Why are educational robots not being used in Special Education schools despite proof that they are beneficial for their students?

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ABSTRACT

Previous interventions have proven that the use of robots in Special Education (SE) is beneficial for children, producing an increase in engagement and goal achievement. However, the use of robots rarely continues after the relevant study ends. In this paper we analyse previous studies that used robots in SE and interviews with SE teachers to obtain their views regarding reasons for lack of uptake of this technology. We propose a solution based on the use of a user-centred design approach for all components of the system, including methods of interaction, learning activities, and the most suitable type of robots.

1. INTRODUCTION

The first recorded use of robots as educational tools dates back to the 1980's, with a mechanical turtle used to teach Science, Technology, Engineering and Mathematics (STEM) subjects (Papert, 1983). However, the role of robots in education was first reviewed during the 1990's, with the first scientific publications highlighting the potential of this technology not only in STEM or Mainstream education, but also in Special Education and rehabilitation, mainly with a focus on children with Autism Spectrum Conditions (ASC) (Bühler, 1998; Cooper et al., 1999; Lees and Lepage, 1996). At the same time, LEGO started to market the Mindstorms robotic line in 1998, a system for inventing and building robots through a modular design and LEGO plastic bricks, that is still being used up to date.

Nowadays, educational robots are mainly used in Mainstream Education (ME) to teach STEM subjects (Armesto et al., 2015; Virnes et al., 2008). However, the use of this technology acquires special importance in the field of Special Education (SE), where studies exploring the use of robotics with children with ASC and Learning Disabilities (LD) have shown that they can be used as an effective tool to increase engagement and, consequently, goal achievement, as well as to raise interest in a specific task or subject (Andruseac et al., 2015; Standen et al., 2014a, 2014c; Virnes et al., 2008). Robots used in studies with children with ASC and LD can be put into two main categories: humanoid robots and non-humanoid robots, and their prices range from around £100 to £10,000, although no price is available for some non-commercially available robots developed specifically for research studies. One of the earliest pilot studies on the use of robotics in Special Education (Karna-Lin et al., 2006), emphasised that this technology can help discover hidden skills of students with learning difficulties, with the potential to offer different ways of interaction and the versatility of fitting within different learning styles. However, despite the benefits that educational robots seem to offer, and the existence of studies that tested various robots in Special Education Schools, these robots do not continue to be used after the relevant study ends. This raises an important question: why? The aims of the study presented in this paper are to answer this question establishing the main reasons for lack of uptake of this technology, as well as to introduce a suggested solution to the issues found. This solution is based on working very closely with the potential users of systems used to control educational robots from the early stages of the design to the final testing.

2. METHODS

In order to discover why educational robots are not widely used, we first conducted a review of previous research studies that have used robots with children with ASC or LD. The characteristics of these studies and the systems that they used were annotated, compared, and analysed, contrasting also with the researchers' previous experience using robots in Special Education Schools (Aslam et al., 2016; Galvez Trigo and Brown, 2014; Hedgecock et al., 2014; Standen et al., 2014b, 2014c). For this analysis, we extracted information about the robot used and its type (humanoid or non-humanoid) and checked its commercial availability and price when relevant, the user group

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chosen, the control devices that were necessary to operate the robot, who was the person controlling it, the availability of an interface for the final users, and finally, the type of activities included during the study. The results of this analysis can be seen in Table 2, and enabled us to compare the different systems used based on those factors. Once these data were collated, a series of informal interviews were conducted with Special Education teachers in schools situated in Spain and the United Kingdom.

2.1 Analysis of previous studies

Due to the changing nature of technology, especially robotics, we decided to focus our analysis on studies carried out from the year 2000 onwards, covering studies from different countries with participants with ASC or LD.

Several studies have been conducted, however, as some researchers highlight (Cho and Ahn, 2016; Pennisi et al., 2016), most of the research in this area focuses on the technical development and construction of these robots, and not on their actual testing in real-life settings. The studies reviewed have used different robots and different methods of interaction with the robots to try and see their effectiveness and effects when used with children with ASC and/or LD. Most of them reached similar conclusions, and although the conclusions were positive, none of the studies has had enough impact to get to the knowledge of SE schools and encourage them to acquire the piloted system, in those cases where the system was commercially available.

