

LEGO Mindstorms™ for informed metrics in virtual worlds

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ABSTRACT

Science education is the meaningful pursuit of comprehension, knowledge and understanding of scientific concepts and processes. In Vygotskian, social-constructivist learning, personal interpretation, decision making and community cooperation fosters long-term understanding and transference of learned concepts. In short, the construction of knowledge requires learners to be actively involved in the process of learning. For effective science learning an instructor's pedagogical approach must be anchored in meaningful contexts so that students experience science. This research paper assesses and defines effective measurements for evaluating strategies for communicating science using LEGO robots and a Mindstorms™ RCX controller collaboratively constructed and programmed by students using virtual technologies while physically situated in different locations.

Categories and Subject Descriptors

H.5.1 [Multimedia information systems]: Artificial, augmented, and virtual realities.

General Terms

Measurement, Design, Theory.

Keywords

Metrics, LEGO robots, communication, virtual worlds, futures.

1. INTRODUCTION

Science education is the meaningful pursuit of comprehension, knowledge and understanding of scientific concepts and processes. In Vygotskian, social-constructivist learning, personal interpretation, decision making and community cooperation fosters long-term understanding and transference of learned concepts (Vygotsky, 1986). In short, the construction of knowledge requires learners to be actively involved in the process of learning. For effective science learning an instructor's pedagogical approach must be anchored in meaningful contexts so that students experience science. Experiential learning (Kolb, 1984) provides learners with opportunities to engage in problems that require retrieval of

prior knowledge, offer multiple perspectives, and facilitate a meaningful process which leads to an achievable outcome.

To enable experiential learning within a social-constructivist space, this research project is comparing different collaborative processes and the effectiveness of each of these in producing specific learning outcomes of remotely located science students. The students in Japan and UK are using collaborative technologies to program robots to follow basic instructions. It is posited that from the research a framework can be developed for successful implementation of collaborative tasks undertaken in emerging Virtual Worlds. This paper summarises phase 1 of the research involving Japanese students.

In this research robots are employed (with reflective and touch sensors, independently driven wheels and a LEGO Mindstorms RCX controller) collaboratively constructed and programmed by students, using virtual technologies while physically situated in different locations. Reviewing research on teaching robotics Barker and Ansoorge (2007) found that: 1) it is an effective tool for teaching science, engineering, and technology; 2) students who have engineered and programmed robots are exposed to other disciplines that are important for robotics, science and engineering; 3) there is exposure to real-world conditions with multiple possible solutions; 4) effective teamwork is a significant outcome; and 5) that female students respond positively to working with robots.

Combining the teaching of robotics with collaborative technologies and task-based design has potential for increasing university students' science and technological skills. However, this potential can only be realised if clear objectives are established and if it is known how to understand and measure the most effective ways to do this. Researching effective quantitative metrics to evaluate strategies for teaching robotics to university students using collaborative technologies provides a needed foundation for future research and academic staff development. The end result of this research will provide a valid, reliable and practicable framework for assessing and evaluating outcomes in the fields of science education, robotics, programming, virtual and augmented reality environments, and collaborative technologies.

Virtual worlds are increasingly evident in Higher Education courses. Yet the enthusiastic adoption and economic investment in virtual worlds such as Second Life often results in a mirror world, one that mimics what is referred to as real life. Research in informed, educational use of technology highlights the need to go beyond replication to an appropriation of digital communication (Warschauer, 1999) facilitated by a constructivist pedagogy (Jonassen & Land, 2000) to support purposeful tasks (Martin & Vallance, 2008). This represents a move from first to second order change (Cuban, 1992) where replication indicates zero order change, exploration indicates

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first order change and innovation indicates second order change.

2. METHODOLOGY

Participating students program robots to navigate courses designed by other groups, and subsequently modify the program to improve navigation on successive attempts. The metrics proposed for assessing the experiment will be Task Effectiveness (TE), Interaction Effort (IE), the number of times the course was navigated, and the time requirement for completing the course. Communication between the student is undertaken using synchronous interactive virtual technologies. All communication is digitally captured, transcribed and analyzed as described in Vallance (2007). The quantitative data set (i.e. Task Effectiveness (TE) - the number of commands successfully programmed into the robot, and Interaction Effort (IE) – the amount of time required to interact with the robot (Olsen & Goodrich, 2003)) is merged with personalized 'meaning' of data collected via a qualitative data set, in other words the follow-up interviews and digital capture of participants on task. Combining both quantitative and qualitative data sets aims to reduce bias.

