Chapter 9

Case Study Two

9.1. Introduction

In this chapter the author details the second of two case studies undertaken. This case study was conducted in 1995 at the University of New England with students from the Presbyterian Ladies College, Armidale. Case study two examines whether there is any discernible difference in student performances when the students form groups of their own choosing instead of the groups determined on a random basis.

9.2. Description of Case Study Two

9.2.1. Experiment Setup

The second case study involved 19 year five students (aged 10 and 11 years). The students completed two series of CAI lessons individually and then undertook one task working in a randomly allocated group, followed by a second task working in a biased group. The students took one day to complete these activities. Firstly, the students were taught basic LOGO commands by a series of five LOGO CAI lessons. The lessons involved teaching:

- the LOGO turtle to show direction and the FORWARD command;
- the LEFT and RIGHT commands with FORWARD to draw a right-angle;
- drawing squares;
- using the REPEAT command; and
- the UP and DOWN commands to move without drawing lines, and CLR to clear the screen.

The students were then given a series of lessons teaching a set of Geometrical concepts. These lessons were selected to fit into the student's current curriculum. Appendix E gives

a system walk through of the second Geometry lesson. Their teacher was asked to assess the lessons to ensure that they were aimed at the correct level of student understanding. The Geometry lessons taught the concepts:

- of turning 180 degrees;
- of creating an acute angle;
- of creating an obtuse angle;
- involved in drawing a rectangle.
- involved in drawing an equilateral triangle;
- involved in drawing a hexagon; and
- involved in drawing a parallelogram.

The students attempted a task related to each of the above topics on an individual basis. Following the completion of these tasks the students were assessed as to whether or not the task was successfully completed. If a student did not complete a task correctly they were given a remedial task on the same topic. The information collected included:

- time taken on each task;
- the student's problem solving techniques;
- whether the student was given the remedial lesson; and
- the student's common errors.

Thirdly, the students were randomly assigned to 6 groups by going round the room and allocating each of the 19 students to Group1, Group2 and so on. Each group was rated by adding the students scores from their individual assessments and inversing this total. The groups then undertook the task of drawing a picture by using some of the shapes they had learned. The groups did not receive any new lessons.

Finally, the students were asked to form their own groups (biased grouping). The students worked through another task of drawing a picture by using the shapes they had learned. The students performance in the groups of their own choosing was compared to their performance in the randomly assigned groups.

It should be recognised that performance on the second group task could be affected by prior learning on the first group task.

9.2.2. Data Collection for Individuals

Initially, the author examined the common errors made by individual students when they completed the LOGO tasks. The results are shown in Table 9.1. In summary, the common errors were found to be:

- Misspelt commands: Repeated y misspelling commands such as FORWARD.

- No space between command and size: Frequently omitting the space between a command such as RIGHT and the size of the turn. For example, RIGHT90 was entered instead of RIGHT 90.

- Confused angle size with length of lines: Instead of entering in the commands FORWARD 70 RIGHT 90, the student was inclined to type in FORWARD 90 RIGHT 70.

- Initially used LENGTH and TURN: The student misinterpreted the initial LOGO instructions and tried to use LENGTH 100 to draw a line instead of FORWARD 100. Similarly, the student would type in TURN 90 instead of RIGHT 90 or LEFT 90.

- Very reliant on TASK command: All the students were shown the TASK command to enable them to review the task set. A student with a checkmark in this column had a tendency to use the TASK command every second or third command rather than attempt to remember any details of the task.

- Trouble with REPEAT command: Difficulties with the REPEAT command included continually forgetting to enter the number of times the instructions should be repeated, continually entering REPEAT and the instructions to be repeated on separate lines, and generally not grasping the concept of REPEAT.

- Used commands without size (or with) when not appropriate: A student with a checkmark in this column showed a tendency to type in commands such as RIGHT and then omit to type in the size of the turn. Similarly, the student would type in UP 100 when UP is a command without any parameters.

- Didn't follow directions closely: This was the most frequently made error. A student would not follow the directions in a task explicitly. One example of instructions not being followed, was when the students were asked to draw a shape and finish in the same direction as they started. A second example was when students were asked to draw lines or angles of a specific size.

The final two columns of Table 9.1 are used to record the following:

- No remedial lessons: A student completed all the original lessons successfully, and did not branch to any remedial lessons.

- Showed ability to self correct: A student would notice and correct her own errors without any prompting. An example of this is when the student notices that she has turned the wrong number of degrees and corrects the mistake.

Student	Misspelt Commands	No space between command and size	Confused angle size with length of lines	Initially used LENGTH and TURN	Very reliant on TASK command	Trouble with REPEAT command	Used commands without size (or with) when not appropriate	Didn't follow directions closely	No remedial lessons	Showed ability to self correct	Ranking
Student1									✓		1
Student2									✓		1
Student3		✓					✓		✓	✓	2
Student4								✓			3
Student5		✓						✓		✓	4
Student6		✓						✓			5
Student7		✓						✓			5
Student8				✓				✓			6
Student9	✓	✓						✓		✓	7
Student10	✓		✓	✓						✓	8
Student11	✓					✓	✓			✓	9
Student12	✓	✓				✓		✓		✓	10
Student13		✓	✓	✓				✓		✓	11
Student14		✓	✓			✓	✓	✓		✓	12
Student15	✓		✓	✓	✓			✓		✓	13
Student16	✓	✓		✓			✓	✓			14
Student17	✓	✓		✓	✓		✓	✓			15
Student18	✓	✓	✓	✓	✓	✓		✓			16
Student19	✓		✓			✓		✓			17

Table 9.1 : Common Errors on LOGO Tasks

Student	180 Degrees	Obtuse Angles	Acute Angles	Rectangles	Equilateral Triangles	Hexagons	Parallelograms	Ranking
Student5			Drew 40^0 angle instead of 60^0 angle		USED REPEAT COMMAND	USED REPEAT COMMAND	Tried to use REPEAT Success without it.	1
Student2					Used 60^0 at 1st but self-corrected.	USED REPEAT COMMAND	Failed to used equal sides but didn't copy!	2
Student1					USED REPEAT.		Copied example instead of doing task.	3
Student3							Had problems but tried own solution.	4
Student11				Confused angle size with earlier task.				5
Student4							Copied example instead of doing task.	6
Student13	Used LENGTH and not FORWARD				Forgot last angle.	USED REPEAT COMMAND	Copied example instead of doing task.	7
Student12			Drew 40^0 angle instead of 60^0 angle				Copied example instead of doing task.	8
Student9			Drew 40^0 angle instead of 60^0 angle				Copied example instead of doing task.	8
Student7			Drew 40^0 angle instead of 60^0 angle				Copied example instead of doing task.	8
Student17			Kept drawing wrong size of angle.				Copied example instead of doing task.	9
Student14						NOT ATTEMPTED	NOT ATTEMPTED	10
Student6				Careless mistakes and didn't self-correct.	Careless mistakes.	At 1st used 120^0. USED REPEAT.	Copied example instead of doing task.	11
Student16			Drew 40^0 angle instead of 60^0 angle	Space missing between RIGHT 90.			Copied example instead of doing task.	12
Student8			Drew 40^0 angle instead of 60^0 angle			Didn't end pointing in correct direction.	Copied example instead of doing task.	13
Student18			Drew 40^0 angle instead of 60^0 angle			Confused angle size with size of side.	Copied example instead of doing task.	14
Student10	Used LENGTH not FORWARD	Used 60^0 angle instead of 120^0 angle				Got confused with angle and side sizes.	Copied example instead of doing task.	15
Student15				Didn't end pointing in correct direction.	Didn't end pointing in correct direction.	Didn't end pointing in correct direction,	UNABLE TO COMPLETE	16
Student19	Very confused			UNABLE TO COMPLETE	UNABLE TO COMPLETE	NOT ATTEMPTED	NOT ATTEMPTED	17

Table 9.2 : Performance on Geometry Tasks

After investigating the methods of the individual students who completed the LOGO and Geometry tasks, the author rated each student according to:

- the number of errors consistently made by the student;
- whether or not the student was given remedial lessons; and
- whether or not the student showed the ability to correct her own mistakes.

A student scored minus 1 for every frequently made error, plus 1 for not branching to any remedial lessons, and plus 1 for demonstrating self-correction. After each student wasallotted a "score" the author ranked all students according to their scores and the type of errors that they made. "Careless" errors such as misspelling commands and forgetting to leave a space between a command and the size of the line or turn were deemed to be less detrimental than errors which showed that the student had not understood a particular concept. The final ranking is shown in Table 9.1 with the students Student1 and Student2 of equal rank (with score of 1), and Student6 and Student7 of equal rank (with score of 5).

