

**Mr. Roboto:**

**Learning to Use Lego Mindstorms Technology**

Submitted to: Colin Lankshear and Michele Knobel

Submitted by: LouAnn Davis, Jackie Dawe, Sara Flynn,

Bev Pearce, Roland Peddle, and Debbie Philpott

July 27, 2007

### Learning to Use a Lego Mindstorms Robot

Everyday new literacies are created, and people are required to learn new knowledge, Discourses, and become members of new affinity groups in order to be considered literate. The goal of this research was to learn a new literacy, being the Lego Mindstorm Robot, and to examine the processes we encounter to learn new skills. During this process we had to become immersed in the new technical language, and programming skills necessary to successfully operate the robot.

Our broad purpose was to build and program a Lego Mindstorms Robot. A Lego Mindstorms robot is a programmable toy designed for children ages 10 and older. It uses NXT computer technology to allow individuals to develop and program basic movements, such as forward, back, rotate, turn, open, close, and speak. The robot has four sensors, including touch, light, sound, and ultrasonic, which allow the programmer to complete extensive combinations of tasks. Our ultimate goal was to become familiar with using a new literacy. While engaging in this new literacy event we achieved a certain level of success within a new Discourse and became very much aware of the process that learners go through when faced with challenging, unfamiliar tasks.

Our objective was to correctly assemble a pre-designed Mindstorms "Tribot" following the pictorial instructions provided with the kit, and have it respond to our programmed sequence of task commands (see Figure 1). Commands for the simple demo program were completed by using just the NXT base demo program options. Our demo program included forward and backward motions using the start button to activate each command. The advanced commands required computer programming software to enable more detailed and specific tasks. The final sequence of tasks programmed for the purposes of this course consisted of the following sequential

commands: forward fast 3 seconds, forward slow unlimited, touch sensor pause, backward fast 1 rotation, forward slow + open claw, touch sensor, close claw + stop, close claw + backwards, fast turn right 2.4 rotations, forward fast three seconds, ultrasonic sensor pause at 28 inches, open claw, backwards fast 3 seconds. The final product was a Lego Mindstorms Tribot that could perform a set of instructions/commands programmed into the NXT computer base by the members of the group using the provided computer software.

### **FIGURE 1 - Steps in Completing the Tribot**

Steps in getting from the box to the final product:

- Examined box
- Opened box
- Flipped through manual
- Looked at building pieces
- Identified and selected each piece and followed manual diagrams closely
- Completed each step until Tribot is complete
- Identified ports and sensors and connected cables
- Used manual and NXT base and went through options/commands available on NXT
- Selected demo and initiated sequence
- Programmed and selected a sequence of movement from the NXT base and tested
- Completed several simple programs to become familiar with how the programming worked and how the Tribot responded to commands/requests
- Moved on to advanced programming – Followed diagrams in manual and built arms
- Connected newly built arms to existing Tribot, and attached the other sensors and cables as per directions in the diagrams.
- Designed many programs in attempt to use all sensors and commands available
- Couldn't get all processes figured out
- Ended with this program

#### *Data Collection*

All of the data used to illustrate the salient moments in our research were examined and triangulated by way of two sets of written field notes as well the digital video recorded data that were viewed and transcribed by Bev. As well, there were group discussions at the beginning of

each day to clarify and make sense of the previous day's activities and recorded data to ensure that all members had an understanding of what had been accomplished and were ready to move on to new challenges.

Before any of the data were even analyzed and assigned categories there was a consensus among all group members that 'trial and error' and 'changes in techno-lingo' were important factors contributing to our learning experience. With these factors identified we set out to pull incidents out of that data to support our assumption that these were indeed significant components in the development of our knowledge surrounding Lego Mindstorms robotics. This method of analyzing data follows the pattern identification strategy as outlined in the Handbook for Teacher Research (Lankshear & Knobel, 2004). "...The researcher begins with a 'mass of undifferentiated ideas and behavior, and then collects pieces of information, comparing, contrasting, and sorting gross categories and minutiae until a discernable pattern of behavior becomes visible'" ( Lankshear, & Knobel, 2004, p. 305,).

Upon careful examination of the data, 'request for feedback and confirmation' became another key factor as being influential in our learning. This third factor came about quite unintentionally, but proved to be an obvious contributor to our progress.

Once the three categories were identified, our group of six was broken into three groups of two and each pair dissected the data to find evidence supporting their individual category. "Pattern matching (like other analytic approaches) includes using 'both creative and critical faculties in making carefully considered judgments about what is really significant and meaningful in the data'" (Lankshear & Knobel, p 306, 2004). Breaking into pairs and sharing the data analysis made examination of the data more manageable.

The data collected in our researched consists of:

**30 digital pictures** taken by various members of the group as well as a few curious onlookers. Most digital pictures were collected with Debbie's, Roland's, Jackie's, and Sara's cameras. All digital pictures are recorded on a CD and are attached as an appendix.

**4 hours of digital video** collected via Bev's video camera. The camera was set up on a tripod on a table during our work sessions at the tables, and was set up and operated manually on the floor during the attempts to run the programs designed for the robot to carry out.

**100+ pages of written field notes** taken by group members two at a time. The field books were rotated so that all members recorded observations and were actively involved in both the note taking and the robot assembly and programming. The field books were labeled A and B and each page was numbered for organizational purposes to allow for easy retrieval of specific data. (eg: page A1 and page B2 recorded the same occurrence)

- **1 hour of audio clips** recorded by Debbie's digital voice recorder. Recorded data from day 1 only, because data was not able to be downloaded onto the computer and saved.
- **Other artifacts** include the NXT Lego Mindstorms Robotics Kit and the programming software CD-ROM, and 3 laptop computers for internet access and word processing programs.