2.1.1 Eligibility criteria. Since the purpose of this study was not to offer a systematic review of the studies that have used robots in Special Education, but to find out why educational robots are not used in the classroom, the following selection criteria was applied. Studies must have been carried out from 2000 onwards, they must include at least a pilot with children with ASC and/or LD, they should not present repetitions or variations of the same experiment with the same system, even in different years, and they must describe the robot and system used. Based on these criteria, we filtered the results obtained and analysed 18 studies that used educational robots in Special Education settings.

2.2 Interviews with teachers

After carrying out the review of the relevant systems, we contacted three Special Education schools in order to schedule a series of interviews with teachers to discuss the reasons why they believe educational robots are not being used in the classrooms. One of these schools had already worked with the research team in previous studies.

2.2.1 The participants. The participants were teachers working in a school for children with ASC and/or LD. One of the schools was a Special Education school from Nottingham, UK, for children aged 3 to 19, whilst the other two were from a state and an independent Special Education school in Toledo, Spain, both for children aged 3 to 21. We selected the three above mentioned schools for several reasons. Firstly, they are all SE schools, having students with high-functioning to low-functioning ASC, MLD, SLD, as well as PMLD that in some cases are accompanied by Physical Disabilities (PD) such as Cerebral Palsy (CP), covering this way a wider range of children with ASC and/or LD. Secondly, from our participation in various projects that used educational robots in SE, we have observed that there are cultural and organisational differences in the way Special Education is approached among different countries (Edurob, n.d.; MaTHiSiS, n.d.), and including participants from two different countries would enable us to obtain a broader perspective, as well as to see if despite the cultural and organisational differences, we would obtain the same conclusions. Lastly, we deemed it important that the participants felt comfortable during the interviews, therefore, conducting them in their native language was the best option, since a member of the research team is a native Spanish speaker we opted to approach schools in Spain. As in Spain there are usually significant differences between state schools and independent schools, we decided to recruit one on each category. In order to recruit participants, we approached the head teacher of each school and presented a summary of the proposed study. They circulated that information among their teachers and directed us to those that were interested in participating. A total of 13 teachers volunteered to participate in the interviews: 3 from the school in the UK, 7 from the state school in Spain, and 3 from the independent school in Spain. Participants came from different generations and backgrounds, with some having previously used robots in the classroom and some others not. Since the study was introduced to the teachers by their head teacher, it was not possible to determine the reasons why not all teachers volunteered to participate, and their personal interest on the use of these technologies in the classroom might have played an important role. However, head teachers indicated that the overall reaction to the study was very positive also among teachers that did not volunteer, and that they considered the participation high, given that most teachers had little time available. The school in the UK and the independent school in Spain had technologies such as iPads, computers, eye-trackers, and other assistive technologies. However, the state school in Spain only had computers available for some of the teachers and none for the students.

2.2.2 The interviews. With the teachers in the UK, one-to-one interviews were organised, whilst, due to time and travel restrictions, two focus group interviews were held with the teachers from the schools in Spain. During the interviews, a first introduction to the topic and past and current research was given, as well as to the robots and systems that had been used, showing them pictures and explaining to them the main characteristics of those studies. This was followed by an informal questions & answers session where we directed them towards indicating why they believed that educational robots are not widely used in SE, and what would be their main reason for not using any of the systems that we presented them.

3. RESULTS

3.1 Analysis of previous studies

The most relevant results obtained from the analysis of previous studies can be classified into three main categories: the robots, the methods of interaction, and the educational activities.

