Before the training, students had learned the concepts of computational thinking and teaching lower elementary students computer science through unplugged activities. They put together the mBot Neo robots in small groups and learned the basic coding to move the robot forward, backward, or take turns.

A forty-minutes training session on distance sensors was offered to students. The traditional PowerPoint lecture explained the function, purpose, and working mechanisms of the sensor. The lecture explained where distance sensors were in mBot Neo® and how it uses ultrasonic waves to detect objects and measure distance. Then students followed the demonstration and coded mBot Neo® to move and avoid obstacles. The coding and testing were conducted in small groups.

3.3 Data Collection

The pre-test was delivered at the beginning of the training while the post-test was delivered after the training. Students had about 15 minutes to complete each test. The pre- and post-tests had the same set of six questions. They each included 5 multiple-choice and 1 open-ended question. The multiple-choice questions focused on the concepts of distance sensors and their coding, with each having four options and only one correct answer. Students who selected the correct answer for a question received 1 point. The open-ended question asked students to describe how the distance sensor worked. Students received 2 points if their answers included both working mechanism (e.g., sending/receiving ultrasonic waves) and purpose (e.g., detect/avoid objects/distance), They received 1 point if only answering one of them, and 0 point if giving wrong answers.

Students were required to complete a reflection immediately after the training. The reflection asked them to answer three questions: 1). What are your first thoughts about today's training? 2). What were some of your most challenging moments and what made them so? 3). What were some of your most powerful learning moments and what made them so?

3.4 Analysis

A paired sample t-test was conducted to examine the change of students' distance sensor knowledge. A qualitative thematic analysis was conducted on students' after-training reflection with an a priori coding method (Stemler, 2000). The two codes were the keywords from two reflection questions: challenges and powerful learning moments.

3.5 Results

Students' distance sensor knowledge had a significant improvement at the training, $t(21) = -7.25$, $p<.01$ (Table 1).

-Insert Table 1 about here.-

The results of qualitative thematic analysis on students' reflection showed that few students reflected their experiences with the distance sensor. Three students reported challenges with the sensors, e.g., "I did not understand the technological aspects of the sensors. This made the coding challenging." (personal communication, March 18, 2022). No one reported any powerful learning moments with the distance sensor.

4. The Redesign

Very few students reflected on their learning with the distance sensor. Most did not name it as their learning challenges or accomplishments. We posed that it could be that the learning was disconnected from students' experiences so they were not passionate about learning the sensors. Based on students' comments, it could also be the difficulty of understanding the sensor terms. If students could not name the parts of the sensor or even the name of the sensor, they would not be able to pinpoint their challenges.

Therefore, Abrahamson and Lindgren's (2014) embodied design principles were applied in the redesign of the workshop, which was extended to one hour. First, physical movement was used in the demonstrations to facilitate students' conceptual understanding. The instructor guided student volunteers in the physical body movement to show how the sensor directed the robot to move. Examples of animals using ultrasonic waves were added to the lecture. Second, a distance sensor sensitivity test was added to require students' use of "perceptual senses and kinesthetic coordination" (Abrahamson & Lindgren, 2014, p.6). In this test, students interacted with the sensor by placing different obstacles in front of it, such as mugs or boxes or hands, and observed the change of measured distance from the robot display screens.

5. Cohort 2

5.1 Participants

Cohort 2 included 25 junior undergraduates in elementary education in Spring 2023. Nineteen students reported their demographic information. Among them, sixteen were between the age of 20 and 25 years old with 3 older than 25. Eighteen were female and one was male. Seventeen students were Caucasian, 2 were Black or African American, and 2 were Hispanic or Latino. Seventeen students took the fundamental training on computational thinking in prior technology courses.

5.2 Data Collection & Analysis

A mixed ANOVA was conducted with pre and post-tests being the within variable. The two cohorts were the between variables. We used the same qualitative analyses as described in Section 3.4.

5.3 Results

Results showed a significant improvement in students' knowledge of the distance sensor as a result of the training, $F(1, 45) = 148.24$, $p<.01$ (Table 1). Cohort 2 outperformed Cohort 1, $F(1, 45) = 6.65$, $p<.05$. In addition, Cohort 2 had more growth than Cohort 1 regarding their knowledge of distance sensors (Figure 1).