### *Key Situations*

Throughout the assembly and programming of the Tribot robot, there were many situations that both encouraged as well as discouraged us in our progress. Despite the obvious fact that there were twice as many frustrating incidents as motivating ones (as seen in Table 1), these incidents were no match for the few incidents of strong motivation that we experienced. Because of frequent unsuccessful attempts, we learned to appreciate the successful attempts, dwell on the positive, and not the negative. "Learning works best when new challenges are pleasantly frustrating in the sense of being felt by learners to be at the out edge of, but within, their 'regime of competence'. That is, these challenges feel hard, but doable... Motivation for

humans lies in challenges that feel challenging, but doable, and in gaining continual feedback that lets them know what progress they are making” (Gee, 2007, p 36)

**TABLE 1 - Several Key Situations**

<b>Key Motivators</b>	<b>Key Frustrations</b>
<p>Going from discussions about building the robot to actually building it.</p> <p>Designing a simple demo command sequence having it respond successfully.</p> <p>Completing advanced program.</p>	<p>Following a strictly pictorial manual/guide (often lacked necessary explanations).</p> <p>Figuring out how to get the tribot to open its claws over the ball, pick it up and move away from the target area.</p> <p>Light sensor programming and the Switch operation.</p> <p>Minimal memory on the NXT</p> <p>Required battery replacement twice in three days.</p> <p>Tribot wouldn't run in a straight line, and compensating with a slight turn was of no benefit.</p> <p>Programming difficulties when attempting new operations</p> <p>Note taking caused lack of hands on participation and therefore key events to be missed. (Out of the loop)</p>

*Analysis of Language Use*

The data show that the type of language used by group members evolved throughout the process of constructing the two robots from informal ways of describing Lego pieces, such as on the first day when Debbie said, “Where does this guy go?” (Referring to a grey piece of Lego) to the group deciding on the second day to refer to that particular piece as a “small gray elbow”.

The data also show that two distinct types of language shift occurred. The first type of

change comprised of increased use of technical terms learned from the documentation accompanying the NXT robot kit (e.g., micro-processor, sensor). The second kind of language change comprised terms developed by the group as part of a shared language for talking about pieces and processes as we were working (e.g., “small grey elbow” to refer to a particular shape of Lego block). Figure 2 presents some additional examples of the language changes across the five days of the project.

**FIGURE 2: Examples of shift in language use.**

<i>battery box</i> B.2 July 9,2007	→	<i>mike</i> B.2 July 9,2007	→	<i>battery pack</i> B.2 July 9,2007	→	<i>NXT Base</i> B.14 July 10,2007
<i>sundial</i> B.2 July 9, 2007	→	<i>light sensor</i> video July 9,2007				
<i>wires</i> B.2 July 9, 2007	→	<i>cord</i> B.22 July 10, 2007	→	<i>cable</i> B.31 July 10, 2007		
<i>arms</i> B.2 July 9,2007	→	<i>cervo motors</i> B.2 July 9,2007				

The changes in language use captured in Figure 2 above were far from random, but were very much embedded in a particular context of use. For example, on the first day, Sara was reading from the construction guide and referred to a piece as a “sundial”. Just prior to this, LouAnn had been perusing the guide book and learned that this particular piece was called a “light sensor”. She shared this insight with the group by explaining, “‘Sun’ is ‘light sensor’”.

An inventive language example of a situated meaning developed by the group itself is the use of the term “hockey stick” for one of the pieces. On the first day when group members were unfamiliar with the Lego pieces they invented their own names for particular pieces. While Bev was looking for a piece that resembled a hockey stick she called it a blue hockey stick and that name stuck with the group because the construction guide did not name the piece and the group needed a name to be able to identify the piece.

Another example of inventive language used by the group was on the first day, when the NXT base was referred to as a battery box, a mike, a battery pack and finally the technical term, “NXT base”. Initially our unfamiliarity with the correct terminology called for the group to name the piece in order to identify with it. Gee (1999, p.46) concurs and has stated “that another way to talk about situated meaning is to say that they are assembled out of diverse features ‘on the spot’, as we speak, listen, and act.” After several inventive names Roland found the correct term in the manual and from then on it was referred to by the technical term.

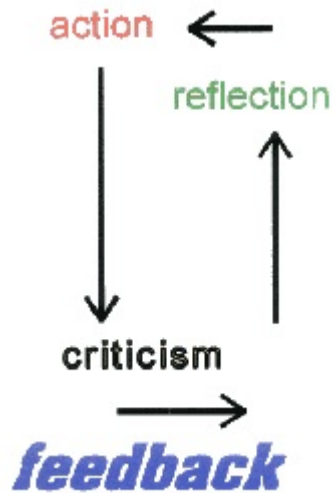
The data contain numerous examples like these (see Appendix 1). These shifts in language resonate with James Paul Gee’s claims about the situatedness of language and meaning-making. For Gee, “words have specific situated meanings” (Gee 1999, p. 46). By this he means that words have specific meanings within a particular situation. For example our group used the term, “arm” to describe the cervo motor because of its resemblance to the human upper limb. The word arm has different situated meanings depending on the context in which it is used. According to the Merriam-Webster online dictionary an arm means a human upper limb or a support for the elbow and forearm (as on a chair). This non-specialized term evolved because of our prior knowledge.

