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Skilling Students in ICT using Long-Distance Controlled Robots over the Internet in a Blended Learning Setting

Megan HASTIE [a*], Akiyuki MINAMIDE[b], Kazuya TAKEMATA[b], Nian-Shing CHEN[c], Richard SMITH[d]

[a]*Education Queensland, Australia*
[b]*Kanazawa Technical College, Japan*
[c]*National Sun Yat-Sen University, Taiwan*
[d]*Southern Cross University, Australia*
*mhast5@eq.edu.au

Abstract: This paper is about the use of a long-distance controlled robot system (LDCR) by learners working in a blended learning setting. We describe an interactive robotic project that was the result of an international collaboration between an Australian school of distance education and a Japanese technical college. After citing research findings about the use of the system across multiple curriculum areas we identify the technological and pedagogical challenges encountered during the project and quantify significant gains for students, teachers and the wider school community. The paper concludes that long-distance controlled robot systems can be successfully integrated into blended teaching and learning paradigms and that this is a potential educational imperative for 21st Century students and teachers.

Keywords: educational robots, long-distance controlled, Lego Mindstorms, synchronous cyber classroom, blended learning

1. Introduction

An imperative for educators in an age of rapid and continuing advances in information and communication technologies (ICT) is to ensure that 21st Century learners become highly skilled in state-of-the-art, cutting-edge ICT. The pace of change demands that high skilling in ICT be escalated over the next decade (Ministerial Council on Education, Employment, Training and Youth Affairs, Melbourne Declaration on Educational Goals for Young Australians, December 2008, p.4). While schools in Australia and internationally are employing a range of technologies in teaching and learning, including educational robots, the use of long-distance controlled robots, as described in this paper, is a relatively new and untested application of ICT in educational paradigms. In this paper we examine the role of the Internet and Web 2.0 tools, as part of our ongoing research and development in e-learning paradigms (Hastie, Chen, Kinshuk, Smith et al, 2010, 2011, and 2012).

We report on an interactive robotic research and development project conducted during 2013 at Brisbane School of Distance Education (BSDE), through an international collaboration with Kanazawa Technical College (KTC), Japan. The study augments previous research undertaken by Kanazawa Technical College (Minamide, Takemata, Yamada & Hastie, 2012). BSDE was chosen as a trial site because the school uses a 'Blended Learning (BL) mode of delivery that combines different instructional methods, modalities and delivery 'media', including online and face-to-face instructional settings in which participants may be physically present and/or 'cyber'. The 'BSDE Interactive Robots Project 2013' used a robot operated by students via a laptop in a Blended Learning setting using a synchronous cyber classroom, facilitated by an e-learning manager using a collaborative, and a negotiated approach to content development decision-making (Hastie, Chen, Smith, Todd et al, 2008, 2011, 2012). The project sought to build bridges across the digital divide to include and empower students living in rural, remote and isolated locations (Hastie, Chen & Leeming, 2010) and strengthen

on-going international collaborations in the Asia-Pacific region (Hastie, Chen, Kinshuk, Smith et al, 2009, 2010).

The main focus of this study, however, was the introduction of robotics to 'distance' students enrolled at BSDE in 2013 through the trial of an innovative Long-Distance Controlled Robot system (LDCR), to develop high level skills in technology (ICT) and skills in multiple curriculum areas. We cite new findings in which we describe an approach that can be adopted by teachers to integrate ICT, specifically robotic technology, into the curriculum and propose strategies to help schools develop Blended Learning modes of delivery. We now examine the literature on educational robots and implications for students, teachers and school communities.

2. Literature Review

In a world where the boundaries between humans and machines are becoming more and more blurred, it is apparent that our relationships with robots are becoming increasingly complex and will continue to do so. We can only imagine the world in which today's children will operate in the future as robots continue their migration into traditional white-collar jobs and all areas of human activity. While the term 'robot' is derived from a Czech word meaning 'forced labour', in this paper we define a 'robot' as a mechanical device that is capable of performing a variety of often complex human tasks on command or by being programmed in advance, and as sometimes resembling a human. While robots have been used for decades to perform tele-surgery and are now routinely used to perform complex tasks on the International Space Station with controllers based on Earth, there is scant evidence in the literature of the use of Long-Distance Controlled Robots in education. This study then is ground-breaking because it addresses the challenges faced by educators everywhere in integrating robotics technology into mainstream education, particularly 'distance' education. With the next generation of potential robotics engineers and innovators already in our schools, we need to prepare them for a future in which robots will be all pervasive.

