An investigation of the impact of LEGO® robotics on the learning of scientific and mathematical concepts at primary level.

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Title
"The impact of LEGO® Robotics on the learning of Science and Mathematical concepts”
Investigated the impact of using LEGO® robotics on the learning of scientific and mathematical concepts for grade three and grade four students.

Abstract
This study analysed the way students at grade 3 and 4 learned to manipulate the design projects that are part of lessons from the LEGO® Mindstorms Robotics Invention system. Students worked in cooperative groups of three to four members. Within the hour allocated for each lesson the participants swapped roles, being either a programmer or LEGO® designer. The students were required to utilise many skills, including design, directional language, communication and evaluation.

The research methods of the study are qualitative. To find out what the students were learning the research relied on observational notes, written records and photographs. The research aimed to compile evidence of how this style of learning affected the outcomes of student’s achievement and attitudes. Students were required to analyse something that was active. They had to write observational notes to show their understanding of what was occurring and they also had to document how they changed the program to effect the robot’s movements.
Declaration

- The thesis comprises only my original work towards the masters except where indicated in the Preface.
- Due acknowledgement has been made in the text to all other material used.
- The thesis is 23,147 words in length, exclusive of tables, maps, bibliographies and appendices table of Contents

Signed:

Carla Maxwell
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Chapter One Introduction

This research analysed the learning of science and mathematics concepts with the LEGO® Mindstorms Robotics Invention system. Little information is documented about how students learn in this situation. This research also aimed to find out how effective a hands-on approach was to assist the learning of mathematics and science concepts. Students were required to manipulate a line of visual symbols in the computer program called Robolab to make a directional visual sentence. The LEGO® Mindstorms equipment was used in the research because it was the only set available in the school at that time. An example of the Robolab screen is shown in Figure 1.

A General Overview

The LEGO® Mindstorms Robotics Invention system is a design package that uses concrete material and a software interface. Students can program in a software page called Robolab. The program has symbolic icons that can be placed in a sentence and read from left to right. This creates directions for the constructed robot to carry out. The sentence can be downloaded to the RCX which then can move independently.
Inside a LEGO® Mindstorms Robotics Invention system there are familiar LEGO® bricks, motors, sensors, gears with beams, (bricks with holes in the side), numerous plastic parts with advanced shapes such as axles, and a small computer (7cm by 15cm) named the RCX. Students are required to build their robots from instruction sheets, which involve skills in visual recognition.

![Image of LEGO® Robot pieces](image)

**Figure 2:** Model of core LEGO® Robot pieces

The core LEGO® pieces are the parts you need to make a working Robot. It includes such things as motors, light sensor, touch sensor, temperature sensor and USB tower.

**Learning benefits**

The benefits from students learning with LEGO® robotics have been investigated by Resnick (1998) who suggested that if we give children new types of digital building blocks, they can learn not only about number, shape, scale, but they can also learn about interaction, communication, dynamics, in the same way that they traditionally learn through direct manipulation. The differences between learning mathematical concepts through manipulative materials and learning with LEGO® Robotics has also been investigated by Martin, Mikhak, Resnick, Silverman and Berg (2000). These researchers explored ways that students aged five to eight can use a new apparatus that allows better observation of scientific phenomena, or explorations of the physical principles. They suggest that the design process is often absent from science in school settings. Their aim
is for a more integrated approach to the learning of science, mathematics and engineering.

**Importance and potential benefits of the research project**

The exploration of LEGO® Robotics is not a regular part of the Primary Education curriculum in Australia. LEGO® Robotics has the potential of meeting the requirements of the new Victorian Essential Learning Standards (VELS). This type of learning project covers some of the Learning Essential Learning Standards; for example

- Interpersonal Development (specifically working in Teams)
- Interdisciplinary learning Design, Creativity and Technology (investigating, designing and producing)
- Thinking Processes (reflection, evaluation and metacognition).
- Science: ICT for creating and making (They identify forms of energy and energy transformations in the everyday world)
- Mathematics: Number, Space and Measurement (Measuring time and distance: describe time elapsed in seconds and can write simple decimal subdivisions of a second)

Outlined below is explanations of how the Victorian Essential Learning Standards function. There are many ways the learning of LEGO® Mindstorms Robotics Invention system in small teams using a journal for reflection can integrate with the requirements of the new standards. Robotics uses computer technology to integrated across all areas of the curriculum to support and enhance new ways of learning and teaching.

The Victorian Essential Learning Standards identify the Arts, the Humanities, English and Language Other than English, Mathematics and Science as the disciplines for the curriculum over the stages of learning from Prep to Year 10. Within the Discipline-based learning strand there is an understanding that learners are able to transfer their knowledge in many different ways depending on how they are encouraged to reflect on their learning, take responsibilities for it and relate it to their own world. These approaches are explicitly defined in the Physical, Personal and Social learning domains such as physical education and personal learning.

Interdisciplinary learning has been defined as Communication; Thinking; Information and Communications Technology and Design, Creativity and Technology. The Interdisciplinary Learning strand identifies a range of knowledge, skills and behaviours which cross-disciplinary boundaries. Within the domain of Design,
Creativity and Technology students are required to develop the knowledge, skills and behaviours related to investigating and designing using appropriate planning processes and design briefs; creating and developing ideas, applying information, and seeking and testing innovative alternatives (VCAA 2005).

The Interpersonal Development domain acknowledges the importance of students being able to initiate, maintain and manage positive social relationships with a range of people in a range of contexts. Working in teams where collaboration and cooperation, sharing resources, and completing agreed tasks on time are highlighted is one aspect of this (VCAA 2005).

Managing personal learning dimension focuses on the knowledge, skills and behaviours required to enable successful management of personal learning. Students develop skills in goal setting and time and resource management and focus on task achievement (VCAA 2005).

Discipline-based learning in Mathematics requires students to test effective applications in science, technology and other domains. VELS includes the use of technology such as data loggers for direct and indirect measurement and related technologies for the subsequent analysis of data, and estimation of measures using comparison with prior knowledge and experience, spatial and numerical manipulations. Science knowledge and understanding dimension focuses on the relationship between science, technology and society both now and in the future (VCAA 2005). When students are learning robotics they are observing and controlling energy and force.

Since the research took place, the Australian Curriculum, Assessment and Reporting Authority (ACARA) has developed AusVELS that incorporates the Australian Curriculum F-10 for English, Mathematics, History and Science within the curriculum framework first developed for the Victorian Essential Learning Standards (VELS). AusVELS outlines that students in year one to six can use computer programs to control the direction of mechanical equipment.

Within the Science domain students working towards level 3 and 4 are required to work with simple machines, gears, levers, pulleys and transmission of motion. Changes in
motion are described in terms of the forces present. Students design their own simple experiments to collect data and draw conclusions and use diagrams and symbols to explain procedures used when reporting on their investigations (AusVELS 2013).

The Mathematics domain includes number, space and measurement and involves students being able to design models and explain how they were used to solve problems. They also use a variety of computer software to create diagrams, shapes, and tessellations and to organise and present data. Students need to use a variety of computer software to create diagrams, shapes, organise and present data (AusVELS 2013).

**Context**

The unit of work investigated what students learnt with the LEGO® Mindstorms Robotics Invention system. The students were required to program their robot to move forward or backwards for a period of seconds. As the lessons progressed through the eight week unit, students learnt more complex building techniques and programming language. In teacher and student discussions I described what the robot could do and students shared their findings. I described action using mathematical terminology. For example, when the robot turns around in a circle, I described that as a 360 degree turn. After discussions, the students wrote up their observations in their robotics journal. The questions the research investigated were the following:

- Are there learning benefits to be gained from primary aged students learning LEGO® Robotics?
- What mathematics and science concepts are explored during construction and programming?
- How can students learn basic science and maths concepts through the exploration of design projects incorporating LEGO® Mindstorms Robotics?
- Does learning to write directional language in a computer program, which controls the movement of a three-dimensional object, create a cohesive learning experience for students?
- Can LEGO® Robotics offer other learning outcomes that students have not been able to experience through manipulation of concrete aids and abstract concepts?
- When students within the ages of 9-10 work in cooperative groups, can they work together effectively to achieve programming and design solutions?
The structure of thesis is as follows: Chapter Two contains a literature review and the questions the research was aiming to answer. Chapter Three contains research methods and information on the way the data was collected from the participants. It also analyses the data and has a comprehensive break down of the activities and the results throughout the eight weeks. In Chapter Four the occurrences of each lesson are described, and in Chapter 5 the result presented in the previous chapter are discussed. The final chapter contains, conclusions of the research and some suggestions for classroom applications.
Chapter Two Literature Review

The Literature Review starts with a discussion of concrete materials compared to abstract thinking, and then defines what constructionism is. After that the history of how the programming language started with LOGO is presented. The chapter describes the LEGO® roboLab construction kit and the program called roboLab. The review then goes on to give examples of design projects, mindtools and the learning benefits of using engineering problem to stimulate the learning.

The LEGO® Mindstorms Robotics Invention system is described as a learning tool that is able to bring objects to life. A majority of learning experiences with computers in education are about creating a world inside an electronic box. According to research into the learning of LEGO® Mindstorms there is a theory that it is different from learning conventional information technology because:

This type of activity is very different from traditional science-education activities. Science is usually taught as a process of detached observation of phenomena, not active participation within phenomena. We believe, however, that role-playing can play a powerful role in science education-especially in the study of systems related concepts (Resnick, 1998, pg 54).

Concrete materials and abstract thinking

In recent years there has been interest into researching how children learn mathematics and science concepts using technology and interactive objects, with one current curriculum focus on designing mathematical and science classroom problem solving lessons to make connections with real-world contexts. The research by Castledine and Chalmers (2011) looked into how LEGO® Mindstorms Education NXT programming and robotics can be an effective problem solving tool.

“Throughout both activities, each group was able to actively monitor, reflect, and adjust their processes in regards to strategically solving the problems. As students efficacy with the robotics heightened, so did their confidence in their problem solving abilities, and accordingly their metacognitive skills increased” (Castledine and Chalmers, 2011, pg 23).
The researchers Cejka, Rogers and Portsmore (2006) were involved in the Tufts University Center for Engineering Educational Outreach into schools. Their analyses of the curriculum framework, motivations, and efforts involved in bringing engineering via LEGO robotics into every kindergarten through fifth-grade classroom in one school through the Systemic School Change in Engineering Project. The goal of the study was to assist teachers to address the integrating of teaching and learning mathematics, science, technology and engineering (MSTE) through robotics. The results of the research found included:

Students in the early grades gain fundamental concepts of construction, force, and programming and gradually reach advanced topics of algorithm development and project management. In the elementary school, children can learn about robotics and engineering through math and science and vice versa. Students learn about the design and construction of robots, intelligence, and control through programming, as well as the process of testing and refining (Cejka, Rogers and Portsmore, 2006, pg 718).

The research has suggested that people form their strongest relationships with knowledge through "concrete", different from the formal, abstract representations and approaches (Resnick, 1998, pg.3). This view calls into question the classic reading of Piaget (1972), which describes cognitive development as a one-way progression from concrete to formal or abstract ways of thinking. More than a decade ago some researchers called for a "revaluation of the concrete" in the study and practice of mathematics and science, suggesting that "abstract reasoning" should not be viewed as more advanced than (or superior to) concrete manipulations (Turkle and Papert, 1990; Wilensky, 1991).

In this view, the detached stance encouraged by traditional science education tends to limit students’ engagement with scientific ideas, making it difficult for them to build on their experiences and make strong personal connections to mathematics and science. There is appreciation for active participation, and not just distant reflection, in the learning process (Wilensky, 1991, pg.2)

The new type of LEGO® learning system has placed emphasis not only on abstract thinking about science and mathematics, but also on the importance of design, proof and real life observation. Research by Resnick (1998) found that students gained deeper
understandings of concepts such as friction and mechanical advantage. In other cases it found that the young begin to develop understandings of concepts such as feedback, that are not traditionally taught until the university level. Overall, Resnick (1998) found that children make deeper connections with mathematical and scientific concepts when they encounter and use the concepts in the context of personally meaningful design projects.

The computer can play an important role in the interplay between abstract reasoning and the concrete; it "has the ability to make the abstract concrete" (Turkle and Papert, 1990). For example, the computer program MicroWorlds, also known as Logo, offers a much more a concrete approach to learning geometry than traditional Euclidean approaches (Papert, 1980). Children can imagine themselves as the turtle as it draws out geometric shapes and patterns— a much more concrete experience than plotting Cartesian coordinates on graph paper (Resnick 1998, pg 3).

Thinking is described by Papert who discusses “the effect of working with computers on two kinds of thinking combinatorial thinking, where one has to reason in terms of the set of all possible states of a system, and self-referential thinking about thinking itself” (Papert, 1980, pg. 21).

Constructionism
Papert (1993) defines the meaning of constructionism as “my conjecture is that the computer can concretize (and personalize) the formal”, (pg 21). Papert describes knowledge as only part of understanding. Genuine understanding comes from hands on experience. This is a powerful message that underpins the theory of a constructivist approach to learning. Previous research on learning by Papert (1980) uses the term "contructionism" to brand his favoured approach to learning, which is learning by making.

Constructionism is built on the assumption that children will do best by finding ("fishing") for themselves the specific knowledge they need. As such, "the goal is to teach in such a way as to produce the most learning for the least teaching” (Harel, 1991, pg 5). In her research Harel expands on the meaning to construct—a sense of constructionism much richer and more multifaceted, and very much deeper in its implications, than could be conveyed by any such formula.
Constructionism is about learning; computers figure so prominently only because they provide an especially wide range of excellent contexts for constructionist learning. Harel’s experiments show that children's attention can be held for an hour a day over periods of several months by making (as opposed to using) educational software, even when the children consider the content of the software to be utterly boring in its usual classroom form. Moreover, here we see constructionist learning as a structure, which integrates mathematics with art and design and the children making the software that enhances the effectiveness of instruction given by a teacher in the same topic (in the case in point, fractions) (Harrell, 1991, pg 5).