The author, then examined the reasons why individual students were not successful on their first attempt at a tasks, and investigated whether the students used the repeat command to draw shapes even though there was no revision of this topic in the Geometry lessons. The results of this second investigation on the methods used by individual students are shown in Table 9.2.

The following "patterns" were noticeable for each task:

- Task to draw an angle of 180°: Two of the students reverted to using LENGTH instead of the forward command. This was despite the fact that they had been using FORWARD successfully in the latter part of the LOGO session. One student did not appear to grasp the concept.

- Task to draw an obtuse angle of 120°: One student confused the idea of the internal angle of 120 degrees and the external angle of 60 degrees, and drew an acute angle of 60 degrees.

- Task to draw an acute angle of 60°: Eight of the students drew an acute angle of 40° (which was the angle used in the lesson example) instead of an acute angle of 60°. Seven of the eight students corrected the mistake in the remedial lesson and successfully drew an acute angle of the required size.

- Task to draw a rectangle: There were five students that did not complete this task successfully on the first attempt. Student19 was unable to complete the task at all and did not seem to understand what was required. Student15 forgot to finish with the turtle pointing in the same direction as it started. Student16 forgot the space between the RIGHT command and 90 on the last angle and didn't correct it despite an error message. Student6 made careless mistakes such as spelling

mistakes and forgetting to give the size of an angle. Student11 confused the size of the angle with an obtuse angle of 120°.

- Task to draw an equilateral triangle: There were five students that failed to complete this task successfully on the first attempt. Student19 was again unable to complete the task even at the remedial stage. Student15 made the same mistake as she made when drawing the rectangle and forgot to draw the last angle. Student13 also forgot to draw the final angle. Student6 continued to make careless mistakes but appeared to have grasped the concept of drawing an equilateral triangle. Student2 was confused with the internal angle of 60° and the external angle of 120°, but managed to correct the mistake and avoid the remedial lesson. Two students discovered they could use the REPEAT command to solve the problem.

- Task to draw a hexagon: There were seven students that did not finish this task on the initial attempt. Student19 and Student14 did not attempt this task. Student15 once again didn't finish pointing in the correct direction. Student8 made the same mistake as Student15. Both Student10 and Student18 became confused with the size of the angles and the size of the sides. Student6 first used 120 degrees for the turns instead of 60 degrees, but corrected this and completed the task using the REPEAT command. Three other students used the REPEAT command to draw a hexagon.

- Task to draw a parallelogram: Only one of the 19 students was successful at drawing the parallelogram on the first attempt. Two students did not attempt the task. Student15 was unable to complete the task. Twelve of the students copied the example given with the instructions rather than drawing the parallelogram set in the task. Student3 experienced problems with completing the task but did attempt her own solution rather than simply copying the example. Student2 failed to draw a parallelogram with equal sides but did not copy the example given with the instructions. Student5 tried to use the REPEAT command to draw the parallelogram, and although she failed in her attempt she successfully drew the required parallelogram without using REPEAT.

It is very clear from the above observations that the lesson and task for acute angles and the lesson and task for parallelograms should be revised before being used for another group of students.

For the purpose of ranking the students, the author assigned points. The students lost 2 points for most errors, 1 point if they corrected the error and did not branch to a remedial lesson, and gained 2 points if they used the REPEAT command to draw a shape.

The author ranked the students according to their scores. Where students had an equal rating the author closely examined the nature of their errors and the frequency of their errors and determined whether one student should be ranked above the other. Using this

technique the ranking shown in Table 9.2 was determined. Student12, Student9 and Student7 were ranked equally.

The author allocated a number to each student in Table 9.1 from 1 to 17 (given that there were 2 pairs of students at the same rank). The students were also allocated numbers from 1 to 17 depending on their position in Table 9.2 (again the positions only reached 17 as there were 3 students at the same level). Table 9.3 shows the final ranking of the individual students.

Students in order of final ranking	Average Score from Table 9.1 and Table 9.2
Student2	1 + 2 => average of 1.5
Student1	1 + 3 => average of 2
Student5	4 + 1 => average of 2.5
Student3	2 + 4 => average of 3
Student4	3 + 6 => average of 4.5
Student7	5 + 8 => average of 6.5
Student11	9 + 5 => average of 7
Student9	7 + 8 => average of 7.5
Student6	5 + 11 => average of 8
Student13	11 + 7 => average of 9
Student12	10 + 8 => average of 9
Student8	5 + 13 => average of 9.5
Student14	12 + 10 => average of 11
Student10	8 + 15 => average of 11.5
Student17	15 + 9 => average of 12
Student16	14 + 12 => average of 13
Student15	13 + 16 => average of 14.5
Student18	16 + 14 => average of 15
Student19	17 + 17 => average of 17

Table 9.3 : Case Study Two : Final ranking of students

9.2.3. Data Collection for Random Groups

The students were randomly allocated to six groups. The author calculated the average combined score of the members of each group, shown in Table 9.4.

Group	Members	Average Combined Rank
Group 1A	Student3 Student18 Student5	(1 + 17 + 3) / 3 = 7
Group 1B	Student9 Student6 Student7	(8 + 9 + 6) / 3 = **7.67**
Group 1C	Student17 Student2 Student13	(14 + 1 + 10) / 3 = **8.33**
Group 1D	Student19 Student10 Student1 and Student8	(18 + 13+ 2 + 11) / 4 = **11**
Group 1E	Student12 Student4 Student14	(10 + 5 + 12) / 3 = **9**
Group 1F	Student11 Student15 Student16	(7 + 16 + 15) / 3 = **12.67**

Table 9.4 : Case Study Two : Average Rank of students in Random Groups

The students were given the task of drawing a house by making use of the shapes they had learned during the Geometry lessons. From the exercise that was carried out, it can be concluded that Group 1B and 1F drew very similar houses. However, Group 1B used the REPEAT command and Group 1F did not. Group 1F drew a house using the simplest method. The details of the activities of each of the groups are described in the following subsections.

9.2.3.1. Group 1A

Two of the members of Group 1A performed extremely well on an individual basis. Student3 had only minor errors and did not branch to any remedial lessons. Likewise Student5 had only minor errors, and she made the connection between using REPEAT and drawing shapes with equal sides and angles. The third member of the group (Student18) revealed many errors when completing the individual tasks, and failed to complete three of the individual tasks on the first attempt.

In the group exercise Group 1A drew the house shown in Figure 9.1. The most common error by the group was failing to give the size of a side and the size of an angle with the relevant commands. The only member of the group to make this mistake on individual lessons was Student3.

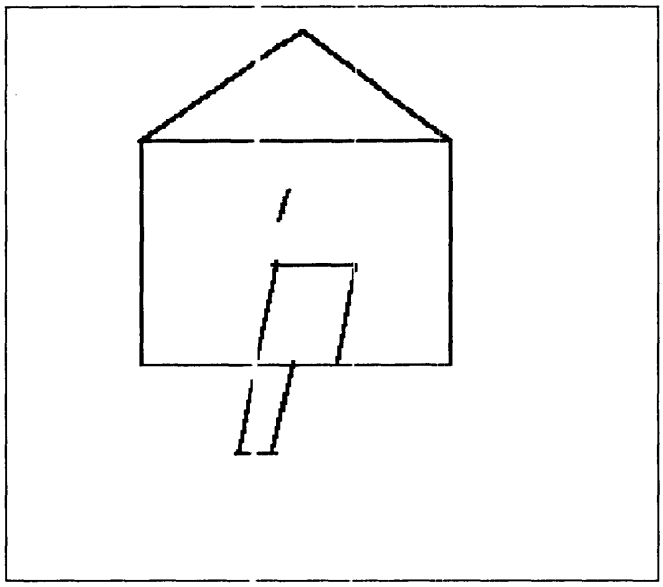

Figure 9. : Group 1A Drawing

The group tended to work by sight as shown by the way the group turned RIGHT and LEFT until the angle looked correct, and the way they moved FORWARD in small steps until they reached the desired length of line. The REPEAT command was not used. The UP command was used successfully, and the group introduced COLOUR.

Overall the students in Group 1A drew a relatively complex house with a door, a path and had started to draw a window.

9.2.3.2. Group 1B

The students who belonged to Group B were found to have very similar levels of ability after the individual tests. Student7 and Student6 were of equal ranking as far as common errors were concerned, and Student7 and Student9 scored equally in the Geometry exercises. Student6 showed a tendency to make careless errors, but managed to work out the connection between drawing a shape with equal sides and angles and the REPEAT command.

