HIGHER ORDER THINKING SKILLS IN A SCIENCE CLASSROOM COMPUTER SIMULATION

by

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Argumentation, computer instruction, computer simulations, critical thinking, higher order thinking skills, scientific reasoning, secondary science, senior biology, social construction
Abstract

Education is rapidly moving away from the instructional models of the 19th century and educationalists are now asserting that not only do students need to be able to learn by rote but also to be able to think in a more profound and complex manner. Students are required to develop new processes to handle the rapidly changing world that they are expected to take part in as they complete their formal learning.

This change is evident in all the developed nations and Australian students are finding that they are being asked to demonstrate a range of higher order thinking skills in all their school subjects.

Science courses in Queensland require students to be assessed on both complex reasoning and scientific process skills. Studies have shown that students can develop these skills in a number of ways that include the exposure to appropriate open-ended hands-on tasks. As higher order thinking skills underlie the development of both complex reasoning and scientific process, it is important that science educators take appropriate steps to facilitate the development of this level of thinking.

This study examined the use of some higher order thinking skills by students using Information Technology in their science classroom. It investigated the degree to which students used their higher order thinking skills when engaged in a computer simulation of a complex science task.

The study involved two pairs of Year 9 students, one pair each from the upper and lower quartiles of the year level, in a private Years 4 to 12 boys’ school in an inner Brisbane suburb. All students had been immersed in Information Technology in Years 4 to 8 as part of a technology-across-the-curriculum project for all year levels in the school and at the time of the study were at the end of their second semester in
Year 9. Students had worked with a large number of computer applications in all their subjects, averaging about one lesson in the computer room per day across all their subjects for the past year of schooling. The school also had a policy for learning and teaching that revolved around the development in students of critical thinking and, specifically in Science, complex reasoning, and scientific process skills.

During this study, students engaged in a computer simulation requiring the application of skills and knowledge already learnt in their science course. The modules of this simulation developed an understanding of the essentials for life and the quantities of a range of items from water to seeds to land areas that would be required for a number of people that would be needed to staff the Lunar Base. Prompts were given on the way, which assisted students in their decision making.

Students progressed through the various areas and stages of the development of the Lunar Base until they were satisfied that each area supported the others and that there was no imbalance that needed to be corrected. Once all stages had been completed, students were free to change variables and experiment further as they saw fit in order that they might produce the most self-sufficient Lunar Base possible.

There was some evidence that the simulation did encourage the students in the pairs observed to think in greater depth about the materials and to argue their convictions in an improved manner.

As well as the students appearing to increase in competency in argument over the period of time, the four students in their final interviews, spoke of feeling satisfied with the results of the lessons. The students also appeared more engrossed in their task and the pedagogy provided in the task was appreciated as it gave meaning to why they were required to learn scientific materials as well also presenting them with ways to find the knowledge for themselves.
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Statement of Original Authorship

The work contained in this thesis has not been previously submitted for a degree or diploma at any other higher education institute. To the best of my knowledge and belief, the thesis contains no material previously published or written by any another person except where due reference is made.

Signed:

Date:
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CHAPTER 1
INTRODUCTION

1.1 Theoretical introduction to the area

1.1.1 Perceived necessity for the development of higher order thinking skills

Our current educational system originated during the Industrial Revolution. It was aimed at training children to read basic material, write at a basic level, do simple mathematics, and follow directions (Burns, 1993). Now, educationalists assert that not only do students need to be able to do the above but also must be able to: create, design, teach, define problems, quickly assimilate relevant data, conceptualise, reorganise information, make intuitive leaps, and work collaboratively to find solutions (Burns, 1993; Engle, & Conant, 2002; Flage, 2004; United States Department of Labor, 1991, as cited in Dwyer, 1994, p. 4; Venville, Adey, Larkin, & Robertson, 2003; Watson, Swain, & McRobbie, 2004).

The type of thinking processes a student needs to develop in order to accommodate changes in both the type and quantity of knowledge with which she/he will be confronted as society continues to change, go beyond the simple learning of facts and content (Bleedorn, 2003; Raghavan, & Glaser, 1995; Renner, Stafford, Coffia, Kellogg, & Weber, 1973; Peters, 2003; Zembal-Saul, & Land, 2002).

Furthermore, it is currently required that students become self-empowered learners (Maher, 2004) who can define problems, research a wide variety of material and media, conceptualise, reason and clearly communicate their solutions (Engle, & Conant, 2002; Schwarz, Neuman, Gil, & Ilya, 2003) using a wide range of media. All this is in strong contrast to merely gathering knowledge by rote learning (Gross, 1991; Kent, 1990; United States Department of Labor, 1991, as cited in Dwyer, 1994, p. 4) which was more typical of earlier times.
Halpern (1996, p. 2) asserts that higher order thinking is “imperative for the citizens of the 21st century.” Further, she quotes from the United States National Education Goals Panel which set as a goal for college graduates in the last decade of the twentieth century, “that the proportion of college graduates who demonstrate an advanced ability to think critically, communicate affectively, and solve problems will increase substantially” (National Educational Goals Panel, 1991, p. 237, as cited in Halpern, 1996, p. 3). Halpern then summarises a series of reports which indicate that the number of students demonstrating higher order thinking skills is declining in America and, finally, cites a statement from a panel of experts on higher education who agreed that “the job of the university today is to turn out students who can think in a rapidly changing world” (De Lopez, 1992, p. 4, as cited in Halpern, 1996, p. 4).

Of course, as with most educational processes, this is more easily said than done, and processes to produce students with these capabilities are still under development (Dori, Tal, & Tsaushu, 2003; Maher, 2004; Schwarz et al., 2003; Venville et al., 2003).

In Queensland Australia, these concepts are reflected in the requirements of many school subjects, the way they are taught, and the way in which they are examined, especially in the senior high school. The junior and middle schools (Maher, 2004) are also teaching the foundational skills for this newer approach.

As examples, consider the number of the skills required in Senior Science subjects (Queensland Board of Senior Secondary School Studies, 2001). The Board requires a student to gain knowledge, develop scientific processes, and display complex reasoning. Again, this is far beyond the mere acquisition of scientific facts. In Senior Physics, specifically, “the course should provide learning experiences which will assist students to develop Scientific Processes, Complex Reasoning Processes and appropriate attitudes and values” (Walding, Rapkins, & Possiter, 1999, p. 7).

The objectives of the Senior Physics Syllabus (Queensland Board of Senior
Secondary School Studies, 2001) as well as Biology (Queensland Studies Authority, 2004) continue to encourage the development of these skills and promote the students’ development of critical attitudes concerning the impact and limitations of science, being concerned for the wise application of science, its ethical use, being open-minded and critically respectful of data and being sceptical, and willing to shift in the face of evidence.

This is also paralleled in most other senior school courses. In Mathematics, students are expected not only to be able to learn the processes of Mathematics, but also have to be able to apply those processes in problems with which they are unfamiliar, that is they have not seen anything like them before. In Health and Physical Education, they are expected to acquire knowledge and skills and then be able to evaluate someone else’s application of that skill and determine whether or not they are, for example, good tennis players, and explain why or why not. In Senior English, skills required include the awareness of purpose and audience and the ability to process writing, referencing, and bibliography. The Listening Test for Senior French requires a student to be able to comprehend the meaning, detail and main points of what is spoken and also to deduce meaning from context, infer the speaker’s intentions and attitudes and understand significant socio-cultural references.

Many of these skills are considered higher order thinking processes and are very difficult to teach (Halpern, 1996; Kent, 1990; Mazarno, & Pickering, 1997; Meyers, 1985; Peters, 2003). They require an understanding of the whole procedure as well as an understanding of the steps within the whole procedure (Flage, 2004; Watson et al., 2004). Yet, the criteria in all these subjects assume that students have the ability to engage in higher order-thinking processes (Raghavan, & Glaser, 1995; Venville et al., 2003). However, most classroom teachers would agree that the teaching of these skills in the traditional classroom requires different instructional methods from those used in the past (Dori et al., 2003; Jonassen, 2000; Kuhn, 1993; Meyers, 1985;
Renner et al., 1973; Schwarz et al., 2003; Windschittle, & Andre, 1998). Teachers are being encouraged to consider the issues of critical thinking, complex reasoning and creative thinking as they develop work programs and teaching strategies for their classrooms (Bell, 1991; Bleedorn, 2003; Chubinski, 1996; Driver, & Newton, 1997; Engle, & Conant, 2002; Mazorno, & Pickering, 1997; Venville et al., 2003). These terms will be discussed in depth in Section 2.2.

Much of the consideration currently being given by teachers to the development of improved thinking skills is centred on discussing and defining the processes that might produce appropriate classroom environments. Then, to attempt to develop suitable educational programs (Venville et al., 2003) that will enable students to both develop and engage in these processes. Concurrently with the implementation of these programs, research aimed at determining their effectiveness is being undertaken.

One outcome of this three-stage process has been the identification of the various types, processes and levels of higher order thinking skills. An aspect of higher order thinking skills that is readily assessable by classroom teachers is argumentation and it is this aspect that is the focus of this study. Schwarz et al. (2003) conclude from their examination of the use of structured argumentation:

> the integration of the evaluation of argument-outcomes, the measure of changes in individual and collective argument-outcomes through successive activities, and an activity theory-based analysis of protocols in which prototypical changes occur constitutes a viable methodology for the study of argumentation in the school context. (p. 221)

One area of research that also has potential to enhance the development of higher order thinking skills is the use of computer simulations. Whilst these have been used for many years in education, the rapid advances in multi-media technology have widened their scope. This development, “strongly influences learning and
development. Most children are well rehearsed in the value of computers for learning and simulation” (Bleedorn, 2003, p. 37).

1.1.2 The use of computer simulations

It is generally accepted that there are presently three educational uses for Information Technology in education: learning from computers, learning about computing and learning with computing (Jonassen, 2000). Simulations fall into the last category and become one example of what Jonassen terms Mindtools©. Mindtools© are computer applications used for “engaging and enhancing multiple forms of thinking in learners” (Jonassen, 2000, pp. 3-4). These Mindtools© require the students to think deeply about the content they are learning and so are “critical thinking devices” (Jonassen, 2000, p. 10). As critical thinking devices they are intended to engage and facilitate cognitive processing and in the process develop critical thinking skills. In the “intellectual partnership” (p. 4) involved in these simulations, the learner has to recognise the content, while the computer performs calculations, stores, and retrieves the information. As we are reminded by Bleedorn (2003), “Technology moved the traditional focus of education from memory storage to the cultivation of talents for processing the overwhelming supply of valuable data …” (p. 70).

Simulations, by processing this data in a short period of time, allow students to model the process of developing hypotheses, changing variables and observing the results, accumulating data, resetting the values of variables, then running the simulation to test the hypotheses. The entire process can be repeated until the learner demonstrates a clear understanding of the various elements in the environment. Students can also carry out experiments that are too difficult (Buckley, 2004; Jong, 1991; Roberts, Blakeslee, & Barowy, 1996) or too dangerous (Kessler, 1995; Riche, & Dawe, n.d.) to conduct in a classroom or that take too long to be practical (Jensen, 1998; Metropolitan Community Colleges General Education
Initiatives, 1996; Windschitle, 1998). In addition to these advantages, they can also work together in cooperative research teams. Then, they can present their results in a professional scientific format using pro forma reports and appropriate statistics, diagrams, and graphs generated by suitable software (Zembal-Saul, & Land, 2002).