There are two important lessons for the classroom here. We need to remember not to

forget the quiet children in the classroom. Just because these children do not say much does not mean that they are not involved in the learning process. You do not have to be actively participating to be learning. Another valuable lesson here is that we do not always have to assign tasks to students to work well together in groups. This can just happen naturally and be very effective as was the case with our group.

### *Feedback*

It is no strange phenomenon that feedback is an important component in the learning process, and every teacher out there has experienced the child who is constantly seeking approval and confirmation with regard to the quality of their work. But not only is feedback important in learning, it is essential in developing the kind of thinking and decision making skills required to take on any new task both effectively and efficiently. “Feedback is like a loop or circle: you start with what you do; you go round to what someone says about what you do or what you think about what you have done; this leads you to alter what you do; you may then get more feedback and carry on improving” (Roberts, 2007, p2).

**Diagram 1 - Feedback and Active Learning**

In examining our written data (Appendix 2), we were surprised to discover how large a role feedback and confirmation played in our learning experience. There are numerous instances throughout our data that illustrated our need for feedback and confirmation as we attempted complicated and sometimes frustrating tasks. Some of the things we did to get confirmation were to: ask each other; check the manual/diagram; check out the help menu; check the internet for information; self/group confirmation; and to seek outsider confirmation from instructors. Requesting and receiving immediate confirmation for what we think and do offers an opportunity

to make the corrections necessary for alterations and, ultimately, success. As a group, we felt that feedback was needed mainly because of the lack of instructions and the unfamiliarity with the Lego Mindstorms Kit. Although instructions were provided, and despite our lack of experience with the kit, we looked to each other to confirm and ensure that our decisions were leading us down the right track. We found that feedback and confirmation was very hard at times to distinguish from the trial and error episodes because they are so closely linked to one another. When you try something you look for feedback to confirm what you are doing is successful so you can move on.

Gee (2007) states on page 36 of the Good Video Games article, “Players get feedback that indicates whether they are on the right road for success later on and at the end of the game...they get feedback about the sort of progress they are making so that at least they know if and how they are moving in the right direction toward success”.

Table 2 illustrates some examples of situations where feedback/confirmation was requested. The categories of satisfactory and unsatisfactory were established through an examination of the data and were determined by the length of time in which the incident lasted. Any incident over one minute was considered unsatisfactory even if it eventually ended in success. Immediate feedback resulted in motivation to continue whereas delays in satisfactory feedback increased the level of frustration, therefore categorized as unsatisfactory.

**TABLE 2: Incidents of Request for Feedback**

Unsatisfactory Feedback (Time delayed)	Satisfactory Feedback (Immediate)
<ul style="list-style-type: none"> <li>▶ (5 mins) B5/6 D wanted to go back and check pieces. J went to the Lego website for names of parts; D listened to R oral instructions; D looked to the manual for final confirmation.</li> <li>▶ (10 mins) B24 Group completed section of robot and need to look to: the manual, and look ahead to get confirmation that previous steps were correct; R wanted to take it apart and start over to ensure that assembly is exact.</li> </ul>	<ul style="list-style-type: none"> <li>▶ B4 S wanted to start over to check proper assembly. R looked at the manual and confirmed it was OK.</li> <li>▶ B7 S went to manual to confirm thoughts on the step in progress.</li> <li>▶ B8 R reread the directions in manual and asked group to confirm his explanation was understood.</li> <li>▶ B12 D questioned left over pieces. Group reassured her they are extras. (Opinion)</li> <li>▶ B16 Demo worked. Confirmed all previous efforts and provided strong motivation to continue with the next step.</li> <li>▶ B18 L asked the group if pieces should be sorted. Group said no, and moved on.</li> <li>▶ B20 J requested confirmation from group about her construction, group reassured her it was fine.</li> <li>▶ B22/24 Various questions concerning loose pieces and cables. Group gave yes or no answers based on their opinions of how it should go, and things went fine based on those opinions.</li> <li>▶ B38 S asked L for confirmation on the light sensor icon and L correctly identified it for S.</li> </ul>

Although none of us were experts at building robots and programming them, we relied on the opinions, ideas, and suggestions from other members of the group to get us through many queries and problem areas. Often times we could provide for each other a source of comfort and understanding (or lack of understanding) and provide confirmation that our thoughts and ideas are

good, even if they are not right. Having a group of people who are all learning a new task together meant that no idea, notion, thought, or decision was wrong, because no one knew what was 'right'. Working and learning in this type of environment lends itself well to risk taking and offers a judgment free workplace; no idea is a bad idea or even a good idea until it's been tested and tried and deemed as such; and there is no way to distinguish the right from the wrong until all ideas have been tried.

In the article *Good Video Games, the Human Mind and Good Learning*, Gee (2007) states on page 27, "The player... comes to gain competence through trial, error and feedback, not by wading through a lot of text before being able to engage in activity." Feedback is the heart and soul of trial and error, without it there would be no opportunity for reflection and subsequently no opportunity for adjustment or change. "Feedback is the modification of a process by its own results" (Roberts, 2007, p2).

### *Trial and Error*

Much of the learning that we do each day involves trial and error. From learning to tie our shoes, to completing complicated tasks on a computer, we are often required to make numerous attempts at the task at hand. Each attempt we make provides us with valuable feedback that furthers our learning of the task. Either we succeed and can continue on with the next step, or we make an error, which requires us to go back and try again.