In the group session Group 1B drew the house shown in Figure 9.2. The group used the REPEAT command to draw the square. The group used UP to reposition themselves, forgot to type down and had to retrace their steps to draw the roof. After drawing the roof the group appeared to be "lost" and spent some time repositioning themselves by moving and turning the turtle after issuing the UP command.

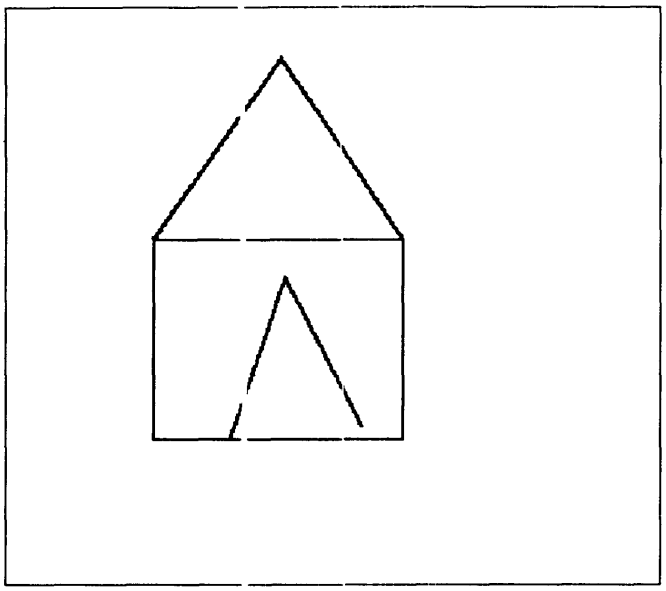

Figure 9.2 : Group 1B Drawing

The group drew a triangle for the door, but whether this was planned or not is difficult to judge.

Although this group had the best score of all the randomly allocated groups there was not a high level of sophistication in the drawing produced. Further investigations with other groups would show whether groups with students at the two extremes of the competency scale performed better than a group of students all at an very similar level of competency.

9.2.3.3 Group 1C

The membership of Group 1C consisted of the highest scoring student from the individual tasks, a student whose score was mid-range and a student with a lower score. Student2 and Student13 both made use of the REPEAT command when completing the Geometry tasks. Student17 initially had many errors in her work but showed a marked improvement when she tackled the Geometry tasks.

The group used the REPEAT command to draw the square of the house as shown in Figure 9.3. Initially when drawing the square they typed in the same size of angle as the size of the sides (100). This mistake was originally only made by Student13. On their first attempt the students in Group 1C misjudged the roof and typed in CLR to clear the screen and start again. The students drew the roof successfully on the second attempt and calculated the angles very well. By the end of the session Group 1C was attempting to draw a chimney.

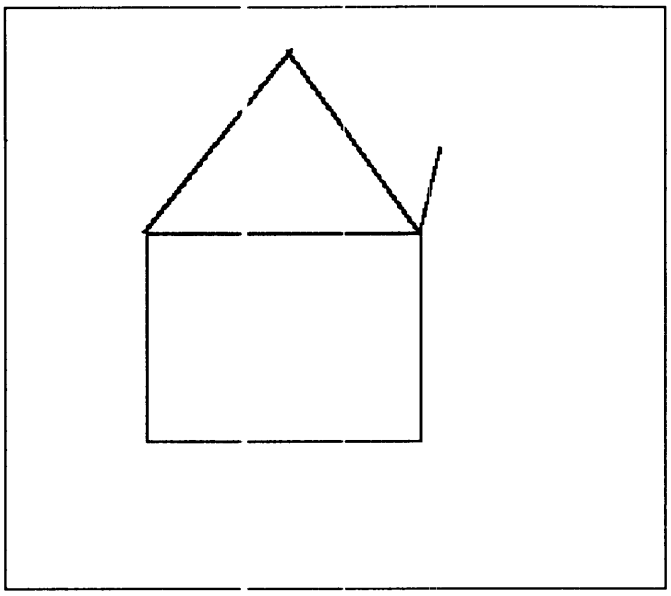

Figure 9 3 : Group 1C Drawing

The group showed the benefit of Student2's membership through the careful drawing of the roof. Although the group cleared the screen and started again they were only marginally behind other groups at the end of the session. The mistakes made during data entry suggest Student13 was at the keyboard.

9.2.3.4 Group 1D

This group was the only randomly allocated group with four members. One of the members was Student19 who experienced many difficulties with the individual tasks, and did not appear to grasp the concepts. Student10 and Student8 had a few frequent errors, with Student10 failing to complete four of the Geometry tasks on the first attempt, and Student8 failing to complete three of the Geometry tasks on the first attempt. Student1 had no frequent errors, used the REPEAT command to draw an equilateral triangle, and only failed to complete one Geometry exercise on the first attempt. Student1 rated second in the individual student scores.

Figure 9.4 shows the house drawn by Group 1D. It is interesting to note that this group used the REPEAT command to draw the roof triangle, and initially made the same mistake as Student1 made in the Geometry task and confused the internal and external angles. As Student1 was the only member of the group to previously use REPEAT in drawing shapes it seems feasible that he suggestion came from her.

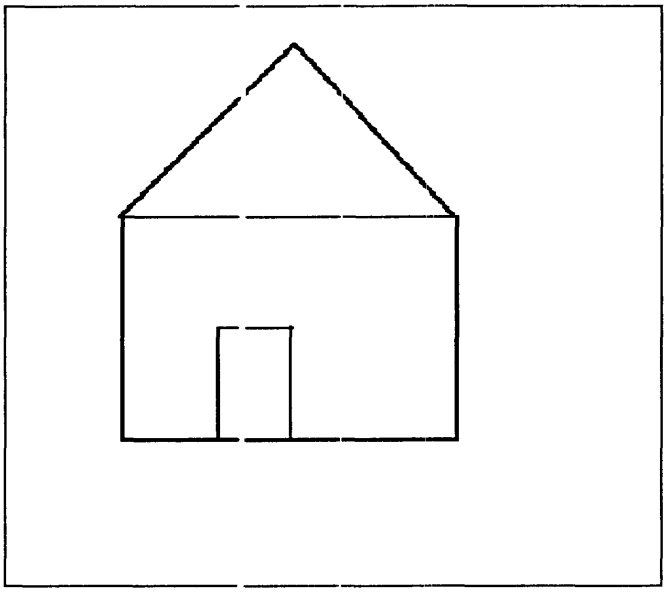

Figure 9 4 : Group 1D Drawing

The group completed the rest of the square in the house with the command with the instruction "REPEAT 3 FORWARD 100 LEFT 90", therefore using REPEAT very effectively. Group 1D made use of the UP command to position themselves for drawing the door, but had to backtrack when they forgot the DOWN command.

Although this was the second lowest scoring group the house drawn was just as involved as most of the others. Student1's influence on the group was very evident.

9.2.3.5. Group 1E

The three members of Group 1E were Student12, Student4 and Student14. Student12 and Student14 made quite a number of mistakes during the individual tasks, whereas Student4 only failed to follow directions closely. Student4 only failed one Geometry task on the first attempt, and Student12 failed two Geometry tasks on the first attempt. Student14 completed the first five Geometry tasks successfully, however she did not attempt the last two tasks of drawing a hexagon and a parallelogram.

Group 1E drew the house shown in Figure 9.5 piece by piece, and in a very careful and well thought out manner. The group became a bit confused when they accidentally moved the turtle "out of bounds" but recovered from this mistake. The students made use of the UP and DOWN commands to trace through their steps before actually drawing them.

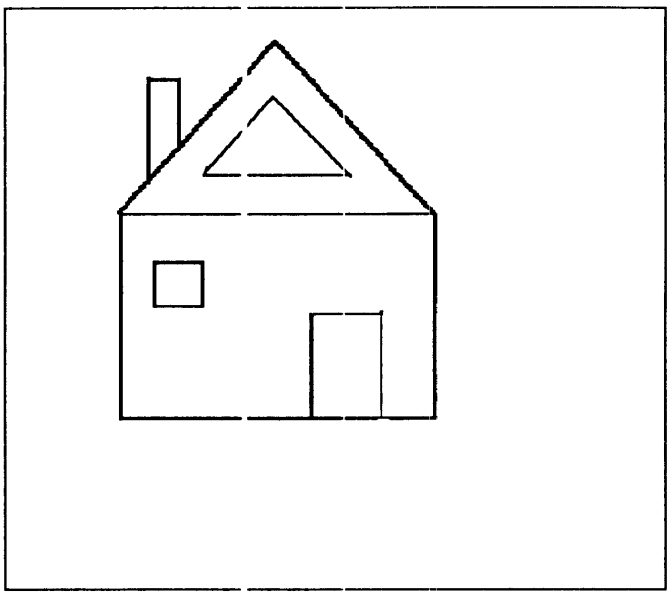

Figure 9 5 : Group 1E Drawing

This group was scored as the middle group, but they drew the most detailed house. It should be noted that although Student4 did not score as highly as some of the other students this was due to the fact that she did not demonstrate an understanding of the REPEAT command (which does not mean she did not know how to use REPEAT). Student14 did not score as highly as she might have in the Geometry exercises as she did not complete two out of the seven tasks. It should be noted that she made no errors in the five tasks she did finish.