Steed (1992) argues that this type of simulation has the potential to address higher levels of thinking, such as evaluation, synthesis, and analysis. Specifically, the building of models requires students to predict behaviour of system components, develop and test hypotheses, reason analytically in order to interpret results, and explain phenomena through the model (United States Department of Labor, 1991, as cited in Dwyer, 1994, p. 4).

Accordingly, this would lead us to expect that in the teaching of senior secondary science, both scientific process and complex reasoning skills have the potential to be developed and/or enhanced by using simulations (Buckley, 2004).

1.2 The study

As part of their Year 9 science course students investigate the inter-relationship of systems both biological and structural. A common basis for all study in the school is the development of higher order thinking skills.

The aim of the study was to investigate the context and situations which give rise to argumentation strategies and hence examine and analyse higher order thinking skills, in particular dialogic argument used by Year 9 students engaged in a computer simulation requiring the application of skills and knowledge already taught in their science course.

The modules of this simulation are designed to develop an understanding of the essentials for life and the quantities that would be required for the number of people
that would be needed to staff the Lunar Base. Prompts are given on the way, to assist students in their decision making.

Students progress through the various areas and stages of the development of the Lunar Base until they are satisfied that each area supports the others and that there is no imbalance that needs to be corrected. Once all stages have been completed, students are free to change variables and experiment further as they see fit.

The study adopted an interpretative design that analysed the student discourse and computer actions of a Year Nine class. Detailed discourse, computer screen dumps, and student and teacher interview data were the data sources.

1.3 The significance of the study

This study is an important piece of research as it investigates the interaction between two major aspects of modern educational philosophy. These are the emphasis in modern curricula on the development of critical thinking skills in science education, especially scientific process and the appropriate use of technology in the classroom. In this case, the technology investigated, a simulation, is a significant genre for use in science classrooms.

1.4 The structure of the thesis

This chapter has provided an outline of the study and its aim. Chapter 2 presents the literature review of related studies to provide a background for the study. Chapter 3 details the design and the methods employed and provides further detail of the nature of the simulation. Chapter 4 presents an analysis of the argument structures evident in the discourse and Chapter 5 discusses these findings. Chapter 6 presents a summary of the thesis, its limitations and avenues for further research.
CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

Education continues to challenge teachers to move their focus away from teaching to developing a more enlightened teaching and learning approach. As a result, teachers are involving themselves in new constructivist pedagogy that includes the development of higher order thinking skills.

This chapter examines some of the literature in this area and particularly the way in which the skill of argument can be developed by the use of appropriate computer simulations. It first reviews the literature on thinking skills in the curriculum and higher order thinking skills in particular, looking to argument as one aspect of these thinking skills. It further reviews the literature and the potential for the development of higher order thinking skills. These literatures are then linked to provide a rationale for the study.

2.1 Thinking skills in the curriculum

Modern education requires much more than the simple recall of information, rote learning of facts and figures or simply preforming various learned techniques. Most school curriculums now have an increased focus on the development of thinking skills (Venville et al., 2003) and the practical application of theoretical knowledge (Engle, & Conant, 2002; Holden, 2004). This is reflected in the report of the conference outcomes of the Australian Education Assembly 2001 which states, “…when students leave schools they should: have the capacity for, and skills in, analysis and problem solving and the ability to communicate ideas and information, to plan and organise activities and to collaborate with others…” (Stephen, 2001, as cited in Australian College of Education, 2001, p. 21)
Thinking skills, as an issue, emerged during the 1970s and 1980s as educators attempted to move away from reproductive lower order learning resulting from teaching by memorising and regurgitating what the teacher or textbook said. This reproductive thinking left students with fragments of information that were not well connected or integrated (Paul, 1992). In fact, the development of thinking skills could be one of the more significant developments in a new education focus in the 1990s and beyond (Bleedorn, 2003; Kent, 1990; Paul, 1994).

So, the purpose of the “thinking curriculums” is to allow students to become “confident in applying what they know to problems and issues in a self-managed manner in both familiar and unfamiliar situations, within acceptable and agreed boundaries” (Australian College of Education, 2001, p. 20). The aims of this approach are to enable students to evaluate knowledge, connect and integrate that knowledge thus deepening the students’ understanding of the topic and allowing students to apply that knowledge in a variety of situations (Dori et al., 2003), and this:

deepening understanding requires thinking about the information by using reasoning processes that are more complex than those used when knowledge simply is being recognized or reproduced. It necessitates using processes that change, extend and refine the knowledge. (Mazarno, & Pickering, 1997, p. 113)

This approach is to enable students to use information meaningfully (Engle, & Conant, 2002). Students are required to use knowledge in “real-life” contexts (Jimenez-Aleixandre, & Pereiro-Munoz, 2002). This meaningful use of knowledge: requires students to engage in thinking and reasoning that is quite different from that required when they are asked to simply recall, restate, recognize, recollect, reiterate or otherwise reproduce knowledge. Using knowledge requires students to engage in complex thinking and reasoning processes as
they complete long-term meaningful tasks. (Mazarno, & Pickering, 1997, p. 191)

However, developing a pedagogy that enables these processes is still an ongoing (Dori et al., 2003) and, sometimes, challenging procedure.

One approach to enabling these processes is the use of Information Technology across the curriculum (Linn et al., 2000). Many genres of Information Technology can be used creatively to enhance the thinking processes for students (Holden, 2004; Slatta, 2004). However, one genre stands out as having a high potential for this dimension of learning. That genre is computer simulations or system modelling (Cuban, 1997; Jonassen, 2000).

2.2 Higher order thinking skills: Critical thinking

In researching the literature on higher order thinking skills, there is a problem with definitions and terminology. Many writers refer only to critical thinking whilst others define critical thinking as a sub-set of higher order thinking skills and include complex reasoning and scientific processes in the same category (Fowler, 1997; Kyzer, 1996). In this paper, critical thinking will be defined as a subset of higher order thinking skills. However, some researchers’ work on critical thinking will need to be discussed in terms of higher order thinking skills. When this is necessary, the discussion will be suitably annotated.

One of the clearer definitions of critical thinking, because it examines the breadth of the content of critical thinking (or in terms of this paper, higher order thinking skills), is, that of the Metropolitan Community Colleges General Education Initiatives (1996), which states that “critical thinking includes the ability to respond to material by distinguishing between facts and opinions or personal feelings, judgments and inferences, inductive and deductive arguments, and the objective and subjective.”
The website of the Metropolitan Community Colleges General Education Initiatives (1996) continues to detail the skills and abilities that indicate the use of higher order thinking skills include:

- the ability to generate questions, construct, and recognize the structure of arguments, and adequately support arguments; define, analyse, and devise solutions for problems and issues; sort, organize, classify, correlate, and analyse materials and data; integrate information and see relationships;
- evaluate information, materials, and data by drawing inferences, arriving at reasonable and informed conclusions, applying understanding and knowledge to new and different problems, developing rational and reasonable interpretations, suspending beliefs and remaining open to new information, methods, cultural systems, values and beliefs and by assimilating information. (http://www.kcmetro.cc.mo.us/longview/ctac/toc.htm)

Other researchers move beyond merely defining the terms to developing full models of the subject. Jonassen (2000) discusses a number of these models. According to Jonassen, there are models that confine critical thinking skills to those that enable the student to stay true to the evidence and draw logical conclusions that lead to emotionless problem solving and critical analysis. This type of thinking is “devoid of imagination, intuition, insight, and the capacity for metaphorical thinking” (p. 24). The literal style of thinking prohibits “imaginative speculation and practical adaptability to novel situations” (p. 24).

There is another more holistic view of higher order thinking skills, which includes not only logical processes but also “intuition, imagination, conceptual creativity, and insight, which can be considered essential components of discovery” (Jonassen, 2000, p. 24). This level of thinking leads to a new kind of solution where there was no obvious answer before and characterises most of the major achievements in science and the arts throughout the ages. This dimension of problem solving may
mean taking more risks, following guesses and estimates, testing and modifying possible solutions, bringing together the available information to form new relationships (Engle, & Conant, 2002; Flage, 2004; Herceg, & Flattery, 2000; Jimenez-Aleixandre, & Pereiro-Munoz, 2002).

The University of Oregon web page (University of Oregon, 2001) on critical thinking is consistent with a more holistic definition of critical thinking:

It is not enough to be able to apply problem-solving strategies to a particular problem, however complex it may be; a truly critical thinker must be able to choose appropriate strategies and even create new ones when necessary.

When attempting to develop a model of higher order thinking skills, most researchers present long lists of sub-skills considered to be part of the overall skills of higher order thinking then try to define these sub skills. This also happens in curriculums based on higher order thinking skills. For example, the new “Rich Tasks” activities being developed by the Queensland Schools’ Curriculum Council lists all the sub-skills required to be achieved as outcomes in each of the Years 1-3, 4-6 and 7-9 (Education Queensland, 2001). All these lists tend to go into great detail and, therefore, cover many pages.

Writers of some Senior work programs being developed for Queensland schools also generate long lists of higher order thinking skill type objectives to be met by the courses. For example, Walding et al. (1999) in a senior science work program for a Brisbane school have generated a list that covers about two A4 pages. Unfortunately, the discrimination between some of the skills presented in these lists is very fine and, in some cases, somewhat difficult to determine.

One of the most detailed higher order thinking skill models is that developed by the Iowa Department of Education. This model, called the Integrated Thinking Model is chosen by Jonassen (2000, p. 25) for the purpose of discussing the usefulness of
what he terms Mindtools©. In this model, the essential core of higher order thinking is referred to as complex thinking which includes “goal-directed, multi-step, strategic processes, such as designing, decision making and problem solving” (Iowa Department of Education, 1989, p. 7, as cited in Jonassen, 2000, p. 25). This complex thinking consists of three basic components: content/basic thinking, critical thinking, and creative thinking.

Content/basic thinking relates to traditional learning. This original content knowledge forms the basis of all other thinking processes (Gatto, 1993; Hanks, 1994). The learner must start with the construction of or recall of some knowledge before being able to pursue higher order thinking skills (Dori et al., 2003). Therefore, in this model basic knowledge is in constant interaction with critical, creative and complex thinking, “because it is the knowledge base from which they operate” (Jonassen, 2000, p. 25). Critical thinking is the “dynamic reorganization of knowledge in meaningful and useable ways” and involves evaluating, analysing, and connecting, each of which also involves various sub skills that are fully detailed (Jonassen, 2000, pp. 27-28). Creative thinking requires going beyond the known to generate new knowledge. The components of creative thinking are: synthesising, imagining, and elaborating, each with its subset of skills as well (Jonassen, 2000). Finally, the complex thinking skills that are at the centre of this model are the skills that combine all the skills and sub skills of the other three areas into larger action-oriented processes. There are three major types of complex thinking processes: problem solving, designing, and decision making (Jimenez-Aleixandre, & Pereiro-Munoz, 2002; Jonassen, 2000).

