Using Assistive Robots to Promote Inclusive Education

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Research team

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Manipulation

- Physical and cognitive development are closely connected
- Motor experience has a critical importance in development

(Butler, 1986; Piaget, 1954)
Manipulation

- Object manipulation promotes:
  - The acquisition of learning skills
  - Symbols emergence
  - Referential communication
  - The perception of the relations between objects

(Piaget, 1954; McCarty et al., 2001)

Motor limitations

- Physical impairments may limit the capacity of a child to manipulate objects
- This can lead to:
  - Compromised learning
  - Loss of motivation
  - Apathetic behavior
  - Decreased self initiative
  - Learned helplessness

(Butler, 1986; Jennings & Mackulk, 1995; Preutz et al., 2010)

Learning

- Multimodal activities foster the learning experience

(van de Waal et al., 2010; NERTA, 2002)

Cuisenaire rods

(sources: mathfor.com, learning4kids.net, augsness.com)
Learning

- Pedagogic theories, namely those grounded on constructivism and neo-constructivism, advise teaching through multimodal activities, providing students with opportunities for seeing, hearing, doing and telling (Van de Walle et al., 2010; NSTA, 2002)

Children with motor and speech impairments may have difficulties accessing the curriculum content.

Robots

- Robots may enable children with motor impairments to:
  - Independently manipulate objects
  - Explore objects and their relations
  - Create play opportunities

(Cook et al., 2012)
### Project UARPIE

**Goal:**
- Develop an integrated augmentative manipulation and communication assistive technology (IAMCAT)

**Hypothesis:**
- The IAMCAT promotes inclusion and learning by allowing children with motor impairments to manipulate educational items while communicating about their experiences, effectively participating in class activities.

### Experimental objectives:

1. Evaluate academic achievement when using the assistive technology (AT) compared to without it;
2. Compare virtual and physical robotic systems in relation to #1;
3. Assess teachers’ perceptions of the use of the AT and its impact on the student and in the classroom.

### IAMCAT - Physical

Manipulation is via a Lego Mindstorms car-like robot with a gripper and a pen attached.

The robot is controlled through cells in The Grid 2 software communication boards. The child interacts with the system through his/her computer access method.
A virtual robot with virtual objects on a computer screen was also developed.

Rationale:
- Decrease cost
- Facilitate the use by non-technical persons
- Facilitate dissemination of the assistive technology

IAMCAT - Virtual

IAMCAT tests

- Nine children with disabilities integrated in regular classes used the IAMCAT to perform pre-school and first grade language, mathematics, science & social studies activities
- Before using it in the classroom, children were trained to control the robot using the IAMCAT

Participants - Children

<table>
<thead>
<tr>
<th>Participant</th>
<th>Gender</th>
<th>Age (years)</th>
<th>Grade</th>
<th>Robot</th>
<th>Access method</th>
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<tbody>
<tr>
<td>#1</td>
<td>F</td>
<td>5</td>
<td>Pre-school level 3</td>
<td>Physical</td>
<td>Direct (Track-ball)</td>
</tr>
<tr>
<td>#2</td>
<td>M</td>
<td>6</td>
<td>1st grade</td>
<td>Virtual</td>
<td>Direct (Track-ball)</td>
</tr>
<tr>
<td>#3</td>
<td>M</td>
<td>6</td>
<td>1st grade</td>
<td>Physical</td>
<td>Direct (Eye-tracking)</td>
</tr>
<tr>
<td>#4</td>
<td>F</td>
<td>6</td>
<td>Pre-school level 3</td>
<td>Physical</td>
<td>Direct (Track-ball)</td>
</tr>
<tr>
<td>#5</td>
<td>F</td>
<td>5 / 6</td>
<td>Pre-school level 3 / 1st grade</td>
<td>Virtual</td>
<td>Direct (Track-ball)</td>
</tr>
<tr>
<td>#6</td>
<td>M</td>
<td>5</td>
<td>Pre-school level 3</td>
<td>Physical</td>
<td>Direct (Track-ball)</td>
</tr>
<tr>
<td>#7</td>
<td>M</td>
<td>4</td>
<td>Pre-school level 2</td>
<td>Physical</td>
<td>Direct (Track-ball)</td>
</tr>
<tr>
<td>#8</td>
<td>M</td>
<td>3</td>
<td>Pre-school level 1</td>
<td>Physical</td>
<td>Direct (Eye-tracking)</td>
</tr>
<tr>
<td>#9</td>
<td>M</td>
<td>3</td>
<td>Pre-school level 1</td>
<td>Physical</td>
<td>Direct (Eye-tracking)</td>
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### Participants - Teachers