Papert’s (1993) research defines the meaning of constructionism so that it differs from constructivism in that "it looks more closely than other educational -isms at the idea of mental construction. It attaches special importance to the role of constructions in the world as a support for those in the head, thereby becoming less of a purely mentalist doctrine (Papert, 1993 pg 139). Resnick, (1998) added to the idea, that constructionism is where people construct new knowledge with particular effectiveness when they are engaged in constructing personally meaningful products.

The course designed by Beisser and Gillespie (2003) was inspired by earlier research by Papert and Harel. Their course was based on a constructionist perspective to learning and teaching which was a hands-on without objective exams. The students involved were college students learning about educational technology and programming. The course was also structured around the beliefs that people learn most effectively when they are engaged in collaboration, design, construction, and problem-solving activities. The research concluded that the students at first were struggling, and eventually succeeded to make the technology work for them in ways that traditional courses with "instructional" approaches failed to do. Students were required to construct their own understanding and to analyse their own learning based on prior knowledge and experience. The constructionist theory used in the course showed that students learn best when they use computers in a way that puts them in the active roles of designer and builder (Harel, 2003, pg 1).
LOGO

Logo was developed in the 1960’s and used a floor turtle connected by a wire to a computer (Papert, 1980). The user would write in a programming language using abbreviations for words and numbers to create a command. This would direct the movement of the turtle. The software evolved to a turtle on a screen where the user can navigate the turtle to make shapes and patterns using directional language and algorithms. With the development of computers in the late 1970s, the Logo community shifted its focus to "screen turtles." Screen turtles are much faster and more accurate than floor turtles, and thus allowed children to create and investigate more complex geometric effects (Resnick, 1998, pg. 4).

In the LEGO® Mindstorms Robotics Invention system the Logo program has merged with LEGO® and has come a full circle, where the object is programmed in reality and the students can create robots that move independently without wire connected to a computer.

LEGO® RoboLab Construction Kit

The RCX box, referred to as the brain, remembers the code that it has downloaded via an infrared signal to the receptor. It can move independently. The researcher Sato (2000) describes the LEGO® pieces from the Mindstorms kit containing building bricks and additional pieces including gears, motors, and sensors. Then the end user can connect their LEGO® constructions to a computer and write programs to control the actions of their constructions.

Because the LEGO® RoboLab construction kit is a typical example of interactive technology, Robotics as a tool can be a way to engage students in meaningful learning; students are learning with technology as opposed to learning from technology (Chambers and Carbonaro, 2003, pg 2).

The students are not the receivers of information: they are constructing an object to receive their thinking about interaction in a 3-dimentional environment (Jonassen, 1999, pg. 2). Also, as Hendler (2000) pointed out, such toys "challenge the very nature of the relationship between children and technologies: Children are no longer anchored
to a PC on the desktop, but able to bring the technology into their everyday world" (Hendler 2000, pg 2).

**RoboLab and LEGO® Mindstorms Education NXT**

The program facilitates a situation where students can easily create a program using recognizable visual icons that cover the scripted coding, enabling the users to easily achieve results without manually script coding. LEGO ® Mindstorms Education NXT was released in 2006, and now in 2013 the robotics system has been updated to EV3. These sets are all based on the fundamental principle that students build, program and test their solutions based on real life robotics technology.

Following your interest level you can take your constructions to where your skill, creativity and confidence allows. During the development of RoboLab, pilot studies with teachers and children indicated that RoboLab designers should be cognisant of the fact that young children often lack the reading level and motor skills required to write and develop complex symbolic programming code (Portsmore, 1999, pg 30). Thus abstract robot control instructions, in the form of the icon-based programs, are designed and constructed separate from the robot. However the actual results from executing these programs can only be realised while observing the behaviours of a robot that has been designed and constructed to match the program code. Linking a physical robot design with the corresponding abstract icon-based representation of its functionality demonstrates a complex knowledge-building interrelationship between form and function (Chambers and Carbonaro, 2003, pg.4).

**Design Projects**

In recent years there has been a growing recognition of the educational value of design projects in which students create external artefacts that they can share and discuss with others. A curriculum that incorporates design projects with RoboLab and the programmable bricks opens up new possibilities for student investigation.

When engaged in a design project in the LEGO® Mindstorms Robotics Invention system, students are designing their LEGO® objects and testing their independent movement through programming. The process of construction of the programmable moveable object and evaluation through design development represents constructionism
in practice. The constructionist perspective suggests that students who are engaged in the designing and construction of robots are actively engaged in their own learning, developing problem-solving skills, using higher-order thinking skills, working collaboratively and intentionally in an intrinsically meaningful and authentic way (Chambers and Carbonaro, 2003, pg.4).

Learning through a robotics design project facilitates students’ ownership of their learning within a constructionist environment. The learner discovers and makes choices as they explore countless avenues for solving design challenges. With innovative LEGO® RoboLab technology, students learn various facets of problem solving while simultaneously mastering numerous mathematical and scientific concepts. This is a recognition of the educational value of design projects, in which students design and create external artefacts that they can share and discuss with others. Students can build and test objects and record their findings. Resnick (1998) found that one group of fifth-grade students, inspired by the movie Jurassic Park, created a LEGO® dinosaur that was attracted to flashes of light from the headlights of a motorised jeep (built by the same team). To make the dinosaur move toward the light, the students needed to understand basic ideas about feedback and control. The students wrote a program that caused the dinosaur to spin in a circle, looking for the jeep’s lights. When the reading from the dinosaur’s light sensor crossed a certain threshold, the dinosaur started driving straight ahead. If the light sensor reading started to fall again, the dinosaur would start spinning again (Resnick, 1998, pg. 5).

**Mindtools**

Another term used by Resnick (1998) is “Mindtools”, which is similar to the thinking process that occurs when involved in a design project that incorporates technology. The student and computer work together to create programs for designed objects. Constructivist advocates including Bruner (1966), Papert (1990), and Jonassen (1999) have found that learners can make their own meaning: “that knowledge representations are built and constructed”. Papert wrote that, learning from computers cannot produce 'good' learning, but children can do 'good' learning with computers” (Harel and Papert 1991, pg. 41).
Jonassen (2000) makes a compelling argument for using computer technologies as "Mindtools" in education, in contrast to using computer technologies as a vehicle to deliver instructional material. The theoretical motivation for including robotics in teaching is grounded in Jonassen's notion that Mindtools can indeed change and enhance the learning process in education. Jonassen (2000) has described the relationship of Mindtools to the educational process, suggesting that students cannot use the application computer technologies without thinking critically (engaging the mind). So the most effective uses of computers in classrooms are for accessing information and interpreting, organising, and representing personal knowledge. Just as carpenters cannot build furniture or houses without a proper set of tools, students cannot construct meaning without access to a set of intellectual tools to help them assemble and construct knowledge (Jonassen, 2000, pg. 4)

The researchers Chambers and Carbonaro (2003) point out that the LEGO® RoboLab program enables students to implement the approach of constructionism, which requires students to think in meaningful ways in order to use the application to represent what they know. Robotics combines a programming language with a manipulative. Chambers and Carbonaro claim that learning through a robotics design project facilitates student’s ownership of their learning within a constructionist environment. The learner discovers and makes choices as they explore countless avenues for solving design challenges. With innovative LEGO® RoboLab technology, students learn various facets of problem solving while simultaneously mastering numerous mathematical and scientific concepts. After numerous studies into technology and learning Martin, Mikhail, Resnick, Silverma and Berg (2000) expressed concern with the widespread introduction of technology in children’s lives, mostly because students are passive participants with technology. For example, the early Sony 2002 robotic dog has a set of automated responses, but users could not change or modify its actions. With the incorporation of design technology children have sense of control, ownership, empowerment and become active participants in understanding and designing our future.

Robotics combines the strengths of three-dimensional manipulation in the educational setting, and the assets of a computer language to program interaction with obstacles in a realistic environment. In summary, robotics represents a constructionist approach for using technology where such activity is intended to engage the learners in
representing knowledge, manipulating virtual and concrete objects, and reflecting on what they have designed and built to improve design and programming.

Constructionists approach knowledge formation with an emphasis on the concrete rather than the abstract, believing that manipulation of tangible objects aids in the process of knowledge representation (Carbonaro, 1997). Using robotics involves the learner in simultaneously building both a functional physical object, and the problem-solving knowledge it takes to accomplish the task. The symbiotic relationship between constructivism and constructionism through the introduction of robotics is interrelated. Some research suggests that students learn more effectively in self-guided tasks. When they are evaluating their work is where the change in thinking occurs, as this is where they have realistic proof about whether or not the object achieved its objective or failed.

**Learning Benefits**

The benefits for students in primary schools learning with LEGO® robotics are expounded by Resnick (1998). If we give learners new types of digital building blocks, they can learn not only about number, shape, scale, but they can learn about interaction, communication, dynamics, in the same way that they traditionally learn through direct manipulation. Differences between learning mathematical concepts through computer manipulative compared to LEGO® Robotics has also been discussed by Martin F, Resnick M, Silverman B, Berg R have explored ways that students aged five to eight can have new apparatus that allows better observation of scientific phenomena or explorations of a physical principles. They suggest that the design process is often absent from science in school settings. Their aim is for a more integrated approach to the learning of science, mathematics and engineering.

The LEGO® Mindstorms Robotics Invention system combines the strengths of three-dimensional manipulatives in the educational setting and the assets of a computer language to program interaction with obstacles in a realistic environment. In summary, robotics represents a constructionist approach for using technology--where such activity is intended to engage the learners in representing knowledge, manipulating virtual and concrete objects, and reflecting on what they have designed and built to improve design and programming. Constructionists approach knowledge formation with an emphasis on the concrete rather than the abstract, believing that manipulation of tangible objects aids in the process of knowledge representation (Carbonaro, 1997). Using robotics involves
the learner in a simultaneously building both, a functional physical object, and the problem-solving knowledge it takes to accomplish the task. The symbiotic relationship between constructivism and constructionism through the introduction of robotics is an interrelated; research has found that students learn more effectively in self-guided tasks. When evaluating their work that is where the change in thinking occurs where they have realistic proof of why or the object achieved its objective or failed.

Research into the impact of LEGO robotics on the learning of scientific and mathematical concepts at the primary level has been designed in different ways to suit the purposes of variety of learning themes depending on the year level. Castledine and Chalmers (2011) point out that “The study found out that several major themes arose from students’ problem solving and authentic reflection skills. Estimation and looking for number patterns were the most common problem solving strategies used by the students in the initial stages of programming. This was closely followed by trial and error. When correlating their problem solving strategies to real-world contexts, transport and general careers were the most prominent themes” (2011, pg 26).

**Conclusion**

The use of concrete materials is a way for students to make connections with abstract thinking in mathematics and science. With the introduction of a design scenario students in teams can work through a variety of solutions to real world problems. The idea is that through trial and error they construct meaning. When testing the robot design and program students learn the scientific process to be able to develop a hypothesis, develop predictions, run a test, analyse the data and draw a conclusion. Students then go back to the program or the concrete design and start the process again. As students gain confidence in the design process they are able to communicate the results.
Chapter Three Methodology

Research questions

This research aimed to investigate what students learn through using the LEGO® Mindstorms Robotics Invention system. The specific overarching question was “What is the impact of LEGO® Robotics on the learning of Science and Mathematical concepts?” The minor questions the research sought to answer are:

- Are there learning benefits to be gained from primary aged students learning LEGO® Robotics?
- What mathematics and science concepts are explored during construction and programming?
- How can students learn basic science and maths concepts through the exploration of design projects incorporating LEGO® Mindstorms Robotics?
- Does learning to write directional language in a computer program, which controls the movement of a three-dimensional object, create a cohesive learning experience for students?
- Can LEGO® Robotics offer other learning outcomes that students have not been able to experience through manipulation of concrete aids and abstract concepts?
- When students within the ages of 9-10 work in cooperative groups, can they work together effectively to achieve programming and design solutions?

The research method used was qualitative, where the researcher observed and was the teacher within the learning process. The researcher obtained information relating to what students were learning about mathematics and science by observing them working with the materials of the LEGO® Mindstorms Robotics Invention system. Students were explicitly taught the program Robolab and were required to learn specific icons over a two-week session programming unit. They were also required to learn how to read instructional design diagrams in order to build the robots from the LEGO® Mindstorms Robotics Invention system. While participating in this activity students were observed and their work was collected for analysis. Individual classes were divided in half, resulting in two groups of 13 to 15 students. They participated in a 50-minute lesson once a week for a period of 8 weeks. This enabled each class to participate in a school term of LEGO® Robotics. The three classes of grade 3/4 at the school had all been involved by the end of the year.
The qualitative research method was chosen because the researcher was able to gather an in-depth understanding of the learning activities and the effects on the students’ behaviours.

- Student work within set tasks.
- Participant observation
- Records of student learning.
- Student digital journal of learning.
- Unstructured student interviewing
- Case Studies of individual students.
- Student self-evaluation at the beginning, middle and end of the lesson.

**Participant groups**

The participating students were from an inner city metropolitan public primary school. Approximately sixty students from grades three and four participated in this project. From this total population only two students’ work was analysed in detail, and they were selected as average examples from that age group.

Groups were decided through student negotiation and year level. At the time students were given one hour of robotics once a week for a one term. The class came in as half classes in their year level, which was approximately twelve students at a time. The class was then divided into three groups of four. The group of four then rotated between being programmer or builder. During the lesson students met up to test their program and the design. Every lesson the group shared their findings with the class, and discussed difficulties and tried to find solutions through a sharing of ideas.