9.2.3.6. Group 1F

Group 1F was the lowest rated of the randomly allocated groups. The members of this group were Student11, Student15 and Student16. Student11 displayed an average number of frequent errors, and only failed to complete one Geometry exercise on the first attempt. Student11 was the only student to draw the parallelogram successfully on the initial attempt. Both Student15 and Student16 had many errors in their answers when they completed the individual tasks. Student16 was unable to complete the final Geometry task of drawing a parallelogram.

The most noticeable feature of this group was the use of colour in drawing the house shown in Figure 9.6. Both Student15 and Student16 made use of colour when completing their individual tasks.

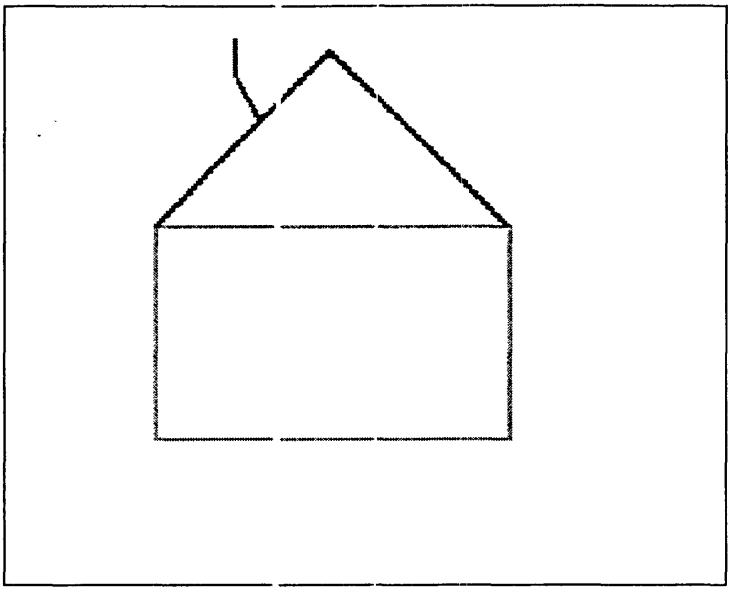

Figure 9 6 : Group 1F Drawing

The group made two attempts at drawing the house. On the first attempt they successfully drew a square and a triangle for the roof, and the students made no use of COLOUR.

9.2.4. Data Collection for Biased Groups

In the final stage of the experimen the students were permitted to select their own groups. The author calculated the average combined score of the members of each of the six groups, shown in Table 9.5.

Group	Members	Rank
Group 2A	Student18 Student19 Student8	(17 + 18 + 11) /3 = **15.33**
Group 2B	Student14 Student16 Student10 Student15	(12 + 15 + 13 + 16) / 4 = **14**
Group 2C	Student5 Student4 Student7	(3 + 5 + 6) / 3 = **4.67**
Group 2D	Student11 Student13 Student1	(7 + 10 + 2) / 3 = **6.33**
Group 2E	Student3 Student2 Student6	(4 + 1 + 9) / 3 = **4.67**
Group 2F	Student17 Student12 Student9	(14 + 10 + 8) / 3 = **10.67**

Table 9.5 : Case Study Two Average Rank of students in Biased Groups

9.2.4.1. Group 2A

The members of this group were Student18, Student19 and Student8. Student18 and Student19 were the two lowest scoring students after the individual tasks. Student8 made only minor errors but failed to complete three of the Geometry tasks on the first attempt. None of the three students demonstrated any comprehension of the REPEAT command. Student19 and Student8 were in Group 1D together. Student18 was in Group 1A. There was no evidence of any ideas from the randomly allocated groups being used in the biased group.

Initially Group 2A started by drawing a rectangle and then decided this was not the way they wished to go about the task and cleared the screen. On their second attempt the students created the drawing a ship shown in Figure 9.7, and then they once more cleared the screen. On their third attempt Group 2A produced the drawing of a ship shown in Figure 9.8. The students experienced difficulties with angles and would change the angle as many as five times in a row as shown by the following extract:

"RIGHT 40 RIGHT 200 RIGHT 30 RIGHT 180 RIGHT 30"

Overall, Group 2A seemed to be confused by the task set.

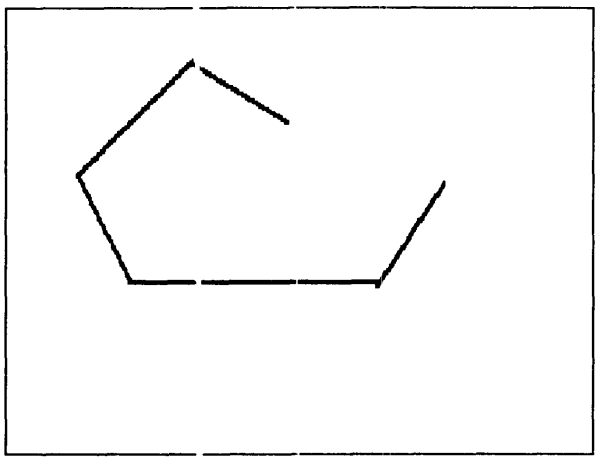

Figure 9.7 : Group 2A Drawing - 2nd attempt

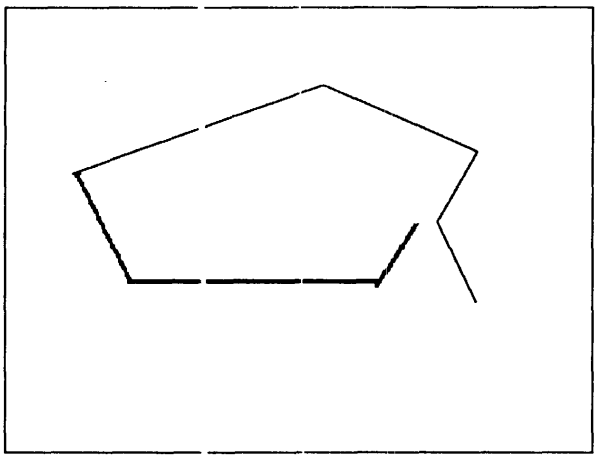

Figure 9.8 : Group 2A Drawing - 3rd attempt

9.2.4.2. Group 2B

Group 2B was the four member group of the biased grouping. The four members were of a similar level of ability at the lower end of the scale. Student16 and Student15 were in Group 1F during the random group session. Student10 had been in Group 1D, and Student14 in Group 1E.

The group had five attempts at drawing a ship. In the first four attempts the students had difficulties drawing the angle between the side and the bottom of the ship. Figure 9.9 shows the results of the students first four attempts.

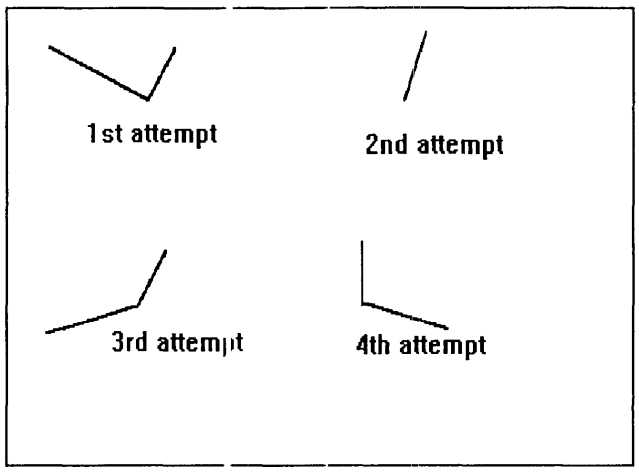

Figure 9.9 : Group 2B - early attempts

Finally the group decided to abandon the idea of drawing a conventional ship and drew a raft as shown Figure 9.10. The raft was drawn with the care and attention to detail previously shown in Group 1E.