<table>
<thead>
<tr>
<th></th>
<th>RE (9)</th>
<th>SE (9)</th>
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<tr>
<td><strong>Age</strong></td>
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</tr>
<tr>
<td>20 - 29</td>
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<tr>
<td>30 - 39</td>
<td>4</td>
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<td>40 - 49</td>
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<td>50 - 59</td>
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<td>1</td>
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<td><strong>Service time</strong></td>
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<td>0 - 9</td>
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<td>1</td>
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<td>10 - 19</td>
<td>3</td>
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<td>20 - 29</td>
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<tr>
<td>30 - 39</td>
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<td>2</td>
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<td><strong>Background</strong></td>
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<tr>
<td>BA / MA Child Ed.</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>BA Primary Ed.</td>
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<td>3</td>
</tr>
<tr>
<td>Other degrees</td>
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<td>1</td>
</tr>
<tr>
<td>Special Education</td>
<td>2</td>
<td>9</td>
</tr>
</tbody>
</table>

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### Training protocol

**Goal of the robot training protocol:** develop the following skills
- driving to any workspace location
- picking and placing objects
- using the pen to trace lines, and
- communicating using the Grid system while controlling the robot

**Familiarization activities:** knocking over stacks of blocks in front of the robot, and to the left and to the right of the robot

**Slalom course trials:** drive the robot through a course with a different number of obstacles
- While lifting the robot pen up and down
- While gripping an object
- While "saying" randomly chosen words

(Adams & Encarnação, 2011)
Clinical observation

- Participants went through a variable number of sessions ending the training when their skills levels stabilized, as evaluated by the clinical perception of the research team conducting the sessions.
- Three of the participants were not able to control the robot in its frame of reference.
- Another participant did not achieve a level of independence using the system, always requiring prompting of the robot commands.

Quantitative assessment

- The following 12 robot skills were graded according to the level of prompting when applicable:
  - Move forward
  - Use long/short steps
  - Drive the robot to the required location
  - Move backward
  - Pen up/down
  - Avoid obstacles
  - Move left/right
  - Open/close gripper
  - Pick up objects
  - Turn left/right
  - Sequencing (equal/different) commands
  - Draw/erase lines

- In each session, worst, best and average performance were recorded.

Quantitative assessment

- Scores were given according to the following prompting hierarchy:
  - GM: Goal met
  - IC: Indirect Cue
  - DVC: Direct Verbal Cue
  - DPC: Direct Pointer Cue
  - PA: Physical Assistance

<table>
<thead>
<tr>
<th>Score</th>
<th>Example for knocking over a stack of blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM</td>
<td>Child performs the activity after being told that he/she should knock over the stack of blocks</td>
</tr>
<tr>
<td>IC</td>
<td>“Have you noticed that you may control the robot to knock over the stack of blocks?”</td>
</tr>
<tr>
<td>DVC</td>
<td>“You need to drive the robot towards the stack of blocks”</td>
</tr>
<tr>
<td>DPC</td>
<td>“You need to select this robot control cell”</td>
</tr>
<tr>
<td>PA</td>
<td>Guiding participant’s hand in order to make the necessary selection</td>
</tr>
</tbody>
</table>
• Participants’ performance shown by coding of the level of prompting required to achieve each robot control or communication goal did not stabilize for all participants along all goals

Participant #1

WP – worst performance; AP – average performance; BP – best performance

Participant #2

WP – worst performance; AP – average performance; BP – best performance

Participant #3

WP – worst performance; AP – average performance; BP – best performance

Participant #4

WP – worst performance; AP – average performance; BP – best performance

Participant #5

WP – worst performance; AP – average performance; BP – best performance
Discussion

- Children may start losing interest after a few sessions, performing below their true abilities and failing to improve
- Task complexity increases along the sessions aiming at improving children’s mastery over the system
- For such young participants, performance measures may have a strong behavioral interference, reflecting not so much their abilities to control the robot but rather their motivation to perform

Discussion

- In the end, it will be a combination of the **qualitative perception** of the child’s performance and the **time available** for the training sessions that **will dictate when to transition** to classroom utilization of the IAMCAT to perform academic activities

Discussion

- **Quantitative evaluation** helps to identify
  - Robot control and communication goals that need to be addressed in each training session
  - The skills that were not mastered by the child and should be addressed by reprogramming the robotic system or by appropriately designing the academic activities
Participants used the system in their regular classes to perform pre-school and first grade language, mathematics, science & social studies activities.

A portfolio of IAMCAT-adapted activities was presented to the teachers for them to better understand the capabilities of the IAMCAT.

Activities were prepared with the participant’s teachers.

Activities were proposed to the entire class: each participant had the opportunity to perform the activities using the IAMCAT and his/her peers did the activities with pencils on paper or cutting and gluing, as required by the particular activity.

All necessary physical materials or the virtual scenarios were prepared by the research team (in one case by the teachers).