-Insert Table 1 about here.-

-Insert Figure 1 about here.-

We observed more students reflecting on their experiences with the distance sensor in the after-training reflection, signaling a heightened level of cognitive engagement with the material. Five students thought their powerful learning moments were to understand how sensors worked, e.g., "the ultrasonic sensors are super sensitive." and "It was very cool to see how to code the robot to do all of these cool things like detecting objects and distance." (personal communication, February 20, 2023). Eleven students reported challenges with the distance sensor, e.g., "Getting the robot to sense objects at the right distance [is challenging]." (personal communication, February 20, 2023).

5. Significance

The results of our study suggested that physically interacting with the distance sensor improved students' conceptual understanding better than listening to the lecture. Although students in the first cohort learned to code the sensor and run the robot, they did not get an indepth chance to concretize their experiences with the working mechanisms of the sensor. Students in the second cohort used the readily-accessible objects, such as mugs or boxes, to place around or ahead of the sensor and test the distance through the sensitivity practice. They understood more about the sensor than the first cohort students. It resulted in their reflection of distance sensor learning experiences, which was rarely observed in Cohort 1 training. For students who were non-STEM majors, it was important to concretize their experiences with key parts of a robot.

References

Abrahamson, D., & Lindgren, R. (2014). Embodiment and embodied design. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (Vol. 2nd., pp. 358-376). Cambridge University Press.

Benitti, F. B. V. (2012). Exploring the educational potential of robotics in schools: A systematic review. *Computers & Education*, *58*(3), 978-988. https://doi.org/10.1016/j.compedu.2011.10.006

Blikstein, P. (2013). *Gears of our childhood: constructionist toolkits, robotics, and physical computing, past and future* Proceedings of the 12th International Conference on Interaction Design and Children, New York, New York, USA. https://doi.org/10.1145/2485760.2485786

Cobb, P., Confrey, J., DiSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher*, *32*(1), 9-13.

Kopcha, T. J., Ocak, C., & Qian, Y. (2020). Analyzing children's computational thinking through embodied interaction with technology: a multimodal perspective. *Educational Technology Research and Development*, *69*(4), 1987-2012. https://doi.org/10.1007/s11423-020-09832-y

Stemler, S. (2000). An overview of content analysis. *Practical Assessment, Research, and Evaluation*, *7*(1). https://doi.org/10.7275/z6fm-2e34

Sung, W., Ahn, J.-H., Kai, S. M., & Black, J. (2017). *Effective Planning Strategy in Robotics Education: An Embodied Approach* Society for Information Technology & Teacher Education International Conference 2017, Austin, TX, United States. https://www.learntechlib.org/p/177387

Table 1. Descriptive statistics of students' knowledge of distance sensor

Cohorts	**Tests**	**N**	**Mean**	**SD**
1	Pre-test	22	3.59	1.65
	Post-test	22	5.95	.79
2	Pre-test	25	2.12	1.51
	Post-test	25	6.08	.86

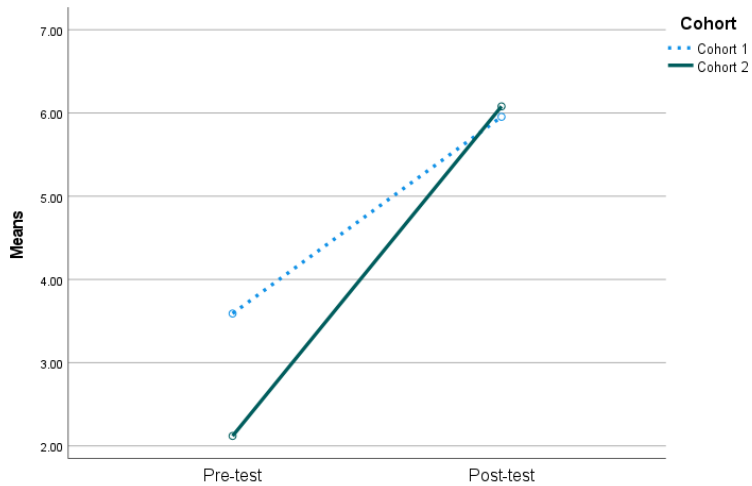

Figure 1. The pre- and post-test performance of two cohorts