Although according to Jonassen (2000) this is probably the most comprehensive model available for describing higher order thinking skills, it is far too detailed, involving too much information for most classroom teachers to have the time or inclination to try to comprehend, let alone implement. This is also true of the other long lists of skills and sub skills. However, in terms of this piece of research this
model and the lists have been the basis for the choice of the particular aspects of higher order thinking skills to be investigated.

In spite of the fact that these models of higher order thinking skills are quite involved, it is still a fact that educational authorities world-wide (Bush, 1990; Dori et al., 2003; Gatto, 1993; Iowa Department of Education, 1989; University of Oregon, 2001) and the Queensland Board of Senior Secondary School Studies (2001) in particular are requiring the development of critical thinking skills in students. So, it is essential for teachers to be given a means of imparting these skills without adding yet another burden to an already content overloaded curriculum.

2.2.1 Direct and indirect approaches to teaching critical thinking

There are a number of ways of approaching teaching and assessment of critical thinking. Two of these ways could be referred to as the direct (Bowell, & Kemp, 2002; Diestler, 2001; Flage, 2004; Frangenheim, 2004) and the indirect (Erduran, Simon, & Osborne, 2004) approaches, each of which will be reviewed in turn.

Both Halpern (1996) and Lawson (1992) summarise the findings of a number of studies (Bell, 1991; Binkler, 1993; Lipman, 1994; Paul, 1992) that show:

1. that it is possible to teach critical thinking skills;
2. that these skills are generalisable across school subjects and transferable to the real-world environment; and
3. that these skills, once learned, are retained over at least several years.

2.2.1.1 The Direct approach to teaching critical thinking

The direct approach to the teaching of critical thinking involves the development of a course of study in which the students are presented with a range of learning exercises to directly teach a number of the elements of critical thinking. This is
occurring in a number of schools and educational system although it does continue to crowd an already overcrowded curriculum (Engle, & Conant, 2002; Paul, 1992; Schwarz et al., 2003; Venville et al., 2003).

This development of course material and the inservice training of teachers or lecturers to present it occurs at the primary (Bleedorn, 2003), secondary (Bleedorn, 2003; Diestler, 2001; Flage, 2004) and tertiary (Diestler, 2001; Flage, 2004; Slatta, 2004; Sofo, 2004) levels and has proven useful to students of all ages.

The rapid development and globalisation of the business life and economies of the world has increased the need for citizens who think, “recent years have seen a proliferation of attention to the study and application of critical thinking in response to the diversity of human challenges” (Bleedon, 2003, p. 41).

Chubinski (1996) favours the direct approach to teaching critical thinking skills. Basing her teaching strategy on Richard Paul’s approach to critical thinking (Paul, 1992), Chubinski (1996) has developed a strategy for teaching the skills described in the direct model. Her courses detail which of the skills listed in section 2.2 are addressed in each of the modules of her course and teachers can relatively easily use the material.

Mazarno and Pickering (1997) also prefer a direct approach and devote three chapters in their book “Dimensions of Learning” to identifying each necessary skill and the teaching of them to students. They state that students of all ages are capable of learning and using all these skills but that younger students may need more guidance and modelling than older students (Mazarno, & Pickering, 1997, p. 115). They also state that the processes need to be applied to appropriate content, that is, not purely learned in isolation. This process is facilitated if the suggested approach is used consistently by all teachers across all curriculum areas.
Simonneaux (2002) demonstrates how the direct approach to critical thinking and particularly argumentation can be taught and evaluated in Biology classes. It is particularly relevant to the concepts being developed in the computer simulation chosen for this study.

2.2.1.2 The Indirect approach to teaching critical thinking

Most teachers would agree that modern curriculums are already crowded and the introduction of yet another subject would be a major problem. So, perhaps a solution is to find a way of enabling students to develop higher order thinking skills within the subjects already being studied (Erduran et al., 2004; Maher, 2004), that is, the skills are developed indirectly in the context of the learning.

The crux of the critical thinking theory and research is reflected in a statement by Lipman (1994, p. 139), “the shift (is) from learning to thinking. We want students to think for themselves, and not merely to learn what other people have taught.” Just how this is to be accomplished is a much-debated question.

Jones (1996, p. 3) builds on this statement by asserting that:

critical thinking is a learnable skill with teachers and peers serving as resources. Further, that methods and evaluation emphasise using content rather than simply acquiring it. This is achieved by courses being assignment centred rather than text or lecture oriented; that students need to formulate and justify their ideas in writing and that students collaborate to learn.

He continues (1996, p. 4), “Instructors need to refocus their thinking from individual mastery of content (which leads to competency) to teaching the process of information discovery (within the learner’s own contextual meaning)” which requires a shift in thinking about how to teach. Traditional instruction methods teach students that the teacher, or the textbook (Gatto, 1993; Hanks, 1994) is the
authority, the expert and that the students learn what they need to learn and what
they are supposed to think from the authority/expert. The concept of the critical
thinking model is that the idea is to teach students how to think so that they can find
their own information and formulate their own solutions. This requires teachers to
re-think how they design courses, assessment items and teaching strategies.

Duldt (1997) describes a number of different techniques that are used by educators
who prefer a more indirect approach, for example: clinical journals (Brown, &
Sorrell, 1993); debating (Bell, 1991); class discussions (Kyzer, 1996), and
questioning (Wink, 1993).

This last concept, that the right type of questioning will foster critical thinking,
evaluation and knowledge application in students, is sometimes referred to as
recommends that teachers use this type of questioning in all aspects of teaching
critical thinking. He describes the types of questions and lists the types of suitable
questions under the following headings:

1. questions of clarification;
2. questions that probe reason and evidence;
3. questions that probe implications and consequences;
4. questions about questions.

This approach also has its problems in that it necessitates teachers being trained and
re-trained in this type of questioning until it becomes automatic (Binkler, 1993;
Jonassen, 2000; Lipman, 1994).

Another approach by the University of Oregon Department of Biology (2001) uses
problem-based learning:

Problem-based learning allows students to identify the information and skills
they need to learn to solve specific problems. Since most of the problems we
deal with in our classes are complex, ill defined, and without a clear right answer, students may also disagree on which information is relevant and valuable in addressing the problem. (http://biology.uoregon.edu/BiologyWWW/WorkshopBiol/model/thinking.html, 2001)

Being able to evaluate information based on its source and its relationship to a problem, as well as being able to search it out in a textbook or in primary literature, are necessary skills for making effective decisions and this advocates the use of an indirect problem solving approach to developing both critical thinking skills and biology content knowledge. Provided the approach is simply integrated by teachers into an already existing program, this could be a most useful technique.

The types of activities listed by Walding et al. (1999) in the senior science work program for a Brisbane school could be classified as constituting an indirect problem solving approach in a science-based subject as the particular skills are developed in the context of the learning rather than as the isolated skills of the direct approach.

Similarly, the “scientific processes” referred to in Queensland senior science documents require students to use knowledge in a practical method in order to devise, test and, if necessary, re-formulate hypotheses which can then be used to develop an accurate model of a scientific process. “Scientific reasoning is characterised by the formulation of theories and models with consideration of the evidence that supports them” (Stephens, McRobbie, & Lucas, 1999, p. 189). In order to develop these scientific processes it is important that students be able to engage in activities “whose purpose is to develop, interpret, or evaluate explanatory models for the phenomena being investigated” (Raghavan, & Glaser, 1995, p. 38).
Higher order thinking skills and social construction

Another aspect of critical thinking, that of group activities and social construction, is discussed by Gokhale (1995, p. 3) where he notes “Proponents of collaborative learning claim that the active exchange of ideas within small groups not only increases interest among the participants but also promotes critical thinking.” Gokhale (1995, p. 1) cites Johnson and Johnson (1986, p. 31) in arguing that “there is persuasive evidence that cooperative teams achieve at higher levels of thought and retain information longer than students who work quietly as individuals.” Further evidence comes from Totten, Sills, Digby and Russ (1991), who claim that “The shared learning gives students an opportunity to engage in discussion, take responsibility for their own learning, and thus become critical thinkers” (cited in Gokhale, 1995, p. 1). Much of this research and observation has been done on primary (Robertson, & Fluck, 2004; Schwarz et al., 2003; Venville et al., 2003) and secondary students (Engle, & Conant, 2002; Maher, 2004)) and especially in Australia “the cooperative learning movement has done a great deal in the past ten to fifteen years to impress upon teachers the value of harnessing the synergy produced by group work” (Frangenheim, 2004, p. 83).

Gokhale’s (1995) research on American college students once again confirms that “students who participated in collaborative learning performed significantly better on the critical thinking test than students who studied individually” (p. 4). Further Simonneaux (2002) also examines the positive effects of group interactions on the development of critical thinking in French students, and studies by Jimenez-Aleixandre and Pereiro-Munoz (2002) in Spain demonstrate the universality of such successes with high school students.

In the discussion of this result, Gokhale refers to the work of Vygotsky and Bruner. According to Vygotsky (1978) students are capable of performing at higher intellectual levels when asked to work in collaborative situations than when asked to
work individually. Group diversity in terms of knowledge and experience contributes positively to the learning process (Hakkinen, 2003; Scott, 2004) and in fact is the manner in which most scientific investigation takes place (Watson et al., 2004). Bruner (1985, as cited in Gokhale, 1995) contends that:

cooperative learning methods improve problem-solving strategies because the students are confronted with different interpretations of the given situation. The peer support system makes it possible for the learner to internalise both external knowledge and critical thinking skills and to convert them into tools for intellectual functioning.

This interpretation fits with the Integrated Thinking Model used by Jonassen (2000) that two of the basic components of higher order thinking skills are content/basic thinking and critical thinking. “Thinking critically does not have to occur in a group … where it does occur in a cooperative group … the result is likely to be enhanced” (Sofo, 2004, p. 62). It is advantageous for students working on the type of problem-solving exercise studied in this report to work in groups as this assists them to both understand the basic knowledge of the scientific model with which they are working and then use critical thinking skills to apply that knowledge (Engle, & Conant, 2002; Hakkinen, 2003; Zembal-Saul, & Land, 2002).

In Gokhale's (1995) study:

the collaborative learning medium provided students with opportunities to analyse, synthesise, and evaluate ideas cooperatively. The informal setting facilitated discussion and interaction. This group interaction helped students to learn from each other's scholarship, skills, and experiences.

The interaction between students in the groups forced them to give reasons for their judgements rather than just give statements of opinion. This resulted in each opinion being subjected to careful scrutiny and the criteria used to make the judgements being carefully evaluated.
2.4 The use of argument as a measure of critical thinking

As evidenced by the range of terminology in the literature, there is little agreement as to what constitutes critical thinking or any of the other terms that broadly come under the heading of higher order thinking skills (Flage, 2004; Gokhale, 1995; Jonassen, 2000; Mazarno, & Pickering, 1997; Walding et al., 1999). However, there is growing agreement about a range of indicators of the successful use of higher order thinking skills.