The literature is emphatic in urging us to escalate the up-skilling of young people in their use of technology, specifically ICT. In the draft *Shape of the Australian Curriculum: Technologies* paper (ACARA, 2012) the subject area 'Technology' is recognised as including the 'creative processes that assist people to select and utilise materials, information, systems, tools and equipment to design and realise solutions' (p. 1). The current Queensland technology syllabus (Queensland Studies Authority, 2003) also addresses this broader view of technology as involving the design and production of innovative and creative products and processes to meet human needs and wants. The syllabus outlines the need for students to work technologically and use resources including materials, systems, and information to create products and processes. As a consequence, technological literacy can enable them to 'use, manage, assess and understand technology' (ITEA, 2007, p.7). There is no direct reference to the inclusion of robotics in the Queensland syllabus. However the Queensland Study Authority, in their Queensland Curriculum Assessment Framework for Technology, advises teachers that students who may be awarded an 'A' will demonstrate a very high level of knowledge and understanding of concepts, facts and procedures, and application of processes (Queensland Study Authority, 2012).

Education Queensland supports schools and students who compete in the First Lego League Robotics program, a robotics competition for middle school students (aged 9-14). In this program mentors and educators work with a team of students and a LEGO Mindstorm Kit to prepare for competitions. Students are encouraged to appreciate science, technology, engineering and mathematics, using real-world context and 'hands-on' experimentation. The students work on-site with their teachers and mentors in a Physical Face-to-Face setting, usually at a school. However, students do not use a long-distance controlled robots system (LDRS), as described in this study. The Long-Distance Controlled Robot system (LDCR) using 'Robocube', was initially developed for use by students in Japan and for an international exchange between Kanazawa Technical College and students at Singapore Polytechnic (Minamide, Takemata, Naoe, Yamada & Hoon, 2008). During trials, one challenge that emerged was related to the user interface not being translated completely into English resulting in difficulties for students using the system (Minamide, Takemata, & Hoon, 2009). This was easily resolved. However, there were high costs associated with the 'Robocube' robot which is manufactured in Japan and therefore not easily accessed internationally (Minamide, Takemata,

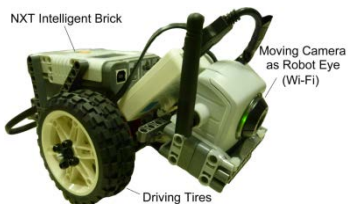
Yamada & Hastie, 2012). A re-designed system sought to reduce costs and increase system security, while ensuring ease of operation of the robot by students and teachers. This resulted in the selection of the Lego Mindstorms NXT (Lego NXT) due to its wider availability (Hung, Chao, Lee & Chen, 2013) and a new purpose-built LDCR system was designed by Kanazawa Technical College (Minamide, Takemata, Yamada & Hastie, 2012).

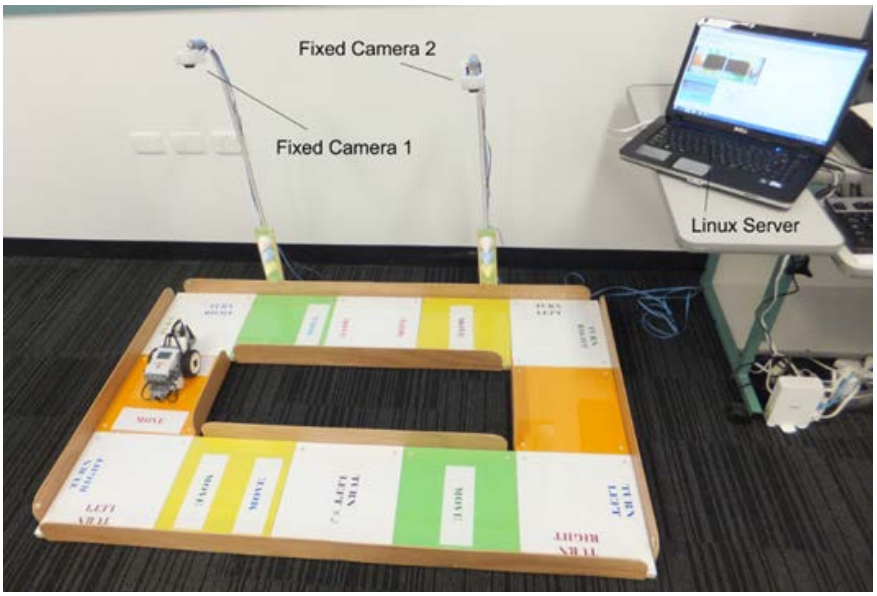
We now describe a case study conducted during 2013 in which primary school students and teachers at an Australian school of distance education participated in the trial of the re-designed LDCR, and how they were introduced to robotic technology in an attempt to skill them at high level in ICT, and enhance their general skill level across multiple curriculum-areas.