3. IMPLEMENTATION

Prior to implementing the science communication and robot programming, a virtual learning space was formally designed in Second Life (SL). Tasks in Second Life were then undertaken by two Japanese students from remote locations. The tasks were completed in two stages. Stage 1 consisted of two tasks with the aim of developing a design of a learning space within Second Life. Stage 2 consisted of four tasks with the aim of communicating a LEGO NXT Mindstorms program.

The two participants involved in this research project had no prior experience of virtual worlds or LEGO NXT Mindstorms programming. The remit for Student A (avatar name - Hotaru Kurmin) was to design a learning space within leased land in Second Life. The remit for Student B (avatar name - Soka Naidoo) was to teach LEGO NXT Mindstorms programming by communicating in the designed Second Life learning space.

To begin the design process a class of design students taught by one of the researchers digitally create a classroom of the future that could then be built within a virtual world. All scenarios were later presented to Student A who then selected one design to initially build within SL. Meanwhile, Student B had constructed and duplicated a LEGO robot. One was given to Student A, the student who had to program the robot to follow a pre-determined circuit as instructed by Student B through communication in SL. During this Phase 1 the four LEGO related tasks further enabled Student A to modify the learning space resulting in the desired tools for effective communication (see Figure 1).

Once the learning space had been built, six tasks were implemented. Each task design aimed to facilitate the process of communication leading to a successful outcome, and to garner feedback on the use of the SL learning space for conducting learning activities. The use of NXT program blocks as manipulative, interactive images was included on the horizontal floor of the SL learning space while NXT block variables were represented as vertical images (see Figure 2). Students were remotely located, so used avatars for communication. The activities were conducted using voice and text. Student A (avatar: Soka Naidoo) re-arranged the NXT

blocks in SL (see Figure 3) to replicate the Mindstorms program (see Figure 4). Student B (avatar: Hotaru Kurmin) simultaneously programmed NXT as instructed. He later uploaded via USB the resultant program to the LEGO robot and tested.

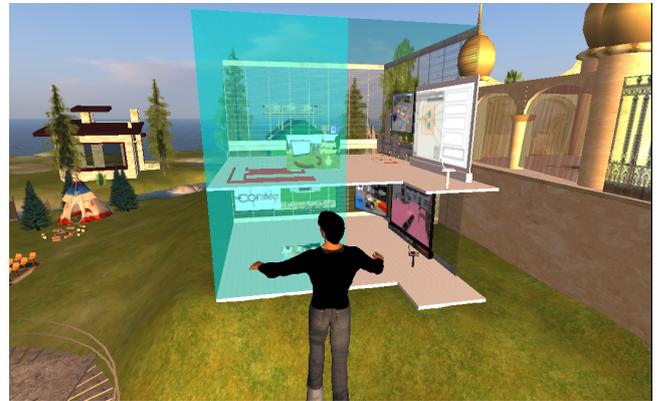


Figure 1. Designed Second Life learning space (outside)

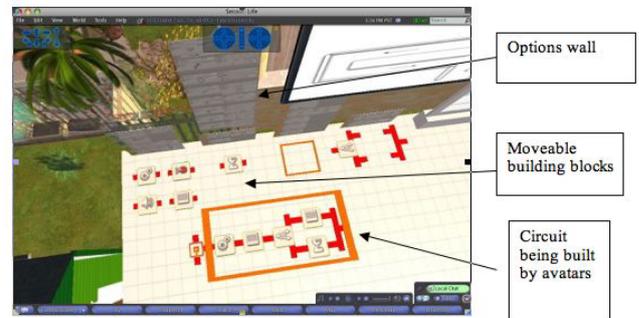


Figure 2. Designed Second Life learning space (inside)

The students also printed the interface images so that they could physically write their answers. They felt more comfortable when blending familiar analogue tools such as a pencil and paper with the new digital collaboration. All the images of the Mindstorms interface and target circuit were also viewable on the media presenter within the customized SL learning space. Both students could select and change the interface images on the media presenter at any time, if desired.