One such indicator that is receiving close attention is dialogic argumentation especially as evidenced in the learning environment (Anderson, Chinn, Chang, Waggoner, & Yi, 1997; Dori et al., 2003; Jimenez-Aleixandre, & Pereiro-Munoz, 2002; Kuhn, Shaw, & Felton, 1997). This interest in argumentation has developed out of educators teaching students to argue effectively in small group discussions and relating this use of argumentation to an improvement in thinking skills (Bowell, & Kemp, 2002; Diestler, 2001; Engle, & Conant, 2002). The ability to argue has also been widely used to measure the acquisition of knowledge, “This centrality of argumentation in construction of knowledge has even led some thinkers to view argumentation as its essence” (Schwarz et al., 2003, p. 222).

The body of research on children’s skills in argument is growing (Driver, & Newton, 1997; Erduran et al., 2004; Kuhn, 1991, 1993; Pontecorvo, & Girardet, 1993; Watson et al., 2004) and is demonstrating that even quite young children (Venville et al., 2003) are able to become involved in in-depth arguments about familiar topics. Primary school children can often express opinions and argue against peers in a most sophisticated manner once information about a topic has been acquired and internalised. Young children often have strongly developed and well thought out positions on the environment, nuclear war, and even the parliamentary processes (Lipman, 1994; Paul, 1993). This ability is being enhanced by the development of
such curriculum approaches as the “Rich Tasks” currently being developed by the
Queensland Schools Curriculum Council (Education Queensland, 2001).

The use of argument in a number of subject specific disciplines and specifically
science classrooms (Anderson et al., 1997; Driver, & Newton, 1997; Kuhn, 1993;
Kuhn et al., 1997; Newton, Driver, & Osborne, 2004) has also been the subject of a
number of studies.

Paul (1993) documents the relationship between argument and the issue of critical
thinking.

   To argue is to give reasons for or against a proposal or proposition. In
   emphasising critical thinking, we are continually try to get our students to
   move from the first sense of the word argue to the second; that is, we try to
   get them to see the importance of giving reasons to support their views
   without getting their egos involved in what they are saying. This is a
   fundamental problem in human life. To argue in the critical thinking sense is
   to use logic and reason, and to bring forth facts to support or refute a point.
   (p. 522)

Argument has been defined in a similar manner as the link between assertion and
justification or the use of reasonable statements to support a claim (Means, & Voss,
1996; Toulmin, 1958). In a social context argument has been a vehicle for the
resolution of moral dilemmas as well as one of the fundamentals of democracy
(Toulmin, 1958). In a learning environment, the use of reasoned arguments is an
essential skill as students seek to move from the acquisition of factual information
into the realm of reasoning about causes and consequences of particular situations
(Dori et al., 2003; Engle, & Conant, 2002; Flage, 2004; Hakkinen, 2003; Jimenez-
Aleixandre, & Pereiro-Munoz, 2002; Pontecorvo, & Girardet, 1993). With the rapid
increase in the number of situations in which students must present an argued
opinion, it would seem to be important for our students to be equipped with an improved ability to argue in a reasoned manner (Erduran et al., 2004).

Kuhn (1991, 1993) investigated the apparent lack of skills in argumentation among learners in a range of ages and found that in all age groupings, including students of high school age, few were able to produce genuine evidence for their theories. Similar studies by Perkins, Faraday, and Bushey (1991) indicate that the difficulty in argumentation reflects over simple mental models of argument rather than logical fallacies in the issues examined.

A number of variables have been explored in an attempt to determine whether skills in argumentation could be taught in a formal manner. Kuhn (1991) found that a developmental improvement occurred between the age of eight and early to middle adolescence, however, no significant improvement occurred from adolescence into adulthood. This could imply that in the absence of argumentation practice and development in the learning environment experienced through the years of formal schooling, skills in the use of argument fall into disuse. It would also point to the validity of appropriate training in argumentation skills in the years at schooling which would in fact advantage students when they reach adult life.

In some situations the ability to use argumentative reasoning was independent of a large or sophisticated knowledge base or knowledge of the content of the argument (Means, & Voss, 1996).

According to Kuhn’s extensive study (1991) and more recently Kuhn et al. (1997), students posses argumentation skills but are in need of development by a number of methods including engagement in thinking about topics in a critical and structured manner (Engle, & Conant, 2002).
Students with better argumentation skills should be better able to advance into new areas of understanding than those who merely learnt by a process of knowledge acquisition (Jimenez-Aleixandre, & Pereiro-Munoz, 2002; Lipman, 1994; Zembal-Saul, & Land, 2002). The development of argumentative reasoning skills may enhance the students’ learning environment and in the process increase their higher order thinking skills.

2.5 Computer simulations in education

Computer simulations constitute powerful instructional tools which aim at providing learners with realistic experiences from which to gain and manipulate knowledge in order to better understand the relationships between the concepts being investigated (Cuban, 1997).

These simulations are programs that “allow the user to interact with a computer representation of either (a) a scientific model of the natural or physical world, or (b) a theoretical system” (Weller, 1996, p. 467). They provide learner-centred environments (Redmond, & Brown, 2004) that allow students to explore systems, manipulate variables and test hypotheses (Windschitl, 1998). Further, “these programs can be used as demonstrations by teachers, or they can be used directly by the students to explore various phenomena that would not be readily available under normal situations” (Riche, & Dawe, n.d.).

So, is there an educational purpose for using simulations in a school environment? Pedagogic theorists have maintained for many years that reading about something, listening to someone teach something or watching something on a video are not as effective as doing it. More recent research has demonstrated improvement in students’ literacy and numeracy results linked to hands-on experiences in computer usage (Robertson, & Fluck, 2004). However, it is not always practical to allow students to perform many of the processes underlying much of the knowledge they are required to learn. This is often especially true in science classrooms and this
impracticality can express itself in a number of forms. The process being studied may be:

1. dangerous;
2. too expensive, for example, splitting the atom;
3. too time intensive;
4. too complex;
5. may take too extended a time, for example, a number of months;
6. the relevant materials may be scarce; or
7. the experiment may be considered environmentally or socially unacceptable. (Bennett, & Bennett, 1996; Steed, 1992)

Riche and Dawe (n.d.) detail these impracticalities even further, and, along with many others (Cote, 1995; Duldt, 1997; Gatto, 1993; Jonassen, 2000) believe that simulations can often overcome these impracticalities. This can allow the scientific process/complex reasoning/critical thinking skills required by today’s syllabuses to occur more readily and more often.

The time and cost requirements of many practical investigations are just too high in school situations (Coleman, 1997). This expense usually prohibits exploring hunches, even though that is where real breakthroughs in learning take place (Coleman, 1997). These hunches constitute the creative thinking aspects of science.

The time constraint is usually in terms of today’s over-full curriculums. Often a simulation completes in minutes what can take days, weeks, or even months to complete in real time. This enables students to investigate more variables and, again, follow up ‘What if?’ type questions. It is generally accepted that these ‘What if?’ type questions are the ones that both demonstrate and lead to higher order thinking skills.
Riche and Dawe (n.d.) state that simulations can also help students see things that are normally too fast, too slow or hidden. For example, “A computer visualization can show the flap of a humming bird’s wing, the life cycle of a redwood tree, the pumping of a human heart, or a bee collecting pollen on its legs as it sips nectar from a flower” (http://graceland.edu/~jackg/sciart/simulation.html, as cited in Riche, & Dawe, n.d.). This surely enables the concretizing of Jonassen’s (2000) model (see section 2.2).


> Dynamic natural processes are difficult to demonstrate in the teaching environment. In the laboratory, experiments can only be performed at limited temporal and spatial scales. Many problems related to the functioning of the soil-plant-atmosphere system such as climate change or soil fertility can only be studied on a long-term basis. (p. 1)

Jansson’s (1993) work in this area has been extensive and includes the examination of the complex interactions between atmosphere, plant and soil which cannot be demonstrated under normal laboratory conditions: “However, by using mathematical simulation models, we can investigate in a graphic way that the natural world may be expected to behave under a range of different conditions” (Jansson, 1993, p.1). Using such models leads the student to a better understanding of how nature works, as it provides the connections between their basic knowledge concerning individual processes and the consequences of these processes in complex, natural systems. It would be expected that this investigative ability of such mathematical simulation models could enable many of the higher order thinking skills in Jonassen’s (2000) model (Center for Educational Technologies, 1997; Geban, Akar, & Ozkan, 1992).

Traditional methods of teaching have presented students with information related to concepts and the expectation has been that this is sufficient for the students to learn
those concepts. Modern approaches are increasingly demanding that the students
move beyond mere knowledge acquisition to develop a sufficient understanding of
concepts to be able to practically apply them in appropriate situations (Lawson,
1992; Linn et al., 2000). So, using instructional simulations provides students with
discovery learning opportunities that allows them to apply their theoretical
knowledge to a simulated situation and receive immediate feedback as to the
accuracy of their actions. This allows students to consider what they have learned,
devise hypotheses, test them and draw conclusions. Coleman (1997) states that this
approach “enables students to understand the workings of a system much better” (p.
1).

Jansson’s (1993) use of a simulation designed to study the interactions in the soil-
plant-atmosphere system and in agricultural production (see Appendix 3) systems
found, among other things, that:

1. students developed a deeper understanding of the processes studied
   than when they were presented with ready-made models;
2. independent and logical thinking by the students increased;
3. discussion and contact between teacher and student increased;
4. if the exercise works well it leads to a higher level of understanding.

The most important reason for using simulations is that the learner will be engaged
in active exploration and learning (Geban et al., 1992; Van Schlack Zillenen, 1992,
as cited in Cote, 1995). Current learning theories also insist that learners should be
actively involved in constructing and reconstructing their basic knowledge
(Anderson et al., 1997; Jong, 1991; Linn et al., 2000; Maher, 2004; Slatta, 2004).
Simulations are designed supposedly to encourage this process.

When using a simulation, a learner engages in problem solving, comes to understand
the effects of certain variables and the interaction of these variables, makes
decisions, and observes their consequences. Before starting work with the
simulation, the learner already possesses a mental model of the processes or system being studied. The simulation allows the learner to test that model, and if necessary reconstruct it and test it again. As this process continues a deeper and more complex understanding of the process/system is developed.

Hennesy et al. (1995) investigated the effectiveness of simulations and practical activities on enabling conceptual changes in students aged between twelve and thirteen years. The experimental group used interactive simulations and relevant practical activities, while the control groups received traditional instruction. The results showed that the experimental group demonstrated more sophisticated reasoning, in other words higher order thinking skills.