Wikipedia defines trial and error as "a general method of problem solving for obtaining knowledge, both propositional knowledge and know-how" (June 11, 2007). When using trial and error, one attempts to use one possible solution to solve a problem. The outcome, whether it be successful or unsuccessful determines the next action. If one finds that their attempted solution

brings about the desired effect, it is considered successful, and a new attempt to solve another problem can be made. However, if the trial results in an undesired result, it would be considered an error, and one would likely try a new solution.

Trial and error is seen as an important learning strategy by a number of researchers (Gee, 2007; Joao-Monteiro, Morgado, & Morgado, 2003; Picene, 1990). Specifically, trial and error is a common learning method in acquiring the skills needed for various new literacies, including computer games (Gee, 2007), and robots (Joao-Monterio et al, 2003). In Portugal a group of researchers have looked that the effects of introducing computer-related technologies to kindergarten students, specifically in the form of “Roamer robot”, an autonomous, programmable toy with a removable shell (Joao-Monterio et al, 2003). These researchers have stated:

*It should be noted that children, upon realizing that the wrong option was taken, don't usually like to make such an error be noticed. The robot lets them make errors without leaving traces. Its patience [is] unmatched by any grown-up, and this turns it into a friend that is always there, with whom the process of learning through trial and error is essential for knowledge build-up.*

A programmable robot, such as the Lego Mindstorm robot, or Roamer robot, provides its user with immediate feedback, which lets the user know if a trial was successful. In our experiences with using the Lego Mindstorm Tribot, we found trial and error to be a very important method of learning. As MacGinite (1983, p. 678) states, “Uncertainty does not mean lack of planning or lack of action. It means planning based on reasonable alternatives. It means action based on the best evidence currently available”. When working with our Tribot we were

required to use our ‘best guess’ to attempt to program the Tribot to do what we wanted. We had to use our prior knowledge regarding computers, DVDs, alarm clocks, and other pieces of technology, to help us decide the next step. “The mind works by storing records of actual experiences and constructing intricate patterns of connections among them” (Gee,2007, p.23). We frequently made educated guesses as what we thought would work. For example, we had great difficulty in getting the Tribot to open its claws. The following excerpt is taken from book A of our observed field notes (11:00am, July11, 2007):

*LouAnn suggested using port A to use claw. Sara inputted a port A movement into NXT program.*

*Ran program - claws opened. Sara thinks taking away port A will close claws.*

*Robot did not close claws - just continued to move forward.*

*Sara took away port C command - robot turned slightly; didn't close.*

*Sara used only port A - robot did not close claw.*

*Roland discovered that claw wasn't hooked on properly.*

*Tried again - still didn't close.*

*LouAnn suggested putting port A with backward motion instead of forwards motion.*

*Robot closed claws to ready position.*

*Going to try A, B, and C port together going backwards.*

*It worked!*

*We tried it a second time - also successful.*

As seen in the above excerpt, we needed to make numerous attempts to program the Tribot to complete our desired movements. In fact, our field notes from book A provides 67 examples of trial and error, and book B provides 72 examples of trial and error (see Table 3).

**TABLE 3: Incidents of Trial and Error**

	Number of Recorded Trials	Number of Recorded Errors	Number of Recorded Successes
Book A	67	35	29
Book B	72	27	33

In analyzing the data (Appendix 3) we found that there were two stages in producing our final product, which were the actual construction of the robot, and the programming of the NXT. Within these separate stages of the development of our Tribot there were commonalities in what we attribute to the causes of errors. First of all, in constructing the Tribot the errors we faced mainly related back to one of two problems, which were: identifying the individual pieces, and difficulty with following the provided instructions. Secondly, in the programming phase, the errors seem to have been caused by the fact that we were unfamiliar with the specific command functions of the NXT program. Similar to the construction phase, there was a lack of instructions provided to help program the robot. Overall, the group found that the manual which came with the Lego Mindstorm program provided very little instructions, and the written instructions on the help menu were over-whelming to follow. The provided manual relied heavily on pictorial instructions, which the group found somewhat difficult to use. We felt that having some labels and short explanations to compliment the pictorial directions would have been beneficial. Due to the lack of textual cues to help us, especially when it came to programming the robot, we were required to learn through trial and error.

We also analyzed our data looking for the successes we achieved when assembling and

programming the Tribot. These successes usually resulted after an error occurred and a new trial was performed using the knowledge acquired from the failed attempt. Success rates seemed to increase after an error had occurred and we continued to look for other possible solutions.

### *Implications for the Classroom and Teaching*

The process that we went through in learning a new literacy was really quite an eye opening and humbling experience. Engaging in this new task allowed us to appreciate the process and take the perspective of a student as they participate in a new learning experience. As a group we decided on two key issues that have implications for learning in the classroom; cooperative versus collaborative learning groups and the use of new literacies to motivate students.

As teachers, we frequently feel the need to create cooperative learning groups, in which students are assigned specific roles, in hopes that all students participate successfully. Through reflecting on our own learning experiences with the Lego Mindstorms robot, we have come to a general consensus that this is not necessarily the best way to promote student learning. When we came together as a group there was no delegating of tasks. The group as a whole shared a common goal, which acted as our motivator and promoted our collaborative learning. We shared tasks rather than assigning individual roles. This encouraged all members to actively participate in all aspects of the learning process within individual comfort levels. Each member came to the group with their own strengths and prior knowledge and it was the combined efforts of our new affinity group which lead to the success of our venture.

