Participation differences when children with physical disabilities control robots to perform hands-on activities compared to their peers

K. Adams[1], B-L. David[2], L. McGarvey[3], K. Loshny[3], P. Esquivel[1]

[1]*Faculty of Rehabilitation Medicine, University of Alberta,* [2]*Glenrose Rehabilitation Hospital, Edmonton, AB,* [3]*Department of Education, University of Alberta*

INTRODUCTION

Students who have severe physical disabilities and/or complex communication needs (CCN) are at risk of not developing a good understanding of mathematics [1, 2]. Current mathematics curriculum and pedagogy calls for the integration of concepts, procedures and processes including problem solving and communication through hands-on and collaborative activities to build mathematical literacy [3, 4]. Participation in hands-on and communicative activities in the classroom by students with disabilities is lower than their peers [5, 6]. This could be due to difficulties grasping manipulatives and/or limitations of their augmentative communication modality. For instance, for children who control speech generating devices (SGDs) by using switches, the speed of creating a message may be slow and there may be a limited selection of vocabulary. There is limited support for teachers on including students with severe physical disabilities and CCN in hands-on and collaborative activities.

In a previous study we conducted with three children with quadriplegic cerebral palsy and CCN, we were successful in meeting current mathematics measurement curriculum and pedagogical expectations in a one-on-one setting [7]. Students controlled Lego robots via the student's own SGD to participate in "hands-on" measurement and communicative activities. Given the importance placed on collaborative hands-on activities, it was important that the next phase of study involve inclusive peer groupings in the classroom.

Unfortunately, it is often the case that children with disabilities merely observe as their non-disabled peers do the actions required for the hands-on activities. One method that gives children with disabilities more involvement in the activity is to direct their peers what to do, for example, to tell their peers what items that the peer should measure in [8].

The aim of this study was to investigate if using a robot could increase the amount of participation of children with disabilities in hands-on mathematics measurement activities. The research questions were:

1) Does the use of a robot by a student with severe disabilities in math measurement activities with a non-disabled peer increase the level of the student's participation?

2) What are the teacher's perceptions on robot use as a tool to increase a student with special needs' participation in hands-on activities, and its impact on the student and peers?

3) What method does the participant prefer to perform the measurement activities, with or without the robot?

METHODS

Research design

This study employed an AB single subject research design (SSRD) to answer research question 1. SSRD is a well-established approach in the testing of new interventions with low-incidence populations, including assistive technology [9] and children with cerebral palsy [10]. The AB phases were:

- Baseline A: Student and peer participate in typical mathematics lessons together (with no robot)

- Intervention B: Student and peer do the same mathematics lessons together with the robot present.

Research questions 2 and 3 were addressed through interviews.

Participants

One participant who had physical limitations, but typical communication skills, and a typically developing (non-disabled) peer participated in this study. The participant was a ten year old girl in grade four who had spinal muscular atrophy with severe physical impairments affecting all four limbs. She propelled a wheelchair using a mini joystick located at her right side. She could operate an Apple iPad Mini™ by holding her right hand and lightly pressing the icons on the screen. The iPad was mounted on her power wheelchair with a Gorilla Mount™. The peer was friends with the participant and they had worked together previously.

Setting

The sessions occurred in the participant's school. The intention was that baseline and intervention sessions would occur in the classroom with the other students doing the same activities, but this did not occur. Instead the baseline occurred in the classroom with the other students doing the same activity, and the intervention occurred in a separate room because the other students had moved on to a new activity.

Figure 1. The student participant is controlling the Lego robot from her iPad Mini. She has just moved the robot and ruler beside a pencil to line up the ends and read the length of the pencil from the ruler. The peer is recording the answer

Materials

The participant controlled a small Lego Mindstorms™ car-like robot, which had a centimeter ruler attached to it. She controlled the robot from her iPad Mini. The iPad had the Lego Mindstorms Commander program installed on it. Several items around the classroom were used as objects to measure. See Figure 1 for the set-up.

Procedure

An interview with the participant's teacher established the appropriate measurement activity (measuring using centimeter units) and identified the peer who works with the student most frequently. In the baseline condition the pair interacted as they would normally, and the activity was to take turns and find three sets of objects that were about 1cm, 10cm, and 25cm long, measure them, and record the items in a booklet (see Table 1).

Table 1: Sets of objects that the pair measured in baseline. The object chosen by the student participant (S) or peer (P) is listed.

Length	1st set	2nd set	3rd set
1 cm	T – Dice	A - Marker tip	A - Pearl
10 cm	A - Card	A – Marker	T - Eraser
25 cm	T – Box	(Tried, pencil box, iPad, table, folder until found one the appropriate length) T – Clipboard	A - Book

After the baseline, there was one training session on how to control the robot which involved activities like knocking over blocks, moving blocks to areas around the table, and driving the robot between several items set up on a table. In the intervention condition the activity was to take turns to estimate and then measure three objects each. For the participant's turn, she measured objects by moving the robot and centimeter ruler alongside the objects. The peer helped as requested.

A structured interview was performed with the teacher after the study. The interview asked about student understanding and perceptions of robot use (the questions are listed in the results). In addition, the participant was asked, "What way did you prefer for doing the activities?"

