LEARNING ACROSS THE KEY LEARNING AREAS: WHAT IS POSSIBLE WITH ROBOTICS IN THE CLASSROOM?

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ABSTRACT

Primary teachers are continually distracted by the literacy and numeracy agenda. This challenges their ability to identify the worth of learning in design technology. Design technology provides a key context for learning literacy and numeracy and the important concepts of design technology. It has potential to provide a purposeful means of engaging those most likely of doing poorly on literacy and numeracy tests such as NAPLAN. Furthermore, design technology gives some learners a reason to learn literacy and numeracy. This paper explores the use of a resource frequently associated with design technology. This resource is LEGO NXT robotics. Robotics in this form is often used in schools. However, it is often an extra-curricula activity for gifted learners after school. Furthermore, it is seen as a resource of use for robotics sake, only. In this paper initial data from a pilot study about learning evident when learners work with LEGO NXT robotics, is examined. The purpose of the study, still in progress, is to question the notion of 'robotics for robotics sake' and identify the potential of robotics to enrich learning across key learning areas for a wider population of learners. The study involves a volunteer group of preservice teachers working in the *Teaching Robotics Education across the Key Learning Areas* (TREK) project at Central Queensland University. These preservice teachers worked with children in classrooms during the school day with LEGO NXT and consequently, created a 'capture' of the work in which they engaged with children. These texts were then analysed to identify elements of learning required in the Queensland syllabuses. The resultant findings provide advice for primary teachers about the worth of robotics as a device to engage learners in deep learning of many aspects of the syllabus in the classroom. It provides an alternate view of how LEGO NXT needs to be promoted to primary teachers.

Keywords: *robotics, design technology, key learning area, literacy, numeracy*

INTRODUCTION

Use of a resource such as LEGO NXT kits has the potential to scaffold learning in many Key Learning Areas. Yet often, this resource is used to teach robotics only. In this form, the resource has no place in the primary classroom. Nowhere in syllabuses for primary schools does it state that children need to learn robotics. In a curriculum already viewed as being overcrowded, few teachers want to teach robotics as it becomes another activity to fit within an already crowded curriculum.

The purpose of this paper is to examine the use of LEGO NXT kits to support learning in Key Learning Areas (KLAs) for all children. In so doing, an argument will be made that the barriers to the use of this resource are manifold. First, the name, robotics, has caused some inappropriate thinking about the use of the resource in classrooms. Teachers perceive LEGO NXT as useful for robotics only. Second, teachers who know nothing about robotics feel that they cannot engage with children with the kits (Mataric, Koenig, & Feil-Seifer, 2007). Third, in some Australian states, Technology (design) is still to be recognised by teachers who often confuse Design Technology with Information Communication Technology (ICT). Fourth, robotics is often associated with Design Technology, which is not viewed with high priority in some states of Australia. Finally, the continual emphasis by government on data-driven literacy and numeracy learning in decontextualised contexts has resulted in decreased attention to contextualised learning. All have resulted in minimal meaningful use of LEGO NXT kits in the primary classroom.

The process being defined for the purposes of this study is the creation of “a device under some kind of autonomous control” (Finger, Zagami, & Scott, 2008). These devices are “interactive artefacts” (Bers & Potsmore, 2005, p. 60). For this purpose, LEGO NXT kits include a programmable block, numerous connectors, motors and sensors. The programmable block has some capacity for programming and this is extended through the use of a Labview-like program, Mindstorms, on a computer. Children construct icon-driven programs to control their builds to respond to a challenge or implement the required task. This is downloaded to the block. Initial inspection of the kit reveals the capacity of this resource to engage children in learning about design and building of machine-like equipment to complete a task. Of particular interest in the study is the capability to construct the device as well as control. Not all resources have this component. This essential learning is in the area known as Technology. However, learning evident in other KLAs or as cross curricula priorities is embedded in this learning.

Technological literacy is a requirement for all citizens. It combines an understanding of the processes and products designed to meet the needs of humans with an ability to make judgements on the appropriateness of the processes and products (Queensland Studies Authority [QSA], 2005). Making judgements requires an examination of the procedures used to design the products and processes, methods of production and the context in which the production occurs. Given the importance of this literacy to the local, national and global community, now and in the future, it is important that primary aged children have the opportunity to learn design technology.

With so much learning vital to the future of learners and the community, it can be valuable if one context can provide learning in more than one area. Potentially, that learning of other essentials is possible through design technology. The use of LEGO NXT kits in a meaningful context is able to provide a challenging learning environment for technology as well as literacy, numeracy and other Key Learning Areas. Furthermore, the context for learning presented by LEGO NXT is an industry-linked, real-life, contemporary context. The question that needs to be answered is: to what extent can NXT kits provide a vehicle for learning design technology, literacy, numeracy and other Key Learning Areas? In this paper an ongoing study that attempted to answer this question is discussed. It is hoped that this discussion will impact upon teacher pedagogy with regard to the use of this resource in the primary classroom.