As well as allowing increased understanding by doing to take place, computer simulations enable learners to have more control over the learning process (Savery, & Duffy, 1995). Generally, it is believed that greater learner control improves the quality and degree of learning, especially in motivated learners (Newton et al., 2004, p. 105). Depending on the design of the simulation, the learner can control the pace of the lesson, choose the sequence by skipping over steps and returning to them later and even control the content by ignoring some steps if desired. Windschitl and Andre (1998, pp. 158, 159) concluded that this learner control is consistent with a more constructivist approach to learning which can allow “learners the opportunity to freely create, test, and evaluate their own hypotheses in a more richly contextualised environment.” This is provided the simulation is not reduced to a “step-by-step cookbook” approach (Windschitl, & Andre, 1998, p. 148) as the constructivist approach to learning assumes that learning is best done by the learner constructing their own understanding, testing that construction and re-constructing if necessary until acceptable learning is achieved (Redmond, & Brown, 2004; Windschitl, & Andre, 1998; Zembal-Saul, & Land, 2002).
Of course, not all simulations are the same (Van Schlack Zillenen, 1992, as cited in Cote, 1995). Certainly, not all simulations are designed as instructional simulations for use in classrooms. In fact, many simulations are designed to meet training demands in a variety of industries, for example, flight simulators, simulations of fire-fighting situations, others to train nurses and/or doctors in complicated medical procedures, and many more of a similar ilk (Alessi, & Trollop, 1985).

2.5.1 Types of computer simulations

In an attempt to clarify which type of simulation is being discussed, Alessi and Trollop (1985) devised four main categories of simulations: physical, procedural, situational/role play, and process.

In physical simulations a physical object which the student can manipulate is displayed on the screen. The learner then manipulates this object until learning takes place (Linn et al., 2000).

Procedural simulations teach how to operate a piece of equipment, for example, flight simulators teach pilots how to operate a plane’s controls. The simulator responds to the student’s actions. The student can then refine the action according to the comments received until the correct sequence of appropriate actions is learnt and the piece of equipment successfully operated.

Situational or role playing simulations allows the user the chance to examine different approaches to solving a problem. For example, software that enables nurses to explore the influence of a number of different variables involved in delivering anaesthetic to patients and how to handle or avoid possible emergencies before actually encountering them on the wards. Many games are of this genre, for example, “Where in Time is Carmen San Diego?©” (Broderbund Software, 1989).
Process simulations required students to select the values of variables involved in the processes being simulated. The simulation then demonstrates the results for those variable values, for example, a simulation of growing plants under different conditions of soil, water, and light. The learner can then change the values of the variables and run the process again until the desired result or results are achieved. Further, there may be several methods to solve the problem that can also be explored. This approach involves generating hypotheses, testing these hypotheses, recording the results, determining the relationships between the variables and the observed results, re-formulating the hypotheses, and so on until an understanding of the process is achieved.

As simulations are becoming increasingly complex, it could be assumed that they would eventually combine more than one of these types into the one simulation.

On the other hand, Windschitl and Andre (1998) divide simulations into three main categories: kinaesthetic, procedural, and process. Flight simulators and others of a similar nature are labelled kinaesthetic. Any simulation that involves moving icons on the screen to imitate or utilise equipment is called procedural. Finally, process simulators are those that model phenomena that have mathematically related variables that can be altered to observe changes. BioBLAST® (Center for Educational Technologies, 1997) is of the third type, allowing students time to develop theories and arguments over a number of lessons and present them to students and their teacher in verbal and written forms.

Although there are different categories of simulations both Alessi and Trolllop (1985) and Windschitl and Andre (1998) describe situations that would be seen to involve critical thinking skills. For example, a pilot training on a flight simulator will be put through various emergency procedures that require high level problem solving skills and require them to be carried out quickly! However, it is the “process” style simulators that most closely model scientific models (Jonassen,
Therefore, these are the ones which should enable students to use and/or develop critical thinking, complex reasoning or scientific processing skills (Jonassen, 2000).

Finally, Riche and Dawe (n.d.) pose the question: ”Are simulations useful?” to which they reply with a qualified yes. With the correct support, resources, and strategies (Linn et al., 2000), simulations are a powerful educational tool: “In conjunction with actual hands-on laboratory activities, simulations can foster conceptual change and promote the building of student knowledge” (Riche, & Dawe, n.d.).

The specific use of computer simulations in science classrooms has been the subject of a number of studies (Buckley, 2004; Center for Educational Technologies, 1997; Coleman, 1997; Geban et al., 1992; Linn et al., 2000; Venville et al., 2003) and these reinforce the more general findings by Riche and Dawe (n.d.).

### 2.6 Interface between critical thinking skills and simulations

Jonassen’s (2000) concept of using computers as Mindtools® for schools is entirely about developing higher order thinking skills indirectly by using various Information Technology genres. Jonassen (2000, p. 22) states:

> So, the primary hypothesis of this book is that the use of computer-based Mindtools necessarily engages learners in critical-thinking about the topics they are studying, which in turn, results in better comprehension of the topics and the acquisition of useful learning skills.

Jonassen then proceeds to compare each Mindtool® in terms of the type of critical thinking skills discussed.
Therefore, it could be argued that the suitable use of a computer simulation would enable students to develop/practice at least the critical thinking skills relevant to the simulation. Obviously, a well-designed computer simulation aims to enable students to design and/or conduct their own investigations and should, therefore, engage students in using higher order thinking skills.

Simulated environments are exploration-based. For this reason, a simulation is “one of the best ways to create abstract concepts” (Gatto, 1993, p. 147). A student using a simulation can “create a very concrete picture of abstract concepts and relationships between concepts, to show dynamically how variables change state, [and] what happens in a process” (Gatto, 1993, p. 147). These are all components of the Jonassen (2000) model of critical thinking.

Gatto (1993) also notes that the learning processes involved in simulations are “defined as transforming information into knowledge. Students formulate and discover for themselves rules of defined principles, preferred procedures, or higher order skills” (p. 152). As a result of this the learner incorporates information into their own cognitive structure as they actively reconstruct the concepts used on the computer. Gatto (1993) further adds “problem solving, discovery learning, and inductive learning are seen to constitute a general framework for the description of learning processes that are invoked within exploratory environments” (p. 152).

So, the student learning with a computer simulation “is involved in a problem solving process which is purpose oriented…” (Gatto, 1993, p. 152). This type of learning can be termed enquiry learning which, again, according to Gatto (1993): allows for and encourages active experimentation and exploration. The learner can discover important concepts and principles, find solutions to problems and so on by not only discovering new information or entities but also by reclassifying and relating known information (p. 152).
Also involved is inductive learning where the “learner formulates rules, based on forming and evaluating hypotheses. This process involves a generalising, transforming, correcting and refining knowledge representations” (Gatto, 1993, p. 150). All of these are also aspects of Jonassen’s model of higher order thinking skills. So, again, it can be said that students actively engaged in learning with computer simulations should be engaged in using some forms/levels of critical thinking.

Roberts et al. (1996, p. 44) report comments by Bliss (1992, 1993) that studies carried out at the University of London suggest that middle school students can acquire the necessary skills to learn science by using computer simulations. Again, these skills fit into the definition of critical thinking as, according to Arons (1979, as cited in Lochhead & Clement, 1979), and Roberts et al. (1996) these skills are:

1. testing behaviour by isolating variables;
2. testing limits;
3. examining interrelationships between parameters; and
4. controlling parameters.

They also state that students need an understanding of issues of internal model validity such as:

1. collecting evidence to see if the model behaves consistently and logically under a wide variety of conditions;
2. looking for patterns in model behaviour; and
3. looking for consistency among the variety of ways simulations display data. (Saeed, 1995, as cited in Roberts et al., 1996)

Finally, Roberts et al. (1996) and Raghavan and Glaser (1995) state that an awareness of issues of external model validity are also important so the student must be able to:
1. compare the model with the target phenomena by comparing data generated by the model with other data;
2. question the simplicity or complexity of the model structure in relation to the observed behaviour.

Windschitl and Andre (1998) concluded from their research that “computer-based simulation offers a suitable cognitive environment within which to test learner’s self-resolution of alternative conceptions” (p. 159). The experimental group for which this conclusion was true had a “context-bound, thematic instruction guide” and were “asked to write predictions, test hypotheses and explain phenomena” (p. 158). In other words, to engage in higher order thinking.

Dwyer (1994), reviewing the results of the “Apple Classrooms of Tomorrow©” project, states that one of the major problems encountered was that “when students demonstrated new learning outcomes such as creative-problem solving strategies or heightened abilities to collaborate in performing tasks,” their teachers didn’t know how to quantify it for their mark books (p. 4). In other words, their exposure to a variety of Information Technology genres had enabled the students to develop higher order thinking skills and that had not been an expected result (Holden, 2004).

In fact, a four-year longitudinal study of these students compared with students from “non-technology” classrooms showed their greatest difference to be in their approach to their work. “Routinely, they employed inquiry, collaborative, technological and problem-solving skills uncommon to graduates of traditional high school programs” (Tierney, Kieffer, Whalin, Desai, & Gale, 1991, as cited in Dwyer, 1994, p. 4).

Further, these skills are compared with those recommended by the U.S. Department of Labor (1991, as cited in Dwyer, 1994, p. 4) which are:

1. abilities to organise resources;
2. work with others;
3. locate, evaluate and use information;
4. understand complex work systems; and
5. work with a variety of technologies.

Dwyer (1994) states that technology “engages students systematically in higher-order cognitive tasks…” (p. 4) that would indicate that the use of computer based simulations are beneficial in the development of higher order thinking skills.

Kessler (1995, p. 1), writing about students using microcomputer-based laboratories reports that, "they don't mind redoing an experiment when the results are questionable.” This is an important aspect of higher order thinking skills – the ability to re-think what has been done, re-formulate the experiment, re-do the experiment and reconsider the new results. One important feature of technology, and its subset, computer simulations, is that they simplify/speed up this process so that the learners are more willing to engage in it.

Gordon (1996, p. 47) defines learning “not so much as the acquisition of knowledge but as the constant reconstruction of what is already known.” So it can be deduced that according to this definition learning requires the use of higher order thinking skills as existing mental structures need to be revised to accept new information or new structures need to be formulated when an existing structure is no longer adequate. In this context of learning/higher order thinking skills, Gordon (1996, p. 47) goes on to report that, “The computer as a microworld by engaging the learner, acts as an interactive medium and allows for the development of the learners personal knowledge acquisition and representation by amplifying their thinking skills.”
The best way to achieve this is by “placing students in an environment that supports the way in which they can construct their own understanding of a particular knowledge base or piece of information” (Gordon, 1996, p. 47).

Of course, there are also disadvantages to be considered. As has already been mentioned, Windschitl and Andre (1998) state that using computer simulations in a systematic cookbook approach reduced the user’s engagement in higher order thinking skills. Rather, learners must be free to “create, test and evaluate their own hypotheses” (p. 148).

These researchers also found that students who have shallow motivations for academic work (those only interested in completing work for marks or beating others) may be frustrated by “constructivist learning environments” (Windschitl, & Andre, 1998, p. 148). Constructivist learning environments are those unstructured environments that best engender the use of higher order thinking skills (Watson et al., 2004). It may be necessary for computer simulations to be highly motivating (or, perhaps, entertaining?) in order to encourage these students. BioBLAST® with its multitude of scenarios and possible pathways meets this criterion for the motivation of such students. At the other end of the continuum, the Bellevue Community College website (1998, p. 2) states that students “at the lower levels of intellectual development may have difficulty participating in, or learning from, inquiry-oriented or reflective activities, since they either do not see what can be learned from them or how such knowledge can be evaluated critically.”