Students in groups of two started with building a simple design of a robot. Once they mastered the concept of control technology they were able to build more complex prototypes with light or touch sensors following the Mindstorms instruction manual. The groups tested how gears can reduce the speed of the robot design. They analysed how the gears assist the function of the robot. Students evaluated their learning of the unit by reflecting on what they learned and evaluated what they had difficulties with to make improvements in future programs and designs. While building and programming students were asked what strategies they were using to find the pieces and connections to make the program work.
Setting
The setting of the study was the Art room, which is a large multifunction space with two main areas. One space had a multimedia facility comprising of five computers. Other parts of the room had large tables for building models. The learning facility had been designed so that while some students programmed on the computers in one space, others built robots with the LEGO® pieces in the workspace area of the classroom.

As the researcher and teacher I assisted the students and observed their learning strategies at the same time. Undoubtedly this limited the amount of data the teacher collected on what learning was occurring. To resolve some of these issues the teacher used evaluation checklists, which were filled in at the time the activity occurred. The teacher also used a video camera to collect concrete evidence of the activities. Also, being the students’ teacher I was aware of some of their learning abilities and had certain biases when grouping students. However this grouping was only planned to benefit the learning situation.

Sampling
Case Studies: Groups of students and individuals were chosen for intensive study in the specific context of the research. The work of groups of students was documented for evidence of developmental phases and understanding of key concepts.

Behind this approach is the idea that children are social interactive beings, who would be able to assist each other to extend thinking. James, Morrow and Richards (1996) suggest that group discussions, when children have the support of their peers, diffuse the normal adult-child power relationship.

Practical considerations for data collection
Action Research
Action Research as described by Cohen and Manion (1994) is:

“Essentially an on the spot procedure designed to deal with a concrete problem located in an immediate situation. This means that ideally, the step by step process is constantly monitored over varying periods of time and by using a variety of mechanisms (questionnaires, diaries, interviews, case
studies, for example) so that the ensuing feedback maybe translated onto modifications, adjustments, directional change, re-definitions, as necessary, In order to bring about lasting benefit to the on-going process itself’ (Cohen and Manion, pg. 192).

Cooperative groups
This study tried to incorporate the practice of AusVELS’ (2013) Interpersonal development cooperative group work, where students interact with their peers, and adults in formal contexts. Through the study of robotics the students in groups were required to develop their skills and strategies for getting to know and understand others within increasingly complex situations.

The research used the strategies suggested by Walters (2005) who recommended strategies to foster interdependence within groups, including assigning a single product for the group, asking students to take on different roles (recorder, facilitator, researcher, presenter, and so on), and assigning one student in each group to become an "expert" in one particular area and report back to the others. This was achieved throughout the study by allowing students to focus and master one element of the design or programming. Towards the end of a lesson students were able to share their finding with the rest of the class.

The intentions was that students not only learn about mathematics and science throughout the robotics projects, but they also become an accountable member of the group and responsible for one element of the process. Students learned from their peers and the feedback they got along the way built up their skills in the subject. Slavin, Johnson and Johnson (1994) are three prominent researchers of cooperative learning and analysing their work lends a unique perspective to formal, structured cooperative learning. They argue that all cooperative learning methods have certain shared central ideas. In cooperative learning, students work together to learn, and are responsible for one another’s learning as well as individual learning (Slavin, 1994, pg. 1096).

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and are responsible for one another’s learning as well as individual learning (Slavin, 1994, pg. 1096).

In the study students were required to work in pairs to designing the program for the robot function. Johnson and Johnson (1996) defined cooperative learning as the pedagogical use of small groups of two or more students who work together to maximise their own and each other’s learning. When students are in pairs they share a computer and program together. During this process they are helping each other program and trouble shooting any problems. Johnson and Johnson identified several key functions of group learning.

“These are positive interdependence, equality of participation, co-construction of ideas, giving and receiving help, primitive interaction, and division of labor, conflict and controversy. Positive interdependence exists within a group when all members of a group believe that success is a joint endeavour. Group members are required to work together to achieve mutual, not individual, success”, (Johnson and Johnson, 1996, pg. 1019).

The mixed grouping enabled teams to develop their communication skills. The mixed grouping enabled teams to develop their communication skills. Groups selection in research gathered by year level. However the students were not matched with each other on the level of computer science knowledge or mathematical skills. The mixed grouping enabled teams to develop their communication skills. Hooper (1992) researched the cooperative behaviours of giving and receiving help while using a computer between higher- and lower-ability students. He found that:

“Most cooperative learning methods group students heterogeneously. That is, group composition is manipulated to include students with diverse ability, ethnic background, social class and gender. Advocates claim that heterogeneous grouping benefits all students: Low ability students gain from receiving help from more able peers, and able students prosper from the mental reorganisation that occurs before explaining a lesson content. Moreover, in heterogeneous groups, students are more likely to be exposed to different learning styles and attitudes” (Hooper 1992, pg 180).
Hooper also states that effectiveness of cooperative learning is generally attributed to group discussion. The nature of group interaction is potentially more important than group composition per se (Hooper 1992, pg 14).

Data Collection

Participant observation:

Requires that the researcher become a participant in the culture or context being observed. “The researcher as a participant is responsible for the collection and storage of field notes, and the analysis of field data. Participant observation is especially appropriate for exploratory studies, descriptive studies, and studies aimed at generating theoretical interpretations. Ultimately, the methodology of participant observations aims to generate practical and theoretical truths about human life grounded in the realities of daily existence” (Jorgensen, 1989, pg.14). Being part of the learning and teaching was my actual employment for the Department of Education. Having an inside perspective on my own teaching and the cohort of students enabled improvement to be made to the teaching of the subject.

When the students were analysing their learning and responded to the questions in their journal they analysed, evaluated the activity as the lesson progressed and documented their own observations. The methodology of participant observation provides direct experiential and observational access to the students’ world of meaning (Jorgensen, 1989, p15)

In the role of the teacher I participated in the learning by assisting with the building of the robot by locating LEGO® pieces and demonstrating how to operate the program Robolab. As researcher I also modelled behaviour in a cooperative group, assisting with, and demonstrating concepts being explained. The students had never learned robotics before and it was important to model how to work as a team so they could understand what they needed to do. The method of collecting information as the participant observation is in the form of direct observation and the writing of field notes.
Record of student learning:
These were kept by making photocopies of student’s self-evaluation and copies of their written journals. Photographs were taken of the models produced by the students. Files were kept on the programming in RoboLab of each group. A tally sheet of indicators of possible outcomes was created for each task to assess students’ achievements. The weekly scores were then added and average calculated. The groups scores were then compared to create a cohort average. Then year level averages were calculated (see Appendix 2).

Techniques to avoid subtle topic control through language included using open ended questions in non-specific language until the informant’s terms can be identified and defined; consistently adopting and maintaining a stance of the learner in research interviews field testing interviews and submitting interview tapes to experienced field researches for critical review and comment; and taking into account subtle sococultural differences in verbal and nonverbal styles when planning and executing interviews (Lipson and Meleis,1989, pg103-115).

Set tasks:
Through clear objectives given at the beginning of the lesson, students were expected to accomplish goal-driven outcomes. Students were given handouts and shown explicit steps for building techniques, and it was intended that they gain recognition of the functions of the icons in the RoboLab program for specified results. Students took alternate roles from one lesson to the other. For example, from initially being a programmer in the first lesson, they changed their role in the next lesson to become a LEGO® builder. This strategy of diversity aimed to give students a deeper understanding of the function of programming and design.

Unstructured Interviewing:
This involves direct interaction between the researcher and a student or group. In this type of interviewing the interviewer is free to move the conversation in any direction of interest that may come up. Much early childhood research has relied on prompts and stimuli to engage children’s interest, foster thought and reflection, and soften of the high control, adult-dominant, question-and-answer format. The research by Morse (1991) suggests techniques to avoid subtle topic control through language, including using
open-ended questions in non-specific language until the informant’s terms can be identified and defined.

The sorts of questions I asked when the students were engaged with the activity varied depending on what part of the lesson we were in. Types of questions the teacher asked throughout the lesson have been divided into which part of the lesson it is.

**Examples of Semi-structured Interview questions**

**Questions when students are programming**
- What is the motor symbol doing when the arrow is pointing right what does this make the robot do?
- What function does the pink line in between the icons do?
- How many seconds do you need to give your motor to make it to the wall?

**Questions when students are testing their program on their robots**
- Can you describe what the robot is doing?
- Have you asked the programmers in your group to check that the robot is doing what they programmed it to do?
- Explain how the robot moves around the table.
- How did you get the robot to turn backward and then move forwards?

**Questions when students are building their robot.**
- Have you built with LEGO® before?
- Are you familiar with the step-by-step instructions in the worksheet?
- Can you count how many holes the piece of LEGO® has in the picture and find that piece in the box?
- Do you know what the motors and sensors might do in this LEGO® kit?

**Questions in group discussion and Journal Entry**
- What did you learn this lesson?
- What worked well?
- What did not work well?

As Hutt (1989) suggests, direct questioning from adults is threatening to children and it is preferable that adults who offer children the chance to put forward personal views, ideas and observations, and by doing so tend to receive a more elaborate and less
predictable response. This is considered to stimulate children to share their own thinking.

Research by Brooker (2001) into interviewing children suggests the importance of familiarity: the researcher should have become a trusted adult within the child’s setting before attempting to elicit information, particularly of a personal nature, from any child. Children can offer information, which, particularly in combination with other evidence, enable us to see and discover aspects of their lives, which no other research method can give (Brooker, 2001, p 184).

Throughout this research there were structured interview questions in the student’s journal and unstructured open ended questioning while students were completing their tasks. The research of Morse (1991) into balancing flexibility in interview procedures suggests that consistency is also essential in the types of questions asked, depth of detail, and the amount of exploration versus confirmation covered in an interview in order for conclusions to be drawn. Thus an important challenge in qualitative research is maintaining enough flexibility to elicit individual stories, which are likely to vary a great deal (at least on first glance), while gathering information with enough consistency to allow for comparison between and among subjects (Morse, 1991, p 192).

**Self-evaluation:**

Since the late 1980s, student self-assessment has increasingly become a normal and regular part of teaching in education. Teaching and learning has evolved from students looking at the teacher for the only source of information. Teaching allows for student self-assessment to assume a more central place in teaching, learning and assessment. Self-assessment is a way for students to analyse their own learning process. Good assessment is built on current theories of learning. We no longer view students as empty vessels to be filled, we prefer to see learners as active participants in the learning process. The wealth of research into constructivist learning theory tells us that meaningful learning occurs when learners are actively engaged in constructing and expanding their knowledge, and in working out how to apply their knowledge to solve problems (Ferrara and McTighe 1992, Herman 1992, Herman 1997, and Ashbacher 1997).
The research of Cooper (1998) with into learner centered assessment suggests that:

“Providing supportive, yet challenging learning environments with rich substantive curriculum is not enough! We must help students understand and make sense of their learning through mindful reflection. Metacognition (being mindful of one's own thinking and processes of learning) is evident in [the] debriefing process as students are asked what they learned, why they learned it and how they learned it. By reflecting on [and being active participants in the formulation of] the academic goals and social goals of the learning experience, the student integrates and synthesizes the learning” (Cooper, 1998, p 59).

This was a continuing strategy that the students evaluated their learning throughout the design process. Students were to write a journal of their learning before, during and after they were involved in LEGO® Robotics.

**Representing data**

There are two basic methods of selecting samples from populations. These are non-probability sampling and probability sampling. The data will be analysed by using a descriptive statistical technique. Which is using a sample of the data to about the learning that took place. This study is using one class of grade three and four as its sample population. In that class the teacher selected a sample of the population. The teacher used a probability sampling, in which each element or member in the population has a known and equal chance of being chosen in the sample. As a result, we can assess objectively the estimates of the population properties that result from the sample.

**Data Analysis**

When analysing the data the researcher looked for common results from the participants. The researcher designed and analysed key data points in the form of a rubric to organise the course content that was covered in the eight weeks. The data analysis is based on how students marked their achievements each week. The student’s result of the rubric and scored were checked and verified by the researcher see Appendix 2 for the data collection criteria. Creating a Robotics Rubric Appendix 1 helped to:
• increase an assessment's construct and content validity by aligning evaluation criteria to the research standards
• to increase an assessment's reliability by setting criteria that can apply consistently and objectively.
• evaluating student work by established criteria reduces bias.
• help learners set goals and assume responsibility for their learning.

What the research aim to achieve clear and concise way of documenting the learning by summarising the Vels criteria in the form of rubric.

To record students’ learning in cooperative groups the students were recorded in their interactions with both video and still camera. The task of analysis consisted of five distinct functions:

• Classifying tasks according to learning outcomes –
• Inventorbing tasks – identifying tasks or generating a list of tasks
• Selecting tasks – prioritising tasks and choosing those that are more feasible and appropriate if there is an abundance of tasks to train.
• Decomposing tasks – identifying and describing the components of the tasks, goals, or objectives.
• Sequencing tasks and sub-tasks – defining the sequence in which instruction should occur that will best facilitate learning (Jonassen, 1999).

**Sampling and data collection**

The structure of the school has composite classes so the grouping that the researcher worked with was a grade three and four class. Primary data has been obtained form actual observations and records that are naturally produced through the robotics program. The data that has been gathered is only a portion or sample of the entire population. Descriptive statistics were used to summarise the actual results in the terms of a numerical measure they enable us to establish the degree of confidence.

This section describes primary data, which has been obtained from observations and records that are naturally produced throughout the robotics program. Descriptive statistics are used to summarise the actual results in the terms of a numerical measure, as they enable us to establish the degree of confidence.
Bias

A selection bias exists whenever there is a systematic tendency to over-represent or under-represent some part of the population. For example, sampling two students from this class, in an afternoon session, could be biased towards their behaviour brought in from the lunch break. Consequently, any inferences made from the sample data would be biased towards the attitudes or opinions of post lunch students, and might not be truly representative of students throughout the entire day.

Selecting Samples

Probability sampling was the chosen method of selecting samples for this study, as it allows for each member in the population to have known and equal chance of being chosen in the sample. As a result we can assess objectively the estimates of the population properties that result from the sample.