Technology as a teaching tool has the potential to enhance the learning experiences that

students are engaged in. Druin and Hendler (2000) argue that “the desire for learning has to do with an animating idea or an engaging project. New technologies enable students of all ages to pursue richer, far more complex learning experiences. With [technology], students can truly be scientists, engineers, designers, and builders”. From our interactions and experiences with technology in this course, we feel that we have grown significantly in our ability and awareness of new literacies. By incorporating these technological learning experiences into the classroom, we can instill in our student the desire and importance of becoming lifelong learners.

## References

- Druin, A., and Hendler, J.(Eds), (2000). *Robots for kids: Exploring new technologies for learning*, San Diego: Academic Press.
- Gee, J. (2007). Good video games, the human mind, and good learning. In M. Knobel & C. Lankshear (Eds.), *A new literacies sampler* (pp. 22 - 44). New York: Peter Lang.
- Gee, J (1999). Situated meaning and cultural models. *Introduction to discourse analysis: Theory and method* (pp. 40 - 57).
- João-Monteiro, M., Cristóvão-Morgado, R., Bulas-Cruz, M., & Morgado, L. (2003). *A robot in kindergaten*. Retrieved July 24, 2007 from <http://home.utad.pt/~leonelm/papers/RobotinKindergarten/RobotinKindergarten.html>
- Lankshere, C., & Knobel, M. (2006). *A handbook for teacher research: From design to implementation*. New York: Open University Press.
- Lego. Retrieved July 9, 2007 from <http://mindstorms.lego.com/eng/default.aspx>
- Picene, J., (1990). Knowledge, skills and judgement!, *CCTE Newsletter*.
- MacGinitie, W. (1983). *The power of uncertainty*, (pp. 677 - 679) Newark, Del: International Reading Association.
- Roberts, A. *Feedback and active learning*. Retrieved July 20, 2007 from <http://www.mdx.ac.uk/WWW/STUDY/Feedback.htm>
- Wikipedia (2007). *Trial and error*. Retrieved July 23, 2007 from [http://en.wikipedia.org/wiki/Trial\\_and\\_error](http://en.wikipedia.org/wiki/Trial_and_error)



Appendix 1 - Development of Language

**Data from July 9 - July 12<sup>th</sup>  
Books A and B**

- A - indicates book "A"*
- B - indicates book "B"*
- C- indicates the video*
- Black font -indicates our terminology*
- Blue font - indicates technical terminology*
- Number after "A" - indicates the page number*
- Number after "B" - indicates the page number*

When we began building the robot we were not overly concerned with using the correct terminology but as we progressed through the project and became more knowledgeable

we became more confident in using the correct terminology.

<b>Date</b>	<b>Page</b>	<b>Roland</b>	<b>Lou Ann</b>	<b>Jackie</b>	<b>Bev</b>	<b>Sara</b>	<b>Debbie</b>
<b>07/09/11</b>	<b>A.3</b>	One cervo motor com- pleted					
<b>07/09/11</b>	<b>A.8</b>	Sensor motor ready to attach to micro- pro- cessor.					

07/10/07	A.17	NXT base is the computer support, ABC are motor ports					
07/10/07	A.20		Hook on the black thing.				
07/10/07	A.20		Lou Ann said every-time touch sensor says oops.				
07/10/07	A.21		Use buttons and go to orange face that says try me.				
	A.23						Looking for touch sensor.
07/10/07	A.28	We need a grey tiny cog.					

07/10/07	A.29						Two arms are not symmetrical so take off and try switching them to see if that will make it match up.
07/10/07	A.30	Take two claws and point them away from you and turn upside down...					
07/10/07	A.31	Black rod needs to be inserted to attach the claw.					
07/10/07	A.31		What piece does the black go on?				
07/10/07	A.31				Long or short hockey stick?		

07/10/07	A.31		Assembling the next claw				
07/10/07	A.32				Sandwich it in between this when attaching the second claw.		
07/10/07	A.33	Take the L and put it... yup, the dowel right here.					
07/10/07	A.33	That is what sensor connects in port two.					
07/10/07	A.36		How close to the black hole is it now?				
07/10/07	A.36	All we need now is the ultrasonic sensor.					

07/09/07	B.2			Lou Ann held the battery box			
07/09/07	B.2	Number two has to be plugged into the mike.					

07/09/07	B.2	Number three is the sundial					
07/09/07	B.2	Put it on the red section					
07/09/07	B.2	The sound sensor is number two.					
07/09/07	B.2			Lou Ann and Roland began putting the wires in the battery pack			

07/09/07	B.3	We need 1x. The little piece.					
07/09/07	B.3				We need to get the do-dickies.		
07/09/07	B.4					Referred to each part as the light grey piece or the dark round piece.	
07/09/07	B.4	Roland said take the other long black piece.					
07/09/07	B.5				arms are called cervo motors		
07/09/07	B.7	We need these two pieces. (Roland pointed at them.)					

07/09/07	B.7				Sara said attach it to the thing-a-ma-jig.		
07/09/07	B.7	Roland said we have to make the jigga ma bob.					
07/09/07	B.7				We need a blue hockey stick.		
07/09/07	B.7	Flip it over, face us and it goes in the arms.					
07/09/07	B.8						Debbie said "Where does this guy go?"
07/09/07	B.10					Sara said she thought the loop meant it would turn. It means repeat.	

07/10/07	B.14	Roland described the NXT (base) system (brain) Two sets of ports.					
07/10/07	B.14	Input ports down, ABC motor ports. Claws connect to A.					
07/10/07	B.15	NXT not responding to commands					
07/10/07	B.16	Lou Ann putting on touch sensor.					
07/10/07	B.19	Group compiling construction of touch sensor to clip to robot...					
07/10/07	B.20	Group referring to parts, small grey elbows.					