Finally, Roberts et al. (1996) found that two important variables affected learning in a computer-simulated environment. These were:

1. “teacher pedagogic style – the teacher needed to empower the student’s exploration by providing the skills needed to explore the simulation and to encourage the student’s own exploration of the simulation.” (p. 56)
2. “learner interest – students needed to have an interest in the topic and, at least, an elementary knowledge base before being able to benefit from simulations.” (p. 51).

2.7 Aim of the study

The aim of this study is to investigate the argumentation strategies used by Year 9 students engaged in a computer simulation requiring the application of skills and knowledge already learnt in their science course.

The research question to be examined in this study is:

What kinds, levels and frequency of argument are evident in the student-student discourse?

2.8 Summary

This chapter has reviewed various aspects of higher order thinking skills and critical thinking as they relate to modern curricula. Argument has been identified as one issue that is essential for the development of critical thinking and higher order thinking skills.

The chapter also reviewed the application of computers in education and the potential of computer simulations to develop higher order thinking skills. Given that the literature recognises this potential, it is instructive to investigate a recently developed computer simulation for the kinds and frequencies of argument evident in the student discourse.
CHAPTER 3
RESEARCH DESIGN AND METHODS

3.0 Introduction

This chapter describes the design and methods of the study including the sample, data sources and analysis of the data. This last section introduces the approach adopted for analysis of the levels of argumentation recorded in the discourse of students. This is followed by an elaboration of the simulation to provide a context for understanding the analysis and discussion of the dialogic argument identified.

3.1 Design and methods

In order to achieve the aim of the study it will be interpretive (Creswell, 1994; Scott, 1997; Watson et al., 2004) as, following in the current tradition of classroom based research in recent years the focus will be on detailed descriptions of the teaching and learning activities from the perspective of the participants in the classroom environment leading to their interpretation in the light of current theory.

The choice of an interpretive case study is in keeping with the epistemological underpinning’s of the research (Stake, 1994). Stake (1994, p. 237) describes the format further as an instrumental case study in which a selection of students “is examined to provide insight into an issue,” and that the aspects of culture associated with the situation of learning are examined. The decision to use both qualitative and quantitative research methods in the study is consistent with Stake (1994, p. 236) who notes, “case study is defined by interest in individual cases, not by the methods of inquiry used.” The study was conducted in cooperation with the Science Department at the researcher’s inner suburban boys’ school.
3.1.1 The sample

Instrumental case studies require that the sample be carefully selected. This is because case studies are usually examples of research in depth rather than in breadth. Two pairs of students were opportunistically selected, one from the top academic group of the class, and another from the academic middle of the class to obtain variation in the achievement levels of the sample. The ranking was based on the results achieved in Science during assessment in the previous semester. The appropriate composition of these pairs was discussed with the classroom teacher. In presenting the results, the students in the Top Academic Pair were labelled ST1 and ST2 and the Average Academic pair were labelled SA1 and SA2. Year 9 students in the school had been exposed to a range of Information Technology experiences during their Year 4 to 8 studies with a minimum of 160 forty-five minute lessons spent using Information Technology in various forms. The uses of Information Technology ranged across all key learning areas and include activities as wide ranging as:

1. word processing in English;
2. learning from interactive CDs in Languages other Than English;
3. using spreadsheets in Mathematics;
4. writing reports in Science using proforma software;
5. writing music using appropriate software;
6. using 3D graphic software for construction and freehand design work in Art and Manual Arts;
7. using the Internet as a major research tool in Christian Education, History and Geography;
8. constructing websites in Geography.

3.1.2 Data sources
As the simulation progressed, students were asked to discuss their difficulties, what worked for them and what didn’t, what they had to change and how they handled specific situations in the simulation. The researcher noted in writing the interactions between the pairs of students and specifically their use of argument as they worked through the program. At the conclusion of the sessions he also involved the students in guided recall of their activities which were also audio recorded. The two pairs were video recorded with a separate simultaneous recording being made of their computer screens. Each pair’s interactions with the teacher are also recorded in the process of recording the simulation.

The teacher was also interviewed and the observations made of the focus students were video recorded. His reflections on the advantages of using the computer simulation to develop skills in argument during classes were also recorded, as were his more general comments about how other members of the class progressed in the simulation.

Classroom artefacts in the form of written notes and word-processed explanations were also examined. The software had a notetaking facility and these notes were used to prepare for interviews following the completion of the eight lessons.

Figure 3.1 shows the screen that the students used to navigate their way through the simulation. The button labelled 1, was a location button, which enable the students to move around the Lunar Base by clicking on the location in which they wished to work. Button 2 indicates the screens that were used by the students to obtain scientific information that enabled them to make informed decisions about the construction of the Lunar Base. The screens included videos from experts on all aspects of the simulation, see Figure 3.6, in section 3.1.7.1, and direct links via the Internet to information databases. Buttons 3 to 10 selected various aspects of the simulation including button 8 that started the program running when all variables
had been selected. Item 11 points to the screen area where the choice of variables was represented by vertical moving scales.

**BioBLAST® Main Interface Features**

![Diagram of BioBLAST interface with numbered points 1 to 11]

The software design also assisted in understanding the thinking skill development by requiring the students to record their findings (see item 3 in Figure 3.1) and decisions on computerised notepads provided by the simulation at the end of each stage of the program. These notepads were printed off at the end of the unit of work and used in the development of the findings of this report.

As there are a multitude of acceptable pathways to establish a fully functioning lunar base, students did not feel that they needed to copy others although at times there was a certain amount of collaboration between pairs when confronted by complex issues. This was permitted.
In addition to the recording of the two pairs, the researcher used a hand held video-recorder to collect information from all the other thirteen groups in the classroom seeking to obtain substantiating evidence on their approach to the software. The recording was random and occurred as the researcher sought to assist the students, as was his customary role in a computer laboratory.

3.1.3 Procedure

At the completion of the unit of work in which they were introduced to systems and specifically biological systems, Year 9 students were timetabled to use a computer laboratory for eight forty-five minute lessons in succession to apply the knowledge they had acquired.

A brief outline of the task involved was given to the students who then worked through the simulation at their own pace and in their own sequence. During these eight lessons, discussion and collaboration with other pairs were permitted.

Interaction between students and teachers was encouraged with teachers supplying prompting and support as needed. These interactions were recorded on a separate video recorder, as well as being observed by the researcher. These recordings provided details of the conversations from which evidence of the students’ approach to solving problems was obtained. Analysis of recording also provided future issues for further research (Smyth, & Shacklock, 1998; Tripp, 1998).

At the end of each lesson, students were required by the simulation to write a group progress report on a computerised notepad. Students could not log out of a session until a written report was entered. These reports were printed at the end of the eight lessons but may be referred to at any point in the simulation. The students were required to use these notes to write a final report on the success of their mission.
The BioBLAST® manual states that, “Students should have basic computer skills. Knowledge of a spreadsheet program such as Excel® would also be helpful” (Center for Educational Technologies, 1999, p. 6). All the students in the study easily met these requirements. As an ability to work in a team is also a feature of higher order thinking skills, the students worked in groups of two. This assisted in the recording of how the students approached the tasks, as their conversations revealed much about their thinking processes.

3.1.4 Analysis

The analysis took the form of examining data sources for evidence of argument between students within pairs. These data sources were searched to identify genuine episodes of oppositional analysis and dialogical argument. Typically these instances were identified by a range of words such as “I disagree with you” and “I don’t think so” or the proposal of alternate suggestions or interpretations.

These interactions were then examined in terms of who was opposed to whom, whether elaboration was being sought or being given, and whether reinforcement of repetition was taking place.

The major elements of argumentation to be identified were (Osborne, Simon, Erduran, & Monk, 2001):

1. Opposition to statements;
2. Elaboration of an issue;
3. Reinforcement of an idea with extra data;
4. Advancing claims;
5. Adding qualifications.

Each time a session of argument was identified, it was analysed using Toulmin’s Argument Pattern (Erduran et al., 2004; Toulmin, 1958) to analyse the major issues
arising from the argument. This evaluation focussed around the belief that students expressed the development of rational and analytic thought and discourse in their ability to present logical arguments in the classroom. Osborne et al., (2001) agreed with Toulmin in this contention that:

A (person) demonstrates his rationality, not by commitment to fixed ideas, stereotyped procedures, or immutable concepts, but by the manner in which, and the occasions on which, he changes those ideas, procedures, and concepts. (Osborne et al., 2001, p. 12)

It was expected that the use of the computer simulation (BioBLAST®) would allow students to examine their claims and change them as the simulation evolved. The discussions and comments made during this period of change provided a valuable insight into the students’ ability to develop their claims and other argumentative skills.

In his early writings, Toulmin (1958) used concepts of claims, counter claims, data, warrants and backings, and these terms have been used by researchers to analyse sessions of argument (Driver, Newton, & Osborne, 2000; Erduran et al., 2004; Newton et al., 2004; Pontecorvo, & Girardet, 1993; Russell, 1983). He defined them as follows:

Claims, assertions or conclusions whose merits are to be established; data is the facts that are appealed to in support of the claim; warrants which are the reasons justifying the connection between particular data and the knowledge claim; and backings which are basic assumptions that provide the justification for particular warrants. (Newton et al., 2004, p. 98)

This analysis has led Osborne et al. (2001, p. 13) to define the quality of argument in terms of five levels of argument in this manner:

Level 1: arguments are a simple claim v a counter claim or a claim v claim.

Level 2: arguments consist of claims with either data, warrants or backings but do not contain any rebuttals.
Level 3: arguments consist of a series of claims or counter claims with either data, warrants or backings with the occasional weak rebuttal.

Level 4: arguments consist of a claim with a clearly identifiable rebuttal. Such an argument may have several claims and counter claims as well but this is not necessary.

Level 5: This is an extended argument with more than one rebuttal.

An example of how this analysis was applied in a discussion about the validity or not of having animals in zoos is as follows (Osborne et al., 2001, p.14):

S1: I don’t think they would hurt them in a professional zoo.
S2: But they might scare the other animals by seeing some sedated animal being dragged off.
S1: Maybe stress.

Figure 3.2. Typical mapping of argument pattern (after Toulmin, 1958)
Figure 3.3. Stage 2 in the argument pattern (after Toulmin, 1958).

Figure 3.4. Stage 3 in the argument pattern (after Toulmin, 1958).
The summary of this example was that it consisted of: claim + data + warrant + backing v counter claim + data + warrant.

Moreover, despite some embedded complexity, as an example of arguing it was essentially weak, as there was no attempt at a rebuttal (by either party) permitting the justification of belief by both parties to remain unexamined. Therefore this was considered to be a Level 2 argument (Osborne et al., 2001).

Interactions which were still unclear at this point were cross referenced to the other data sources to enable the researcher to obtain as clear a picture as possible of the way in which the simulation encourages students to use logical processes of argument. They were also discussed at length to agreement with an experienced senior researcher.
Once the units of argument had been categorised according to the level of argument, the frequency of arguments at each level by pair and within the groups was analysed. Finally, results were analysed by their chronological position in the transcripts. The transcripts were divided into four quarters, each representing a pair of lessons. As the lessons had actually been in pairs and the students covered one of the four sections in each pair of lessons, it seemed a logical division for the purpose of this analysis.

