Introduction

The Assistive Technology (AT) Team at the University of Alberta has compiled and created the following resources for AT Teams in Educational Settings. The intention of this resource document is to help AT Teams understand what kinds of activities can be done with the Lego Mindstorms Robot to help students with physical disabilities develop mathematical skills.

This document includes links to research articles, presentation posters, instruction manuals etc. The resources are organized into the following sections:

- Using the Lego Mindstorms Robot along with Speech-Generating Devices (SGD)
- Using the Lego Mindstorms Robot for hands-on math measurement
- Implementing the Lego Mindstorms Robot and a Virtual Robot for more independent learning
- Studies comparing the benefits of using Physical Robots and Virtual Manipulative Programs.

Some examples of activities from the articles and manuals mentioned will be highlighted in this document to provide a quick and brief overview of the possible ways to implement the robots.

7 Mathematical Processes

The Government of Alberta's Education Mathematics Kindergarten to Grade 9 Program of Studies incorporates seven interrelated mathematical processes that are intended to guide teaching and learning. The activities in this resource document will be labeled according to which of these mathematical processes they can help the student fulfill.

1. Communication **[C]**: students should be able to communicate in order to learn and express their understanding
2. Connections **[CN]**: students should be able to connect mathematical ideas to other concepts in mathematics, to everyday experiences and to other disciplines
3. Mental Mathematics and Estimation **[ME]**: students should demonstrate fluency with mental mathematics and estimation
4. Problem Solving **[PS]**: students should develop and apply new mathematical knowledge through problem solving
5. Reasoning **[R]**: students should develop mathematical reasoning
6. Technology **[T]**: students should select and use technologies as tools for learning and for solving problems
7. Visualization **[V]**: students should develop visualization skills to assist in processing information, making connections and solving problems.

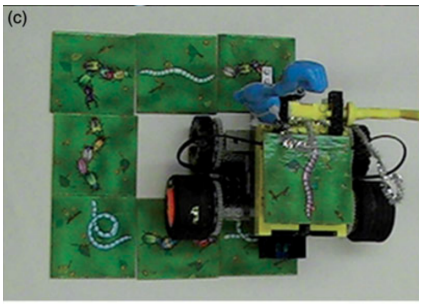
Lego Mindstorms Robot and Speech-Generating devices (SGD)

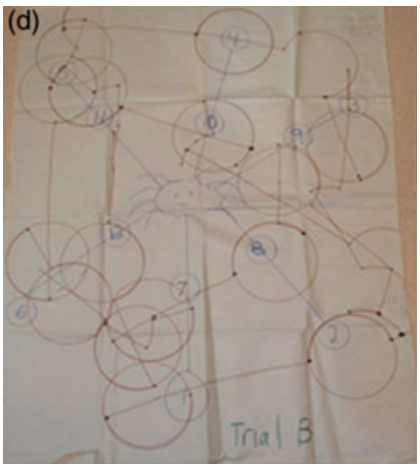
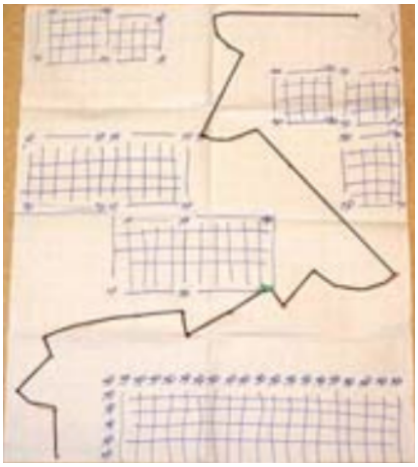
Children who have severe physical limitations may present complex communication needs and difficulty with manipulating objects. To address communication and manipulation issues in these children, two assistive technology strategies, Speech Generating Devices (SGD) and infrared controlled Lego robots, have been implemented in several studies.

Researchers at the Assistive Technology Lab at the University of Alberta developed an integrated communication and robotic control system where the child's SGD was used to control the robot for educational tasks in math and social studies. A 12-year-old girl with cerebral palsy tested this system.

Her teachers reported that the participant:

- increased the number of academic interactions with classmates during puzzle making, math games, a social studies project (Adams & Cook, 2015)
- improved skills with her SGD in daily communication increasing the number of word utterances from 1 to 2-4 (Adams, Yantha, & Cook, 2008a; Adams & Cook, 2015)
- increased her knowledge on numbers from 1 to 15 (Adams, Yantha, & Cook, 2008b)
- demonstrated an understanding in robot programming (Adams & Cook, 2013; Adams, 2011b; Adams & Cook, 2009)

Activity	Objective	Photo
Puzzle solving	To learn geometry concepts (shapes and orientation), requesting items and counting by using the robot to put together a puzzle. **[CN,PS,T,V]**	 Adams & Cook, 2015