In this chapter the research methodology employed to collect and analyse data have been presented and justified. In the next chapter the results of the data collection and analysis are presented.
Chapter Four Presentation Of Results

This chapter presents the Robotics Rubric categories utilised to organise the data. These categories are journal/note book, design and operation, modification and testing, scientific knowledge, team Interaction, construction-materials, oral presentation, time management and accumulative results for the robotics program. During the eight-week project each group recorded their progress using the rubric as a guide. The chapter also looks at the results of two students from the cohort. The rubric categories are explained and the accumulative results graphed analysed. When looking at the results for the grade three and grade four. The latter had slightly higher expectations than the former. The results of the grade three are lower and the overall average would be moderated for assessment purposes.

Throughout the chapter the rubric categories are explained and the accumulative results graphed analysed. When looking at the results for the grade three and grade four. The grade four had slightly higher expectation then the grade three. The results of the grade three are lower and the overall average would be moderated for assessment purposes.

Journal/Note book

The Journal/Note book forms a valuable resource for both the teacher and student. The constant process of self-assessment allows students to consolidate their knowledge through describing, reflecting and recording their learning experience. This process establishes the assessment structure that enables the teacher to track individuals as they progress through the program.

The graph in Figure 1 shows the change in the assessable outcome for the sample of a Grade 3 student’s performance over the 10 week program in comparison to a Grade 4 student. The graph documents the students’ performance against the established criteria that are set out within the Robotics Rubrics (Attachment 1). The illustrated trend line shows experiential growth throughout the program. However it should be noted that the Grade 4 student within the initial period was not allocated enough time to explore this area and as a result there is only a marginal improvement after week 4. The Grade 3 student had predictable growth throughout the program.
Figure 1: Journal/Notebook: Grade 3 and Grade 4 student’s performance
**Design and Operation**

This section describes the assessable results of the Design and Operation area within the student evaluation. The robotics lesson structure allows the opportunity for students to focus on specific areas and tasks. Moving through the program students are expected to shift rolls, changing tasks from building one week to programming the next. Design and Operation explores both the building of the robotic hardware solution so that it will enable run smooth running, and creating an executable program for this system.

The learning through solving problem with technology builds confidence throughout the lessons. During the course students establish problem-solving strategies as they familiarise themselves with the resources and requirements of the lessons.

Figure 2 below shows the change in the assessable outcome for the Grade 3 sample student over the 10 week program in comparison to the Grade 4 student. The graph documents the student’s performance against the established criteria that are set out within the Robotics Rubrics (Attachment 1). The illustrated trend line shows experiential growth throughout the program. Highlighting a moderate drop from the Grade 4 student within the middle period, this may be a result of their open design brief that starts to explore unfamiliar structures without the aid of concise instructions. While the Grade 3 student has been provided with some detailed instructions, this shows a more predictable pattern of growth.

**Figure 2:** Design and Operation: Comparison of Grade 3 and Grade 4 students.
Modification and Testing

This section describes the assessable results of section called Modification and Testing within the student evaluation. Modification and testing allows for an inclusive environment for problem solving to take place in. Team members from both the programming and construction areas are encouraged to openly discuss how the process is working. Modifications may be required as a result of the testing, troubleshooting, refinement based on the data or scientific principles; for example students might find that a program made for the robot intended to move it in a straight line, but instead it might be moving in circles. The problem might be in the programming or building, but through the process of consultation with other members a solution should result. Evidence was observed and documented by the researchers and discussed in the reflection and evaluation part of the lesson.

Figure 3 shows the change in the assessable outcome for the sample student from grade 3 over the 10 week program in comparison to the grade 4 student. The graph documents the student’s performance against the established criteria that is set out within the Robotics Rubrics (Attachment 1). The illustrated trend line shows experiential growth through out this program, highlighting a moderate drop from the grade 4 within the middle period week 4 indicates a regression and beyond shows a significant improvement through the program.

Figure 3: Modification and Testing: Comparison of Grade 3 and Grade 4 students
**Scientific Knowledge**

This section describes the assessable results of Scientific Knowledge area within the student evaluation. Robotic kits come with a myriad of components and students encounter some complex scientific and mathematical concepts relating to ratio and dealing with the work of real scientists, which involves the construction of new apparatus that allows better observation of phenomena or exploration of a physical principle.

The graph in Figure 4 shows the change in the assessable outcomes for the sample student from grade 3 over the 10 week program in comparison to the Grade 4 student. The graph documents the student’s performance against the established criteria that are set out within the Robotics Rubrics (Attachment 1). The illustrated trend line shows experiential growth throughout the program. However the Grade 3 student who was unfamiliar with this program for half of the 10-weeks remained at an entry level of confidence. However in week 5 the accumulative effect of the program structure enables them to achieve a substantial improvement and then proceed to increases growth until the end.

![Figure 4: Scientific Knowledge: Comparison of Grade 3 and Grade 4 students](image-url)
Team Interaction

This section describes the assessable results within the Team Interaction area as part of the student evaluation. Each team consists of 4 students who are equally divided into a building unit and a programming area. Within this team environment students are expected to communicate throughout the process of building and programming, enabling them to have a cohesive project outcome. If communication between programmers and builders is not cohesive, usually once they test their robot they can rectify problems. For example the robot RCX has a series of ports for taking input cables to run the motors, and if these don’t correspond to the program then there is an unpredictable outcome when the testing occurs. However if a good flow of communication has been achieved within the whole team they should be able to predict the results when testing begins.

Figure 5 shows the change in assessable outcomes for the sample student from Grade 3 over the 10 week program in comparison to the Grade 4 student. The graph documents the student’s performance against the established criteria that are set out within the Robotics Rubrics (Attachment 1). The illustrated trend line shows experiential growth throughout the program. A good example of how difficult it is to grasp new concepts while trying to communicate is highlighted in the significant drop that occurred in week 2 for both students. Despite this we see that the grade 3 student who was unfamiliar with a cooperative structure have achieved substantial growth after week 2.

![Team Interaction Graph](image)

**Figure 5**: Team Interaction: Comparison of Grade 3 and Grade 4 students
**Construction-Materials**

This section describes the assessable results of the Construction-Materials area within the student evaluation. The Construction-Materials component tests students’ understanding of the core components that form the foundation of material requirements involved with building a stable programmable robot. Students utilise these parts to form a unified structure that has the ability to meet the hardware requirements for the programmers and allow a tangible framework that will withstand the challenges involved with the testing process.

Figure 6 below is a line graph that shows the change in the assessable outcome for the sample student from Grade 3 over the 10 week program in comparison to the Grade 4 student. The graph documents the student’s performance against the established criteria that was set out within the Robotics Rubrics (Attachment 1). The illustrated trend line shows experiential growth throughout this program, however in week 2 a drop occurs, this may be due to an orientation period as both sets of data indicate this and beyond showed a significant improvement through the program.

![Figure 6: Construction-Materials: Comparison of Grade 3 and Grade 4 students](image-url)
**Oral Presentation**

This section describes the assessable results of the Oral Presentation section within the student evaluation rubric. Through the lessons students were questioned about current processes they are working on, allowing them opportunities to describe and show examples of the work involved in programming and building. This type of unstructured interview, combined with teacher observations, form the environment that allowed for this data to be collected.

Figure 7 shows the change in the assessable outcome for the sample student from Grade 3 over the 10 week program in comparison to the Grade 4 student. The graph documents the student’s performance against the established criteria that was set out within the Robotics Rubrics (Attachment 1). The illustrated trend line shows experiential growth throughout this program, while each alternative week a levelling off occurs, this is may be due to the students shifting from building to programming environment. The alternating trend is supported within both sets of data; the similarity of the finding in this process illustrates a broader influence of skills that these students have established.

![Oral Presentation Graph](image)

**Figure 7**: Oral Presentation: Comparison of Grade 3 and Grade 4 students
Time Management

This section describes the assessable results of the Time Management area within the student evaluation. Students have an expected outcome to achieve within the lesson structure, combing the actual results achieved with observations, to form the background for the collection of this data set.

Figure 8 is a graph that shows the change in the assessable outcome for the sample student from Grade 3 over the 10 week program in comparison to the Grade 4 student. The graph documents the student’s performance against the established criteria that is set out within the Robotics Rubrics (Attachment 1). The illustrated trend line is showing experiential growth throughout this program.

Interpreting the results for this data set shows the Grade 3 student initially found the idea of time management hard to come to terms with. However after this adjustment period they rapidly improved to eventually outperform the Grade 4 students. The Grade 4 student was exposed to this type of environment previously when they were in Grade 3, so had previous opportunity to participate in this program. Allowing for the effect of prior experience within the time management results, and as a result of this process, the Grade 4 student undertook an unfamiliar task that was unstructured. Grade 4 students are achieving their results within a different set of rules that allowed them to explore a verity of designs instead of the more structured approach of Grade 3.

The overall result shows how the Grade 3 student has achieved a significant improvement, becoming familiar with the components that are involved and in the time management area of this program. The outlier data point was in week 4 for the Grade 3 students, although it seems to be excessive drop off. This shows that students in the early period of the robotics unit are still mastering the timelines and learning the routines of the lesson. The continue improvement in time management in the weeks that follow week 4 shows how the students confidence increased with the LEGO® Mindstorms invention system.
Accumulative results for the Robotics program

This section combines the overall results from the data collection points to look for any global trends that might become evident within this study. Figure 9 shows the change in the overall assessable outcome for the sample student from Grade 3 over the 10 week program in comparison to the Grade 4 student. The graph documents how the students performed against an accumulative established criteria that was set out within the Robotics Rubrics (Attachment 1). The illustrated trend line shows experiential growth through out the program.

The combining of data allows us to explore comparisons between the Grade 3 and Grade 4 students. This highlights a significant increase after week 4 in the learning of the key concepts for Grade 3 compared to the example for Grade 4 students, which shows only a marginal improvement.
Rigour and trustworthiness

To ensure rigour and credibility for the research project was decided to include the school community in later stages of the study by sending the transcripts of the interviews for verification, and then providing the stakeholders with drafts of the research outcomes. A robotics program was incorporated into the school, which continues outside the research project. A final stage will be for the field researcher to make presentations of the research findings to various groups.

As researchers, we need to be able to capture this process of interpretation through an empathic understanding or the ability to reproduce the feeling, motives and thoughts behind the actions of others, while at the same time remaining as objective as possible (Bogden and Taylor, 1975; Maykut and Morehouse, 1994).
Chapter Five Discussion of Results

In the Grade 3 eight week course of LEGO® Robotics the important content ideas were the focus of the sequence: The unit of work investigated what science and mathematics concepts students learnt through using LEGO® Mindstorms Robotics Invention system. In the weekly 1 hour lesson students were involved in activities that required them to program their robot to move forward or backwards for a period of seconds. As the lessons progressed through the eight week unit, students learned more complex building techniques, programming language constructs and team dynamics improved. The complex building techniques required students to build robots with more complex gearing systems. Also the robots had different ways of moving with tracks and legs.

In group discussions between students and teacher we observed the robot’s actions. Students observed their robots and analysed whether the robot achieved the results that the programmers intended. At the end teams had to present their findings by describing the action. As knowledge was gained about robotics, this information was then shared with the group. An awareness evolved where learning was at the centre and knowledge was shared about the function and features of robotics. For example, when the robot turned around in a circle, I described that as a 360 degree turn. After each discussion, the students wrote up their observations in their robotics journal.

The underlying principles of the eight week course of robotics was based on the developing genuine understanding comes from hands on experience. This is a powerful message that underpins the theory of a constructivist approach to learning. Previous research on learning by Papert (1980) uses the term "constructionism" to brand his favoured approach to learning, which is learning by making.

Learning Objectives

In this activity students should:

• Identify key characteristics of a robot
• Create their own programs and download them to a robot they build
• Control up to three output devices (motors or lamps)
• Control motor direction
• Become familiar with the RoboLab Inventor level 1, the Function Palette and other software navigation.

Section 1: teacher notes to the student activities

In the introductory lesson students who were participating in the programming lesson became familiar with the function and tool palette of RoboLab. Through exploration they learnt where the icons were in the function palette. By clicking the yellow seconds icon button the Wait For Toolbar was revealed.

Figure 10: Basic Icon function: Lesson 1

To start the lesson the teacher used a computer connected to a data projector. The students watched the demonstration, discussed what the program did and followed as the teacher explained what was happening in the program. The teacher explained what the pink lines were doing to the icons to make the program work. The teacher achieved this by running the mouse over the upper right corner of the icon to highlight the begin section of the icon. This needs to be clicked when students want to wire in their program. The upper left corner features the output sections. See Figure 11 below:

Figure 11: Motor icon port C

Here is a sample program the teacher could use:
Figure 12: One motor program
These icons constitute a program. This program instructs the robot to move forward for 2 seconds and then stop. Because only one motor is programmed the robot will turn slightly to the opposite side of where the motor is placed on the robot.

**Recommended student answer:**
This program had the robot turn on motor A in the forward direction for 2 seconds and then stop motor A.

After watching an explanation of the programs on the white board, the students made their own program by modifying it to make the robot go forward instead of turning. Here is a sample solution: students were given time to make a program on their own computer, then they made a prediction of what the program would make the robot do.

Figure 13: Two motors program
This program had the robot turn on both motors (A and C) in the forward direction for 2 seconds and then stop both motors.

In the next part of the lesson students were shown RoboLab. The teacher began by explaining the difference in the new programming from the last program on the board, describing the function of each icon as it is used. The I/O tower was explained with instructions on how to use it properly. Then the teacher arranged the students into their groups and challenged them to create a program that would make the robot go forward, backward, turn at least 360 degrees and stop.

Figure 14: Student A Programming Sample week 1 (Motors going forward and backward)
In the first programming lesson the student had written a very experimental program by using several music notes.
Learning Objectives and teaching requirements of this programming lesson.