3. Research Methodology

3.1 Project instigation

In this paper we present findings from an interactive robotic research and development project conducted at Brisbane School of Distance Education (BSDE), Australia, during 2013 in collaboration with Kanazawa Technical College (KTC), Japan. The project was instigated in 2009 by Professor Takemata and Professor Minamide (KTC) through an approach made to Ms Megan Hastie, an Education Queensland Senior Experienced Teacher (BSDE), to test the use of a long-distance controlled robot system (LDCR) by students operating in a 'distance' education technology enhanced learning paradigm. In 2010 the Professors visited BSDE and demonstrated their Long-Distance Controlled Robot system over the Internet. Initial interest and enthusiasm amongst BSDE administrators and teaching staff for the robotic project was high and in 2011 the Professors returned to BSDE. During the second visit the Professors donated a Lego NXT robot, cameras, a Dell laptop computer, a router, cables and tools to BSDE, and installed a robotic field in the BSDE Library as depicted in the photographs below:





3.2 Robotics Project launch

In 2013, Megan Hastie, re-launched the project with a focus on the BSDE Year 6 student cohort. Students in this year level are typically aged ten and eleven years and are the 'senior' students in the Junior School. The Holistic Blended Learning Model was applied to the project with Mode 10, the optimal mode, being the preferred e-learning pedagogy, as outlined below in Table 1:

Table 1: The Holistic Blended Learning Model (Hastie, Hung, Chen, & Kinshuk, 2010)

1	(PA + PS)	Physical Asynchronous + Physical Synchronous
2	(PA + CA)	Physical Asynchronous + Cyber Asynchronous
3	(PA + CS)	Physical Asynchronous + Cyber Synchronous
4	(PS + CA)	Physical Synchronous + Cyber Asynchronous
5	(PS + CS)	Physical Synchronous + Cyber Synchronous
6	(CA + CS)	Cyber Asynchronous + Cyber Synchronous
7	(PA + PS + CA)	Physical Asynchronous + Physical Synchronous + Cyber Asynchronous
8	(PA + CA + CS)	Physical Asynchronous + Cyber Asynchronous + Cyber Synchronous
9	(PS + CA + CS)	Physical Synchronous + Cyber Asynchronous + Cyber Synchronous
10	(PA + PS + CA + CS)	Physical Asynchronous + Physical Synchronous + Cyber Asynchronous + Cyber Synchronous

Using Mode 10, students and teachers accessed print and multi-media resources (PA) related to robotics, attended physical lectures on-site at BSDE (PS), accessed online digital resources (CA) through links to robotics demonstrations and participated in weekly cyber synchronous session (CS), including guest speaker events.

In February 2013, Year 6 students who were able to attend a physical lecture (PS) met on-campus at BSDE for an 'Enrichment Day'. Students were introduced to the robot and the robotics project proposal was explained. Student and parent enthusiasm for the project was determined at very high level with corresponding high-level support from the school's Principal, Parents and Citizens Association and the Year 6 teaching team. Following the Enrichment Day, an invitation was issued to all Year 6 students via the school's Blackboard noticeboard to join the 'BSDE Interactive Robots Project 2013'. Participation in the project was voluntary and was open to all students irrespective of their physical location with students informed that they could participate in the project through a Blended Learning (BL) mode of delivery. Nineteen students (30%) out of a total sixty-five Year 6 students nominated, including eleven students (58%) located in Brisbane, seven students located within one to two hours drive of Brisbane (37%) and one student (5%) located overseas. Five students (26%) were female and fourteen (74%) were male.