3.1.1 The robots. After the analysis, we found out that 6 out of 18 studies were conducted using non-commercially available robots that were built purposely for those research studies, and none of them have become commercially available to date, with another one using both a commercially and a non-commercially available robot (Billard et al., 2007; Jimenez et al., 2016; Kozima et al., 2005a; Lathan and Malley, 2001; Marti and Giusti, 2010; Robins et al., 2003; Wainer et al., 2014). These robots can be seen in Fig. 1. A major explanation regarding why those robots are not widely used in SE schools is that schools do not have access to them. Therefore, we will not elaborate further on these systems. Instead, the remainder of our review focuses on studies that used commercially available robots. Among these, the most used robot is the robot NAO (Aslam et al., 2016; Barakova et al., 2015; Lewis et al., 2016; Shamsuddin et al., 2012b; Standen et al., 2014c; Warren et al., 2015), a humanoid robot manufactured by Softbank Robotics that measures 58cm and offers 25 degrees of freedom (DoF), various sensors, and a toy-like appearance. One of the main drawbacks for use of NAO is its price, as it currently retails for a price of approximately £6,000, with retailers offering maintenance plans for extra money. For that price, a school needs to see a very high value-for-money and have the budget to decide to buy it. NAO has been used in 6 of the 12 studies that used commercially available robots, and it was most likely selected for education studies due to its friendly toy-like appearance, its capabilities, and its programmability. However, it is possible that marketing and publicity of the NAO robot, as it has been featured extensively in showcases, public events, and news reports, may have influenced interest in this specific robot type. Indeed, there are several other, more affordable robots that are very similar in appearance and features to NAO that have not been used in any published studies. Cheaper robots that have been used in other studies such as LEGO Mindstorms (a robotic kit that lets its user build a robot in different shapes and configurations using LEGO bricks, also with various sensors), used in 3 studies, and Sphero (a spherical robot that can be navigated and can produce sounds),, used in 1 study, do not have as many features or capabilities as NAO. However, there is no evidence that they offer less benefits than the more expensive robots, and several studies featuring them have equally highlighted their potential in the field of SE (Golestan et al., 2017; Karna-Lin et al., 2006; Kozima et al., 2005b; Marti and Giusti, 2010), with a recent study comparing both types of robots finding little or no difference between their effectiveness and benefits (Aslam et al., 2016). The prices of the robots used in the studies analysed in this paper can be seen in Table 1. The reason why these robots are not widely used in SE yet may be because teachers do not see them as representing sufficient value-for-money. Some teachers might not know about the existence of some of them, and many might not know how to use them or will not have the time to spend in learning how to use them and creating activities for their students with them. The commercially available robots used in the analysed studies, Keepon, LEGO Mindstorms EV3MEG , R25 Milo, NAO, Sphero, and Topobo can be seen in Fig. 2.

3.1.2 Methods of interaction. An important consideration for implementation of educational technology beyond the research study is: How and who controlled the robots during each study? If teachers, or teaching assistants, are not directly involved in the use of the technology during the research investigation, it can be very difficult – even impossible, for them to take up use of the technology without the support of the research and/or technical team. Analysis of the reported studies, showed that, in 12 of the 18 studies (Barakova et al., 2015; Billard et al., 2007; Jimenez et al., 2016; Kozima et al., 2005a, 2005b; Lathan and Malley, 2001; Lewis et al., 2016; Marti and Giusti, 2010; Robins et al., 2003; Shamsuddin et al., 2012b; Standen et al., 2014c; Warren et al., 2015), the robot was controlled using a Wizard-of-Oz approach, relying usually on a member of the research team to remotely control the actions and responses of the robot, normally without the knowledge of children who were interacting with it. The reason for this was, most likely, that control of the robot required a separate laptop interface and knowledge of the control interface/editor or programming language used, that is different for each robot. In many cases, teachers would not possess the skills and/or time needed to operate the robot. Lack of a user-friendly interface that teachers and children can use to interact with the robot can be a decisive factor when choosing if they should or should not buy a robot, as they must be able to use it in order to benefit from it. Additionally, robot sensors were not sufficiently sensitive or reliable to pick up a child's vocal response or gestures. This meant that a Wizard-of-Oz approach had to be used for some other studies thus limiting the teacher's ability to focus on other aspects of the interaction of the children with the robot, rather having to stay behind a computer controlling its actions. Apart from those considerations, 2 of the studies that did not use a Wizard-of-Oz approach did so because the activities consisted of building and programming the robot rather than controlling it and/or interacting with it. Another aspect to consider is that most studies focus on children with high-functioning ASC and/or Mild Learning Disabilities (MLD), and only 2 of those with Severe Learning Disabilities (SLD) or Profound and Multiple Learning Disabilities (PMLD)(Aslam et al., 2016; Standen et al., 2014c). Children in the latter two groups could have issues if they do not have an appropriate way of interacting with the robots that adapts to their needs. These ways of interaction might include the use of different Assistive Technologies (AT) such as micro-switches, joysticks, or different sensors that could interpret their orders. Only a few studies have used this kind of controlling devices, and this can be another reason why SE schools might have decided not to acquire one of these robots, since many students would not be able to benefit from them.