Students were divided into two teams, one half used the LEGO® Mindstorms Robotics Invention system and the others were programmers. When students were ready to program they made sure the Robolab program was loaded on the screen, and then they clicked on the training mission section. They then clicked into programming inventor 1. Working in pairs students clicked the interactive video and followed the arrows and instructions. The interactive video introduced students to the program and what they were required to do to make the robot move. The video used arrows to direct the students where to click. This was a great way to introduce the program to students, and they quickly became familiar with how to program using Robolab. The teacher reinforced any new techniques when students were programming independently by asking the students to demonstrate the new technique or explain what the icon are making the robot doing.

Throughout the lessons students are expected to evaluate and reflect on their learning by responding to:

Describe what you did in the lesson.
What have you learnt in the lesson?
Did you have any difficulties?

One-difficulty students often faced in the first few lessons occurred when they programmed and tested their robot. The robot will move in the opposite direction to what the programmer has instructed the robot to move. This occurrence can be rectified in two ways, either by changing lead connections to the motors or by changing program.

Learning Profile of Student A

Student A was a high achiever in all subjects. She was engaged in any task that was required and usually finished first. She was able to help other students with technical issues and had a good recall of facts covered in the learning sequence. When working through problems, student A self corrected and used a variety of strategies before asking for assistance. Her building skills with LEGO® were well developed and she had been able to achieve every task.

Specific learning goals for student A

- To achieve the learning goals of the CSF II and the VELS domains and indicators
- To progress through the lesson set out in the planner
• To achieve incidental progress such as being able to co-operate and work well in a team.
• To be able to reflect on learning and recognise strategies that were used to solve problems during the lesson.

Annotation of work samples from student A:
• Students had a number of opportunities to demonstrate their learning, including observation of group work, class work, and a function worksheet to monitor progress and a journal for self-assessment.

Student A Work Sample week 1 (Appendix 2)

Student A’s journal reflection stated she had no problems in the first lesson. She also described the motions of the robot, which showed an evaluation of the programming that was achieved.

Figure 15: Student journal entry from week one
Building a Robot: Lesson 2

Figure 16: All the Sensors and Motors

Main components of the robot

Inside LEGO® Mindstorms Robotics Invention system are familiar LEGO® bricks, motors, sensors, gears with beams, (bricks with holes in the side), numerous plastic parts with advanced shapes such as axels, and a small computer (7cm/15cm) named the RCX. A sample robot was shown briefly to students, but removed once the building started. The teacher made use of the pre-programmed routines to demonstrate why some designs work better than others.

The two activities were part of the same lesson. Working in groups the students had a weekly rotation where they changed activities. Both activities required students to reflect on their learning and also comment on what other group members had achieved.

There were many incidental learning experiences. Students in teams had an opportunity to improve co-operative skills by sharing, taking turns and working towards a shared goals. Individual students needed to be able to follow instructions and also be able to work through problems by learning to problem solve. By thinking through programming and building, students were learning skills of testing and trying different ways of working with others to achieve positive results.

Students should have reported the following in their journal.

- What they did in the lesson.
- How they overcame any difficulties.
- Drawn a diagram of the robot they made.

When students built their robot each group of two had a LEGO® Mindstorms Robotics Invention system and instructions on how to build a robot that has two motors, two wheels and an RCX.
Whole group and individual discussion occurred where students reflected and analysed their learning.

Students in groups of two built a simple robot from the instruction manual. In the journal entry shown here the student stated that they had difficulties with their partner. The questions are there to document how students were working as a team. In this activity students were required to find LEGO® pieces and get their partner to cooperate in the building task. Team dynamics was something that improved throughout the lessons.

**Figure 17:** Student A Work Sample week 2

**Student journal sample.** The page shows their response to questions about what they were learning when building.

**Figure 18:** Diagram of the robot from an aerial perspective.

This study tried to incorporate the theories of Ausvels (2013) Interpersonal development cooperative group work is where students interact with their peers, and adults in formal contexts. Through the study of robotics the students in groups were required to develop
their skills and strategies for getting to know and understand others within increasingly complex situations.

**Exploring motor functions: lesson 3 and 4**

In weeks three and four students explored the way gears move from a small gear to a large gear. In a classroom discussion the students were asked to make a prediction about what happens when you place a small gear powering by a large gear. The teacher asked the students, “Does this slow the robot movement down or does it speed the robot’s up?” During the lessons students observed their robot’s behaviour and wrote their findings in their journal.

**In this activity students should:**

Learn about how to program the motors with different power levels.

Students experimented with different ways they could program their motors to run forwards, backwards and around in circles. First they downloaded the program to make the robot’s motors run forwards. Second they observed how the robot moved with different power levels. Then they experimented with putting the motor icon arrows facing in different direction to effect the robots movements.

**Recommended student answer:**

This program has the motors A and B on full power level and moving forward for an unnamed number of seconds. The touch sensor is activated by being pushed in. This causes motors A and B to stop.

**Question and teaching requirements**

The teacher was required to constantly supervise the students’ programming and assist with technical issues that arose. Students wrote about what role they played in the group, for example programmer, builder, tester or observer.
Building Lesson: lesson 5

Students in groups of two built a simple robot from the instruction manual. Students also experimented with gear reductions on their robot. They consolidated the new concepts by documenting their observations of the robot’s movements.

Introduction to Touch Sensor: lesson 6

Learning Objectives

In this activity students should:
- Program a robot that uses sensors to respond to its environment.
- Learn how the robot sensors and human sensors are both similar and different.

Question and teaching requirements

While students were building and programming the teacher made sure they were working effectively in their teams by rotating among groups. Students wrote observational notes and verbally described their robot’s actions from the downloaded program. During this process the students were checking if their program was doing what they wanted it to do. If the robot did not achieve the desired result the programmers went back to the computer and changed their program.

Learning about how to program the motors for a touch sensor.

![Program with the touch sensor](image)

Figure 19: Program with the touch sensor

Recommended Answer

This program is turning both motors on and moving forward

Activity

Students watched the interactive video and were able to follow the arrows and click the right steps to progress forward. The students should be able to program the robot with a touch sensor that reacts to something. Once the touch sensor is activated this causes the robot to turn around, play a song or carry out some other action. The students were also introduced to the idea of a power level on their motors. They could then measure how fast or slow their robot moves.
Question and teaching requirements

Once students had finished programming, the teacher made sure the programs worked by checking that each group’s robot actually did have a touch sensor that worked, was on the right port on the RCX box, and correlated to the icons on the RoboLab program. Students filled out a worksheet on the RoboLab icons and wrote descriptions of their functions. Students handed in their Journal for assessment.

The research used the strategies suggested by Walters (2005) who recommended that to foster interdependence within groups, including assigning a single product for the group, asking students to take on different roles (recorder, facilitator, researcher, presenter, and so on), and assigning one student in each group to become an "expert" in one particular area and report back to the others. This was achieved throughout the study by allowing student to focus and master one element of the design or programming. In the study by Castledine and Chalmers (2011) found that throughout both activities, each group was able to actively monitor, reflect, and adjust their processes in regards to strategically solving the problems. As students efficacy with the robotics heightened, so did their confidence in their problem solving abilities, and accordingly their metacognitive skills increased.

Student A Programming Sample week 5 (Appendix 2) 30/5/2005

![Figure 20: Program with touch sensor, light and music](image)

In this lesson student A programmed well and was able to get her program to work on the robot. When analysing the program the teacher noted some confusion about where the student has attached port B to the touch sensor, and placed a power level on port A for a set number of seconds. They have named a motor with a drop down icon and then used a pre-named motor icon. They have also used a lamp icon which was not required in that activity.
Resnick (1998) sees several reasons to encourage children to design and build their own scientific instruments, including that students are more likely to feel a sense of personal investment in a scientific investigation if they design instruments themselves, when students design their own scientific investigation, they find that standard scientific instruments are not always well suited to the tasks; by creating their own instruments student are less constrained in their investigations and too often students accept the reading of scientific instruments without question. By designing their own instruments and thus understand the inner working of the instruments, students should develop a healthy scepticism about the readings (Resnick 1998).

Building Lesson: Week 6

Gears, Ratios and Measurement.

At the end of lesson students observed the effect of gears on their robot. We discussed what they noticed when the size of the gears was changed.

Journal entry, notes taken when students was building.

During this building lesson the students worked in teams. One child assembled the robot while the other student located what was next in the instruction booklet and then found the pieces.

Figure 21: Journal Reflection

“Today most of the early childhood settings are populated with Cuisenaire Rods, Pattern Blocks and other manipulatives carefully
designed to help children build and experiment, and at the same time, develop a deeper understanding” (Brosterman, 1997). More recently, but in the same spirit, “digital manipulatives” (such as programmable building bricks and communicating beads) have been created to expand range of concepts that children can explore (Resnick pg.46).

In Castledine and Chalmer’s (2011) study indentified several major themes from students’ problem solving with robotics and developing authentic reflection skills. Estimation and looking for number patterns were the most common problem solving strategies used by the students in the initial stages of programming. This was closely followed by trial and error.

![Students Building Robots at Their Tables.](image1)

Sometimes the student would count the number of dimples on the brick to check whether it was the same size as the one in the diagram. They took turns to be building or finding the pieces for the robot. Groups built a robot with a touch sensor with a pivoting action that presses in the touch sensor in when in force is applied.

**Figure 22:** Students Building Robots at Their Tables.

![Robot Activating the Touch Sensor.](image2)

**Figure 23:** Robot Activating the Touch Sensor.

Above is a picture of the robot touching the wall, activating the touch sensor and then sending the motors backwards. In this lesson all students were able to get their robot to recognise the touch sensor and change the behaviour in some way.
During this lesson the teacher asked students to comment on what the gears had done to the robot compared to the robot in the first lesson. In response they all agreed that the gears had slowed the robot down. Asking the students to observe the robot developed their observational skills and assists them to become aware of the effect of gears on the robot.

**Student A Journal Sample**

This diagram by Student A shows the robot with the touch sensor. There is a progression in the quality of the drawing and the added key parts show a depth of knowledge about robotics.

*Figure 23: Diagram of the robot with a touch sensor.*

**Introduction to Light Sensor**

**Programmer Inventor 3: Computer Decision-Making: week 7 and 8**

**Learning Objectives**

In lesson 8 students learnt how to program their robot to react to input from the light sensor. In their program they were expected to get the robot to react to light and dark. There was an activity sheet with a black line on it so when the robot moved over the line it reacted to any change in colour, which activated the light sensor. The light sensor could be programmed to react to light or dark. The teacher recommended that for this activity the students program their robot to react to dark so they could observe the changes in the robot’s behaviour when it crossed the black line.
In this activity students should:

• Learn to program decision-making into their robots using three control structures: Loops, Forks and Multitasking.
• Become aware of robot intelligence.

Also in this lesson students were expected to use the Jump and Land commands that were used to make the program run continuously, so they have to press Run on the RSX to stop the program.

Figure 24: Motors and Light Sensor

Questions and teaching requirements

In this lesson students were expected to program the robot to react to a dark line and do something that indicated a change in the program. In the introduction students were reminded to write a response to the questions in their journal. For example they needed to write what they were working on and draw a diagram of their program or their robot. In the middle of the lesson, when the students had completed the program, they were asked to write a prediction of what they thought their program was going to achieve.
Towards the end of the lesson the teacher checked that students had answered their questions. Once they had observed what their program had done to the robot they had to modify their program or describe what they had observed. The teacher checked all the student journals, and those who had not completed their work were given time to finish the documentation of their learning.

**Figure 25:** Students Programming and Taking Notes in Their Journal.

**Student A Programming Sample week 7 (Appendix 2) 10/7/2005**

![Program with Light Sensor](image)

**Figure 26:** Program with Light Sensor.

In week 7, Student A was having minor difficulties getting the light sensor to interact with the dark line on the work sheet that the robot drives over. The student was able to think through the possibilities and resolve the problem through trial and error.

**Building Lesson 8**

**Questions and teaching requirements**

Students in groups of two built a more complex robot from the instruction manual. They also had to use a light sensor from the instructions. The groups used gears to reduce the speed of the robot, which helps to control the robot. Students evaluated their learning of the unit by reflecting on what they have learnt and reflect what they had experienced difficulties with.
The two students were asked how they were working together to find the pieces. They replied that they were taking turns in reading the instruction sheet. The two students worked together very well using this strategy.

In student A’s journal, there were also observational notes and diagrams made of the robot’s actions when it was programmed for a light sensor.

In the group discussion, the student was able to share her learning with other members of the class.

**Figure 27**: Students Working Collaboratively

**Figure 28**: Student A Work Sample Week 5

**Teacher Reflection of the Learning**

**What worked well in the teaching program to assist student learning? Why?**

Organised LEGO® kits assist students learning because when they are building the robot they have all the pieces they need. Towards the end of the lesson the students and teacher discussed what the students had achieved and we sum up of the key concepts. The instructional video in RoboLab worked well in familiarising students with the type of
programming they need to learn. They learnt through visual examples of what they needed to know, which has a higher success rate than students programming on their own. The teacher found that this technique of allowing students to use the interactive video gave them confidence to use the program independently.

What did not work as well as expected for both you and the students? Why?
Some groups did not work well together, so when building their robot they were not able to function as a team, were off task, and did not complete the task in the given time. Student A did not go into detail in her robotics journal. For example when drawing diagrams, icons and writing reflections. This showed me that students in future classes may need more training in analysing and presenting their learning. There needed to be more time spent on what are the agreed expectations of what a good journal looks like and how the diagrams need to look to explain the learning and new understanding.

What would you do differently given the opportunity to teach this idea or concept again?
I would teach students the physics involved in the LEGO® gears and test their knowledge of ratio prior to the teaching activities, to see if student knowledge improved. This could be achieved in the development of a work sheet for students to fill out. Within the learning sequence, students should record the amount of seconds their program went for and measure how far the robot travelled.