Connect the dots drawing	To complete the 12-dot pattern of a spider's web by connecting the numbered dots by driving the robot, with the felt-tip marker attached, from one numbered dot to the next. **[C,CN,PS,T,V]**	 Adams & Cook, 2015
Write and act out a story	A social studies activity that involves writing a story (requiring the student to make two or three word sentences), then acting out the story during the robot sessions. **[C,CN,T,V]**	 Adams & Cook, 2015
Board game	Students can roll the dice using the robot arm and answer questions with their SGD to move through the board game with the marker attached to a robot. **[C,CN,T,V]**	 Adams, Yantha, & Cook, 2008a

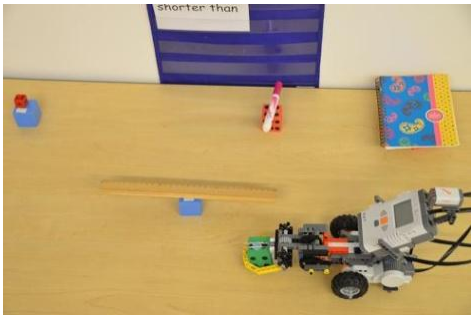
Mathematics measurement

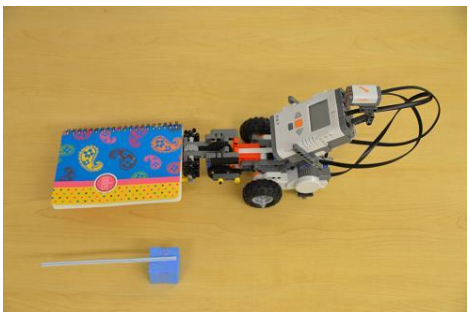
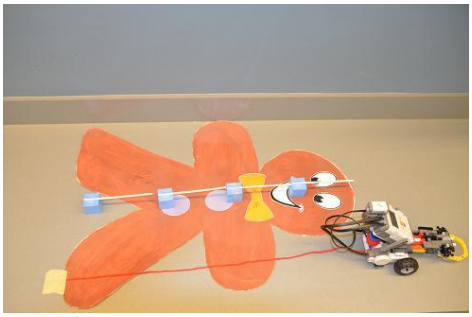
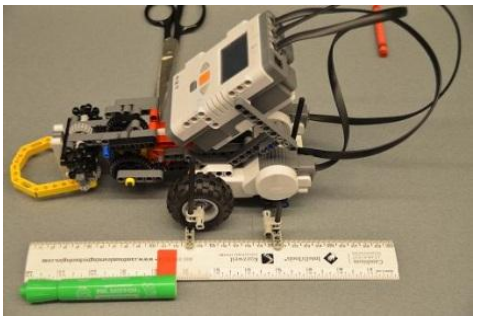
Adams (2011a) evaluated the use of an integrated communication and robotic control system in hands-on math measurements lessons in three children with cerebral palsy. The findings in this study showed that controlling the robots from SGD enabled the children to perform hands-on math measurements activities and reflect and report their results. Results were published in RESNA (Adams & Cook, 2012a). Other studies were conducted to analyze participant's satisfaction (2012b); analyze stakeholder's opinions about the system (Adams & Cook, 2014); and study the use of the robotic system for Grade 1 measurements concepts (Adams & Cook, 2016). All of these studies support the findings in Adam's study (Adams, 2011a).

Adams & David (2013b) analyzed three methods to do the manipulation tasks in grade 3 math measurements activities. The participants were three children with cerebral palsy and their teachers. Teachers agreed that the robot was the most effective of the three methods to "show what the student knows". The authors created a manual called "Making Hands-on Activities for everyone" directed to teachers. This manual provides adapted math activities using the robot in math measurement lessons for Grades 1, 2 and 3 (Adams & David, 2013a).

Additionally, two students with physical limitations and their non-disabled peers participated in a study that examined whether the use of the robot in mathematics activities increases student's participation with their peers. The student and peer did the math lessons together with the robot present. Results showed that:

- Using the robot increased the amount of participation of the students with disabilities (Adams, Commandeur, David, Tuck, & Loshny, 2016).
- Participants preferred to do the activities with the robot because they could do more (Adams, David, McGarvey, & Loshny, 2018).

Activity	Objective	Photo
Comparing objects: Grade 1	Student grasps the selected reference object with the robot and controls the robot to drive alongside the object to be measured. Then identifies whether the object is shorter than, same as, or longer than, the object on the robot. **[C,ME,R,T]**	 Adams & David, 2013a

Comparing lengths: Grade 1	Student grasps the object to be compared and holds it next to the reference length. Then determine if the object is the same, longer or shorter than the reference length. **[C,ME,R,T]**	 Adams & David, 2013a
Measuring lengths: Grade 2	Student uses the robot to place craft sticks/straws on the gingerbread man so that they can determine "How tall he is". **[C,ME,PS,T,V]**	 Adams & David, 2013a
Using a Ruler: Grade 3	Student grasps the ruler with the robot and drives the robot forward and lines up the end of the ruler with the object. **[C,ME,PS,R,T]**	 Adams & David, 2013a