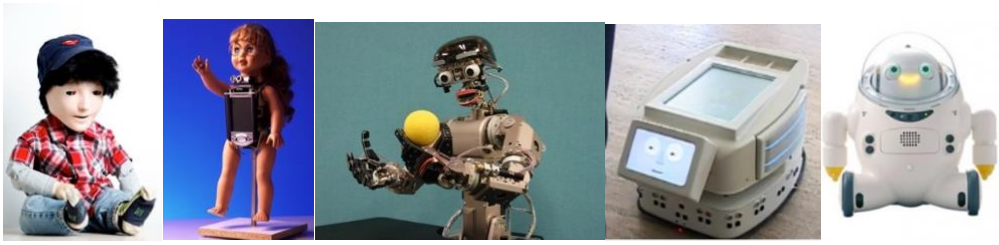

Figure 1. *Non-commercially available robots. From left to right: Kaspar* [University of Hertfordshire], *Robota* [EPLF], *Infanoid* [NiCT], *IROMEC* [IROMEC], *and ifbot* [Futaba]

Figure 2. *Commercially available robots. From left to right: Keepon* [CMU], *LEGO Mindtorms EV3MEG* [LEGO group], *R25 Milo* [RoboKind], *NAO robot* [SofBank Robotics], *Sphero* [Sphero], *and Topobo* [Topobo]

3.1.3 Educational activities. The activities featured in the research studies analysed can also be seen in Table 2. Most studies used imitation games and prompts to motivate the children to initiate a social interaction with the robot (Billard et al., 2007; Golestan et al., 2017; Kozima et al., 2005a, 2005b; Lathan and Malley, 2001; Leo et al., 2015; Lewis et al., 2016; Robins et al., 2003; Shamsuddin et al., 2012b), however, these type of activities are more relevant for children with ASC than for children with LD, especially for those with SLD or PMLD. For these activities the children were generally able to interact independently with the robot, although supervised by a teacher, and with a researcher controlling the robot in most cases. Two of the studies involved building and programming a robot using a graphical interface (Karna-Lin et al., 2006; Virnes et al., 2008). This was reported as challenging and required more support from teachers, with some students indicating that they would prefer the use of a remote control or buttons to control the robot rather than having to program it on the given computer interface. Only a few studies included activities focused on helping the children develop other skills such as choice-making, cause and effect, or motor skills (Aslam et al., 2016; Standen et al., 2014c; Wainer et al., 2014). We believe that the lack of an appropriate and wide enough range of activities might be a decisive factor for schools and teachers when deciding whether acquiring a robot will offer sufficient value-for-money.

2.2.3 The teachers' views. The results of the interviews were very consistent, with nearly all teachers showing great interest in the use of educational robots in their classrooms. Only one teacher from the independent school in Spain showed scepticism but agreed that interventions using educational robots may be beneficial for some students. Only two of the teachers, from the UK, were involved in studies using robots in the classroom in the past or had previous experience in using these kind of robots. Most teachers were only aware of the existence of those robots with a stronger marketing presence, such as NAO and the LEGO Mindstorms, or others that they had previously seen in toys or technology retailers, with almost none of them used in previous research studies.