07/10/07	B.22	Roland looking for dark grey, #3. Light grey have already been attached.					
07/10/07	B.22					Attaching cord to sensor and robot.	
07/10/07	B.23	We need another spider?					
07/10/07	B.23	Where did this black piece come from?					
07/10/07	B.26		Lou Ann realized that the spider shaped blocks needed to line up so that they work together.				

07/10/07	B.26					Sara said, “Oh yeah! Duh!”	
07/10/07	B.27	Roland is building the ball holder. Rubber piece is missing.					
07/10/07	B.27					Sara is building the sound sensor arm.	
07/10/07	B.27					Sound sensor attached to back of robot.	
07/10/07	B.27					Removed touch sensor to attach light sensor undernea th( some difficulty reattachi ng touch sensor)	
07/10/07	B.28					touch sensor needs to be flush	

07/10/07	B.28					light sensor connected to robot	
07/10/07	B.28					ultra-sonic sensor being attached to top	
07/11/07	B.35		Program was downloaded but light sensor didn't seem to work properly.				
07/11/07	B.35		Still not going ahead first. It's picking up the sensor too quickly.				
07/11/07	B.35					Try adjusting the sensor again.	

07/11/07	B.35					Ultra-sonic sensor is now not working that well.	
07/11/07	B.36		It has an error. NXT ran out of memory.				
07/11/07	B.37	Try light sensor again.					
07/11/07	B.39					Sara looked up in the manual how the NXT picks up the colour with the colour sensor.	
07/11/07	B.40		Lou Ann said it was difficult to control the light sensor.				
07/11/07	B.44					The touch sensor is gone.	

07/09/07	C					The mike has to be plugged into that one	
07/09/07	C					Number two has to be plugged into the mike.	
07/09/07	C					Number three is the sundial.	
07/09/07	C		Sun is the light sensor.				
07/09/07	C					Four is the satellite.	
07/09/07	C	The other one is the light sensor.					
07/09/07	C	Touch sensor goes to number one.					
07/09/07	C	Sound sensor is number two. That should be port two.					

07/09/07	C	Light sensor, port three.					
07/09/07	C	Ultra-sonic sensor, port four.					
07/09/07	C		The eyeballs.				
07/09/07	C	Yes, the eyeballs.					
07/09/07	C		Does it matter where the cords go.				
07/09/07	C	How many wires are there altogether?					
07/09/07	C			In my notes I call it a battery pack or a power pack.			
07/09/07	C	The correct name is the NXT system.					

07/09/07	C	Number one is the light sensor.					
07/09/07	C	Number two is the sound sensor.					
07/09/07	C	NXT technology base.					
07/09/07	C	A,B,C are all motor ports.					
07/09/07	C	Sound sensor, did you have it in Port two?					
07/09/07	C					No, Port one.	
07/09/07	C	Sound sensor on this one says Port two.					
07/09/07	C		Where is the black piece?				
07/09/07	C				This is the touch sensor.		

07/09/07	C		The light sensor is pointing down. Can you move it?				
07/09/07	C	The sensor is down again.					
07/09/07	C				The sensor has to hit dead on.		
07/09/07	C				I think it is the cords		
07/09/07	C		The other two we tried were the light sensor and the ultra-sonic sensor.				
07/09/07	C		The light sensor needs to be connected to Port three.				
07/09/07	C			Building the tri something.			

07/09/07	C	The tribot.					
07/09/07	C		The hockey one was in here.				
07/10/07	C						This piece is for the claws.

---

## Appendix 2 - Feedback and Confirmation

Some examples of request for feedback/confirmation:

- B2 July 9 2 pm kept referring back to the box
- B4 2:12 S wanted to start over to see if she had it assembled properly
- B4 R looked for confirmation on whether we should start the next part
- B5 2:25 D wanted to go back and check the pieces
- B5 J checked out the mindstorms website
- B6 2:30 D followed the oral instruction given by Roland, but also used the diagram for confirmation
- B7 S needed to see the visual direction
- B8 D said "Where does this guy go?"
- B8 D said she wasn't good with measurement. R said give it a little twirl
- B8 2:57 R reread the directions and asked for confirmation (from the group) regarding the connections made
- B12 July 10 11:15D said, pieces left over. S said, think extra pieces. J mentioned car story with left over parts
- B13 J: "What are we suppose to research?" D: "We need to get them over here."
- B13 L: "Questions related to learning in classroom?" Michelle: "In the conclusion would be a good place for that."
- B16 11:45 Demo worked! Provided confirmation that all has gone as it should and that despite our lack of knowledge that this task is not something outside the realm of our capabilities. Motivated us to continue on with more challenging and complicated building and programming.
- B17 11:55 Testing the sensors before attaching and programming them to confirm that we know what they are suppose to do so that we know when they are and are not working once integrated into the system.
- B18 L: "Should parts be kept with original grouping?" Group consensus: makes no difference
- B19 Group referring back to pictorial instructions (to confirm correctness of completed tasks)
- B20 1:25 D noticed an extra piece and questioned did it fall off.  
J doubting her construction. Group reassured her that it was fine and that it was OK.
- B21 1:33 Group problem – loose part. Taking structure apart to ensure correct construction. Referring back to illustrated version. S questions the blueprints and the color of pieces to be used. S notes that we should continue with blue print, L agrees that separate parts should be completed as per blueprints. (Started over)
- B22 1:41 "Are they suppose to be loose?" Group decides, no.
- B22 R suggests using a shorter wire. Group: "I can't see why not?"
- B23 "Will it interfere with the movement?" Group: No