Following up students who had difficulties in the prior lesson could resolve issues so they can continue with clearer expectations. Also the teacher would print off a screen shot of students’ programs for records to be kept in their journal to document development. The students need to use a digital journal with weekly questions, facilitate a place draw diagrams, add video and photo documentation of their work.

What have you learnt about your teaching practice and about your students and their learning?
All students learn at different rates. They all need to experience success to feel confident in the learning situation. Preplanning and organisation are keys to good lessons. Students learning robotics investigate the principles of STEM (science, technology, engineering, and mathematics education) awareness. Another link to learning with robotics is that it is
a tool that can help make abstract ideas more concrete, as children can directly view the impact of their programming commands on the robots’ actions (Bers 2008).

In a most recent study by Kazakoff et al (2013) highlighted that robotics can also assist students with sequencing skills. “For example, retelling a story in a logical sequence, ordering numbers in the correct sequence, and understanding the sequence of a day’s activities are all sequencing activities represented in curriculum frameworks for children in kindergarten in both language arts and mathematics.”

Results from this study seem to indicate that it is possible to see increases in the sequencing ability of pre-kindergarten and kindergarten students participating in a robotics and programming curriculum in as little as 1 week, as long as the week is intense (at least 10 hours of robotics and programming work). We hypothesize this may be because the same cognitive structures involved in programming robots with a particular sequence of programming commands, are also used when children tell stories in a sequential order.
Grade 4 second year 8 week course of LEGO® Robotics

Revision of Basic Icon function Lesson 1

Learning Objectives

The subject was introduced by the teacher asking the students, “What do you remember about robotics?” The class then discussed all the things they made the robot do in the previous sequence of lessons. This activity refreshed the students’ memories and had them recall most of the basic facts. The teacher then organised the students into groups of 4 with mixed ability and gender. Then LEGO® Robotics journal was handed out and the questions in the workbook were explained. For example the teacher asked the students to describe what a diagram is. The teacher showed some of the basic icons on the board and asked, “Can anyone tell me what the first icon means and what purpose does it have in a program?”

Here is a sample program that was used:

![Figure 29: A Program Using Jumps and Light Sensor](image)

**Recommended Answer**

This program had the jump and land icons. This allows anything in between these icons to go on repeating without pressing the run button. The program features a wait for light icon. When activated it plays a tune, the lamp lights up for one second and then the program stops.

**Questions and teaching requirements**

In the introduction of the lesson the whole group was together, and then it was divided into two different activities. The students in groups of four were then divided into two pairs. The first pair was programming and the second pair was building a LEGO® car. Once both pairs had finished their task they joined up and uploaded their program to the robot. The team then observed the robot’s actions on a table to see if the program worked and the robot was stable. Once the robot had been programmed the whole team discussed their findings. In the last five minutes of the lesson the whole class discussed their
findings. The teacher directed questions to relate to their journals. Students shared what they may have had difficulties with and how they solved those problems. Students described what their programs made their robots do. The teacher emphasised the importance of working in a team and that everyone has a part to play to get their program and the robot to work.

Also pointed out in the research by

A picture sequencing assessment was chosen based on the similarities between programming a robot and telling a story that involves ordered steps (i.e., putting the beginning, middle, and end of a story together vs. putting together the beginning, middle, and end of a sequencing of code). Pg 250

**Learning Objectives and teaching requirements of the programming lesson.**

Students revisited the programming lesson in the Robolab training mission level 3. They ran through the interactive video and then programmed on their own or with their partner. In this part of the lesson students were encouraged to write notes as they went along. They enjoyed clicking the arrows but did not take in the information. Some students had difficulty with finding the tool palette, which is the fifth column along, named (window).

![Figure 30: RoboLab Tool Palette from Level 3.](image-url)
Students then had to click on that word to activate the drop down function in the list of program features. In the middle of the list is the, “show diagram and show function palette” button. In this part of the lesson there was a parent helper who was aware of all the programming difficulties the students had, and was there to help if students are having any difficulties.

**Learning Profile of focus Student B**

Student B – Year 4 Male, 9 years old. This student enjoyed working in groups, however he tended to become distracted. Once encouragement was given, the student was very focused on the learning activities. The student enjoyed mathematics and wrote relevant comments in his journal when interested in the topic being investigated. However he did lose concentration easily by discussing irrelevant topics and not achieving the aims of the activity.

**Specific learning goals for student B included:**

- To achieve the learning goals of the VELS domains and indicators.
- To progress through the lesson set out in the teaching and learning plan.
- To show incidental progress such as being able to co-operate and work well in a team.
- To be able to reflect on learning and recognise strategies that were used to solve problems during the lesson.

**Annotation of work samples from student B:**

The work samples are from journal entries made over the period of the learning sequence. The first two examples shown below are from the programming lesson.

![Figure 31: Student B Programming Sample week 1 (Appendix 2)](image)

This is the first example of RoboLab programming from student B and his partner. In this programming lesson the student B programmed with a female student, and they worked very well together. There was a developed knowledge of the function of inventor level 4. A lot of their programs featured notes rather than sounds. They also had a touch sensor
icon and had a significant change where the music starts to show if the touch sensor is activated by being pushed in.

Figure 32: Student B Programming Sample week 1

When filling in the description of the function worksheet, the student was able to correctly answer all the questions. He wrote what all the icons did and understood how they affected the program. He also showed an awareness of how that program effected the robot’s movements. According to the research of Castledine and Chalmers (2011) when students are learning to program their robot they are using authentic problem solving strategies. The researches noticed throughout two programming activities, each group was
able to actively monitor, reflect, and adjust their processes in regards to strategically solving the problems. As student efficacy with the robotics heightened, so did their confidence in their problem solving abilities, and accordingly their metacognitive skills increased.

**Building a Robot Lesson week 2**

Students were asked to choose something to make from the LEGO® Mindstorms For Schools instructional manual. They chose what they wanted to make, which depended on how confident and familiar they were with the LEGO® technique pieces. Groups decided on what type of robot they wanted to make. When doing this students decided on a variety of activities, for example three wheeled racer, crane or a simple two wheeled car or zoobot. The idea of Constructionism inspired this start to the lesson built on the assumption that children will do best by finding ("fishing") for themselves the specific knowledge they need (Harel 1991).

**The specific learning goals for student B for the learning unit are:**

**Measurement**

Being able to identify bricks that correlate to the size requirement in the instruction manual.

**Physical science**

4.1 Design, build and describe the operation of simple devices that transfer or transform energy.

4.2 Describe the motion of objects in terms of simple combinations of forces.

**Shape and Space**

4.3 Make congruent copies of three-dimensional objects.

When building the robot, the student worked through the diagrams and followed the instructions in the worksheet. He checked the pictures and counted the bricks to see if they matched. The student was able to complete the robot in 15 minutes.

**The learning goals they were working towards were:**

- To be able to describe the motion of objects.
- To identify bricks that correlate to the size requirement in the instruction manual.
- To work in a co-operative group.
- Complete a finished robot in their group.
Journal Reflection

Figure 33: Work Sample from Activity 1: LEGO® Building and Journal Reflection

Observations of the lesson

Working in a group 3, Student B helped built a crane from the LEGO® Minstorms for Schools instruction manual. They used skills of comparing ratios and working out the actual size of the required rods by categorising all the rods from smallest to largest. Only then could they work out which piece was required for the crane. When working out which was the right piece shown in the diagram students were using their problem solving skills. There was also a list of which pieces that should be in the kit, so this could be constantly used to identify the pieces. They were also counting the number of holes in the bricks to make sure they had the right piece. They were checking each other’s work and then referring to the diagram to make sure.
Team members from student B’s group are comparing the beam, robot and pieces with the one required in the diagram. The research of Carbonaro (1997) suggests that using robotics involves the learner in simultaneously building both a functional physical object, and the problem-solving knowledge it takes to accomplish the task. The symbiotic relationship between constructivism and constructionism through the introduction of robotics is interrelated. Some research suggests that students learn more effectively in self-guided tasks. When they are evaluating their work is where the change in thinking occurs, as this is where they have realistic proof about whether or not the object achieved its objective.

**RoboLab Programming Lesson week 3**

**Questions and teaching requirements**

This program employs the Jump and Land commands which are used to make the program run continuously, so it is not necessary to press Run on the RCX to keep restarting the program.

RoboLab forks are equivalent to the traditional If-Then-Else statements used in many programming languages. When a fork is reached, one of two paths must be taken. There are many different Fork commands available. Fork commands start with a Fork and must end with a Merge command.

Decision making is one of the fundamental aspects of computer programming. Conditional statements – statements that have more than one outcome – are what gives programming its flexibility. The Fork command is an important conditional statement.
The Fork command tests one condition and then decides to do one of two possible outcomes.

This is like turning left or right at a fork on the road. In RoboLab programming, forks split the decision of the program and Merge commands tie it back together. Each fork command needs a merge command.

![Figure 35: The Fork Command](image)

Forks are found in the Structures menu. At Robolab Inventor Level 4, some forks are the touch sensor fork, the light sensor fork, the fork merge and the task split.

![Figure 36: Touch Sensor Fork](image)

The touch sensor fork causes motor A to turn forward and when the touch sensor is pressed the motor turns anticlockwise. The jump causes the program to loop infinitely.
In the next part of the lesson the students were shown RoboLab. The teacher began by programming in the previous program from the board, explaining each menu and icon as it was used.

Student B had started the lesson well and was able to start programming on his own because the other team member was away. A teacher and student discussion was instigated to get the student to remember the crane they started the previous week.

The student programmed in a way typical of most students of this age group. The usual scenario was that the robots moved forward and activation of a touch sensor or light sensor caused the program to make the robot to make a series of sounds. The lesson’s objective was for students to practice using the jump, land and task splitting icons into their programming. Student B and myself discussed the issue that he had to program for a crane or arm and something else was to happen simultaneously.

**Teacher:** “Explain how the arm of a crane moves?”

**Student B:** “The arm has to pick up something”.

**Teacher:** suggested that this mechanism would need to make the motors move forward and back.

**Student B:** “This is too hard I don’t understand”.

**Teacher:** Further explained the use of a fork icon in the program to split the program into two commands, enabling the robot to do two things at once. With the forks and the jump icon this would cause the program to move back a forth through the list of instructions and provide time to observe the robot’s behaviour.
The conversation then evolved the use of a loop, but this concept seemed too difficult for the student to comprehend at that point. After the initial discussion student B programmed independently while the other team member built the crane or arm to pick up things.

Towards the end of the lesson the two students came together to download their program to the RCX. As usual before the programming, students had to check that their program is working and the arrow in the corner is not broken. So the student went to the Window menu selected error list, and read the statement that came up. The error stated read that each row needed a stop sign symbol. At this point student B suggested he couldn’t handle the pressure. That was when the other team member stepped in and fixed the program. They then downloaded the program and pressed run on the RCX. The arm proceeded to move, clench and release. The other team member rushed to find something for the arm to pick up, and then placed the LEGO® brick down where the arm was reaching. Student B then remarked it needed more strength to pick up the brick. So the other team member went and found something lighter. The lesson time was up and all team members left feeling very proud of their accomplishment.

![Figure 37: Student B Programming Sample week 3](image)

The idea of testing your program until you get it right is a great example of the research of Resnick (1998). If we give learners new types of digital building blocks, they can learn not only about number, shape, scale, but they can learn about interaction, communication, dynamics, in the same way that they traditionally learn through direct manipulation.

Differences between learning mathematical concepts through computer manipulative compared to LEGO® Robotics has also been discussed by researchers including Martin, Resnick, Silverman, Berg who have explored ways that students aged five to eight can have new apparatus that allows better observation of scientific phenomena or explorations.
of a physical principles. They suggest that the design process is often absent from science in school settings. Their aim is for a more integrated approach to the learning of science mathematics and engineering.

Figure 38: Student B Journal Notebook

Student B wrote notes about wanting their robot to do something in particular, for example to use a touch sensor to trigger the playing of music. He had made predictions that did not work. This is showing that he observed the robot’s actions and how they correlate with the programming. The reflections were showing that the student analysed and evaluated his work.

Figure 39: Student B Programming Sample
Building a Crane Lesson week 4

The student continued to build projects started the previous week. During this lesson Student B started making a robot that had an arm that moved up and down with a hand that picked things up.

Questions and teaching requirements

When building from the LEGO® Mindstorms instruction manual the students needed support when finding the pieces. The teacher directed them to the box content sheet that listed all the pieces.

Programming Lesson week 5

In this lesson students are expected to use the Jump and Land commands that are used to make the program run continuously, so you have to press Run on the RSX to stop the program. They are also required in this lesson to use the light sensor with the setting for dark.

Figure 40: Light Sensor Light Meta Reading

In the above program the motors A and C are running forward on power level 2. The dark sensor is activated when crossing a dark line and then the robot will stop.

Student B Programming Sample week 1 (Appendix 2)

Figure 41: Programming on Computer Screen.
This photo shows a student in group 3 describing what the Jump, Land and Split tasks are.

**Building a Tracker Robot Lesson week 6 and week 7 Lesson**

I started the lesson by showing the students a robot with the light sensor attached, and explained what it was and how it worked. The light sensor used infra-red light to determine how bright something is. The light sensor produced a value between 0 and 100. The value 100 being complete light and zero being complete dark.

Then the teacher showed the students how to view what the light sensor was currently reading. First they had to turn on the RCX and press the view button until the arrow at the top of the screen is under the port and the light sensor was plugged into achieve this. For example, my light sensor was connected to port 2. The teacher turned on the RCX and pressed the View button twice. Next to the image of the robot man running is a number between 0 and 100; this was the value being read by the light sensor.

The students then had to try the light sensor on a nearby object, such as their desk. The teacher then asked the students what numbers they got and wrote that on the board. The results from the students were all different this showed the different light that was around the room. The students then used the light sensor on the posters that have white, black and green sections. Students wrote down their result this was then tabulated on the board. Again, the numbers were similar but not the same.

