Assessing the Effectiveness of Teaching Basic Programming Skills Using Hands-On versus Web-based Activities

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Abstract: This paper describes a study about which medium best introduces programming concepts to those without programming knowledge, a blocked coded robot (Cozmo) or online Scratch coding. Participants were taught basic coding concepts such as if statements and while loops in both instances and given a task to test their newly attained knowledge. Results showed that even though Scratch coding on computers was more successful as a tool to teach students programming concepts, the Cozmo robot brought more engagement and interest to the students.

Keywords: teaching, CS, education, IT, outreach, programming, block-coding, student engagement

Introduction

It is not a secret that minorities are underrepresented in the Information Technology field. In fact, there are many efforts that have been initiated to address this issue such as the NSF's Broadening Participation in Computing Initiative (NSF 2024). The Technology Ambassador Program (TAP) at Georgia Gwinnett College (GGC) was started in 2012 to encourage more students, especially minority students, to pursue and persist in the Information

Technology field. In addition, the program was designed to encourage participation in computing in younger students through outreach in the community (Dekhane 2018). This outreach is conducted via technology workshops that introduce IT concepts in a fun and engaging way to break the misconception that Information Technology is difficult and boring. While conducting these workshops, we have found that all students can learn programming if the concepts are introduced in a simplistic manner without overwhelming students with complex technology (Mosquera Reina 2021) and if it is introduced in an engaging way, such as programming a game (Robertson & Doloc-Mihu 2023). While we have had great success in our previous outreach workshops (Mehicevic 2024), we have never directly compared the results between the various workshops. In this study, we wanted to test the difference between two types of workshops - programming using hands-on technology such as a Cozmo robot and programming using a website such as Scratch.

Our Study

The goal of this study is to gather insight into how to best introduce programming concepts to our students by learning which medium, hands-on or web-based, is more effective. For this study, we used two of our previous TAP projects. Our web-based project was "Teaching Programming Fundamentals with Candy Catch" (Coralic et. Al 2021) which uses Scratch (MIT 2024), and our hands-on project was "Using Interactive Technology to Teach Basic Algorithmic Instructions" (Mayorga et. Al 2019) which uses the Cozmo robot (Anki Cozmo Robot 2024) and its own block-coding application.

Methods

Both of our workshops, hands-on and web-based, used block coding, which is a drag-and-drop-based programming language, to teach algorithms and while loops. We introduced both of these workshops in two Introduction to Computing classes at GGC. Each workshop consisted of a pretest to assess previous knowledge of programming concepts, a teaching component where programming concepts were introduced, time was given to apply the concepts to the technology used in the workshop, and a posttest to assess what they learned in the workshop.

Results

This study was conducted in two sections of our Introduction to Computing class. Both workshops were run in both sections, but the order of presentation of the workshops was alternated to avoid bias in the data. Group 1 attended the web-based Scratch workshop first and the hands-on robot workshop second. Group 2 attended the hands-on robot workshop first and the web-based Scratch workshop second. There was a total of 45 participants in this study between the two sections, ranging in age from 18 to 30. 46% of our participants were male and 54% were female. There was a wide range of majors (13) represented in our participant pool.

We administered a pretest to gauge each student's programming knowledge prior to the workshops and a posttest to assess the effectiveness of our workshop. Of the 45 participants, only 39 of our participants answered both the pretest and the posttest. The rest of the results discussed in this paper reflect the survey data of these 39 participants.

There were 16 coding questions that we gave on both the pre and posttest to assess prior knowledge and acquired knowledge from our workshops. We analyzed the participants' scores for these quiz questions for each group (Tab. 1).

Table 1. Quiz Scores for each group from pretest and posttest

	Workshop 1 Pretest	Workshop 1 Posttest	Workshop 2 Pretest	Workshop 2 Posttest
Group 1	26%	45%	45%	43%
Group 2	54%	57%	55%	63%

In general, Group 1 has less prior knowledge about programming than Group 2 and saw the greatest gain in knowledge (19%) in the web-based Scratch workshop. And they had slightly lower (-3%) scores on the posttest after attending the robot-based workshop.