### 3.1.5 Rationale for selecting the design

This design has been used for a number of reasons:

1. The students were used to working with Information Technology as part of their learning process. Information Technology has been part of their learning in all subject areas since Year 8 and, for many of the students since they entered the school in Year 4.
2. The students were used to writing reports using word processors.
3. The students were used to having a video camera in a computer laboratory as one of the laboratories is on a live web camera as part of the school’s web page.
4. The students were used to the presence of the researcher in the computer laboratories along with their classroom teacher because of the researcher’s role as mentor for the classroom teachers in terms of Information Technology usage across the curriculum.
5. The focus on critical thinking skills in the College had accelerated in the last twenty four months

As a result, the students felt at ease in the Information Technology rich environment and did not perceive anything unusual or artificial in the experience. They were able to immerse themselves in the lessons and were willing to express themselves quite freely as they explored the simulation.
3.1.6 Assumptions underlying the design

The following assumptions are inherent in the design of the study:

1. That an analysis of the dialogue engaged in by the students will actually reveal the higher order thinking skills they are using.

2. That this dialogue is sufficient to observe and describe the higher order thinking skills used by the students.

3. That it is not necessary to administer pre- and post-simulation critical thinking skills inventories or tests.

4. This study is not meant to be an attempt to determine whether this type of simulation increases the students higher order thinking skills, rather it is merely a description of what is observed to be happening while the students are engaged in the task.

5. That the students’ involvement with a wide range of Information Technology genres will mean that they are comfortable with this type of simulation that they have not encountered before.

3.1.7 The stimulus material to be used

Students accessed simulation software called BioBLAST® using the college network in a computer room. The software enabled them to simulate the construction of a lunar base and focused particularly on the interaction of Biological systems.

3.1.7.1 Description of the material

The software was developed by the National Aeronautics and Space Administration in an attempt to provide students with a realistic understanding of the complexities of such a project and the inter-relationships that exist in such a project. The
The process commenced with an instructional phase in which students were tutored to an understanding of the concept of a “System” and how the change in inputs controlled the variety of outputs that could be achieved. Students were able to work their way through this module as many times as they wanted to until they felt that they fully understood the concepts.

The stimulus material being used in the study is a computer simulation designed by the National Aeronautics and Space Administration. As stated in the introduction to the software, the aim of the simulation is to:

- draw students into a futuristic, problem-solving scenario in a simulated lunar research facility. In the virtual lunar base environment, students use graphic simulation tools and resources to prepare for their mission goal: to design and test a model for a plant-based life-support system that can sustain a crew of six for three years. (Center for Educational Technologies, 1999, p. 5)

All the information necessary for this exercise was available on the simulation CD.

This figure is not available online. Please consult the hardcopy thesis available from the QUT Library.
At any time the students could exit from the planning process and access the information relevant to that stage of planning. This information includes an ‘Ask a National Aeronautics and Space Administration Expert Page’ where students could type in a question. The system searches a database of previously asked questions to find an approximate match. There is also an ‘Experts in Science™ CD’ which featured interview questions with twenty-one scientists and engineers who work in life support (Center for Educational Technologies, 1999).

There are three area-specific simulations, each of which:

- includes a background section with a description of related National Aeronautics and Space Administration Advanced Life Support research projects. Each simulator also contains a series of ‘Challenges.’ These are structured investigations that show students how to use the simulator as a research tool. The simulation settings and outputs can be saved and incorporated into a text or spreadsheet program for further analysis and presentation of results. (Center for Educational Technologies, 1999, p. 16)

These three area-specific simulations are:

1. Plant Production (PP) Simulator. The PP simulator is used to investigate plant

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*Figure 3.7. Screen for Plant Production Simulator (Center for Educational Technologies, 1999, p.16)*

This figure is not available online. Please consult the hardcopy thesis available from the QUT Library.
lighting requirements; seed-to-harvest schedules (see Appendix 3); and water, oxygen, and biomass production rates. Students select crop type, growing area, planting/harvesting schedule, photoperiod for each crop (see Appendix 2 & 3), and length of experiment in which they are testing each of these variables. This simulator provides dynamic graphical representations of the oxygen, potable (drinkable) water, edible biomass, and total biomass produced. Figure 3.7 shows the areas that can be planted and asks the students to allocate each area to a crop. Students select an area of the screen to plant and once selected the area opens up to permit the students to enter details of the types and amounts of product to plant. The simulation reports on the water, oxygen and carbon dioxide inputs and outputs. Based on these students can proceed with the next stage of the simulation or alter their current inputs.

2. Human Requirements (HR) Simulator. The HR simulator is used to investigate human requirements, inputs/outputs, and how changes in nutrition and activity schedules affect human health and nutritional requirements. Students set the food servings per day of the four crops; the individual crew member’s gender, age, and mass; the crew activity schedule for 24 hours; and oxygen and water inputs.

![This figure is not available online. Please consult the hardcopy thesis available from the QUT Library](image-url)

Figure 3.8. Screen for Human Requirements Simulator (Center for...
amounts available. Figure 3.8 shows the four major screens on which students balance the food available to the astronauts with the activities and oxygen and water requirements. The top left screen is used to select and input the types and quantities of food to meet the astronauts’ requirements. As the food types and amounts are selected, the screen indicates the calories, vitamins and minerals available from each source. The top right screen allows the students to input data about the number age and gender of the astronauts. The simulation indicates the dietary requirement for their crew as well as air and water to enable the astronauts to complete successfully their activities in the Lunar Base. The bottom left screen is details the activities undertaken by the astronauts are compared with their dietary needs and general health. The students allocate each astronaut to activities that cover the 24-day. The fourth screen covers a range of other inputs including the medical effects of living on a given diet and exercise regime. These are then adjusted to fit the age, gender and number of astronauts.

3. Resource Recycling (RR) Simulator. The RR simulator is used to test and compare oxygen, water, and nutrient production rates based on different settings for the bioreactors and the incinerator. This simulator provides “dynamic graphical representations of the liquid waste, inedible biomass, solid waste, evaporated water, carbon dioxide, nutrient solution, and ash that is produced” (Center for Educational Technologies, 1999, p. 16). Figure 3.9 shows the bioreactors and incinerators and the type and nature of their products. The drums on the top left are the bioreactors and those on the top right incinerators. The five tanks below them are for water storage. The students input values into these and the simulation then feeds back data to the rest of the system. The eight buttons across the bottom of the screen allow for interaction with other aspects of the software.
Finally, there is a BaBS Simulator that “ties together the components of the three area-specific simulators” (Center for Educational Technologies, 1999, p. 17). The simulator provides a number of tools including spreadsheets for energy and cost-analysis. Students were encouraged to analyse their data using the spreadsheets that assisted them to discover any problems in their designs.

For clarity of presentation the four simulations have been discussed as Topics in the remaining chapters of the study. Thus the Plant Production Simulator becomes Topic A, the Human Requirements Simulator Topic B, Topic C refers to the Resource Recycling Simulator and the BaBS Simulator is Topic D.

As well as these simulations there is an initial game called Tons O’ Tyns that:
  introduces students to the concepts involved in designing and maintaining a closed system. As students progress through the levels of the game, they
must create connections and make adjustments to balance the increasingly complex system. In the final level, students solve a puzzle that bridges the gap between the fictitious elements of the game and the components of a biological life-support system. (Center for Educational Technologies, 1999, p. 18)

There are four phases in the simulation:
Phase 1 is the Orientation Phase with a number of activities that “present thought-provoking problems related to life-support design” (Center for Educational Technologies, 1999, p. 21).

Phase 2 is the Research Phase that contains three types of activities:
1. research support activities that teach students how to use spreadsheets and interpret graphs (students can already do this);
2. the laboratory experiments for each of the area-specific simulations. These include “hands-on labs” and “original hands-on labs” (which the students brainstorm for themselves);
3. computer-based investigations for each of the area-specific simulations. (Center for Educational Technologies, 1999, pp. 20-30)

Phase 3 is the Mission Phase in which students “set parameters for crops, crew, and bioreactors to find out how long their astronauts can survive without resupply. Students then optimize their designs by adding cost-, energy-, and living-conditions parameters” (Center for Educational Technologies, 1999, p. 30).

The students then integrate the material collected from the hands-on labs and computer-based research investigations, complete the Journal concept-diagram then design and test their models using the BaBS simulator (Center for Educational Technologies, 1999, pp. 20 & 30).
Phase 4 is the Reporting Phase in which “students formulate and defend original research ideas that address the overall problem of how to support humans in space” (Center for Educational Technologies, 1999, p. 32). This includes:

1. writing up their original research proposals and/or laboratory research projects;
2. writing up their BaBS results and rationalising their BaBS settings;
3. sharing their findings.

When engaged in the simulation, students investigated a range of issues that would not have been possible except in a computer simulation. These centred on how Earth’s biological systems could be studies in a plant-based space habitat. The investigations were focussed on issues in the three focus areas of plant production (see Appendix 3), human requirements, and resource recycling. Students were encouraged to explore in the hands-on laboratory activities and computer-based simulations a range of questions that produced a range of Levels of argument. These questions included relationships between the effect of light intensity and plant growth; the effect of exercise on caloric and nutritional requirements; how is resource recycling affected by the crop harvest cycle? (Center for Educational Technologies, 1999, p. 5). Appendix I gives a detailed breakdown of the relationships explored in the simulation and how the exploration of these relationships is facilitated by the various stages of the BioBLAST® simulation.

3.1.7.2 Assumptions underlying the material

The name BioBLAST® stands for:

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The goals of the simulation are for “teaching and learning through the effective use of educational technology”:

1. Incorporate an inquiry-based approach to the topics of human requirements, plant production, and resource recycling.
2. Motivate student interest in research.
3. Investigate life science issues currently being researched at the National Aeronautics and Space Administration (NASA).
4. Provide a meaningful context in which student teams use computer-based tools and conduct hands-on laboratory experiments.
5. Guide students through the processes of scientific inquiry: hypothesis creation, data collection and analysis, and reporting of results. (Center for Educational Technologies, 1999, p. 5)

So, the designers are aiming at encouraging students to think scientifically, that is, to use/develop higher order thinking skills.

Another of the aims of BioBLAST® is to immerse students in a problem-solving context (Center for Educational Technologies, 1999, p. 19). This assumes that the students can gain an understanding of the complex relationships in a “Bioregenerative Life Support System” (BLiSS) from the activities undertaken in the simulation. That is, that they can develop a theoretical knowledge of a BLiSS.

It is then assumed that the students can apply this theoretical knowledge to the practical situation of building an appropriate lunar base.

The BioBLAST® manual states that “most tasks in BioBLAST® can be done in any order” (Center for Educational Technologies, 1999, p. 19). This is again considered to be an important factor in enabling students to engage in higher order thinking skills.
It also requires that the students be able to identify any weaknesses in their reasoning, re-assess what they have done and develop an appropriate model.

All this necessitates the students being able to actively use most of the higher order thinking skills described in the section 2.2 of this thesis.