We then discussed why the numbers were not all the same. A student suggested that there were differences in lighting and coloration. The teacher then stated some reasons for light variation, for example that one student’s desk may be slightly darker than another’s. One student could be near a window or directly under a light. To show this the teacher then turned off the lights in the room and had the students see how the values changed.

Now they understood why the numbers were different. The teacher then explained how they were similar. The numbers in each column should be similar to each other and different from the other columns. So for example, black should always have smaller numbers than white. The teacher showed this by mapping the numbers on a line to show
that all the black readings are at one end, green in the middle and white at the opposite end from black.

Building on the above example the teacher then described boundary values. This was how to pick a number that marks the difference between black and white lights. Later they added green back in and came up with a boundary between black and green, and green and white.

After the students understood the new concepts of programming their light sensor to detect colour, the teacher was ready to re-introduce if/else, loops and wait-fors. Starting with the wait-fors, the teacher placed my enlarged icons on the board to represent a program and asked students what they thought they would do.

**RoboLab Programming Lesson week 7**

**Building and programming a line tracker**

**Questions and teaching requirements**

The following icon is a start a loop. The default setting was to loop twice. The end loop was also needed somewhere in the programming sentence after the first loop command. The jump back loop will start the program back where the first loop was introduced.

![Start a loop](image1.png) ![Jump back loop](image2.png)

**Figure 42:** Loop Programming Icons

Students were given the following worksheet.

![Line Tracker Program](image3.png)

**Figure 43:** Line Tracker Program
A direct translation of this program follows. See if you can follow along in the diagram as you read the text. The teacher had capitalized the words that are represented by a symbol above: The program comes from the research of Freeman, (2005). He translated the program:

When the run button is pressed, repeat the following 1000 times: repeat the following 1000 times: If the value of the light sensor at input 2 is greater that 50, turn on the motor at output A at power level 3. Wait for 0.02 of a second, and then turn off output A. On the other hand, if the value of the light sensor at input 2 is less than or equal to 50, turn on the motor at output C at power level 3. Wait for 0.02 second, and then turn off output C. Go back to the repeat point. Go back to the other repeat point. Stop the program (Freeman, 2005).

**Building Lesson Week 8 Building and Ratio**

**Questions and teaching requirements**

**MATERIALS:** Black electrical tape making course on a white table, LEGO® Mindstorms Instruction Manual to build tankbot and rover.

**Objective three:**

Students built a car of their own design or from teacher provided instructional manuals. The car had to complete the challenge of following a dark line on the floor. The objectives of the lesson were to be able to:

- Create a car with enough mobility to follow a line.
- Write a program for their car in inventor 4 which can follow a line.
- Choose the sort of car they wanted to design that would meet the lesson objectives.

In the introduction to the lesson students were given the option of the type of vehicle they wanted to design. They had to ask themselves “Should it be a dragster that is long and has lots of friction in the wheels? “ In the teacher and student sharing time we put different wheels on the table and turned them to see how much friction they each have. There was emphasis on maneuverability being a better choose for a line tracker robot.

The teacher suggested to the students that there were two things to take into account when building a car. First the structure must be strong enough to support the RCX, the biggest brick in the box! Second, the car must be sturdy enough to stay together when the motors are running creating torque. If you slap the motors on the bottom of the
RCX they will fall off just about every time you pick up the car. Students then built and programmed their cars.

**Figure 44**: Examples of Students Building a Track a Line Robot

**Comment on Student B’s progress toward the learning goals, and the effectiveness of the teaching and learning plan**

The teaching and learning plan was met by this student. He attended all lessons and his journal showed a response to some of the key learning in the unit. The programming lessons were challenging for Student B who was able to document important information to remember about the icons. The student had made written observations in his journal and then improved on his learning in the subject.

The 8 week unit for the grade four tried to cater for the needs of all the students who had participated, and built on their prior knowledge. The learning plan tried to cater for students in the lower group by allowing them to revisit concepts they didn’t understand in the first year of robotics. Students with more experience with LEGO® where able to challenge themselves to higher levels of building and programming. In summary, all the students were able to extend their knowledge of robotics and were able to pursue individual learning projects.

**Summary**

Sometimes the hour was not enough time, and all students can not achieve their goals. Inconsistency in the weekly lesson and disruptions can lead to students forgetting concepts. When they finally have the Robotics lesson they need to remember the concepts
coved in the last lesson. The teacher had also observed that the time of day affects how well students perform in the lesson and how much they achieve.

The material presented in this chapter demonstrated that throughout the eight week course students could work on projects that continued from week to week. They also enjoyed having an objective, for example building and programming a line tracker robot. Students got an enormous sense of achievement when they accomplish their design brief. When programming, students were anxious before testing their program. Once their program was tried they achieved a huge confidence boost and then went on to changing their program several times in a lesson. When working in a team students improved their communication skills. There was also time allocated for them to work on individual projects.

The teaching moved towards encouraging students to be responsible for their learning, and becoming independent as they became familiar with what was required. Students were also encouraged to help each other, for example when they needed help understanding the programming they could ask the students next to them.
Chapter Six Conclusion

This chapter looks back at the research questions and the benefits gained and discusses them in relation to the results from the study.

Are there learning benefits to be gained from primary aged students learning LEGO® Robotics?

When students were learning with the LEGO® Mindstorms Robotics invention system they were engaged in being designers, programmers and team members. Throughout the study the students showed a gradual improvement in all the requirements of the lessons. The learning was organised into eight categories: journal, design and operation, modification and testing, scientific knowledge, team interaction, construction materials, oral presentation, and time management. Mathematics integrated into all the eight categories, for example in drawing diagrams in the journal, problem solving in the programming design and testing, or identifying LEGO® pieces.

It took at least three lessons for most students to comprehend the process of the structure of programming and building. Once they understood the procedure they could start to understand and practice the learning scenarios. Most students enjoyed the construction part because it was hands on and they built a robot from a pile of LEGO® pieces. As they became more familiar with the LEGO® pieces confidence and skill at building different robots and using various, accessories improved. Teamwork improved as the group members built up their skills together and shared in the successes of the programming missions.

The learning benefits from the program over all were that students worked as a team to problem solve in a design project that incorporated mathematics and science. Through understanding the programming language they gradually improved their control over the robot. Using concrete materials they built the robot from scratch and learned about the mechanics of the object. This study of systems taught students to use abstract reasoning rather than a distant reflection of machines and automation.

The idea that students found out about robotics while they either making them or programming was described by Resnick (2004), “Design activities engage children as active
participants, giving them a greater sense of control over (and personal involvement in) the learning process, in contrast to traditional school activities in which in which teacher aim to transmit new information to the students” (Resnick 2004, Pg 1).

The Grade 4 students were creative in using the constructionist approach where their learning guided the lessons and they choose to build their own simple machines and take ownership of the direction of their learning. Students made cranes, an arm with hand, and a walking robot. The constructionist style of learning created an atmosphere where students could share their learning using an inquiry learning approach. The structure developed a community where every one learnt at their own pace by picking projects they could achieve and that they were interested in building.

Encouraging the inquiry approach in learning created a classroom environment that was exciting to teach and learn in. Students who avoided doing work some other subjects became interested in their learning. Believing that controlling the robot was their total focus, they asked a lot of questions to clarify how to use Robolab. Once testing their robot they questioned why it might have not of achieved the programming objective. Students could also learn at their own pace and by revisiting previous misunderstandings and previous multimedia lesson in Robolab.

**Mathematics and science concepts explored during construction and programming.**

The mathematics involved when building a robot includes requiring students to count dimples, identify foreign shapes and compare ratios. Students learn basic mathematical strategies which gives them the ability to identify objects, explore mechanisms and problem solve. The basic concepts student learn from robotics is an ability to follow and remember instructions, comprehend, apply and analyse their learning. The skills they need to have when building the robot include being able to recognise a picture of an object and then find it the three dimensional replica. Also students use their knowledge of number, scale and shape. Mann et al (2011) argue for making engineering implicit in the K-6 education programs in order to create opportunities to develop concept skills and habits of the mind that are valuable in all disciplines while providing opportunities to discover and develop talent in the science, technology, engineering and mathematics (STEM) disciplines.
LEGO® Mindstorms integrates the STEM disciplines. Students learn about mechanical advantage, when the first robot they build has one gear to power the motor. When students observe it moving around the table, they usually notice how quick it moves. In the third lesson students build a robot with three gears, and this robot moves slower. During class discussions the students talk about the mechanical advantages of each design. Students refer to the first robot as being useful for racing. The second robot is good for hauling a load. The students then can discuss how objects are designed for different purposes. By week 5 students learn to add additional control to their robots, for example with the touch sensor. This relates to real life situations and, depending on the instructions in the program, the robot will react accordingly. According to Mann et al (2011) children enjoy building and are often intrigued with how things work. “There are numerous anecdotal stories from parents about their child’s elaborate constructions or items around the house that have been disassembled to see how they work. Children natural inquisitiveness leads to an opportunity to introduce engineering activities at an early age”, Mann et al (2011), pg 640.

The overarching science involved in the LEGO® Mindstorms Robotics course was about how to visualise and control the motion of an object. Students were learning to observe and write about real world phenomena. They also explored the touch and light sensors, which taught them about mechanisms and triggers that can affect a program. Students were creating external artefacts that they could share by working collaboratively. Learning robotics has shown that students can learn effectively from computers. However if they program as an individual activity, their enthusiasm for the project disappears. Students benefit from external artefacts that respond to what they have been programming and that they can share. “Given good programming language, I see children struggling to make the program work in a way that they seldom sweat at their paper-and-pencil mathematics”, (Papert, 1999).

Students learnt about the touch sensor, which reacts to contact with a solid object. Students programmed their robot to drive up to something to activate the touch sensor, with an outcome of the robot changing its movement by either changing direction or playing a song. When asking students what this type of function would be useful for, they
usually said for detecting bombs. The discussion then usually focuses around machinery, such as when you are on a train and you need to press the button for the door to open.

Much of the work of real scientist involves the construction of new apparatus that allows better observation of phenomena or exploration of a physical principle. Yet this design process is often absent from science in school settings. “With Beyond Black Boxes program, we argue for a more integrated approach to science, mathematics, and engineering, a sort of, Engineering for All”, (Martin, Mikhak, Resnick, Silverman and Berg, 2000, pg 17).

The light sensor can be used in a sliding door that opens when you walk up to it. This light sensor detects a shadow and then opens a door. Control technology is useful for students to learn to program their robot to detect light and dark so the robot can react to a dark line. The light sensor is used in industrial machinery and also used in household appliances. When students learn about robotics they start to broaden their understanding of where machines are used to automate the process of production and make peoples lives easier.

**How can students learn maths and science concepts through the exploration of design projects incorporating LEGO® Mindstorms Robotics?**

Science learning requires students to observe phenomena, analyse what occurred and improve a design in relation to the desired results. When programming students are introduced to the symbols and icons that represent different scientific concepts, for example light sensor activities allow students to read variations of light and program their robot to sense and react to it.

Mann et al 2011 state that “as students engage in the design process, educators can use engineering projects to integrate a number of disciplines, including science technology, mathematics, language art, and history; foster problem solving skills; involve students in project-based learning; and develop a child’s ability to function in three dimensions”, (Mann et al 2011,pg 4).
When building and testing their robots the students are introduced to the idea of friction. They encounter this phenomenon when the wheels are not connected properly and the robot won’t move. Also, if something is obstructing the movement of the gears or the motors this can also cause the robot to stop moving. In order to follow instructions and write programs students have to be clear on their intention for the robots to move in the desired way.

**Does learning to write directional language in a computer program, which controls the movement of a three-dimensional object, create a cohesive learning experience for students?**

Programming requires students to learn the programming language, identify the icons and understand the affect of a programming sentence. They also learn the Robolab program interface and how to cut past, use drop down menus and use their memories to recall facts. They learn the computer program so that they can get an object to move on its own, separate from the computer screen. This does create a classroom environment that has a buzz and is exciting to teach and learn in. There is a feeling of anticipation and uncertainty about how the robot will move when placed on the table. According to Swiss psychologist, Jean Piaget (1952), children are not simply empty vessels into which adults pour knowledge. Piaget has shown that children actively construct knowledge out of their own experiences. Building on this idea that Piaget had, where Resnick, (1998) added that constructionism is where people construct new knowledge with particular effectiveness when they are engaged in constructing personally meaningful products.

There can be many time consuming issues when setting up the RCX boxes. For example if there is too much light in the room the firmware will not download to the robot. When they have a short period of time to learn robotics, student’s personality and learning attitude can play a crucial role in success in achieving the goals of the lesson. If working with a small group and a student in another part of the room does not know how to find a LEGO® piece and is waiting for the teacher to help, they can start to misbehave and get off track. At the same time there is a queue of programmers asking simple questions. This can become a very busy classroom for the teacher to work in.
Abstract robot control instructions, in the form of the icon-based programs, are designed and constructed separate from the robot. However the actual results from executing these programs can only be realised while observing the behaviours of a robot that has been designed and constructed to match the program code. Linking a physical robot design with the corresponding abstract icon-based representation of its functionality demonstrates a complex knowledge-building interrelationship between form and function (Chambers and Carbonaro, 2003, pg.4).

Students have to work in teams to get their robot to work. Division of the team into builders and programmers can sometimes does not work when students don’t achieve their lesson objective. This leaves spaces where team members are pressuring others to finish the task. Usually the programmers finish their activity first. The teacher often asks them to extend their program or there is a pre built robot for them to program. When only having a one hour lesson each week, there is no margin for error. Students also have to have a small amount of self-initiative projects and time to develop an inquiring mind. In some lessons the programmers left disheartened because that they didn’t get to finish their programming. According to Ber and Portsmore (2005) the “robotic manipulative encompasses hands on construction that can promote three-dimensional thinking and visualization, building students’ technological literacy, which has become a component of basic”, (Ber and Portsmore, pg 60).