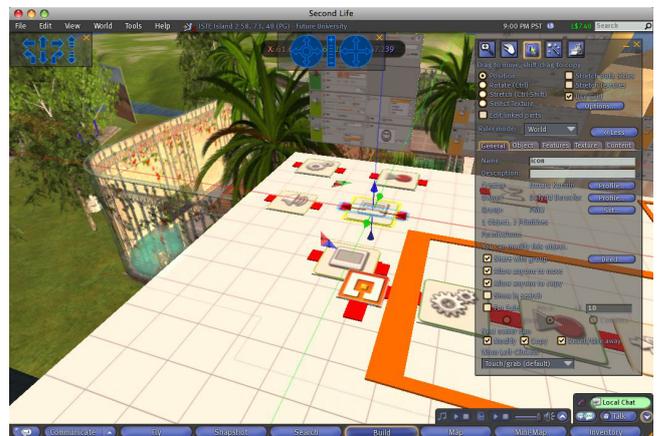


Figure 3. Manipulating LEGO NXT Mindstorms blocks in Second Life.

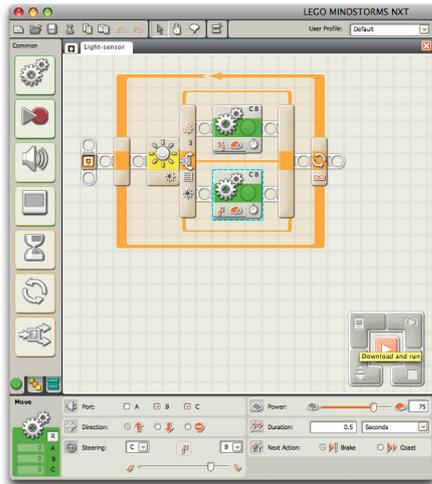


Figure 4. LEGO Mindstorms interface

Once the learning space had been built six tasks were implemented. Each task design aimed to facilitate the process of communication leading to a successful outcome, and to garner feedback on the use of the SL learning space for conducting learning activities. In summary:

- The NXT program’s ‘building blocks’ were created and maneuvered within SL;
- On the SL space walls were the various options for each block. The blocks were moved by both avatars;
- Communication was by voice and text;
- A thick blue arrow allowed avatars to point for physical direction and focus;
- Two media presenters enabled images to be uploaded and changed. For example, an image of the robot was uploaded so that the USB ports could be identified.

Table 1. Reflection on Task 6

Task	Reflection (+/-)	Implementation
Student A (avatar: Soka Naidoo) to teach student B (avatar: Hotaru Kurmin) how to program the LEGO NXT Mindstorms software so that the robot would traverse a particular circuit: forward/ stop/ turn 90 degrees left/ forward/ stop/ turn 90 degrees left / forward/ stop/ turn 90 degrees left / forward/ stop. Return to original position.	<p>What was difficult? The final USB connection to the physical robot as it failed first time but tried again and succeeded.</p> <p>What was easy? Prior familiarity with NXT interface.</p> <p>The interactive NXT building blocks in SL helped very much.</p> <p>Moderator’s comment. Activity lasted 20 minutes and successfully completed.</p>	<p>What would you like to do next time? Teacher (Soka Naidoo) did most of the actual building. Need to allow student (Hotaru) to move building blocks too.</p> <p>Add more pictures to image presenter during the programming process. This will be more applicable as the program becomes more sophisticated.</p>

The negotiated programs were then uploaded via USB to the robot and tested for comparison.

All actions, text and voice data were digitally captured. The voice data was transcribed and analyzed using language function codes in the TAMS analyzer (see Results section). Table 1 highlights the reflections made by the students in a follow up interview.