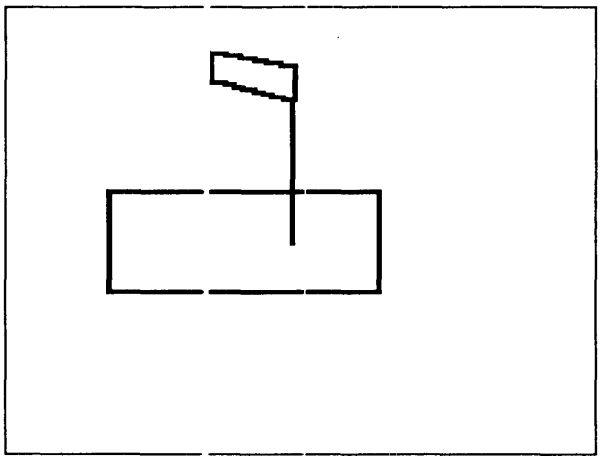

Figure 9.10 : Group 2B Drawing

9.2.4.3. Group 2C

Group 2C like the previous group contained students with a similar level of ability, but in this instance at the higher end of the scale. Student5, Student7 and Student4 had been the highest scoring individual members of the random groups Group 1A, Group 1B and Group 1E.

The students created the drawing shown in Figure 9.11. The group carefully drew each step, drawing the triangle for the sail first, and using the UP command to position themselves for drawing the mast. Group 2C calculated the angles very well in drawing the

bottom half of their ship. The style used was reminiscent of Group 1A and Group 1E, the groups Student5 and Student4 belonged to in the first group session.

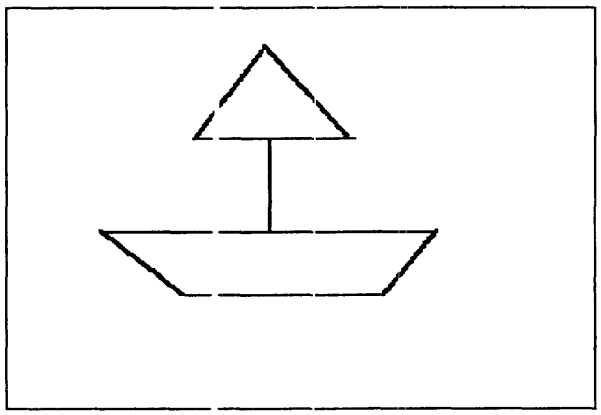

Figure 9. 1 : Group 2C Drawing

9.2.4.4. Group 2D

The members of Group 2D were Student11, Student13 and Student1 who were in the randomly allocated groups 1F, 1C and 1D. The individual tasks showed these three students to be at quite different levels of ability with Student1 having a high score, Student11 a mid-range score, and Student13 a lower score.

On the group's first attempt at drawing a ship they started off by drawing a rectangle, but abandoned this idea. The students typed in CLR to clear the screen and drew the ship shown in Figure 9.12. Group 2D would turn several times until an angle looked correct, and moved forward gradually unit the line was the correct length. On occasions they turned LEFT instead of RIGHT and had to correct themselves. The group used the UP command to reposition themselves for the sail, and judged the angles in the sails very well.

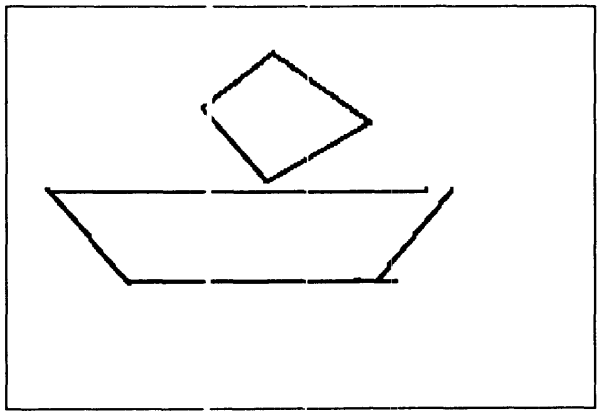

Figure 9.12 : Group 2D Drawing

The group's method was similar to Group 2C, but the students in Group 2D did not demonstrate the same level of accuracy.

9.2.4.5. Group 2E

The students in Group 2E were Student3, Student2 and Student6. Student2 rated very highly in the individual tasks. Student3 made a few minor errors, but did not use REPEAT when completing the Geometry tasks. Student6 also made minor errors, and continued to do so throughout the Geometry exercises. Student6 failed to complete three of the Geometry tasks on the first attempt, but made use of the REPEAT command to draw a hexagon. The students were in the randomly allocated groups Group 1A, Group 1B and Group 1C. Group 2E's drawing of a ship shown in Figure 9.13 was the most "traditional" ship.

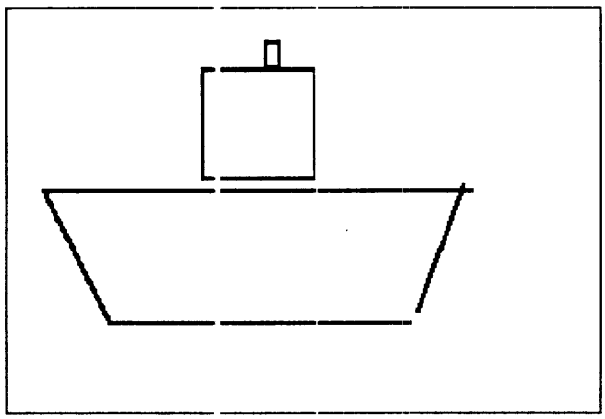

Figure 9. 3 : Group 2E Drawing

During the group session Student3's mistake of not leaving a space between the command and the size was noticeable. The students used a series of FORWARD commands until they were happy with the length of a line. During the group session the group used the UP command was used to position themselves to draw one side of the ship, and the square on the top. The square was created using the REPEAT command. The funnel was a rectangle.

9.2.4.6. Group 2F

The members of Group 2F were Student17, Student12 and Student9. All three students were prone to repeated errors, especially Student17. Student12 and Student9 had the same score for Geometry lessons. Student 17 was of a very similar level of ability with the exception that she had difficulty with the instruction to draw an acute angle of 60 degrees. The students were in the groups Group 1C, Group 1E and Group 1B in the previous group session.

None of the students used the REPEAT command to draw shapes when completing the individual Geometry tasks. However, Group 1B and Group 1C made use of REPEAT and Student17 and Student9 belonged to these groups. The students transferred this knowledge into the biased group by using REPEAT to draw the bottom of the ship. Group 2F made use of the UP command to test possible steps before actually drawing the lines. The students compensated for having drawn the ship on a slant by drawing a wave.

Group 2F drew the most detailed ship drawing which is shown in Figure 9.14.

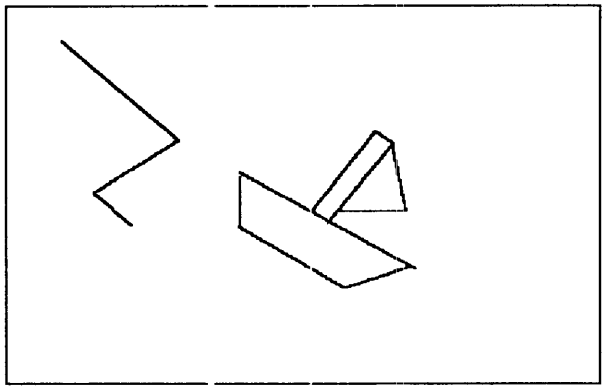

Figure 9.14 : Group 2F Drawing

9.3. Conclusion

The interaction between students with different levels of ability and students with the same level of ability, was examined. It appears that students generally benefit from working in groups, as it helps to correct inefficient/incorrect modes of thought, and presents them with alternative solutions.

The most noticeable pattern in the randomly allocated groups of students was the problem solving strategy of each group was very similar to the problem solving strategy of one particular student in the group. It is notable that this student was not necessarily the highest ranking student (from the individual tasks) in the group. The members whose problem solving strategies were prevalent in the groups were:

Group 1A: Student3
Group 1B: Student6
Group 1C: Student13
Group 1D: Student1
Group 1E: Student4
Group 1F: Student11

When one examines the best random group results in terms of the intricacy of the house drawing, and the most efficient methods used, the order of the groups matches the order of the highest ranking student in the individual task assessment. The intricacy of the house drawing was judged by the level of detail; whether or not colours were used appropriately; and the accuracy of the drawing.