Data analysis

Morae™ coding software was used to code the action events while watching videos of the baseline and intervention sessions. An example of the coded data for the second task in the intervention is shown in Table 2. "Math action" means a choice to be made or a manual task. "Helper eyes for S" means that the typically developing peer helped by looking at the object and the ruler to tell the participant if the objects were lined up (because it was hard for the participant to see them since she was in her wheelchair and could not lean forward).

Table 2: Example of the coded data for the participant's participation.

Time	Details	Code	Notes
06:59.1	Student participant	Math action	Choose object to measure, dice
07:53.3	Student participant	Math action	Moves the measuring tool along the object, dice
08:29.2	Peer	Helper eyes for S	Establishes measurement, dice

08:34.1	Student participant	Math action	Establishes measurement, dice

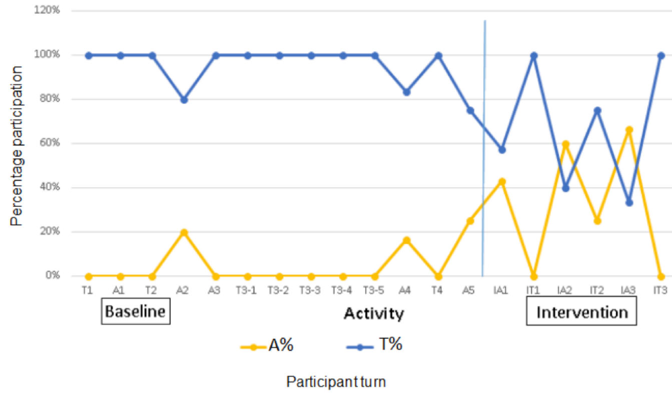

Figure 2. Percent participation of the student participant (A for atypical development) and the peer (T for typical development). Percent participation is along the y axis. Each measurement performed is along the x-axis:
-T1 means typically developing peer's first task, T3-1 to T3-5 were all for the typically developing peer's third turn when she measured 5 different objects to find one to match the criteria (an object about 25cm long).
-A1 means the atypically developing participant's first task, etc.
- IT1 means the typically developing peer's first

08:52.7	Peer	Helper hands for S	Records, answer for dice

The dependent variable for the intervention was the participation of the participant and peer in the mathematics activity. Participation was measured as percentage of action steps done during a measurement task. In the example above 3 out of 5 actions were done by the participant (e.g., 60%). Qualitative observations were also made (e.g., to see what type of tasks each student did). The interview responses were transcribed and summarized.

RESULTS

Participation

As can be seen in Figure 2, the participant's participation increased during the intervention with the robot. In the baseline, the only participant actions were to choose the item to measure, which she did by verbally telling the peer the object name. In the intervention, the action that the participant did during the typically developing peer's second turn was to move robot accidentally. All of the typically developing peer's actions during the participant's turn were as "helper hands", e.g., to help move the robot as requested by the participant.

Teacher's perceptions of robot use

Questions asked during the structured interview, and the teacher's responses were as follows:

1. What do you think about the student and peer’s participation in mathematics activities? Was it different between when the student did and didn't use the robot?

The teacher noticed that there was an increase in motivation, and a difference in participation when the participant used the robot. Normally the participant is sitting and watching someone do the activities.

2. Was your ability to assess the student’s understanding of the measurement lessons different when they used or did not use the robot?

The teacher thought the student would have a better understanding of the math concepts after using the robot.

3. Do you feel that using a robot as a tool to assist students with severe disabilities is a viable option? Why or Why not? What would be needed to increase the ease of using a robot in a classroom as a tool to assist with students with disabilities in hands-on activities?

The teacher considered the robot a viable tool, and thought that the only obstacles would be the cost of the robot and the knowledge of how to operate it.

4. Do you feel that the peers' perception of the student as a learner changed through the use of the robot?

The teacher felt that perception of the participant by her peers did change. They gained respect for the participant's ability to drive the robot.

5. Do you feel that the student's perception of themselves as a learner changed through the use of the robot?

The teacher thought that the participant's perception changed in the sense that she was less resistant to trying new things that make her look different to her peers.

Participant preference

The participant's preference for doing the activities between using the robot and watching her friend, was to use the robot because she could "do more with it".

DISCUSSION AND CONCLUSION

Regarding research question 1, results showed that using the robot did increase the amount of participation of the student with disabilities. In the baseline, the typically developing peer performed almost all the actions for both her and the participant's turn. During the intervention, the participant did some actions of the activity using the robot, and the only actions the peer did were for helping the participant with the robot. The participation of the students in the intervention with the robot was more balanced than it was during baseline.

Regarding research question 2, the teacher noticed that there was an increase in student motivation to do the mathematics activities and she thought that the student would have a better understanding of some of the math concepts after using the robot. Related to research question 1, she noticed an increase in participation over how the activities are normally done (observing the peers). She felt that using a robot as a tool to assist students with severe disabilities was a viable option as long as the cost of the robot and how to operate it were considered. She felt that the peers gained respect for the participant (because she could control the robot), and that the participant's self-perception changed, by being more open to trying new things.

Possibly most important, is the fact that the participant preferred to do the activities with the robot because she could do more. This is an important outcome if increasing participation can increase engagement and impact learning. Elementary school students with severe motor impairments could benefit from using robots as a means of demonstrating their knowledge (in a hands-on method, similar to their peers), interacting with learning materials, and working in paired groupings.

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