In this paper, the associated literature is reviewed and the study explained. The initial findings of the study are then presented and analysed.

LITERATURE REVIEW

Earlier writings by Papert (1982) suggested that computers provide an environment in which children think in new ways about new ideas in many areas. He asserted that a misuse of the power of the computer in learning was to limit children to learning that was already in the curriculum. While not specifically a computer, it can be argued that LEGO NXT with its programmable block in combination with parts that can be used divergently, has the potential for children to create new knowledge in new ways. Papert also suggested that in so doing, old learning or learning that had been valued over time, would also occur, but in the context of futures-oriented learning.

Research associated with robotics kits in education has been of interest since the mid 1990s. The literature for learning with robotics draws upon: areas of learning robotics, learning Information Technology, learning with ICTs, learning design technology, learning science and mathematics, and many other areas. This literature is examined for its contribution to understanding learning across the curriculum in the context of robotics. “What are the students learning from these activities?” (Sklar, Eguchi, & Johnson, 2003, p. 238) Specifically, the literature of interest to the research question under examination is that which makes connections between using robotics in the primary classroom to enable learning in all KLAs.

In examining the literature with reference to curriculum, it is important to define the meaning of curriculum for these purposes. Curriculum encompasses both declarative and procedural knowledge and learning processes that penetrate all areas of learning (e.g., thinking). This definition impacts substantially on the research relevant to this paper. In viewing the potential role of LEGO NXT, some studies examined the declarative knowledge only (e.g., gearing, knowledge of programming). In considering curriculum for the purposes of primary school learning, it is vital that a wider definition including both declarative and procedural knowledge is used because current syllabuses require this scope of learning (Australian Curriculum and Reporting Authority [ACARA], 2009).

In identifying relevant studies to do with “digital manipulatives” (Bers & Potsmore, 2005, p. 60), two categories of studies have been evident. These include studies of robotic toys (e.g., Highland) and studies of robotic kits such as LEGO RCX and NXT. This review focuses on the later category. The focus here is on those studies that investigated the use of LEGO NXT kits as a resource for learning beyond design technology, engineering or programming.

The potential of LEGO NXT activities to provide opportunity for children to work scientifically, mathematically and technologically has been studied. Ritchie and Norton (2009) proposed that design challenges provide a rich context for science and mathematics learning. Design challenge experiences provide opportunities to introduce science concepts as they are needed. They also provide a context in which children can use the definitions and words of their teacher to talk about science. They provide purpose for mathematics. (Norton & Cooper, 2008) However, Norton and Ritchie (2009) suggested that the science and mathematics often remains implicit. This supported the earlier work of Wagner (1999) who found that it did not improve general science achievement but did improve programming problem-solving.

Opportunities for engagement and child-centred learning in the context of NXT activities are many but are dependant on a range of factors. RoboCup Junior is a global competition that focuses attention on robotics and resources such as LEGO NXT kits in the 1990s. In this context, Sklar, Euguchi, and Johnson (2003) questioned the overall learning environment provided by groups working in team robotic activities. Mechanical engineering, computer programming, electronics, experimental skills and team work rated highly. Fifty per cent of students rated robotics as helping in learning with Science, physics and mathematics. Indications are that cross curricular priorities such as team work are developed.

Finger et al. (2008) studied the curriculum benefits in the context of robotics, taking a wider perspective than science, maths and design technology. Teachers and students from 17 schools were surveyed. Teachers listed five reasons for an interest in the project: progress the implementation of the technology syllabus, understanding robotics, future technologies, integrated curriculum, and problem solving. Teachers suggested that the use of robotics in the Key Learning Areas was for learning in Technology (92.5%), Science (48%), Mathematics (39%) and Study of Society and the Environment (33%). However, the actual use for these areas was found to be much lower with minimal use in The Arts, Health and Physical Education and English. Teachers reported that robotics did impact greatly upon problem solving, collaborative learning and teamwork and to some extent on student numeracy and literacy. The suggestion from teachers was that they need greater direction on purposeful integration.