In March 2013, twelve student members (63%) of the 'BSDE Interactive Robots Project 2013' along with three Year 6 teachers participated in the first meeting of the project. Nine students (75%) participated PF2F at BSDE and three students (25%) joined the meeting CF2F, via Elluminate, including one student (8%) from overseas. Three students (25 %) were female and nine (75%) were male. Students were officially welcomed to the project launch by the school's Deputy Principal who stressed the innovative and ground-breaking nature of the robotic project for BSDE. Students were then invited to 'name' the robot with the name 'DCR13' (an acronym for Distance-Controlled Robot 2013) being selected by popular vote. The students completed a Survey, a questionnaire comprising seven questions, to determine their prior knowledge of robots, their learning expectations including their expectations of project membership (frequency of meetings, meeting modes and locations). Students and teachers discussed the broad aims of the project. These included learning about technology with a specific focus on robotic technology, the 'hands-on' operation of robots, the design of 'terrain' for robots to traverse, collaborative research and development on the application of robots in everyday life, invitations to 'expert' guest speakers, and the contributions our project could make to the fields of Science and Technology. Students then took turns to 'drive' the robot around a field using directional keys on the laptop, with the three students connected via Elluminate interacting with teachers and classmates using webcam and VoIP. Students spontaneously redesigned the field to create different pathways and simple variegated terrain for the robot to traverse. Student discussion during this time involved them in the identification of specific mediums (such as sand, gravel or water) that may damage the workings of the robot and thereby eliminating these (through the substitution of mediums to simulate these) from the terrain design. Students came together at the end of the first meeting to plan future meetings. This included a timeline for the current phase of the project with plans for the design of the terrain, the writing of a script to tell the story of the robot's travels, the role of the Narrator, rehearsals, leading to a presentation for parents, classmates, teachers, and school administration at the end of Semester One (mid-June 2013).

Following the first meeting the student survey data was collated and analysed, as shown in Table 2 below:

Table 2: Student Survey 1:

Question 1	Student responses	
I've had previous experience with robots.	Yes	80%
	No	20%
Question 2	**Student responses**	
What would you like to learn about robots?	How robots function (technical) How robots can do chores How to build my own robot How to program robot better (programming, coding)	
Question 3	**Student responses**	
What would you like the robot to do?	Household chores and gardening Transport objects Be remotely controlled and armed with a ball shooter Help old people by making a cup of tea Perform plays Motion controlled (eg. wave = go forward) Fly like a helicopter Generate music Look and move like R2D2	
Question 4	**Student responses**	
What type of terrain would you like to design for the robot to traverse?	A mixture of sandy, rocky, muddy and hilly terrains Dirt and stones Jupiter Investigating Europa (Jupiter's moon) Jungle Mars Sky Underwater A helipad for it to land on Ramp course I have too many to count.	

Question 5	Student responses	
Would you like to meet guest speakers who are experts on robots?	Yes	100%
	No	Nil
Question 6	Student responses	
How often would you like our group to meet for the robot project?	a. Once a week	45%
	b. Once a fortnight	22%
	c. Once a month	33%
Question 7	Student responses	
Where would you prefer to meet?	Always on-site at BSDE	45%
	Always virtually via Elluminate	Nil
	A mix of on-site (at BSDE) and virtual (Elluminate) meetings	55%

In response to the student survey, students met CF2F with the lead teacher, Megan Hastie, once per week via a synchronous cyber classroom (Elluminate) during May-June 2013. Using the interactive synchronous whiteboard, VoIP, webcams and the chat-room, students planned and designed terrain for the robot to traverse, and wrote a script for the presentation. In early-May, students who were able to attend a PF2F on-campus session at BSDE built the terrain using a range of art and craft materials. Those students unable to attend PF2F joined the session via a synchronous cyber classroom (Elluminate) to participate in the assembly of the terrain and to rehearse the script for the presentation. Students volunteered for various roles and duties for the presentation including Narrators, robot operation, lighting, music and special effects. A date for the presentation was determined and invitations to parents, BSDE staff and administration and fellow students for the presentation were designed and emailed.

During this time (May-June 2013) several expert guest speakers gave presentations on robotics to the students. Students and teachers linked via the synchronous cyber classroom to a professor of Robotics at Cornell University, USA, and an academic working in robotics at the Queensland University of Technology (QUT) on topics identified by the students in the survey data above, and included question-answer opportunities for students.