Teachers highlighted five points as the main reasons why they would not use one of the systems discussed:

- *Price.* The price was considered the major concern and barrier for which their school would not acquire the technology. All 13 teachers highlighted that if the school has no budget for it, it will not matter how good it is and what a great value-for-money it offers.
- *Lack of a user-friendly interface.* The lack of a user-friendly interface that both teachers and students could use to interact with the robot was mentioned as the second most important factor, with all 13 teachers indicating this issue as an important one.
- *Lack of appropriate alternative ways of interaction for their students.* Another great concern for teachers was that some students could not benefit from the use of this technology if it does not offer compatibility with alternative assistive ways of interaction, such as micro-switches, or movement-trackers. This was highlighted at first by 7 of the 13 teachers (those working with children with SLD and PMLD), although in the group interviews all teachers agreed on this point after their colleagues mentioned it, raising the number of teachers considering it an issue to 11 out of 13 teachers.
- *Contents not being appropriate for their students.* All 13 teachers highlighted that the contents or activities that the robot could perform would play a decisive role on whether the robot is being used or not. Some teachers mentioned that they would like to be able to create their own activities in an easy way, even if it is choosing and making combinations from a predefined set.
- *Not being able to use different robots with the same controlling interface.* 6 teachers (1 from the UK, 1 from the independent school in Spain and 4 from the state school in Spain) indicated that it may be necessary to use different robots to benefit a wider range of students, since a humanoid or a vehicle-like robot may not be suitable for all of them. From that remark, they indicated that having to learn and possibly buy two different software systems for that purpose would be very time consuming and confusing.

Table 1. *Table of prices of commercially available robots used in analysed studies*

Robot	Manufacturer	Price
Keepon	BeatBots	\$279.99 (~£200)
LEGO Mindstorms	LEGO	£299.99
R25 Milo	RoboKind	~\$5,000 (~£3,600)
NAO	Softbank Robotics	~£6,000
Sphero	Sphero	£119.95
Topobo	Topobo Korea	\$149 to \$1,250 (~£107 to £900)

3. DISCUSSION AND CONCLUSIONS

The benefits of the use of educational robots in SE are evident from the studies analysed. The teachers interviewed confirmed that they agree and would like to be able to use these robots in the classroom. However, there are still several factors that prevent schools from acquiring robots and integrating them within their curriculum.

Not being able to access the relevant robot, either because it is not commercially available, or its price is too high, is one of the main factors for non-uptake that we observed from both the analysis of previous studies and the interviews with teachers. This, together with the lack of a user-friendly interface that teachers and children could use to control the robot are the two main reasons why educational robots may not be widely used in SE schools. We also learnt that the range of activities that robots performed is not enough, and that more flexibility in this regard is needed, as well as more varied means of interaction for those with SLD or PMLD. Furthermore, 6 teachers mentioned during the interviews that they would like to be able to use more than one robot with just one interface, as they could try to acquire different cheaper robots instead of an expensive one if they believed that this approach would offer benefits to a larger group of students.

We suggest addressing these issues with the involvement of the users from an early stage in the design of the systems used in studies that use educational robots in SE. This way, the use of very expensive robots that will never be commercialised or that do not meet the requirements of children with ASC or LD could be avoided. Since teachers and parents are the ones that know these children best, we propose to embark with them and their children on the design of a system that uses educational robots in SE to try to produce a system that can be adopted by schools. This solution follows a study carried out by a member of the research team in 2014, were an interface to control NAO using tablets was developed, using feedback and design suggestions given by teachers during the design process with positive results (Galvez Trigo and Brown, 2014).