There is the suggestion that the programming elements of Labview, the software associated with LEGO NXT, consumes the endeavour such that other declarative learning is left undone (Norton, McRobbie, &

Ginns (2007). However, there is acknowledgement of learning of problem-solving and thinking processes, for example: autonomy, creativity, strategic thinking and metacognitive thinking (Roman, 2007; Wyeth, Venz, & Wyeth, 2004). Many of these processes are enhanced through engaging with programming. “Children are able to think deeply and creatively about their designs, and to critique their designs in order to make the best possible creation” (Wyeth et al., 2004, p. 1). Furthermore, the problem-based learning approach supported by these activities provides motivation, engagement in problem-solving, teamwork and cooperation (Verner, 1998). These elements are included in the declarative and procedural knowledge of the essential learnings of many Key Learning Areas (Queensland Studies Authority, 2007) and, in the case of the Australian National Curriculum, compose the cross-curricula priorities. (ACARA, 2009) For teachers, this poses the conundrum of which knowledge is more important, declarative or procedural, or are both, equally important in the twenty-first century. If the later is the case, then it can be concluded that the use of this resource is highly beneficial to curriculum requirements for contemporary learners.

The theme evident in some studies (e.g., Norton & Ritchie, 2009; Norton, McRobbie, & Ginns, 2007) with regard to learning through the use of LEGO NXT and similar kits, relates to teachers. Teachers need to identify and actively teach to the opportunities that present themselves during experiences. Norton and Ritchie suggest that skilful teacher intervention is required for learning of concepts to occur. In her work, Niess (2008, p. 240) suggested that, when working with ICT, there is a need to enable children to “explore the capabilities, test the functions, and see what they can do with the technology.” This approach places many demands on teacher’s pedagogical content knowledge. Integration enables engagement with concepts from a range of key learning areas but these remain implicit unless teachers plan for learning them in the context of use of LEGO NXT. Furthermore, there is an implication that teachers need to be able to identify the learning inherent in the experience.

On a pedagogical note, Bers and Potsmore, (2005, p. 60) used the term “robotic manipulatives.” This terminology infers such pedagogical terms as open-ended learning environments, innovative curriculum, integration, learning from everyday contexts, personally meaningful play and social learning. Focused on these as the potential of LEGO NXT, thinking is then focused on constructivism as a means of learning. There is also an inference that children physically participate with the resource, an approach known as play or kinaesthetic learning. This is considered by some as another reason not to bring LEGO NXT into the classroom because classrooms are not places for play.

In summary, an analysis of the literature reveals potential for learning with LEGO NXT beyond robotics to other parts of the curriculum. This potential is infrequently reached with learning related to Key Learning Areas often implicit. The research indicates that resources such as LEGO NXT challenge the pedagogical content knowledge (PCK) of some teachers. In the next section, the findings of a study of eight cases in Queensland are considered. These cases relate to primary schools.

THIS STUDY

This study commenced in 2009 with preservice teaching students at Central Queensland University in Bundaberg, Queensland. In observing the ‘buzz’ from some teachers about robotics in 2004, the author developed an interest in how and where teachers saw ‘the fit’ of robotics in the primary classroom. By 2008, the uptake of resources such as LEGO NXT did not match the ‘buzz’ of years before. Thus, this study had its beginnings.

This interest specifically related to LEGO robotics materials such as RCX kits (an earlier version of NXT) and LEGO NXT kits. Though other robotics resources exist, for example, Probots and Beebots, it was the versatility of the programmable LEGO block and the potential to create many builds to meet various needs at the centre of this study.

Observations of secondary environments identified robotics as supporting learning in Information Technology (IT) or science. IT teachers use the kits as a context for learning programming. Science teachers used the kits to provide experiences with science concepts such as gearing. The question remained as to the perspective of primary teachers. Further investigation revealed that primary teachers who were interested (and found the funds) offered robotics as a program for gifted and talented children.

Usually, these programs were offered out of school hours. Furthermore, those schools involved, focused on participation in competitions such as Robocup.

From observations that the potential for RCX and NXT kits was not readily recognisable in many learning approaches, a group was formed and investigations commenced as outlined now.

Background

From the need to answer the question, “to what extent can robotics support learning across the curriculum”, the Teaching Robotics Education across Key Learning Areas (TREK) developed in 2009. TREK came into being with the financial support of CQUniversity, and the enthusiasm of a group of preservice teaching students. These students identified use of LEGO NXT kits as having potential to enthuse primary children in learning. Furthermore, as a component of the course, Technology Curriculum and Pedagogy in the Bachelor of Learning Management (BLM) education degree, the students began to identify the potential of robotics to contribute to learning design technology, consistent with the requirements of the Queensland syllabus in Technology (QSA, 2005) and a means to motivating children to learn. Substantially, work in this study was performed outside of the course requirements for the degree.