- B23 "Where did this black piece come from?" "What is the purpose?" Group decided to take it off
- B24 2:00 B asked for confirmation about whether or not what she was doing was right.
- B24 LDR speculate whether or not what they were doing was correct
- B24 Group examined the diagrams for quite a while before they felt they knew what to do or thought they had to do
- B24 Group looked ahead to see what it would look like because they were not sure of what to do
- B25 2:10 R thought we may need to take the pieces apart and start from scratch. D agreed
- B25 D questioned whether something was right and wanted to put it next to the picture to check the assembly
- B25 R took the piece and laid it by the diagram to ensure it was right
- B25/6 B said someone else could do the next part. RD assured her she was doing fine
- B27 2:30 L thought we shouldn't use the long wire because it might interfere with the claws. Group rearranged the short wire and it seems to work
- B28 "I think touch sensor needs to be flush" Group looks back at picture to figure out the mistake
- B31 July 11 10:15 R: "connect NXT to computer and then turn it on" L: "connect it first?" R: "connect the cable and then turn it on"
- B34 11:55 R: "What's happening?" RLS discovered sensor was set to pick up objects too far away.
- B35 12:55 L: "Its still not going ahead first. It's picking up the sensor too quickly."  
S: "Try adjusting the sensor again."  
L: "Ok, it went ahead that time. Let me change this one from color to a sound sensor. Ultrasonic is not working that well. I'm changing the sound to a softer sound, it should go backwards."  
S: "I think the batteries aren't strong enough." Added new batteries and that made a difference
- B36 1:15 L: "I wonder what the sound does?"  
J: "Ok, lets try that."  
L: "We are trying a sound file."  
S: "Can it say 'hi, I'm Mr. Roboto?"  
L: "It should! Download it and see. It has an error." NXT ran out of memory.  
S: "Delete it and start again."  
J: "Can we make the sounds louder?"  
R: "Yup, volume is there."
- B37 R: "What are you doing J?"  
J: "Changing the rotations so it doesn't take so long."
- B38 S looked to L for confirmation on the icon for the light sensor.
- B39 Looking for a dark spot. S thought we could use a box. L suggested trying the cushions from the couch. (it didn't work)

- B40 1:45 D thought the red color might have reversed the tribot, but upon a second run we realized it wasn't
- B40 L wondered if we could download a program from the computer. R checked the manual to see if we could. But no, we need Bluetooth to do that.
- B42 2:20 R: "Do we delete that file?"  
 L: "No we just modify."  
 L: "Try it again."  
 S: "Insert a pause."  
 L: "I'm inserting a one second pause."  
 R: "Are we good?"  
 L: "Yeah." But program unsuccessful  
 L: "I don't know what else to do. Let's start over. I've changed action from pressed to bumped to see what happens."
- B44 2:30 R wanted to slow it down to see if it would solve the problem of bumping the ball off the platform. YES this worked.
- B45 2:55 D thought they should try the mat again because the robot wasn't bumping the ball off when we used the mat. No or very little difference.
- A12 July 10 11:45 D: "If the wire was underneath it would hold it up"  
 Group tested it and it works better with the wire underneath
- A15 1:25 D questions if piece fell off.  
 R says no
- A16 1:33 D wonders why piece is loose  
 S thinks may be wrong piece
- A17 S goes back through diagram to find mistake
- A18 1:45 R "We need grey tiny cog."  
 B "right here?"  
 R "yeah right through there"  
 B "needs to go right through?"
- A18 R "see that little section? Where did that come from?"  
 Reviews diagram
- A21 2:10 S wonders if something else would work and it did. Directions not specific enough.
- A21 L "What piece does the black go on?"  
 R looked at the directions and found proper pieces
- A23 2:45 S "I need to take it like this and put the big piece right here?"  
 R "Take the L piece and put it...yup the dowel right here."
- A24 R "We have it done...yeah...correct?"  
 S "hmmm. Over here."  
 R "Ok, Ok, gotcha. See it here? This is where it fits in."  
 S and J "Oh, yeah"  
 S "We need a screwdriver"

- Group agreed.
- A24 S "I think it goes here."  
R "Try it and see what happens"  
S "There we go...perfect."
- A25 3:00 A "I think we need to take it apart and put the cable in."  
L "I hope we don't have to start from scratch!"  
Took apart section to make it fit properly
- A26 J "Does this part line up here and here?"  
S "yeah... no it doesn't"  
J "I'm so tired now!"  
R "Let's put it away"
- A33 11:00 L suggested using port A to use claw  
S input A port movement and ran program, claws opened
- A34 L suggested putting A port with a back motion instead of forward motion. Tried ABC motion and it worked!
- A34/5 11:15 L "Read the switch thing again. Forget the switch right now and just do something else until we know..."
- A41 2:10 L "wait I need to adjust A, let's try that again"  
R "are we good?"
- A42 2:35 R "can we slow it down?"  
L "oh yeah – let's try that. Perfect."  
S "much better, that is so cool."

Appendix 3 - Trial and Error

**Trial and Error  
Data from July 9 - July 11<sup>th</sup>  
Book A**

*A - indicates book "A"*

*Number after "A" - indicates the page number*

*Trial - an attempt to complete a task*

*Error - an attempt to complete a task that is unsuccessful*

*Success - an attempt to complete a task that is successful*

As with much learning, we found that learning how to assembly and program the Lego Mindsets Tri-bot was based a great deal on trial and error. Below is a listing of all the trials, errors, and successes as described in set A of fieldnotes, which were recorded over a three day period when building and programing our Lego Tri-bot.