Although LEGO® robotics organised with students in teams can be difficult, it is also rewarding when students become familiar with their team and then develop a positive team dynamic. This is sometimes not harmonious in the first few lessons. Students have to become accountable for their learning, and build strategies of working well with their strengths and combine that with their partner learning strengths. These skills are sometimes still developing in young students and the learning structure facilitated the opportunity to develop those skills. Learning LEGO® robotics assists students to extend their thinking as they switch roles between being the programmer, recorder, facilitator, researcher and presenter.
Can LEGO® Robotics offer other learning outcomes that students have not been able to experience through manipulation of concrete aids and abstract concepts?

To be able to observe the robot interacting in the immediate environment is useful learning tool for educating students about the mechanisms of machines. Students of this age group do not always immediately grasp the learning connections that robotics can demonstrate. Many times throughout the lesson the teacher has to ask leading questions, to get students to realise where they may of gone wrong in the programming or building part of robotics. The teacher found that if the lesson objectives were clear and there is not too much information, then they stay open to continued growth and gain confidence in their abilities to program and build the robot. Design technology is a predominate part of LEGO® robotics and students learn about programming and automation on the computer. The LEGO® Mindstorms challenge set can offer students a variety of concrete building activities that teach them the basics of engineering. For example students can make cars, cranes, washing machines, alarms, kitchen accessories, leavers and pullies.

How we make sense of the world is deeply influenced by the tools and media at our disposal. If we are given new tools and media, not only can we accomplish new tasks, but we can begin to view the world in new ways. All too often, however, people to the representation and ideas of the past, even in the presence of new media. Most applications of computers in education, for example, use computers in rather superficial ways. They take traditional classroom activities and reimplement them on the computer (Resnick, 1998Pg 2).

The RCX box is sometimes difficult and time consuming to work with and the programming can be very challenging for students of this age group. If the infrared light doesn’t match up with the robot or it needs new firmware. However they have been able to achieve fantastic results. Now LEGO® education has brought out a new and improved Robot NXT with all the technology of the old RCX except with added features. The programming has multimedia incorporated on the right side panel and students can watch videos of what they want they want the robot to do and then follow step-by-step programming advice to achieve specific results.
Bers and Portsmore also stated in (2005) that curriculum for young children needs to consider the importance of objects for supporting the development of concrete ways of thinking and learning about abstract phenomena. It is in this context that the computer (and later robotics), as a powerful tool to design, create and manipulate objects both in the real and the virtual world, acquired a salient role in the vision of the Logo group.

**When students within the ages of 9-10 work in cooperative groups, can they work together effectively to achieve programming and design solutions?**

Students can work together however sometimes they find it difficult to help students who aren’t in their group. Most of the time they achieved the goals set by the task. Throughout the course student’s group work continued to improve. They never wavered in their enthusiasm to learn and try new things. Team collaborative activities that were project based incorporated field research, independent tasks, constructivist pedagogy, integrated curriculum and explicit instruction. The creation of a learning community that centred on design technology can open up a variety of learning experience for teachers and students. Group work and LEGO® Mindstorms creates a relationship that is quite foreign to the students who are used to normal group working experience. The four people in the group also have quite different work requirements. While the other two students are building robots out of LEGO®. Most students prefer making robots rather than to using the computer. This age group of students are more interested in working with concrete materials rather than abstract principles of mathematics and science. However it does depend on the learner, soon as they understand how to program the robot they want to design a program to make their machine move. So there is an ownership over what they create, and they build a relationship with what they make.

**FIRST® Challenges**

The next step for LEGO® Mindstorms Robotics invention system is to extend to team orientated scenarios to where students are working on challenge mats and have to achieve different missions. Examples of this are integrated curriculum that is organised around a central theme that integrates science concepts, visual literacy and numeracy.

There are many resources available that integrate Mathematics, Science, English and Robotics. For example the organisation called FIRST® (for Inspiration and
Recognition of Science and Technology) and the FIRST LEGO league (FLL) write challenges that utilise a robotics mat that has LEGO® techniques and props. For the last five years annually in November they have held regional events countries around the world. Among the themes they have used are Ocean Odyssey in 2007 and Food Factor in 2011. For a FLL challenge teams of students and practice a series of challenges at their school then they attend an interschool competition and show off their robot movements.

A major concern is that, “using robots in education should not be a one-off project for the sole purpose of participating in a competitive event. Rather, it should be a sustainable long-term progression spanning the primary school to pre-university level” (Lye et al, 2013, pg 142). The idea that once students have mastered the basic skills of robotics they can move towards the idea of scenarios. The research suggests that young children may participate in the challenge using robot construction kits such as Lego NXT and Fischertechnik. Once the early phases have been achieved, students will then be more prepared to attempt the next level of SAR (search and rescue) competition and thus ‘allow participants to progress from one phase to the next as their technical knowledge and skill improves’.

In addition to learning the basics of robotics students can take their learning to the next stage and apply that to a real world problem. For example how to push a carbon dioxide ball into an underground reservoir. There are then points to be scored for each ball the teams can navigate their robot to that area of the mat. In a lesson student can then play a three dimensional interactive learning game or challenge that requires students to work as a team and program the robot to move around an obstacle course. The use of themed missions and an interactive mat can facilitate a learning activity that links science concepts with real world scenarios and simulates how robotics can be planned to interact with the environment.

Overall this has been a very successful and rewarding project for both teacher/researcher and students. Following a basically constuctivist approach, they engaged with the robotics construction material both conceptually and practically. Throughout the research there has been gradual improvement in student problem solving skills. The research project required students to keep a journal sharing their learning and work in a team.
Using this structure for learning the students have been able to improve their metacognition, science and mathematical skills.
References


http://www.physics.ohio-state.edu/~jdw/LineFollow.pdf


Morse, J. M. (1991) Qualitative Nursing Research, Ca: Sage


Victorian Curriculum and Assessment Authority (VCAA) Victorian Essential Learning Standards (VELS), URL:

Walters. (2005) Talk it, Solve it: Reasoning Skills in Maths years1 and 2. Beam Education.


## Appendix 1: Robotics Rubric

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<td><strong>Journal/Notebook</strong></td>
<td>Clear, accurate, dated notes are taken regularly.</td>
<td>Dated, clear, accurate notes are taken occasionally.</td>
<td>Dated, notes are taken occasionally, but accuracy of notes might be questionable.</td>
<td>Notes rarely taken or of little use.</td>
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<td><strong>Design &amp; Operation</strong></td>
<td>Robot exceeds one or more of the design challenges.</td>
<td>Robot meets all design challenges.</td>
<td>Robot meets all but one of the design challenges.</td>
<td>Robot meets only one design challenge.</td>
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<td><strong>Modification/Testing</strong></td>
<td>Clear evidence of troubleshooting, testing, and refinements based on data or scientific principles.</td>
<td>Clear evidence of troubleshooting, testing and refinements.</td>
<td>Some evidence of troubleshooting, testing and refinements.</td>
<td>Little evidence of troubleshooting, testing or refinement.</td>
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<td><strong>Scientific Knowledge</strong></td>
<td>Explanations by all group members indicate a clear and accurate understanding of scientific principles underlying the construction and modifications.</td>
<td>Explanations by all group members indicate a relatively accurate understanding of scientific principles underlying the construction and modifications.</td>
<td>Explanations by most group members indicate relatively accurate understanding of scientific principles underlying the construction and modifications.</td>
<td>Explanations by some members of the group illustrate little understanding of scientific principles underlying the construction and modifications.</td>
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<td><strong>Team Interaction</strong></td>
<td>All group members worked cooperatively with excellent team effort to achieve the goals of the challenge.</td>
<td>Most group members worked cooperatively with strong effort to achieve goals of the challenge.</td>
<td>Some group members worked cooperatively with good effort to achieve the goals of the challenge.</td>
<td>Some group members worked cooperatively with minor effort to achieve the goals of the challenge.</td>
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<td><strong>Construction-Materials</strong></td>
<td>Appropriate materials were selected and creatively modified in ways that made them even better.</td>
<td>Appropriate materials were selected and there was an attempt at creative modification to make them even better.</td>
<td>Appropriate materials were selected.</td>
<td>Inappropriate materials were selected and contributed to a product that performed poorly</td>
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<td><strong>Oral Presentation</strong></td>
<td>Students could identify all shapes and describe the process with no difficulty.</td>
<td>Students could identify most shapes and presentation was good.</td>
<td>Students had difficulty identifying shapes and presentation was below average.</td>
<td>Students could not identify all shapes or present the project.</td>
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<td><strong>Time-management</strong></td>
<td>Routinely uses time well throughout the project to ensure things get done on time. Group does not have to adjust deadlines or work responsibilities because of this person's procrastination.</td>
<td>Usually uses time well throughout the project, but may have procrastinated on one thing. Group does not have to adjust deadlines or work responsibilities because of this person's procrastination.</td>
<td>Tends to procrastinate, but always gets things done by the deadlines. Group does not have to adjust deadlines or work responsibilities because of this person's procrastination.</td>
<td>Rarely gets things done by the deadlines and group has to adjust deadlines or work responsibilities because of this person's inadequate time management.</td>
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### Appendix 2: Tally Sheet from the Robotics Rubric

**Sum of Weekly Scores**

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<th>Scientific Knowledge</th>
<th>Team Interaction</th>
<th>Construction Materials</th>
<th>Oral Presentation</th>
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Appendix 3: Robotics Assessment Criteria

LEGO® Robotics Level 3, DATE: June 2006 CHILD’S NAME:

TEACHER’S NAME: Carla Maxwell

Program description
The unit of work investigated what students learn with LEGO® Mindstorms Robotics Invention system. The learning students were involved in required them to program a robot to move forward or backwards for a period of seconds. As the lessons progressed through the eight-week subject students learned more complex building techniques and programming language. In teacher and student discussions we observed the robots actions. The teacher described the action using mathematical terminology.

For example when the robot turns around in a circle, the teacher describe that as a 360 degree turn. After discussions the students wrote up their observations in their robotics journal.

Assessment Criteria

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<td>Science</td>
<td>Qualitatively describe changes in motion in terms of the forces present.</td>
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<td>Design their own simple experiments to collect data and draw conclusions.</td>
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<tr>
<td>Mathematics</td>
<td>Use diagrams and symbols to explain procedures used when reporting on their investigations.</td>
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<tr>
<td>Number, space and Measurement</td>
<td>Describe time elapsed in seconds and can write simple decimal subdivisions of a second.</td>
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<td>Technology</td>
<td>Ability to use Robolab to create working programs.</td>
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<td>Personal and Social Learning</td>
<td>Is able to concentrate and follow through a task cooperatively and/ or independently</td>
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<tr>
<td>Thinking processes</td>
<td>Capacity to use imagination to create innovative alternatives when creating simple machines out of LEGO®</td>
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<td>Thinking</td>
<td>Demonstrates critical thinking to analyse and evaluate their own and others programs and work.</td>
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Self Assessment
In this project, I tried to:

One choice I made was:

Something new I learnt was:

Something I would change:

Teacher Comments
## Appendix 4: Journal Questions for the Programming Lesson

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### Before you begin

What do you plan to work on today?

---

Any relevant diagram(s) or program planning

### During the construction and programming

While you working please take notes of what you are currently noting what works and what doesn’t work?

---

Any relevant Diagram(s) or program planning
If you had any problems, why do you think you had the problems?

Any relevant Diagram(s) or program planning

Any other relevant diagram(s) to explain your construction(s) or room for program planning

**After construction**

What do you think worked well during the session?

What do you think did not work well during the session?

Any other relevant diagram(s) to explain your construction(s) or room for program planning
Hello! My name is Carla Maxwell, I am the Art and Multimedia Teacher at Carlton North Primary School. I am also currently a student at the University of Melbourne. I am doing a project to find out what people your age know about how to make and program LEGO® Robots. When I finish my project it will be part of my degree, called a "Masters". Dr Anthony Jones, helps me with my project and is my "supervisor". We both work in "the Department of Science and Mathematics Education ", at the University of Melbourne.

Your school principal and your teacher have given me permission to send you this letter to tell you a bit about my project. Once you have read the letter you can decide if you would like to take part. You must talk to your parents about the project too and get their permission for you to participate if you choose to.

If you want to be part of the project, I will ask you to work in a group to make a LEGO® car that you program so that it moves, follows a path, has a light and touch sensor. You and all the other people from your class who are taking part would go into the Art room for an hour over a period of eight weeks. You will create fast and slow cars, one that hits a wall and turns around. I will be there to explain about the computer programs and to show you the function of the LEGO® that you will be using. You will be asked some questions about what you made and learnt in each lesson. At anytime you can leave the project and go back to the classroom. If you don’t know an answer, or you don’t want to answer a question, that’s fine too. The rest of your class will be doing another activity with your teacher.

Only my supervisor and I will see your responses and journal record of your learning, so please don’t worry that your regular teacher might look at them. The project will have nothing to do with your school report or your grade for maths or science.

After the project is over, I will lock all the records away safely in the Department of Science and Mathematics Education for 5 years. I have to do this because it is a University rule. After that my supervisor will destroy them.
Remember, you don’t have to take part unless you want to. If you have any questions you should talk to your teacher or a parent. If they don’t know the answer to your question, they can contact me Carla Maxwell at Carlton North Primary School, or my supervisor Dr Anthony Jones at the Department of Science and Mathematics Education, The University of Melbourne, Parkville Vic 3010 Australia 613 8344 8534, or the Research Ethics Office at the University for you.

If you want to be part of my project, and your parent/s agree, please sign your name on the next page where it says "student", and get your parent or guardian to sign as well.
Author/s:
Maxwell, Carla Dawn

Title:
An investigation of the impact of LEGO® robotics on the learning of scientific and mathematical concepts at primary level

Date:
2013

Citation:

Persistent Link:
http://hdl.handle.net/11343/38407

File Description:
An investigation of the impact of LEGO® robotics on the learning of scientific and mathematical concepts at primary level

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