The TREK project consisted of preservice students working in primary classrooms. The project coordinator negotiated with teachers who were interested in robotics but had neither the funds nor the knowledge to implement their own program. After engaging in a series of workshops, the preservice teachers worked with children in their classrooms, using the kits acquired by the project for a term. Teachers supported the preservice teachers and used these sessions as professional development to build their own competencies. From this work, the preservice teachers observed the learning of the students. From this work, eight case studies developed.

Significance of the study

The significance of the study in our western society in which future citizens need to be technologically literate, a purpose for which LEGO NXT can serve well but teachers will not give time to this activity unless other learning is explicit in the process. The outcome of the study aims to provide advice with regard to the potential use of NXT in the regular primary classroom to enhance learning for all children across a range of Key Learning Areas. The advice should extend to providing substantial information to teachers as to how they can use LEGO NXT.

Design of the study

The study has two phases. It involved preservice teaching students in their second and third years of study. Phase one identified potential learning across Key Learning Areas. Phase two identified the learning enacted in the classroom when using NXT resources. Phase one required preservice teaching students to engage with the NXT resources to respond to design challenges in the context of their university study. Consequently, they were asked to examine curriculum documents to identify potential learning from these experiences.In phase two of the study, a case study approach was adopted. Each of the eight cases consisted of the work of a preservice teaching student in a primary classroom for approximately six months for two to three hours per week, for the purposes of using NXT robotics with children.

The primary classrooms were Years five, six or seven or combinations of these year levels in smaller school settings. Most classrooms had about thirty students. Each preservice student and the class in which they worked became a case study. The preservice teaching students were participant observers, observing as they worked with primary children. The students were asked to record the experiences they had with the children in the primary classrooms.Primarily, the context for working with robotics was initially developed around individual design challenges, culminating in a narrative, a presentation or a documentary. For example, one case documented an assessment piece where Year seven students in groups were required to identify a suitable nursery rhyme, prepare a script for the group and the robot, design and construct costumes and props, and choreograph the robot’s moves.

Three preservice students then examined each report. They used the Queensland syllabus documents to identify which Essential Learnings were evident in the reports. Essential learnings include both Knowledge and Understanding and Ways of working. Furthermore, students examined the reports for examples of literacy and numeracy learning.Annotations were made on each report. These annotations were then examined for recurring themes (Miles & Huberman, 1985). A comparison was then possible between potential learning and enacted learning in primary classrooms.

RESULTS AND DISCUSSION

The results of this study support many earlier studies (e.g., Finger et al., 2008). While it is possible to identify many essential learnings that can be learned through the use of LEGO NXT, these are not always evident when learning is enacted. Data from phase one suggested extensive potential learning. The themes identified in the data in phase two relate to some areas of the potential learning in Key Learning Areas identified in phase one and cross curricular competencies (ACARA, 2009).

In identifying potential learning, many Key Learning Areas were identified (Table 1). The breadth of this finding confirms the findings by Finger et al. (2008) in which teachers identified that Technology, Science, Mathematics and Studies of Science and Environment could be enhanced. However, in this study, there was strong evidence that much of this learning was procedural in nature. While contemporary syllabuses attribute value to procedural learning, general commentary would suggest that it is not attributed the same value in the classroom. Consequently, though NXT resources have the potential to contribute to learning, where that learning is not valued and hence, not *visible to teachers*, it will provide few reasons to plan for use of the resource in the classroom. The concept of visibility relates to teacher understanding of the Learning and Teaching focus of the syllabus and the *Knowledge and understanding* and *Ways of working* strands (Queensland Studies Authority, 2007) and how they are represented in enactment in the classroom.

There is strong evidence that use of LEGO NXT resources can potentially accommodate learning in Science and Technology (design). These are two areas to which most teachers readily attribute some worth for this resource. The areas of English, SOSE, The Arts (e.g., drama and dance) and Health and Physical Education (HPE) are evident in substantial ways in this data from Phase 1 of the study. This underlines the nature of LEGO NXT resources to act as a transdisciplinary learning tool. Furthermore, in comparing this list with the National Curriculum (ACARA, 2009) it is evident that this resource can support many of the cross-curricula elements (e.g., thinking, teamwork).

In comparing this potential learning with the enacted learning, considerable disparity is evident. In discussing the enacted learning, one case (Case 41) is analysed followed by a general collection of examples and the identified themes. Then, the list of potential learning identified is presented and compared to the themes.

Preservice teaching student, Shontelle, worked with a Year 7 class for one term, known as Case 41. Shontelle involved the children in working with the NXT kits in association with rewriting a nursery rhyme as a script for the group and the robot. The robot was constructed as an element of presentation for the Prep children. Children were required to design and construct props and costumes for all characters including the robot. In analysing this case, it is possible to identify English (writing, oral presentation), The Arts and design technology. Further learning differed from group to group dependent on techniques needed to choreograph the movements of the robot. While there were differences from group to group, this procedural knowledge was based around self-managing ways of thinking, creatively and divergently.