Time / Date	Page	Trial	Error	Success
July 9 9:30pm	A1	played around with new sequences		
10:00	A1	attached sound sensor		robot completed sequence
10:08	A1	attached ultrasonic sensor	did not work	
10:15	A1	tried touch sensor		robot successfully sensed touch and completed sequence
10:20	A1 / A2	tried light sensor	attempted few times - did not work	
July 10 11:35am	A8	trying sound sensor	didn't work on 1 <sup>st</sup> try	(11:40) "We discovered the importance of the ports"
11:40	A9	Debbie tried the robot using voice commands		

11:45	A11		trying touch sensor	sensor kept falling down	
	A12		“If wire underneath it would hold it up”		tested it and it works better with the wire underneath
	A12		tried light sensor		sensor made sounds with different colours
1:05	A13		trying to assemble tribot		
	A14		trying to put pieces together		
1:25	A15		A 15 trying to put pieces together	“pieces falling our. J takes it apart because pieces won’t move”	
	A16		A16	“It doesn’t lock”	
	A17		trying to find mistakes		
1:45	A18		attaching cable	“difficulty adjusting long cable...”	“...so opt for the shorter one for time being”
	A18		took off piece that didn’t appear to belong		
	A19		“ 2 arms are not symmetrical so take off and try switching them to see if that will make it match up”		
2:05	A20			“no that’s still not right”	
	A20		attempts to correct by taking apart		

2:10	A21		wondering if something else would work		... and it did!
	A21 /	A22	assembling claw	“no we did it wrong!”	
	A22		“switch it over”		
2:45	A23		assembling		“Ahah! Perfect”
	A25		“try it and see what happens”		“Perfect”
	A25		trying to connect the cable	“This piece doesn’t fit!”	
	A25		discovers the piece		“Oh, right!”
3:00	A25 /	26	trying to get pieces to fit / taking apart section to make it fit properly	“Doesn’t look right there now. It isn’t flush”	
	A26		attempting to reassemble robot	“Let’s put it away”	
3:10	A26 /	27	attempts to attach ultrasonic sensor		“Hallafreakinluiah!”
	A27		adding own parts		tribot built
July 11 10:20am	A31		attempting to program robot	having trouble moving robot	
	A31 /	32	trying different commands to get robot to move as desired	program: forward to touch, back 1, forward unlimited is unsuccessful	
	A32		Tries program again		Success
	A32		adds to program		Success
11:00am	A33		suggest to use port A to use claw		Claws opened successfully

	A33	suggests to take away port A command to close claws	Claws do not close	
	A33	tries taking away port C	robot turned, but claws did not close	
	A33	tried using only port A	claws did not close	
	A33	discovered that claw wasn't hooked on properly. Fixed claw and tried again.	claws did not close	
	A34	Suggest to use A port with a backwards motion		claws moved back to resting position
	A34	tried ABC ports with backwards motion		robot responded as hoped
11:15am	A34	trying to add a turn		turn worked
	A34 / 35	attempting to do random program where NXT makes its own decisions	switch program not working. Group decides to move on.	
	A35	adds a turn		successful
	A35	attempting to activate the ultrasonic sensor		successful
12:55pm	A37	attempting to create a movement with the light sensor	couldn't get it to work very well	
	A37	batteries seemed to be low. Replaced them to see if it helps.		improved quality of movements
	A37	adding sound component ("Have a nice day!")	NXT ran out of memory	

A37		deleted program #2 to make more room for new program		successful in running new program
A37 / 38		adjusted program to make it longer (added more rotations to movements)	Program worked, but we realized that the rotations must mean rotations around the track because it went on for a very long time.	
A38		changed rotations to seconds		worked successfully
A38		attempting to get light sensor to work	having difficulty	
A38		tries using unlimited movement	did not work	
2:26pm A39		changed light level to 0%		detected change immediately and skipped over steps
A39		changed to 100%	didn't detect change	
A39		changed to 78%	didn't work	
A39		changed to 25%	didn't work	
A39		found complicated program online. Will attempt to download	discovered we need blue tooth, and realized we don't have most of the icons on our computer	

	A40		attempts to download program	realized that the program is only an image and you can't download it	
2:05pm	A40		programmed in new program manually		program worked
2:10pm	A40		designing new program for obstacle course	ran out of memory again	
	A40		deleted all programs off NXT		did a test run and found the back up movement was too fast
	A40 / 41		adjusting the speed for back up command. Also decided to use a full rotation instead of a part rotation	found that a 1 sec pause was needed between commands in order to be able to pick up the ball	
	A41		"Wait! I need just A" (port A)		
2:30pm	A41		changed action from pressed to bump on the touch sensor	robot still not responded to touch sensor	
2:35pm	A42		<i>(Data does not indicate what was changed)</i>		Program worked
2:35	A42		Adding on to program		worked

2:45

A42		<p>“Can we slow it down? Because it knocked over the ball instead of picking it up.” “Oh yeah. Let’s try that!:</p>		<p>“Perfect!”</p>
A43 / 44		<p>decided to try using the mat to keep the ball from knocking over</p>	<p>mat didn’t improve success</p>	
A44		<p>tried again with mat placed sideways</p>	<p>it worked</p>	
A44		<p>“It needs a slight right turn on the last movement” - trying to compensate for the tires</p>	<p>didn’t worked as hoped</p>	