It is anticipated that the Global IP address will be activated during September 2013 to enable the project to achieve its initial aim of allowing students to control the robot long-distance. The robot will remain on-site at BSDE and students will control it from their individual locations off-campus. In September students will complete a second Survey in which they will have the opportunity to reflect on the project and their expectations of future participation in the 'BSDE Interactive Robot Project 2013'. This will assist with the planning of the next phase of the project which extends to the end of 2013, and it is anticipated that phase two will provide further research data.

4. Findings and Implications

The main finding in this paper is that the skilling of primary school students and their teachers in the use of educational robots is not only possible, but is an imperative for 21st Century education. This change is being driven by rapid and continuing advances in information and communication technologies (ICT), particularly robotics, and this in turn demands the escalation of high-level skilling in ICT over the next decade. As our relationships with robots become increasingly complex and as robots continue their migration into all areas of human activity, 21st Century learners must be fully prepared to live and work with robots. It is of paramount importance that the usual ICT suite of subjects be broadened to include the study of robotics and for robotics courses to be given more prominence at all levels in education. This will help grow the next generation of robotics engineers, innovators and designers, starting at primary school and during the formative years of early childhood. This means the study of robotics must become a key content area and that schools need to be appropriately resourced. With teachers identified as the most transformative factor in the teaching-learning dynamic (Hattie, J, 2003), the up-skilling of teachers in the application of robotics technology is critical.

Our second finding is that the use of a Long-Distance Controlled Robot system (LDCR), as described in this study, has the potential to provide unlimited access to educational robots for students and teachers in rural, remote and isolated situations, irrespective of their physical location. Through the use of the Internet and Web 2.0 tools, specifically the LDCR and the synchronous cyber classroom, students and teachers were able to operate in a Blended Learning setting that put the world of robotic expertise at their fingertips, helped them develop networks both within Queensland and internationally, and built bridges through cyberspace and across the 'Digital Divide'. As such the project was totally inclusive and an indictment of the power of the Internet.

Our third finding is that primary school students and their teachers can work collaboratively with experts in robotics to develop situation-specific projects that yield quantifiable academic and social gains for participants at local level and internationally, and across multiple curriculum areas. While students and teachers in this study focussed predominantly on the speciality area of robotics, they also worked in the curriculum areas of Science, Technology and ICT, English, Mathematics and the Arts.

A fourth finding is that risk-takers are needed to make projects of this type work. This is because innovation involves risk and schools, with typically over-loaded curriculum, seldom have time for anything extra. It takes vision and energy and key personnel in schools like BSDE, and in institutions like Kanazawa Technical College, to recognise opportunities for students and to drive innovation, as demonstrated in this study. Without the key teacher, the robot would have stayed packed in its box. Instead the robot came to life, enchanted students and teachers, put the focus squarely on Technology and high-level ICT skilling, and lead participants in new adventures in thinking and learning, and as a consequence galvanised the collaboration between BSDE and Kanazawa Technical College.

Finally, evidenced-based research of the sort gathered in this study can contribute new findings to the fields of Science and Technology. This in turn will create career pathways and employment at the cutting-edge of innovation for young Australians.

5. Conclusions

In this paper we have described a ground-breaking trial of a Long-Distance Controlled Robot system (LDCR) conducted during 2013 at an Australian school of distance education. The trial supports a growing body of research in which the skilling of primary school students and their teachers in the use of educational robots is identified as an imperative for 21st Century education. Globally educators need to give higher prominence to the study of robotics to ensure students are adequately prepared to live and work in a world where robots will pervade all areas of human activity. In the next decade, an escalation of high-level skilling in ICT is critical if we are to develop situation-specific projects that yield quantifiable academic and social gains for communities of learners at local level and internationally, and across multiple curriculum areas. This will require vision, energy and the support of key personnel in schools if the quantum shift to Blended Learning is to be achieved. In particular, Australian educators need to optimise opportunities to collaborate with experts in robotics in the Australasian region to ensure Australian students achieve world-class training in ICT that will lead to career pathways and employment at the cutting-edge of innovation in what is described as the 'Asian Century'. One thing seems certain – it will be the century for robots.

Further technological support is required to determine the logistics around a Global IP address that will allow students to control the robot long-distance, and thus achieve the project's initial aim. It is also recommended that consideration be given to the extension of the project to include other year levels and faculties within Brisbane School of Distance Education, with potential to include other Education Queensland schools of distance education and interested international partners in a wider, longitudinal study.

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