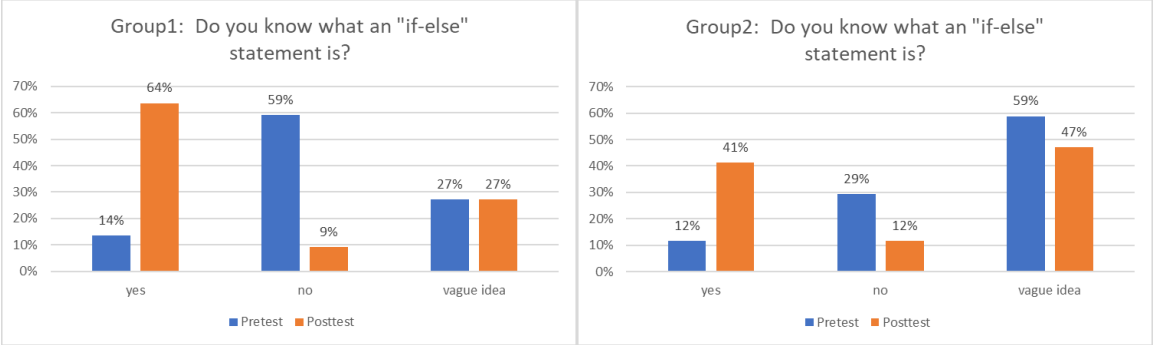

Figure 1. Student perceived knowledge of if-else statements

Group 1 and Group 2 had similar perceived previous knowledge of what an if-else statement was (Fig. 1). However, the web-based Scratch coding group showed a greater increase (50% increase for Group 1 as opposed to a 29% increase for Group 2) in learning than the hands-on robot group in the posttest.

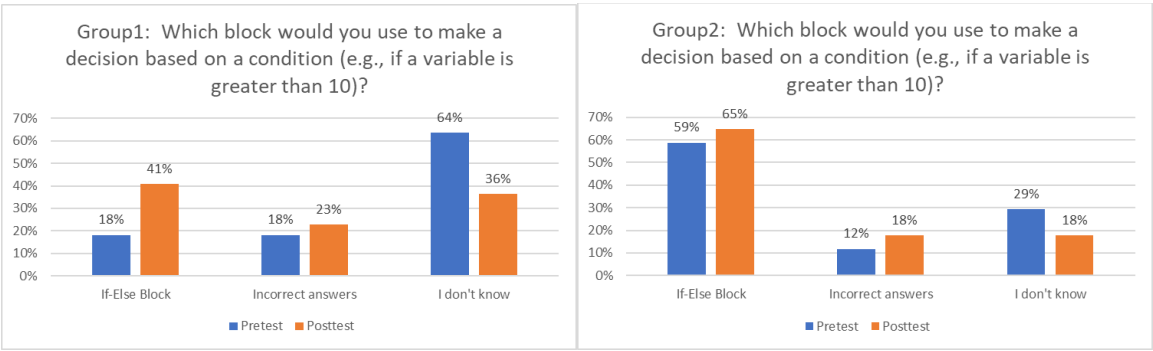

Figure 2. Quiz results of if-statement questions

One of the topics that we assessed on our pre and posttests was student knowledge of if-else statements (Fig. 2). When asked the question, "Which block would you use to make a decision based on a condition?," Group 2 had more previous coding knowledge than Group 1 by 40%. Because of this, Group 2 did not have as high of an increase in knowledge after their workshop (6%) as opposed to Group 1 (23%).

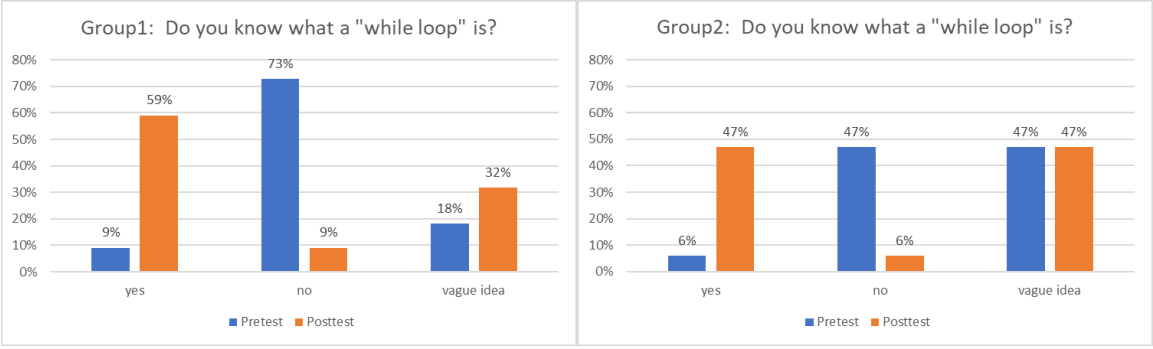

Figure 3. Student perceived knowledge of while loops

We also wanted to observe student perceived knowledge of while loops (Fig. 3). Again, Group 1 had more students who thought they understood what a while loop was compared to Group 2, where more than half of the participants didn't completely understand what it was.