The task provided a context in which children planned and organised a spoken presentation with a logical sequence. They interpreted a nursery rhyme and investigated scripting for every member of the team. Scripting needed to include words and movements of all members including the robot. This required students to identify and build characters and to portray those characters, including the character allocated to the construction, using parts from the LEGO NXT kit. Consequently, children needed to “establish a distinctive voice in own writing” (QSA, 2008).

Table 1: *Potential learning from the use of LEGO NXT resources in a primary classroom*

KLA	Declarative Knowledge	Procedural knowledge
Science	Friction – how does movement change dependant on the floor surface? Time? Forces – push/pull Velocity Gearing to carry heavy loads Drawing on science concepts to investigate the context of the design challenge Anatomy	Fair testing and variables Collecting data Making predictions Drawing conclusions Testing strength of structures (e.g. strength of claw to move objects) Use materials (NXT parts) for purposes other than for what they were designed
Technology	Use of robots in society to solve problems that may put humans at risk, carry loads too heavy for humans	Designing a robot for a purpose Designing what the robot looks like, naming Designing modifications required to achieve a challenge (e.g., claw to move objects) Think divergently about the design challenge/task and how to achieve the end Designing and modifying programs Solving problems with the sequence of computer program Thinking creatively Thinking critically to evaluate own design Comparing and evaluating different designs/robots and their ability to achieve the same outcome (pros, cons, issues_
The Arts	Aesthetic element of design Dance routines	Thinking creatively Spatial awareness in dance Timing movements with music Scripting movements
English	New vocabulary visual literacy English genre: Communication Documentary Journals	Reading procedural text Visual literacy in using NXT manuals and identifying parts Communicating respectfully, concisely, clearly with other members of the group Writing stories to which a sequence in movement plays out
Mathematics	Spatial knowledge: angles of movement; Measurement: length of movement required; time taken to travel Percentages Graphing data logging	Estimating and measuring angles and distances/length Timing trails – how long does it take your robot to remove all the 'bodies' for the square Calculating averages of time over several trials Calculating speed Graphing data from trials across performance on different surfaces
Study Of Society and Environment (SOSE)	Technology in society – ethical uses of robotics History of automation Rules and ethics Impact of robots on the workforce Interact with people and places	Making ethical decisions Using robots to solve environmental problems
Health and Physical Education	Movement and how it happens (e.g., what joints are needed for something to bend) Knowledge of rules and fairness	Exploring ways of movement

Social learning (across HPE, SOSE, Prep curriculum)	Know personal strengths and weaknesses; everyone is different and has different viewpoints/solutions to offer Know ways of contributing to a group and benefits of working in a group: 1. learn from others who think differently 2. use the strengths of different members of the group 3. we don't have to like people with whom we work Difference between competition, collaboration	Working in groups – enabling all members of the group to participate, taking roles Using encouraging language Celebrating achievements and learning of others Valuing the ideas of other groups Being respect of the abilities and backgrounds of others Respectfully evaluating the ideas of others Being open to evaluations of your ideas by others (resilient) Wanting to be a member of a group (attitude)

The themes from Case 41 are evident in an examination of the other seven cases. (See Table 2) While some Knowledge and understanding is evident, Ways of working (procedural knowledge) dominates in these themes. As identified in the table, the eight general capabilities of the National Curriculum, thinking skills, creativity, teamwork, ICT, literacy, numeracy, ethical behaviour and self-management are readily identified.

ICT is inherent in the use of LEGO NXT resources due to the programming element. However, programming provides opportunity for visual literacy, multiliteracies, thinking sequentially, and reasoning. Thinking differently about how elements, both physical and software, come together to make a whole represents the higher order thinking of analysing, synthesising and evaluation (Bloom's taxonomy). While it can be argued that there is no place to teach children programming in the primary curriculum, the cognitive behaviours required are the same as for many Essential learnings and relate directly to the general capabilities. In the context of LEGO NXT resources, programming is purposeful, child-friendly, collaborative, visual and creative.

In working toward the challenge in Case 41, children were required to design a character and represent that character in the robot. Children needed to think about the way a robot moves and how those movements need to be manipulated to create the character in the nursery rhyme. These movements must then be designed in Mindstorms, selecting icons that represent the movements required. This thinking integrates the capabilities within the context of character analysis and construction.