In two of the biased groups (2B and 2C) students with very similar levels of ability grouped together. In the biased groups any dominance of one particular student was not discernible. In fact, student showed a greater tendency to try different ways of solving the problem (drawing a ship), demonstrated by groups 2A, 2B and 2D. The way these groups solved the problem indicates there was discussion of different methods of solving the problem.

Group 2C showed a merging of group 1A and 1E problem solving strategies. Student5 and Student4 came from these groups, with Student4 appearing to be the dominant student in group 1E. Group 2E also showed parts of the individuals problem solving strategies in the group's strategy.

In group 2F none of the students had attempted to use the REPEAT command when they completed the individual tasks. However, two of the students (Student17 and Student9) used REPEAT in the random groups and brought this knowledge into the biased group.

In the biased groups it is not very obvious that the performance of each group is dominated by any one individual within each of the groups.

In conclusion, this small population of students showed that if the students were free to choose their own groups there appeared to be greater cooperation and discussion amongst the students. However, there were limitations from working with such a small population of students and the following factors must be considered:

- the biased groups performed better than the random groups because the students in the biased groups could have built on their experience from completing the house drawing task; and
- information is always shared more readily in biased groups than in random groups.

Chapter 10

Comparative Studies

10.1. Introduction

In this chapter the author discusses the characteristics of effective CAI and how the characteristics can be used to evaluate the components of the CAI system developed. The author's system is evaluated in terms of these characteristics, and compared with a commercial system designed to teach students anatomy. The author examines the design of the LOGO lessons in "LOGO Works: Lessons in LOGO" (Cory and Walker, 1995) the manual used by the Chapel Hill and Carrboro City Schools, USA, for their LOGO and Geometry curriculum. The design of the lessons in the author's system are compared with the design of the lessons in "LOGO Works".

10.2. Comparative CAI Study

The successful designer of instruction capitalises on the strengths of the selected medium (Hannafin and Peck, 1988). Following is a list of criteria which are considered to be the strengths of CAI and can be used to measure the effectiveness of CAI:

- Flexibility of the system:

  It is possible for a CAI system to be flexible enough to be used across a wide range of ages and ability levels. A CAI system that is informational at one grade might be remedial at another.

  CAI systems can occasionally be used in more than one way. For example, a single CAI system may be used to practice a previously taught concept, be used primarily for instruction in a new topic, or be used for problem solving.

  Some CAI systems allow the teacher to adapt the teaching material.

- Quality of directions:

  Lessons that indicate to a student where they are going and what is expected of them generally produce higher achievement levels than lessons that do not. Behaviourally stated objectives that are shown to the student at the beginning of a lesson act as organisers and have found to be related to student achievement (Simonson and Thompson, 1990). Objectives help the student by clearly defining the topic. The student's attention is then focused more intensively on attainment of the specified topic.

  The concepts and terms used in lessons should be correct, clear and concise. Directions can be as simple as "Press ENTER to continue ..." or as sophisticated as "solve the problem using the following steps ...". Overall, the content, terminology and teaching style should be consistent with those generally encountered by the student. The reading level must also be appropriate for the target audience. If vocabulary or sentence structure is too difficult, learning may not take place. If, on the other hand, vocabulary and sentence structure are too simplistic for students, the lesson may be viewed as condescending (Hannafin and Peck, 1988).

- Quality of screen design:

  Student attitudes are important. If students do not like the instruction they receive, they are less likely to subsequently use and benefit from CAI lessons. With this is mind the CAI lessons must be well presented.

  Recently, considerable research on screen design has been reported, and more is underway (Simonson and Thompson, 1990). Screen design is a critical component of a computer lesson. If design is haphazard, then learning will be affected.

  Word, graphics and space are the three kinds of "information" on a computer screen. Generally, all are used in effective screen design. Graphics should be designed according to the level of realism required.

  Usually, it is best if one topic is represented on one screen at a time. Simpler is better. Multiple topics shown on one screen have a tendency to confuse. On the other hand, if topics are closely related, then it may be desirable to repeat portions of one screen when a new topic is presented.

  The screen should provide orientation information to the student. Lesson section titles can be used. Good screen formatting is essential. There should be good

spacing, text should not roll off the screen, and "flashing" displays should be avoided. Important facts should be highlighted, for example in capitals.

Since the resolution of a computer screen is lower than for a page of a book, extra care must be taken to ensure readability. Firstly, writing should be simple and to the point. Secondly, upper and lower case lettering should be used as it is easier to read. Thirdly, justified right margins should be avoided as ragged right margins show up better on computer screens. Fourthly, shorter rather than longer lines are best. Finally, one letter size should be used for all text.

- Quality of responses:

The immediacy of feedback provided by CAI is difficult if not impossible to replicate in other media. Most answers can be evaluated instantaneously and CAI systems should take advantage of this fact.

The acknowledgment of correct answers is one technique identified by both research and theory as important (Simonson and Thompson, 1990). The student should have correct answers reinforced in a positive manner. It is also important to give clues to the student when an incorrect answer is given.

Responses should positively reinforce what was right about an answer and should give the student directions about how to correct what was wrong with the answer. If the student has not learned, additional instruction should be provided.

Responses to incorrect input should be neutral. The tone of an effective CAI lesson should approximate a conversation between a tutor and a student in a one-to-one session.

The student should not be penalised for making errors. One reason many students enjoy CAI is that they perceive it as a comfortable, non-threatening medium (Hannafin and Peck, 1988). Mastery-based lessons, where the emphasis is on reaching specified performance levels without penalty for time taken can do much to sustain the non threatening nature of CAI.

- Level of student interaction and control:

The attribute most often credited as attributing to the effectiveness of CAI sessions is interaction. In CAI, progress through the lessons is directly related to student input. In an interactive program student input is used to indicate when a lesson is understood by the student and therefore when the program should move to the next topic. If the student is distracted the computer waits patiently. If the student has not learned, remedial instruction can be provided. Effective CAI

lessons encourage appropriate interaction in order to solicit and maintain student involvement (Hannafin and Peck, 1988).

The student can control when to proceed, whether to obtain instruction and the level of instruction required.

The student must be aware when to give input and what form of input is needed. Input locations on the screen should be standardised throughout the program.

- Self-contained or need for external information:

Generally, the more self-contained the CAI program, the better it is. With self-contained programs it is possible to have several students studying different topics with little or no supervision.

Many CAI lessons are developed for schools and are used by individual students in standard classroom environment while the teacher and other students are engaged in other activities. Consequently, the lessons must require minimal involvement on the part of the teacher, and the student must be able to start the lesson and complete it without assistance. Data on student performance should be recorded by the program so that the teacher may evaluate it later. Lessons should be modular and should allow the student to resume the lesson with minimal redundancy following interruptions.

- Suitable for use by individual students or small groups:

One important aspect of CAI is that it tends to be individualised. Students proceed through learning activities by themselves, at their own pace. Advocates of mastery learning principles have demonstrated the "90/90 Rule", which states that 90% of students can learn 90% of what is important about any topic, given adequate time (Simonson and Thompson, 1990). Research has tended to support this idea. In classroom situations a uniform pace must be set. This pace is too fast for some and too slow for others. Individualised instruction eliminates this problem.

Some CAI systems are also suitable for use in small groups. Working in groups fosters competition and cooperation between the students. Competition between students or between a student and the computer is generally motivating. The need for cooperation among students when they complete a task together is also desirable.

- Collection of student performance data:

Another characteristic of effective CAI is assessment (Simonson and Thompson, 1990). Students should be assessed during and at the conclusion of lessons.

Testing in each segment of the program gives the student feedback about how well the lesson is being completed and is helpful to the teacher. The collection of student performance data can verify that instruction and learning actually took place.

Less obtrusive assessment can also be taken. Student response times can be monitored to determine if information is easily understood or if students must "think things through" before answering.

The one-to-one nature of CAI makes it possible to monitor student understanding constantly and to respond based on the needs of each individual student (Hannafin and Peck, 1988).

The computer's ability to store and manipulate relatively large amounts of data can be utilised to simplify interpretation of student performance over time, and to compare performance among students and among groups.

- Quality of testing student performance:

When testing student performance the tasks set should be directly related to the objectives set, and should measure the student's ability to respond in the specified manner. The tests will have to be interpreted correctly by a variety of students. Therefore the tests should contain the same vocabulary as the lesson, and should clearly specify the action the student must take.

CAI should look for three types of answers, namely: correct answers; incorrect answers; and, unanticipated answers (Hannafin and Peck, 1988). When an unanticipated answer is received, the CAI system should inform the student that the answer had not been expected and ask the student to revise the answer. This is preferable to treating an unexpected form of the correct answer as if it were incorrect.