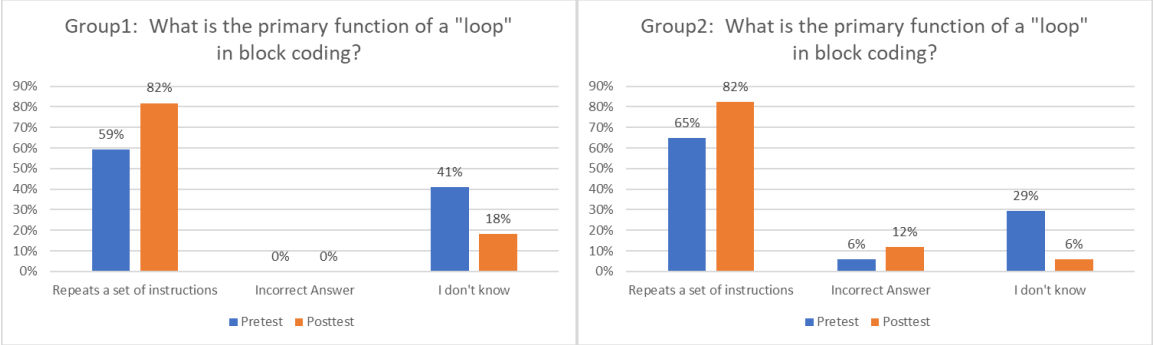

Figure 4. Student perceived knowledge of a loop in block coding

The students in Group 1 and Group 2 had an identical percentage of correct answers on the posttest for "What is the primary function of a loop in block coding?" (Fig. 4) However, while no one in Group 1 got the loop question wrong, more of the Group 1 students did not know the answer to the question.

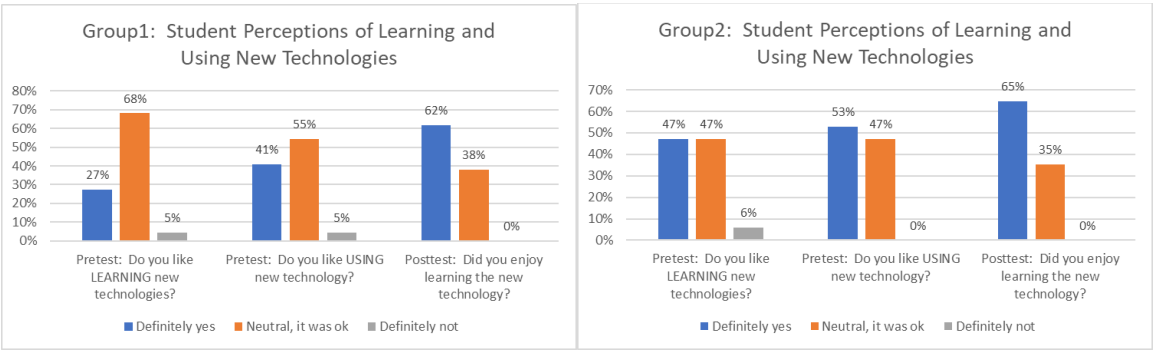

Figure 5. Student perceptions of learning and using new technologies

We wanted to assess if our participants like to use and learn new technologies (Fig. 5). In the pretest, students in Group 1 indicated that they were less likely than Group 2 to want to learn (27% vs. 47%) and use (41% vs. 53%) new technology. However, after our workshops, we saw a larger increase in Group 1's opinion of learning new technology as opposed to Group 2's.