Learning to self-regulate and/or self-manage actions and thinking (Marzano et al., 1997) as a member of a group is strongly evident. Children "work as a member of a team" (Case 11) to "bounce ideas off each other to solve problems" (Case 19) and "come to agreement" (Case 11). In so doing, with appropriate intervention from the teacher, children monitor their own thinking, view situations differently, identify and use the resources and perservere. (Marzano et al., 1997) Children learn to evaluate the ideas of others (Marzano et al., 1997), identify multiple solutions to the same problem (Technology), and persuade, justify thinking and state a case (English – oral language).

Children are working with complex reasoning processes such as decision making, problem solving, invention, experimental inquiry, investigation and systems analysis. (Marzano et al., 1997) Inherent in the process of designing a robot/machine under autonomous control and a program, children decide which resources to use, how to use them, and how to modify and edit.

Table 2: *Phase two data: Enacted learning*

Essential learning	Key Learning Area	Examples from cases (Quotes from case reports)
Thinking: **Problem-solving** **Creativity**	Cross curricula capability	"Bounced ideas off each other to solve problems" (Case 19) "Opportunity to explore and come up with a program" (Case 19) "imagination" (Case 11) "robot had a mind of its own" (Case 11)
Thinking: **Planning and sequencing**	Cross curricula capability	"programming the robots both through the program and the robot itself" (Case 19) "editing was a major part of the process" (Case 11)
Team work - **Mutual respect** - **self-management** - **group roles** - **self-management**	Cross curricula capability HPE Personal Development Technology - collaboration	"Work as a member of a team" (Case 19) "Coming to agreement" (Case 11) "hard time cooperating with the opposite gender and in large groups" (Case 26) "He wanted the leadership of the group at all times" (Case 5) "Builder, seeker and reader" (Case 69) "to work independently (Case 23) "to share the computer program to allow every student has the opportunity to make the robot work" (Case 23) "how to care for other team members" (Case 23)
Technology practice cycle (investigate, ideate, produce, evaluate) **Make products to match design ideas by manipulating and processing resources** **Identifying resources**	Technology (design)	"stocktake of kits" (Case 19, 26) "Close look at different parts in the kits and where parts belonged" (Case 19, 26) "Responsibility of using and looking after the kits" (Case 26, 23) "the students started building" (Case 19, 69) "had to modify their robot" (Cas 11)
Length, mass, time, angles, shape - **measuring** - **equating formal measurements with program measurements**	Mathematics	"Sensors programming" (Case 19) "Children associated shapes of the LEGO parts with things that already exist in the world" (Case 5
Oral language - **listening** - **oral story telling**	English	"practising active listening skills" (Case 11) "creating a storyline (Case 11) "using robot to tell a story" (Case 86) "create a character (Case 11) "present in a safe environment and verbalise" (Case 11) "After each robotics lesson we all sat on the carpet to talk about sharing" (Case 5)
Following instructions - **visual** **Vocabulary**	English -Visual literacy	"Children could make up their own names for each of the parts" (Case 5) "I began building a robot to model how to read the instruction booklet and seek, find and put together all the pieces" (Case 69) "Icons from Mindstorms program" (Case 69)
Personal development **- self-management**	Cross curricula	"taking the risk in taking that first step" (Case 11) "be proud of their achievements" (Case 11) "some students jumped ahead"

Inherent in the findings are two points that need to be studied further in the context of this data. First, 'robotics' often occurs in schools as a one-off experience. Second, the term 'robotics' is synonymous with the LEGO NXT resource (or previously, LEGO RCX). Both points are now examined.

Often, knowledge of construction with the resource and designing a program with Mindstorms is experienced at the threshold level only in the primary classroom. The experience is included in wider learning contexts such as "Gadgets and gizmos" or a theme on robotics. Children build the standard build and program it to achieve some basic tasks. This approach ensures that curriculum learning is limited because children are grappling with the challenges of a new resource; how the parts fit together or how the program works. In this study, children engaged in their first experience with LEGO NXT. As a result the enacted learning did not match the potential learning as children explored the resource. Children engaged in learning as evident in Table 2 but this is limited by comparison to the listings in Table 1. This supports Norton and Ritchie’s (2009) finding that much curriculum knowledge remains implicit. Challenged by the complexities of familiarising themselves with the new resource, children fail to learn that for which the teacher has planned. It may be assumed that potential curriculum learning would be more likely to occur in repeated use of the resource in different contexts for different purposes.