Finally, a student's inability to spell should not be confused with his/her inability to provide the correct answer.

The above criteria can be used to evaluate the effectiveness of the three main components of the extendible CAI system: Lesson Component; Student Monitoring Component; and the Human-Computer Interface Component (c.f., Section 3.3). Table 10.1 summarises which components of the extendible CAI system are evaluated by the criteria used to measure the effectiveness of a CAI system.

Criteria	Extendible CAI system component
Flexibility of design	Lesson Component
Quality of directions	Lesson Component
Quality of screen design	Human-Computer Interface
Quality of responses	Human-Computer Interface
Level of student interaction and control	Human-Computer Interface
Self-contained or need for external information	Human-Computer Interface
Suitable for use by individual students or small groups.	Human-Computer Interface
Collection of student performance data	Student Monitoring Component
Quality of testing student performance	Student Monitoring Component

Table 10.1 : Relationship between criteria and system components

The criteria were used to compare the extendible CAI with the Bodyworks CAI system developed to teach students anatomy. Bodyworks was chosen as it is a professionally developed CAI system that is suitable for use by 10 - 11 year old students in a classroom environment.

Bodyworks allows the student to study the human anatomy by viewing a large database of anatomical drawings. The CAI system provides lessons on different internal systems of the human body such as the skeletal, muscular and cardiovascular systems. The student selects which internal body system he/she wishes to work on by selecting the appropriate button at the top of the screen.

Lessons and the associated tests are separated into two different modules. In Bodyworks, the student may complete all the lessons and ignore the tests (called quizzes). There are ten multiple choice questions associated with each internal body system. The ten questions are fixed questions and the student can improve his/her score by answering the set of questions quicker each time he/she attempts them. The system keeps a record of the "champion" for each set of ten questions.

The lesson screen is divided into four main areas. The first area is the picture view box which displays the anatomical drawing. The second area is the item list with topics relating to the current drawing. The third area is the text for the current topic, and the fourth area is the control buttons. Figure 10.1 shows the lesson screen layout for Bodyworks.

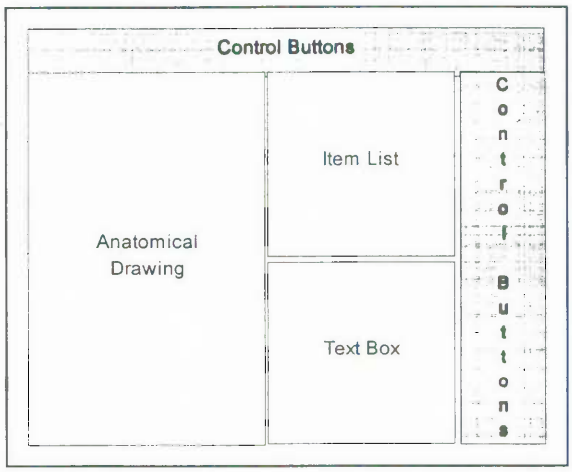

Figure 10.1 : Bodyworks Lesson Screen Layout

Other features of the Bodyworks CAI system include:

- an image list which is an index of all the pictures in the system;
- a speech option to help the student with the pronunciation of certain words;
- a backtracking option which allows the student to backtrack along his/her line of exploration;
- a bookmark function that allows the student to place "bookmarks" throughout the system so he/she can return to a particular lesson screen directly; and
- several "movie" sequences which demonstrate items such as the beating of the heart, and the blinking of an eye.

The results of comparing the extendible CAI system with the Bodyworks CAI system are given in Table 10.2.

Criteria	Extendible CAI system designed to teach LOGO and Geometry	Bodyworks CAI system designed to teach anatomy.
Flexibility of design	Suitable for use with a range of different age groups from upper primary school to lower secondary school students. Can be used for teaching or for class projects. Teachers can add to the teaching material or alter the existing teaching material.	Suitable for use with a very wide range of age groups from older primary school students to adults. Anatomical drawings can be exported. Tests questions are fixed and new questions can not be generated.
Quality of directions	Every lesson has a title screen which displays the topic about to be covered. Lesson and task directions are very explicit. To view the next screen the student can press any key. Students can review the task that has been set by typing in a command. To discontinue a task, the student types in STOP. Every lesson includes an example, and a demonstration of the picture drawn by the system when the particular code is processed.	Lesson topics are selected by the student via control buttons, or item lists. Bodyworks has a speech option to pronounce certain words for the student. There is a very small set of commands required to view lessons. They include the command to proceed to the next lesson, the command to backtrack to the previous lesson and the command to discontinue with the lessons. Similarly, the student may "surrender" a question if he/she does not know the answer, or may discontinue the test.
Quality of screen design	The amount of information on each screen that the student must absorb has been kept to a minimum. The same layout has been used for every lesson and task (c.f. Figure 4.2). Students can proceed through the instruction at their own pace. Important information has been emphasised by the use of capitals.	Bodyworks has a very high quality of detailed graphics. The same layout is used for every lesson (c.f. Figure 10.1). The multiple choice questions all have the same format with an option of 4 answers for every question. Students proceed through instruction at their own pace. Important information is highlighted, and if selected a more detailed explanation is given.

Table 10.2 : Comparison of two CAI Systems

Criteria	Extendible CAI system designed to teach LOGO and Geometry	Bodyworks CAI system designed to teach anatomy.
Quality of responses	Spelling mistakes, forgetting to leave a space between a command and a parameter, or forgetting to give the length of a line or the size of a turn are errors which are responded to immediately. This gives the student the opportunity to correct such mistakes and continue with the task without any penalty. Lessons include a list of explanations relating to the common errors that are made. When the student has completed a task the system checks the student's response with the set of expert solutions to the tasks. If the student's answer is incorrect, the system displays relevant error messages, reinforces the correct portions of the student's answer, and demonstrates the expert's solution to the problem.	The student selects the test (quiz) topic. There is a set of 10 questions for each topic, and the same questions are asked every time. The time taken to answer the question is recorded and the possible score for obtaining the correct answer drops as the time taken lengthens. The student receives immediate feedback as to whether his/her answer to the multiple choice question is right or wrong. If the answer is incorrect the student is told the correct answer.
Level of student interaction and control	High level of student interaction. The student can chose to complete full lessons, do an activity or explore on their own. The stucent decides when to leave a topic, and proceed to the next lesson. Input is via LOGO commands and students are gradually introduced to more complex commands as they proceed through the lessons. When students have completed the LOGO lessons and are working in the Geometry lessons, the system still displays error messages relating to any LOGO command mistakes.	Students select which topic they wish to view next through control buttons and item lists. Students can review any topic or discontinue lessons at any time. The students can choose whether or not they wish to do tests, and the topic of a test. Questions are multiple choice and are answered by indicating the correct anatomical drawing, or selecting one of four possible answers.

Table 10.2 : Comparison of two CAI systems (Cont...)

Criteria	Extendible CAI system designed to teach LOGO and Geometry	Bodyworks CAI system designed to teach anatomy.
Self-contained or need for external information	Self-contained. Student performance data is collected, and can be viewed by the teacher at a later time. Lessons are modular, although later lessons depend on earlier lessons having been completed and understood.	Self-contained. Student performance data limited. Student "competes" with current champion to better the champion's score. Lessons are modular and one section does not depend on another section having been completed.
Suitable for use by individual students or small groups	Students complete instruction and tasks at own pace. Level of task is dependent on whether an earlier task on the same topic was completed unsuccessfully. The system lends itself to group activities as demonstrated by the two case studies.	Students can complete lessons at own pace. However, the score a student gains during a test is dependent on the time they take to answer the questions. Level of questioning is not individualised. Capacity for group activities are very limited.
Collection of student performance data	Detailed student performance data is collected, which may be reviewed by the teacher at a later time.	Not available.
Quality of testing student performance	Tasks use the same vocabulary as used in the instruction. The student's answer is compared with a set of expert answers. There is usually more than one correct answer.	Tests are multiple choice and are simply right or wrong.

Table 10.2 : Comparison of two CAI systems (Cont...)

In summary, the Extendible CAI system was stronger than the Bodyworks CAI system in the following areas:

- flexibility of design;
- quality of responses;
- level of interaction and control;
- suitable for use by individual students or small groups;
- collection of student performance data; and
- quality of testing student performance

The Extendible CAI system was weaker than the Bodyworks CAI system in the following area:

- quality of screen design.

The two CAI systems were of comparable levels in the following areas:

- quality of directions; and
- self-contained or need for external information.

In comparison the Lesson Component and Student Monitoring Component of the extendible CAI compared favourably with the commercially developed CAI system. The Human-Interface component of the extendible CAI system was weaker than the Bodyworks CAI system only in terms of the screen design.