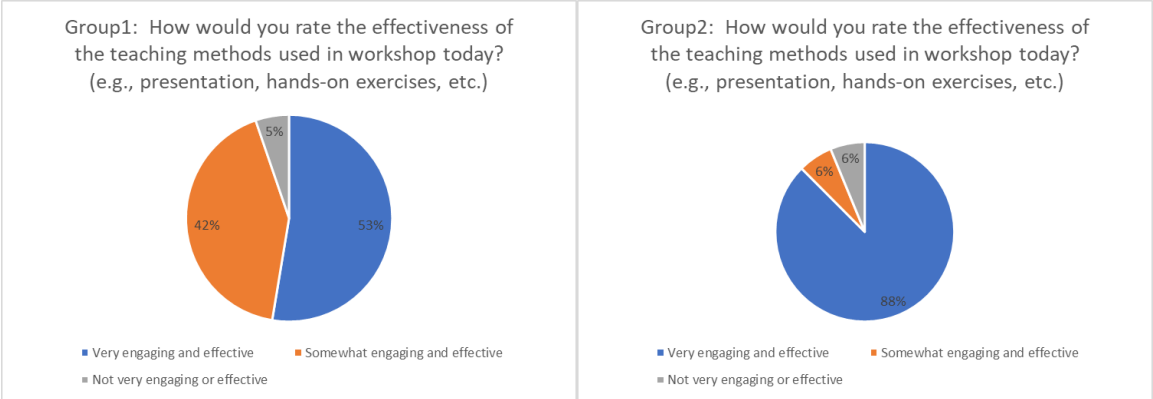

Figure 6. Student engagement during the workshops

Despite not learning as much as Group 1, Group 2 showed a much higher level of engagement during our workshop (Fig. 6). 88% of the Group 2 participants found the workshops very engaging and effective, as opposed to only 53% of the Group 1 participants.

Both surveys contained block coding questions followed by some questions involving simple Java code. Java coding was never explained to the participants, but we wanted to see if they could apply their newly attained programming skills on while loops and arithmetic thinking to a traditional coding language. For Group 1, 9% got the Java coding questions correct on the pretest and 13.5% on the posttest. Group 2 on the other hand scored 21% on the pretest and 18% on the posttest.

Discussion

Since our Introduction to Computing class is a general education course required by all students on our campus, most of the participants were non-IT majors. We anticipated that the results of the pretest would show little to no previous coding knowledge and we were correct. Group 2's participants showed that they possessed more prior knowledge of coding than Group 1 due to how well they answered the quiz questions in the pretest; however, Group 1 seemed to learn more in this workshop and had higher gains after the workshops. This difference could be explained by how the workshops were run and could be a possible topic for future work.

Group 1 ran the Scratch-based workshop first, and in that project, all of the participants had their own computer and coded their own games. This allowed every student to be engaged in learning and actively participating in the workshop. Group 2 ran the robot-based project first; however, due to the limited number of robots, students had to be split into groups of 4 - 5. We observed that while sharing, most times there would usually be one student using and operating the iPad and robot. Sometimes other students would work with the user while other students would be left out and not participating in the workshop. This did not allow for as much individual learning as Group 1's experience and may be the reason that we saw higher gains in knowledge in Group 1. These findings are supported by research that has found that as activities move from passive to active to constructive to interactive, student learning increases (Chi & Wylie 2014). We do not believe that the students who watched moved on from passive to active. Therefore, they did not get the stimulation needed to engage in learning while those who had their own computers to program in Scratch were actively engaged with the concepts taught in the workshops.

While the online Scratch programming taught if and while loops, the Cozmo robot-based project's programming language did not use actual if and for loop statements. The programming for that project was more logic-based. This seemed to not teach the programming concepts as well. There were fewer gains in knowledge for Group 2 even though the participants in that workshop indicated that they were more engaged.

We found that neither group learned how to apply their newly attained coding knowledge. Only 9% of Group 1's participants got the Java coding questions correct on the pretest and 13.5% on the posttest. Group 2, on the other hand, scored 21% on the pretest and 18% on the posttest. This shows that while they theoretically learned about if statements and while loops, they could not apply that knowledge to real coding syntax, and in the case of Group 2 they got more confused.

This study is just a preliminary look into how to use various resources to introduce programming and there were a few limitations to our study. One of the limitations was that the study groups were small (39 people were not enough participants to make any significant findings), and there were fewer people in Group 2. Another limitation was the lack of robots to distribute to the participants in Group 2. Lessons were also not consistent with both workshops with the online Scratch-based project going more in-depth into if statements and while loops than the Cozmo robot-based project. This is because the Cozmo robot's programming language used more logic-based blocks. A future study should use hands-on technology that uses a language similar to Scratch.

Future Work/Conclusion

While we discovered some interesting results pertaining to hands-on learning and engagement, we would like to make improvements to our study. In order to allow people to engage and learn more with the Robot project, we want to be able to provide each individual participant with their own robot. We would like to ensure that our testing groups have more comparable programming knowledge prior to the projects. Finally, we would like to redesign the lessons in this study to ensure that participants are learning the same information. This might require a change in the technology used. We believe these changes will help us better understand the relationship between knowledge acquisition and engagement.

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