Consequently, the term ‘robotics’ minimises the potential of the resource. Robotics has connotations of humanoid forms, popularised by the media. This represents one small aspect of robotics and the LEGO NXT resource. Much of that which is robotics takes many forms and is used in industry to achieve tasks under autonomous control (Finger, Zagami, & Scott, 2008), in particular tasks too dangerous or onerous for humans. This study supports preference for the term “digital manipulatives” (Bers & Potsmore, 2005, p. 60) as defined as objects that can be combined in many forms to be controlled digitally. LEGO NXT can be used in a unit examining robotics. Professional development about the use of LEGO NXT, however, needs to widen the common definition of robotics, beyond that of robots in some human form. By doing this, it is to be hoped that the one-off use of the kit to teach robotics will be expanded to multiple uses of the resource as “digital manipulatives” (Bers & Potsmore, 2008, p. 60) to enhance learning in different curriculum areas at different times in different year levels.

The concept that one use, that being the time at which children familiarise themselves with the resource, is the sole potential of the kit is challenged here. Consequently, the potential learning identified in Table 1 may become evident in enacted learning. Children may then begin to use the resource to learn wider concepts, implementing their familiarity from the initial use as a tool. Under these circumstances over time, an alignment between the enacted and the potential learning may be evident. As with so many resources, LEGO NXT is not a Year 7 resource or a Year 2 resource but a resource that is suitable to support learning across a wide range of declarative and procedural knowledge, in a wide range of year levels.

ASSUMPTIONS

The possible assumptions from the data are now considered. These relate to content and pedagogical content knowledge (PCK). Some of these assumptions are implicit in the data, the most important of which is the nature of the resource. LEGO NXT is a multi-dimensional resource. It can contribute to learning across topics, year levels and types of knowledge. It is a worthwhile resource that is of use for learning much more than robotics. With this as the baseline assumption, other assumptions are now presented.

Content

LEGO NXT is a resource with potential to contribute to learning, particularly procedural knowledge. This is relevant in two ways. First, teachers need to value procedural knowledge such as collaboration, team building decision-making, testing and validating. Second, learning is not *visible* to all teachers. Teachers need to be able to recognise this learning in the context of LEGO NXT. Some teachers need documentation which clearly identifies the learning that can be achieved and how it will represent itself in the context of the resource. (Norton & Ritchie, 2008)

Pedagogical Content Knowledge

Two challenges exist for teachers in the use of LEGO NXT as a learning resource. They are control of learning for every child and total knowledge of the learning associated with the resource. Teachers have been heard to say, “if I can’t use it, how can the children?” and “I can’t teach it if I don’t know how to use it.” Teachers who perceive that they must know everything about the resource before children can engage with the resource may find it difficult to use the LEGO NXT resource in their classroom. Its vast applications ensure that there will be discoveries made by children that cannot be contemplated by the classroom teacher.

LEGO NXT is a resource that readily provides children with control of the direction of the learning and its pace. Children come to a design challenge and move toward it and through it with different knowledge to which the teacher responds. This is why teaching is complex and ill-structured (Koehler & Mishra, 2008). As a resource that enables multiple solutions to any one challenge or problem, LEGO NXT is a resource that enables different learning and different pacing of learning within a group of learners (Niess, 2009). Subsequently, the use of LEGO NXT for learning requires approaches that value diversity and in particular, digital diversity (Niess, 2009; Thrupp, 2008).

For the potential of LEGO NXT as a learning resource to be realised, specific conditions need to be met. Teacher design of challenges needs to be accompanied by interaction with children at critical times in learning. Interaction needs to focus on the problem or issue for that group at that time and work toward children solving the problem. Timing is critical to ensure continued learning and engagement. Interaction needs to be characterised by an open-mindedness that children have many ways of viewing the challenge, some of which will provide a solution. In all, technological pedagogical content knowledge is required (Koehler & Mishra, 2009).

CONCLUSIONS

In summary, LEGO NXT is a generic resource to be viewed for its potential to contribute to many Key Learning Areas in both declarative and procedural knowledge. Some conceptualisations of the word ‘robotics’ limit the use made of the resource in a primary classroom. It would be of greater use to ask, “how can LEGO NXT engage children in learning a particular concept? How can NXT kits advantage learning in the curriculum, make it more purposeful, and real-life learning?”

These conclusions have implications for the primary classroom. The following points can inform teachers and may benefit those working with teachers and preservice teachers. These points provide a way of thinking about LEGO NXT that may decrease the barriers and provide more palatable reasons for use of LEGO NXT to primary teachers.

1. LEGO NXT is a multi-dimensional resource that supports learning about aspects of autonomous control as a means of meeting human needs and solving problems
2. The use of LEGO NXT is not about teaching robotics according to the definition of a humanoid form
3. A wide range of learning including literacy and numeracy can be achieved through the use of LEGO NXT, though like any ICT tool, children need to learn about the tool before learning with the tool. One-off use of LEGO NXT will not achieve the potential learning
4. The use of LEGO NXT requires conditions for learning that involve open-endedness, child-control, children moving at different pace
5. Some teachers need support to identify the learning that is possible with LEGO NXT and meaningful ways to integrate the resource
6. Watching where the children take the learning, identifying the learning that is evident and facilitating the direction of learning is the essence of teaching for learning with LEGO NXT that is different from teaching for covering content.
7. There is a need to map the curriculum for that learning which aligns with the use of LEGO NXT as a learning resource including both declarative and procedural knowledge and general competencies.