10.3. Comparative Study of Lesson Design

In this section the author compares the computerised LOGO lessons with a recently written text book of LOGO lessons. This text book was chosen as the author wished to compare the lessons in the Extendible CAI system with proven LOGO lessons readily available to teachers.

The "LOGO Works, Lessons in LOGO" (Cory and Walker, 1995) manual was developed by the computer coordinator and faculty members of the Chapel Hill and Carrboro City Schools, USA. The manual contains forty-seven (47) lesson sets which can be used by the teacher to teach LOGO and Geometry to their students.

Initially a set of prototype materials were developed and used by the students. The teachers provided feedback about where more information was needed, and the lessons were revised and expanded to meet their needs.
Each set of lessons in the manual introduces the student to a new topic or aspect of a topic, provides several activities so that the students can practice the new concept, and finally provides an exploration exercise to encourage the students to discover for themselves.

An example of a lesson set from the manual is the lesson introducing REPEAT. The lesson reminded the student that to draw a square with sides of 50 "turtle steps" the student had repeated the commands FORWARD 50 RIGHT 90 four times. The lesson then explained that the same results could be achieved by using the command REPEAT 4 FORWARD 50 RIGHT 90.

There were three to six activities given for each lesson in the manual. The introduction to REPEAT offered six activities as follows:

- Using REPEAT to make a square with sides of length 25.
- Using REPEAT to make several squares of different sizes.

- Using REPEAT to make a square with sides of length 30 and turns to the right, then drawing a second square with sides of length 30 and turns to the left.
- Creating a four-square court as shown in Figure 10.2.
- Predicting the results and then trying the command REPEAT 3 FORWARD 50 LEFT 90.
- Predicting the results and then trying the command REPEAT 4 FORWARD 65 BACK 20 RIGHT 90.

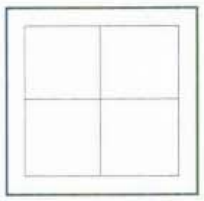

Figure 10.2 : Four-square court

The exploration for the introduction to REPEAT involved creating the "stage" shown in Figure 10.3, using the UP command to prevent the turtle from drawing and repeat a series of given commands to make the turtle do a "dance" on the stage. The students are then asked to create their own dances for the turtle.

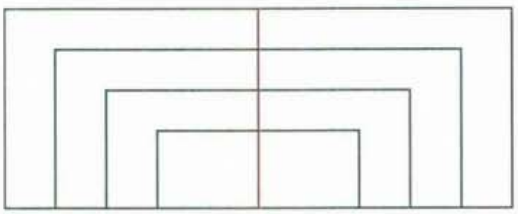

Figure 10.3 : Turtle Stage

In comparison, the CAI system also uses the concepts of presenting some instruction, giving the student a well defined activity to complete (a task), and offering the opportunity to complete an "open-ended" exercise.

In the CAI system the student also has the opportunity to freely explore, with the system only prompting the student if he/she makes a syntactical error in the LOGO commands.

10.4. Conclusion

The CAI developed was compared with the "Bodyworks" CAI system. In summary, the following conclusions can be drawn. Firstly, "Bodyworks" has a high quality of graphics, whereas the CAI system developed has a greater depth of student testing, and better responses to student behaviour. The "Bodyworks" system did not collect any student performance data. Some of the differences between the two systems was due to the

subject matter which causes a greater emphasis to be placed on one attribute rather than another.

Secondly, the structure of the lessons in the CAI system compared favourably with the comprehensive set of LOGO lessons in the manual developed for a school district in the USA.

Chapter 11

Conclusion and Future Directions

In this chapter, the author will attempt to summarise this thesis and provide an outline of possible research directions that need to be addressed in the future. In doing so, the author will initially outline the research aims addressed in this thesis in Section 11.1. Following this, the author will describe the major achievements of this thesis and how it was attained in Section 11.2. In Section 11.3 the author will conclude this thesis by identifying limitations of the developed CAI system and suggest appropriate research directions to take in the future to address some of these limitations.

11.1. Research Aims

The research aims of thesis were as follows:

- identify suitable teaching strategies for teaching LOGO programming concepts and Geometry concepts;
- identify techniques for organising and presenting instructional material to promote learning;
- collect student performance data to help the teacher study the learning abilities of individual students and groups of students;
- implement a means of comparing the student's answer to a task with the set of expert solutions for the task and consequently detect common errors and misconceptions; and
- design a suitable human-computer interface between the student and the system, and a suitable human-computer interface between the teacher and the system.

To achieve the above aims the author designed and implemented an extendible CAI system for which some case studies and comparisons were undertaken to demonstrate and evaluate its capabilities.

11.2. Major Achievements

The major achievements of this thesis are as follows:

- development of an extendible CAI system which can be used to teach the LOGO programming language and Geometry; and
- demonstration of the CAI system as a means of collecting data on individual students and small groups of students to help the teacher investigate learning abilities and the student's misconceptions.

The developed CAI system has the following capabilities:

- highly flexible design where the system can be used for a range of different age groups. It can be used for teaching or class projects, and it can be used by teachers to add to or alter existing teaching materials;
- ability to handle high fault tolerance in dealing with user responses;
- high level of student interaction with limited control of lesson sequencing;
- suitable for use by individual students or small groups of students;
- ability to record relevant data that could be used by the teacher to study the learning process of the students;
- ability to accept a variety of correct solutions to the same task; and
- to enable the students to learn by free exploration once they have completed learning LOGO and Geometry.

This CAI system also has the following features:

- uniform and flexible structure for presentation of teaching material;
- uniform screen layout; and
- the system does not require additional medium such as books and manuals to help the student during the learning process.

To achieve the above, research was carried out in identifying suitable teaching strategy and appropriate teaching tactics suitable for teaching LOGO and Geometry concepts. A tutoring teaching strategy was selected to teach the students new material. The teaching tactic used by this strategy monitors the student's progress and adjusts the sequence of instruction accordingly. New concepts are presented only when the student has been tested on the previous concept and appears to understand the previous concept. If the student does not understand a concept remedial instruction is given. Discovery learning strategy was also incorporated into the CAI system. This teaching strategy provides the students with an opportunity to explore and discover the solutions to problems by themselves.

To implement the above teaching strategies the author identified, developed and evaluated appropriate techniques for:

- organising and presenting instructional material in tutoring teaching strategy;
- monitoring student progress;
- identifying correct and incorrect answers in tutoring teaching strategy; and
- human-computer interface between the student and the CAI system, and the teacher and the CAI system.

There were two case studies undertake to demonstrate the CAI system's potential for teaching and its ability to record data for research purposes. The number of students in each case study was too small (26 and 19, respectively), to make any accurate judgements but the case studies did serve to illustrate the quality and quantity of data that is collected.

The objective of the first case study was to identify the level of effective understanding of the subject area by students that are categorised as serial thinkers, and those that are categorised as parallel thinkers. The first case study also demonstrated the type of data that can be collected by the CAI system.

The objective of the second case study was to determine if there is any discernible differences in student performances when the students form groups of their own choosing instead of groups determined on a random basis. The study found that there was a greater degree of cooperation and discussion of methods in the biased groups.

The overall achievements outlined in this section demonstrates the successful achievement of the objectives of this thesis (c.f., Section 1.2).

11.3. Future Directions

Even though the author has successfully developed a CAI system and demonstrated its capability for data collection for research purposes, there are many areas that can be improved in this system. Some of the future enhancements for the CAI system that one may consider are as follows:

Firstly, the CAI system could be improved by giving the student the option of viewing a list of completed lessons, and allowing the student to repeat one or more lessons. A further extension of this facility would be to allow the student not only to repeat a previous lesson but also to view his/her last answer to the lesson task. In other words, give more control to the students.

Secondly, there is always the possibility that a student will answer a task correctly, but the particular solution has not been entered as an expert solution. To be told that he/she has an incorrect answer is at best confusing for the student and at worst case the student to lose confidence with the system. A more appropriate response may be that the system does not recognise the student's answer and asks him/her to revise it.

Thirdly, the system offers a limited number of lessons and only one task per lesson. The students can choose to complete extra activities relating to a topic by selecting to do exercises instead of a lesson. However to make this selection the student must exit from the system and re-enter. A more appropriate point to make this choice would be at the end of each lesson. The system could ask the student if he/she wishes to continue with the next topic or do some more exercises on the current topic.

Finally, over a period of time a library of exercises could be provided for the teacher. The teacher could build a full lesson around an library exercise if desired.