4. RESULTS

The design of the virtual space in Second Life followed a prescribed form that, in the opinion of the authors of this paper, provides credibility and functionality over often observed commercial design and aesthetics. The process involving design and science students provided ownership of the space to the participants.

The next stage involved the implementation of tasks developed iteratively (six in total in this phase of the research). The aim of each task was to communicate the programming of a LEGO robot. The quantitative measure of amount of success was Task Effectiveness (TE) - the number of commands successfully programmed into the robot, and Interaction Effort (IE) – the amount of time required to interact with the robot. Upon reflection, the tasks at this stage of the research were quite straightforward, possibly less challenging than anticipated but certainly with achievable outcomes. Given the innovative application of such educational practice the cautious approach resulted in rich qualitative data. As mentioned, all multiple media actions and communication (text and voice) were digitally captured. After transcribing the communication the text was tagged for communicative functions using the TAMS Analyser software. The instances of the communication could also be linked to the digitised video capture of the task process. The functions were: independently providing information (22%); asking questions (21%); confirming information previously provided (18%); answering a question with an affirmative statement (15%); expressing an observation (8%); making a suggestion (4%); giving a direct instruction (3%); praising (3%); making a request (2%); answering a question with a negative statement (1%); apologizing (1%); greeting (1%). As the students progressed through the tasks they gained a familiarity with and developed continuity of process as they engaged more deeply with the task. Such cognitive familiarity reduces communicative stress and increases cognitive processing (Skehan, 1998) evidenced by better organization of the information being communicated, a clarity of information through question and confirmation discourse, a greater amount of information being communicated in later tasks, and the type of information being more specific, concrete and contextualized to the task objectives.

5. DISCUSSION

This is the first phase of a longer research project involving international collaboration and communication to develop much-needed metrics for informed, meaningful and effective educational practices within virtual worlds. Designing worthwhile tasks that engage students and support learning through inductive and deductive reasoning is challenging enough. Yet when immersed in virtual worlds good task design becomes essential if students are to meet the intended aim. Tasks are primarily constructed to facilitate a challenging and meaningful process which draws upon students’ prior knowledge and transference to new contexts and ultimately leading to an achievable outcome. The iterative task design and implementation draws upon the work of Vygotsky and Kolb.

The results reveal that successful tasks must encourage students to communicate using prominent functions, student enjoyment through challenge (affective factors), and promote metacognition and role-shifting (second-order ecology).

The next phase of the research will involve tasks with more challenging circuits. Task effectiveness and interaction effect will then be measured along with coded communicative functions. It is anticipated a framework for informed task design when conducting science-based, robot tasks in virtual worlds will be developed. The framework will be linked to learning outcomes and academic competencies as described in Martin and Vallance (2008). In addition, a technical challenge will be to develop a software translator that will translate the information in the NXT block images in the SL learning space to NXT program commands for the Mindstorms software so that a direct transference of the program can be undertaken.

6. CONCLUSION

Currently, measurements used to assess the pedagogical effectiveness and associated knowledge uptake of a given science skills curriculum is measured using standardized achievement tests. Such tests commonly measure changes in acquired basic knowledge but are often incapable of measuring critical thinking ability, task effectiveness, and the contribution of collaborative interactions when engaged in tasks. This research is investigating metrics that can be applied to general and focused science, technology, and engineering learning environments that will be capable of measuring a wider range of students' knowledge and competencies. The controlled experiments with a purposive select group of participants can help establish a framework for effective and successful implementation of a science-based task within virtual collaborative environments.

This research limits the virtual world context to the familiar Second Life space. It is anticipated that other virtual worlds will become available to educators in the near future but that our resultant framework and protocols for effective collaborative tasks will still apply. The research is not simply an intellectual pursuit within a novel educational technology environment, but rather an attempt to further the effective and informed use of ICT and the necessary considerations of task design processes and outcomes, teaching pedagogies, and measurements of actual learning. It is anticipated that collaboration with and in virtual immersive interactive environments will become more prominent in mainstream Higher Education within the next five years, and this research aims to provide educators with a framework upon which to

construct their curricula, design effective tasks, and assess learning outcomes within such environments.

7. ACKNOWLEDGMENTS

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