In conclusion, this study supported the findings of many that have preceded it, bringing those findings into a contemporary context. That is, that the use of LEGO NXT in primary classrooms is not substantially supported and the benefits of its use need to be made more visible to teachers. These findings have grown in importance in the context of 2010 and for children who live in an increasingly technological world.

REFERENCES

Australian Curriculum and Reporting Authority (2009). *The shape of the Australian Curriculum.* Retrieved on 5 January, 2011 at http://www.acara.edu.au/curriculum/curriculum.html

Bers, M., & Potsmore, M. (2005). Teaching partnerships: Early childhood and engineering students teaching maths and science through robotics. *Journal of Science Education and Technology, 14*(1) DOI 10.1007/s10956-005-2734-1ti

Finger, G., Zagami, J., & Scott, A. (2008). Exploring the curriculum benefits of advance microprocessor programming and robotics in primary schools. In H. Middleton & M. Pavlova (Eds.), *Exploring Technology Education: Solutions to issues in a globalised world*. Volume one. Brisbane: Griffith Institute for Educational Research.

Koehler, M., & Mishra, P. (2008). Introducing TPCK. In J. Colbert, K. Boyd, K. Clark, S. Guan, J. Harris, M. Kelly, A. Thompson (Eds.). *Handbook of technological pedagogical content knowledge for educators* (pp. 3-30). New York: Routledge.

Mataric, M., Koenig, N., & Feil-Seifer, D. (2007). *Materials for enabling hands-on robotics and STEM education*. Retrieved on 26 August, 2010 from www.aaai.org/Papers/Workshops/2007/WS-07-15/WS07-15-002.pdf

Marzano et al., R., Pickering, D., Arrendondo, D., Blackburn, G., Brandt, R., Moffett, C., Paynter, D., Pollock, J., & Whisler, J. (1997). *Dimensions of learning*. USA: ACSD.

Miles, E., & Huberman, A. (1994). *Qualitative data analysis*. Thousand Oaks: Sage.

Niess, M. (2008). Guiding preservice teachers in developing TPCK. In J. Colbert, K. Boyd, K. Clark, S. Guan, J. Harris, M. Kelly, A. Thompson (Eds.). *Handbook of technological pedagogical content knowledge for educators (*pp. 223-250). New York: Routledge.

Norton, S., & Cooper, T. (2008). Teaching mathematics and technology through design practice. In M. Goos, R. Brown, & K. Makar (Eds.), *Navigating currents and charting directions. Proceedings of the 31st annual conference of the Mathematics Education Research Group of Australasia* (pp. 377-384). Brisbane: The University of Queensland, St. Lucia.

Norton, S., McRobbie, C., & Ginns, I. (2007) Problem solving in a middle school robotics design classroom. *Research in Science Education*, *37*(3), 261-277.

Norton, S., & Ritchie, S. (2009). Teaching and learning science and mathematics through technology practice. In A. Jones & M. deVries (EDs.), *International handbook of research and development in technology education*, 00-00 Sense Publishers.

Queensland Studies Authority (2007). *Essential learnings.* Retrieved on 5 January, 2011 from http://www.qsa.qld.edu.au/7299.html

Sklar, E., Eguchi, A., & Johnson, J. (2003). RoboCup junior: Learning with educational robotics. In G. Kaminka, P. Lima, & R. Rojas (Eds.) *RoboCup 2002, LNAI 2752*. Pp. 238-253. Heidelberg: Springer-Verlag.

Thrupp, R. (2008). *Social groups and information communication technologies: Exploring primary-aged learners' identities.* Doctoral study. Rockhampton: CQUniversity.

Verner, I. (1998). *The survey of RoboCup '98: Who, how and why. In RoboCup-98: Robot Soccer World Cup II, Lecture Notes in Artifificial Intelligence.* Vol 1604, Springer Verlag.

Wagner, S. (1999). Robotics and children: Science achievement and problem solving. *Journal of computing in childhood education*, *9*(2).

Wyeth, P., Venz, M., & Wyeth, G. (2004). Scaffolding children's robot building and programming activities. In D. Polani et al. (Eds.), *RoboCup 2003, LNAI 3020*, (pp. 308-319). Berlin Heidelberg: Springer- Verlag.