In general, classes were conducted by the regular teachers.

The special education teacher or one of the researchers provided technical support for the robot, and academic and robot control support to the study participant.
Classroom sessions

- Three classroom sessions were organized for each child, one dedicated to each curricular area
- Classroom sessions were videotaped
- To evaluate teacher's perceptions, participants' teachers were interviewed and a content analysis of the interviews was performed using the Atlas.ti® 6.2 software

Results – teachers' perceptions

Assessment of project development

Pedagogical process:
- Careful selection and planning of the activities
- Adequacy of activities and resources
- Insertion of the activities in the class/group dynamic

Inclusion of the participant during the sessions:
- Class positive reaction to the activities
- Interaction with peers during the activities
- Peers collaboration attitudes during the activities

Results – teachers' perceptions

Assessment of project development

Difficulties identified by the teachers:
- Group management (e.g., distribution of attention time)
- Individual support to the child (e.g., extra time needed to complete the tasks)
- Use of the AT (e.g.: physical robot space requirements; regular teacher lack of experience in using AAC devices)
## Results – teachers' perceptions - robot

### Project UARPIE 2013-2015

#### Assessment of project development - global

<table>
<thead>
<tr>
<th>Category</th>
<th>Physical robot</th>
<th>Virtual robot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of the AT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work with the participant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management of the group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitude of the group towards the participant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reaction of the group to the activities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interaction with peers during the activities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inclusion of the activities in the class dynamics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adaptation of activities and resources</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selection and planning of strategies and activities</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Results – teachers' perceptions - robot

#### Project results - global

<table>
<thead>
<tr>
<th>Category</th>
<th>Physical robot</th>
<th>Virtual robot</th>
</tr>
</thead>
<tbody>
<tr>
<td>On the school community</td>
<td></td>
<td></td>
</tr>
<tr>
<td>On the teacher</td>
<td></td>
<td></td>
</tr>
<tr>
<td>On the group dynamics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motivation</td>
<td></td>
<td></td>
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<tr>
<td>Autonomy</td>
<td></td>
<td></td>
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<tr>
<td>General performance</td>
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<td></td>
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<tr>
<td>Manipulation</td>
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<td></td>
</tr>
<tr>
<td>Communication</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motivation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autonomy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unsatisfactory academic performance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satisfactory academic performance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A – Child assessment wrt goals; B – Relevance of the AT in the child performance; C – Irrelevance of the AT in the child performance; D – Impact in school and class

### Project impact on the class and on the school (examples)

- **In the group dynamics:**
  - Enriching experience to the group
  - Acknowledgement by the group of the child capabilities

- **In the group learning experience:**
  - Possibility of addressing different curriculum content

- **On the teacher:**
  - Facilitator of the communication with the child

- **On the school community:**
  - Acknowledgement by the other educational agents of the child capabilities
### Results – teachers’ perceptions - robot

#### Project sustainability

<table>
<thead>
<tr>
<th>Provision of human resources</th>
<th>Physical robot</th>
<th>Virtual robot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forms of continuation</td>
<td>11.8</td>
<td>50</td>
</tr>
<tr>
<td>Of the activities</td>
<td>20</td>
<td>41.1</td>
</tr>
<tr>
<td>Of the AT</td>
<td>41.1</td>
<td>20</td>
</tr>
<tr>
<td>Need for training</td>
<td>11.8</td>
<td>30</td>
</tr>
<tr>
<td>Provision of human resources</td>
<td>20</td>
<td>41.1</td>
</tr>
</tbody>
</table>

i) Teacher support; ii) Suggestions and iii) Proposals

### Conclusions

- Teachers considered the IAMCAT a valuable resource that can be integrated in regular classes and that is compatible with the teachers’ curricular planning and management.
- However, they pointed out the need for proper training and the presence of another teacher/teaching assistant in class.

### Available resources

- **SISTEMA INTEGRADO DE MANIPULAÇÃO E COMUNICAÇÃO AUMENTATIVAS**
  - **MANUAL DO UTILIZADOR**
  - **USER MANUAL**

- **INTEGRATED AUGMENTATIVE MANIPULATION AND COMMUNICATION ASSISTIVE TECHNOLOGY**
## Available resources

![Image of available resources]

## Acknowledgements

![Image of acknowledgements]

## Funding

<table>
<thead>
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<th>Support</th>
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<tr>
<td><a href="#">FCT logo</a></td>
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## Contacts

<table>
<thead>
<tr>
<th>Contacts</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedro Encarnação</td>
<td><a href="mailto:pme@ucp.pt">pme@ucp.pt</a></td>
</tr>
<tr>
<td>Teresa Leite</td>
<td><a href="mailto:teresa@eselx.ipl.pt">teresa@eselx.ipl.pt</a></td>
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References