Table 2. *Comparison table with main characteristics of the analysed studies*

Study	Country	User group	Robot	Humanoid robot?	Commercially available robot?	Controlling devices for robot	Robot controlled by	Graphic User Interface available for users	Type of activities
(Lathan and Malley, 2001)	USA	PD,CP	GIR-T	No	No	Laptop	Researcher, children	No	Imitation, storytelling
(Robins et al., 2003)	UK	ASC	Robota	Yes	No	Laptop	Researcher	No	Imitation
(Kozima et al., 2005a)	Japan	Mainstream	Infanoid	Yes	No	Laptop	Researcher. Automatic mode to fix attention	No	Prompting social interaction, joint attention
		ASC	Keepon	No	Yes				
(Kozima et al., 2005b)	Japan	ASC	Keepon	No	Yes	Laptop	Researcher. Automatic mode to fix attention	No	Emotion and attention exchange
(Karna-Lin et al., 2006)	Finland	MLD	LEGO Mindstorms	No	Yes	Laptop	Teacher, children	No	Building the robot, programming the robot
(Billard et al., 2007)	UK	Mainstream	Robota	Yes	No	Laptop	Researcher	No	Imitation
	France	ASC					Automatic imitation		
(Virnes et al., 2008)	Finland	ASC, Behavioural, Emotional and Social Difficulties (BESD)	LEGO Mindstorms	No	Yes	Laptop	Teacher, children	No	Building the robot, programming the robot
			Topobo			Remote			
(Marti and Giusti, 2010)	USA	ASC, MLD, PD	IROMEC	No	No	Laptop, switches on robot's body	Researcher	Yes: XML-based	Turn-taking, follow me
(Shamsuddin et al., 2012a)	Malaysia	ASC, MLD	NAO	Yes	Yes	Laptop	Researcher	Yes: Choregraphe	Prompting social interaction
(Standen et al., 2014c)	UK	ASC, PMLD	NAO	Yes	Yes	Laptop, joystick, micro-switches, smartphone	Researcher, children	Yes	Choice-making, response, speech, cause and effect, motor skills
(Wainer et al., 2014)	UK	ASC	KASPAR	Yes	No	-	Children	No	Collaboration
(Warren et al., 2015)	USA	ASC	NAO	Yes	Yes	Laptop	Researcher	Yes	Joint attention
(Barakova et al., 2015)	The Netherlands	ASC	NAO	Yes	Yes	Laptop	Researcher	Yes	Prompting to build LEGO
(Leo et al., 2015)	Italy	ASC	R25 Milo	Yes	Yes	Laptop	Children	No	Emotion imitation
(Jimenez et al., 2016)	Japan	Non-diagnosed ASC, LD	Ifbot	Yes	No	Laptop	Researcher	Yes	Storytelling
(Lewis et al., 2016)	USA	ASC, MLD	NAO	Yes	Yes	Laptop	Researcher	Yes	Attention, imitation, joint attention, turn-taking, initiative
(Aslam et al., 2016)	UK	ASC, PMLD	NAO	Yes	Yes	Tablet	Children	Yes	Directions, listening, choice-making, speech
			LEGO Mindstorms	No		Remote			
(Golestan et al., 2017)	Iran	ASC	Sphero	No	Yes	Smartphone, tablet	Children	Yes	Speech, prompting social interaction

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Teachers and parents will be asked about aspects of the design such as the type of robots it should be compatible with, the control devices that it should work with, and the activities to be included. Children expressing willingness to participate, for which parental consent is also given, will be able to take part, giving us design suggestions and using the system during the different piloting stages. This study was also introduced to a local group of young adults with LD, and we will continue to present updates during this group's regular meetings and to use their advice to improve the system. In order to achieve this, and based on the fact that many teachers knew only the robots with a stronger marketing presence, or those that, although have not been used in studies, are sold in stores, we will not only consider robots used in previous studies, but other commercially available and affordable robots that teachers and parents identify as good candidates. The same will apply to control devices and activities.

Being able to develop a user-friendly system that can be used to control different robots in SE classrooms, would also enable fellow researchers to conduct larger and longer studies, with more reliable data obtained from a real-life setting rather than from a controlled experimental scenario.

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