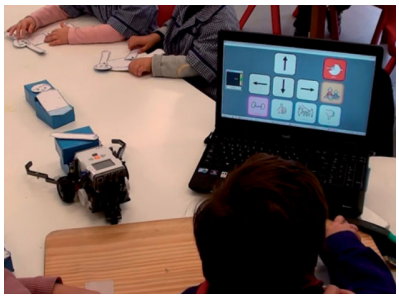
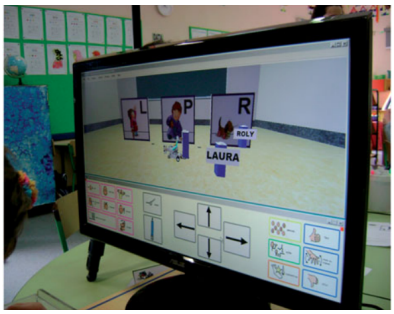
Lego Mindstorms Robot and Virtual Robot

Adams and Cook have collaborated with (Encarnação et al. 2014) to develop an integrated augmentative manipulation and communication assistive technology (IAMCAT) in both forms: a physical robot and a virtual robot. In their paper they compared the advantages of these systems and activities that can be done with them. These authors suggested further research to evaluate the effectiveness of virtual tools compared to physical tools (Encarnação et al., 2015, Encarnação et al. 2016).

The IAMCAT enables children with physical impairments to manipulate educational items while communicating their experiences. The authors implemented this system with nine children with physical limitations and their corresponding teachers in language, math, science, and social studies activities (Encarnação et al., 2014b).

The findings showed that the IAMCAT:

- increased the child's communication with his/her peers
- contributed to demonstrating academic skills
- and was compatible with the teacher's curricular planning

Activity	**Objective**	**Photo**
Reading Comprehension: "A Taste of the Moon" by Michael Grejniec	Listen to the book story reading. Then summarize the story by placing each character by the order of appearance, as requested by the educator (from the beginning – the mountain, to the end – the moon), using the robot (gripper) and AAC system to ask and answer questions. **[C,CN,R,T]**	 Encarnação et al. 2016
Vowels and Rhymes	Answer questions and identify the vowels using the AAC system: "What is the first letter of the word … (e.g. **under**)?" Play a "vowel's bingo" marking the words started by a requested vowel: Answer the question "Who have words that start with A? Mark the words starting with the A letter" using the	 Encarnação et al. 2016

	robot's gripper to move and place the respective vowel chip in the bingo card. Match the rhyming words by drawing a line from the robot's position (main word) to one of two answering options (rhyming word and non-rhyming word). **[C,CN,PS,T]**	

Physical Robot and Virtual Manipulative Programs Comparison

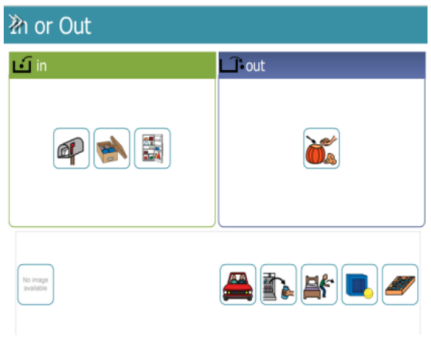
Another study investigated the performance and experience of students with physical disabilities when they use: a) observation of peer/staff to learn mathematics concepts; b) robot control of concrete manipulatives to learn mathematics concepts; c) or computer control of virtual manipulatives to learn mathematics concepts. This study also analyzed opportunities and challenges for teaching and assessing mathematical concepts when students use these strategies.
Results showed that participants:

- Improved their mathematics understanding with the robot and the computer, but obtained different results with both devices (Adams, McGarvey, David, Esquivel, & Morgan, 2018).

Another study explored the influence of contextual factors that surrounded three students with physical disabilities when they used Lego robots and Information and Communication Technologies (ICT's) to handle manipulatives.
Results showed that:

- Personal factors influenced how the students used the device during the sessions.
- The devices were easy to use for students and increased independence.
- Social support by the research assistant facilitated the participants completing the questions and contributed to an increase in the level of engagement of the participants (Esquivel, 2022).

Activity	**Objective**	**Photo**
Sorting objects	Sort objects using a single attribute using concrete manipulatives with the robot. **[CN,PS,R,T]**	 Adams, McGarvey, David, Esquivel, & Morgan, 2018

Sorting objects	Sort objects using a single attribute using virtual manipulatives on a computer. **[CN,PS,R,T]**	 Adams, McGarvey, David, Esquivel, & Morgan, 2018
In/Out lesson	Describe the relative positions of objects using terms such as in and out. Indicate whether there are items "in" the object or items "out" of the object. **[CN,PS,T,V]**	 Esquivel, 2022

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