Proponents of problem-based learning recommend that a sequence of tasks is consistent with the ‘whole to part’ approach. This software achieves that by using an overarching problem scenario to allow students to see the overall problem and the parts that must be addressed to achieve an outcome which is satisfactory to their goals. The problem-based approach increases student interest and allows for a range of different perspectives on important issues (see Appendix 2). This would best support students who can grasp the overall concepts and start to investigate the individual parts of the scenario before drawing all the individual information back together into a refined model. Some students may prefer to start with the individual information and gradually build up a full picture. This, too, should be possible with the way in which the simulation is presented.

According to the BioBLAST® manual, the teacher:

“Rather than being a dispenser of information, the teacher acts as a coach who helps students discover how to learn more effectively. This new role for the teacher is reinforced in the National Science Education Standards (U.S.A.), which encourages teachers to move away from direct transmission of knowledge toward the more effective goal of engaging students in the process of scientific inquiry. A problem-based learning context requires teachers to coax, prompt, and demonstrate analytical and critical thinking skills. (Center for Educational Technologies, 1999, p. 19)

This implies a whole new mindset for most teachers and students and will create an entirely different classroom ethos than most are used to. A major
assumption of the stimulus material is, therefore, that both teachers and students will be happy to work in this manner.

If, for example, a teacher decided to take tighter control of the situation and reduce it to a “step-by-step cookbook” approach (Windschitle, & Andre, 1998, p. 148) the entire scientific process/higher order thinking skills aspect would be changed.

The types of assessment items suggested for use with BioBLAST® once again emphasise “process skills, creativity, and diverse interpretation” and emphasise that there is not a “single correct answer” (Center for Educational Technologies, 1999, p. 19). So, again it can be seen that the creators of the simulation are aiming at engaging students in higher order thinking skills according to Jonassen’s (2000) model that includes creative thinking.

3.2 **A description of the context**

An understanding of the complex interrelationships in a biosystem necessary to sustain life is an essential learning area in Secondary Biological Science. The understanding of such complex systems can be difficult to appreciate theoretically because of the complexity, size, and number of the interrelationships.

Meaningful practical work is difficult because it is not possible to genuinely model the complex interaction of so many different variables. Also, even the modelling of a few variables requires too long a time period and is often fraught with failure (plants have a bad habit of dying even in close to ideal conditions).

All this often results in a “teacher talk” or, at best, a PowerPoint type presentation in an effort to impart theoretical knowledge.
The main objective of the Science teaching staff in the school is not just to impact theoretical knowledge but also to empower students in developing the complex reasoning and scientific process skills required by the Queensland curriculum. Therefore, the staff is keen to try methods that are suggested to be able to empower students to attain these skills. A model of instruction that enables the students to experience a suitable practical application of the theoretical knowledge has to be advantageous to these complicated themes if it proves to be successful (see Appendix 2).

Whilst this simulation does not enable students to develop practical laboratory skills, it does enable them to develop the thinking processes of scientific enquiry. It also enables them to deal with handling large quantities of information, learn how to study the impact of variable on variable and to start to understand how to build a cognitive model of complex systems.

The simulation frees the students from the necessity of recalling facts from memory by giving them access to data both internally and on the Internet. Thus it allows them to concentrate on understanding the relationship between the facts they have been taught.

3.3 Ethical issues

The school at which the study took place is at the forefront of both Information Technology usage and the development of a structured approach to the use of critical thinking in all aspects of the curriculum. As such, the senior executive was very keen to see any scholarly inquiry into these programs especially if the study points to or indicates a successful direction to take in the years ahead. The school believed that an open examination of what had been a very expensive exercise on their part would only serve to reinforce their commitment to educational excellence.
in the teaching/learning process. The Headmaster had given permission for the study to be conducted in the school under the auspices of the Director of Studies. The parents of the students gave permission before the classes were videoed and explanations were given about the relationship between this study and the other work that is currently taking place to enhance the teaching/learning process in the middle school.

The actual videoing of students was as non-intrusive as was possible. Students were used to having cameras in the rooms as there has been a live “web camera” filming in the school from 8.30am to 3.00pm each day. The videoing excluded all other students in the class as far as possible with the focus on the selected students. The researcher was well known to the students and it was common practice for him to be in the rooms, assisting teachers and students in the normal running of computer based lessons. Permission was also sought from the teacher to have his lessons videoed, but once again he was used to that happening. The parents were also happy with the videoing of classes and often watch their own children on the live web camera. For the purpose of the study, all parents were asked to provide written approval before the videoing.

3.4 Conclusion

This chapter detailed the design of the study including discussion of the rationale behind the selection of the students, the sources of data, the procedure for the study and the way in which the analysis took place.

The use of high quality software was essential to the study and therefore the description of the stimulus materials used was detailed to enable readers to have as clear a picture as possible of the material used in the simulation.
4.1 Introduction

The first section of this chapter analyses the discourse of the students into units of argument and categorises them according to the level of argument. In the second section, the frequency of arguments at each level in the total group and within the separate pairs is analysed. The next sections present an analysis of the argument units as they were recorded within each of the four topics constituting the software, both in the total group and within the separate pairs.

4.2 Levels of argument

The nature of the software encouraged argumentation and facilitated students’ consideration of their responses to their partner’s comments. It also enabled them to attempt to resolve an apparent endless range of issues.

The transcripts were examined and the conversations sectioned so that they best represented sections of argumentation as categorised according to the work of Osborne et al. (2001, p. 13). This categorisation was confirmed by an experienced science education researcher and where there was disagreement, resolved by discussion. The categorisation was assisted by the development of the theory in the years following the initial study which clarified a number of decisions which had been made (Erduran et al., 2004; Osborne, Erduran, & Simon, In press). In the categorisation process, the researcher’s important goal was for consistency across all transcripts. Following this, each segment was categorised as a Level 1 to Level 5. These levels were then summed to form the basis for the tables in the rest of the chapter.
The students demonstrated a wide range of levels of argumentation as categorised according to the work of Osborne et al. (2001) and demonstrated a range of length of argument unit. The longer dialogues could be of up to 60 comments, 30 from each student. However, the length of unit of argument and Level of argument did not correspond with even lengthy units often only displaying Level 1 argumentation.

Table 4.1 reports the argumentation scheme as proposed by Osborne et al. (2001, p. 13) and repeats the details from section 3.1.4.

Table 4.1

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Arguments consist of simple claim versus a counter claim or a claim versus a claim.</td>
</tr>
<tr>
<td>2</td>
<td>Arguments consist of claims with either data, warrants or backings but do not contain any rebuttals.</td>
</tr>
<tr>
<td>3</td>
<td>Arguments consist of a series of claims or counter claims with either data, warrants or backings with the occasional weak rebuttal.</td>
</tr>
<tr>
<td>4</td>
<td>Arguments consist of a claim with a clearly identifiable rebuttal. Such an argument may have several claims and counter claims as well but this is not necessary.</td>
</tr>
<tr>
<td>5</td>
<td>This is an extended argument with more than one rebuttal.</td>
</tr>
</tbody>
</table>

Examples of each level of argumentation will now be presented in the following sections.
4.2.1 Examples of Level 1 argumentation

Level 1 argumentation, “a simple claim versus a counter claim or a claim versus claim” (Osborne et al., 2001, p. 13), usually focused around discussions concerning the basic facts used in the program and were often derived from facts that the students recalled from previous lessons. The simplest of these, from the Average Academic Pair was (claim versus claim):

SA1 We need fuel cells, BioBLAST® needs fuel cells or else we won’t be able to live for more than six years.  (Claim)
SA2 It’s the three things near there, that’s them there, that’s it there.  (Claim – pointing at the pictures on the screen representing the number of fuel cells – see Figure 3.8))

The first student made the simple claim concerning the fuel cells required to provide energy for the running of the station and the second responded by making a supporting claim drawing attention to where the gauges might be found to make adjustments to the fuel cells. The need and use of the fuel cells had been discussed in previous class work.

A second argument type of Level 1 argument was (claim versus counter claim):

ST1 Nutrition from edible biomass, where do we go to get that? That's what we need, potato is the most edible biomass. Potatoes mass is fourteen and twenty-four for wheat (see Appendix 3).  (Claim)
ST2 Huh? Oh. Change that (amount of potato), it needs more light.  (Counter claim)

In this dialogue from the Top Academic Pair, the first student made the simple claim concerning the use of potato as the most suitable food to provide the maximum carbohydrate input relative to the type of food production required. The second responded by making a counter claim that related to the amount of light required to
produce the food product. His concern was that although the potato might not require as much area to produce, its light requirements made it not the best choice of food to produce the greatest amount of carbohydrate per unit of area.

In the third type of Level 1 argument, in the following passage, the two claims complemented each other (Claim and supporting claim):

SA1 You’re only allowed nine square metres. (Claim)
SA2 We would need more than one square metre wouldn’t you? (Supporting Claim)

The first student made the simple claim concerning the amount of space available for the production of food and the second responded by making a supporting claim drawing attention to the actual area required to produce this particular food type for their nutritional needs.

4.2.2 Examples of Level 2 argumentation

Level 2 arguments, “consisting of claims with either data, warrants or backings but not containing any rebuttals” (Osborne et al., 2001, p. 13), were often distinguished from Level 1 arguments by their use of appropriate data from the BioBLAST® program. The students became very adept at sourcing this data using the on-line videos and even the Internet at times. Examples of Level 2 argument units included:

SA1 They require 24 litres of water. (Claim with data)
SA2 What? As if you’d drink that much in a day? (Weak rebuttal)
SA1 They might need showers or something. (Counter claim)

Here the first student made a simple claim with data, that the crew needed 24 litres of water a day. This data was readily available from sources in the simulation. The second responded by a weak rebuttal demonstrating he had only considered the
water usage was for drinking water only. The first then explained what he saw as the reason for the astronauts using 24 litres per day.

Other nutritional facts were explored and were recorded in the students’ conversations. In the following segment of conversation the first student was exploring vitamin and mineral inputs and made the claim about Vitamin A. His partner immediately related the existing intake to that fact and used the data found elsewhere in the program to advocate the reduction of the amount of food eaten at that time:

ST2  Vitamin A is good.  (Claim)
ST1  We want to lower all of them …  (Weak rebuttal)

Other examples of Level 2 argumentation that also occurred around warrants that were derived from data available through the program included:

SA2  Oh okay, we’ve got too much oxygen.  (Claim)
SA1  Yeah.
SA2  Everything else is like perfect.  (Claim)
SA1  Except for laundry.  (Weak rebuttal)
SA2  Personal hygiene … we need more calories; the calories reduce the oxygen.  (Counter claim from data - warrant)
SA1  50(the number of calories). How much do we need … okay, thanks so much.

In this apparently aimless series of claims, the two students were independently thinking their way through the finer details of exercise and food intake to see if the decisions that they had already made would produce an acceptable solution to living in the Lunar Base.

4.2.3 Examples of Level 3 argumentation
Level 3 argumentation, “consisting of a series of claims or counter claims with either data, warrants or backings with the occasional weak rebuttal” (Osborne et al., 2001, p. 13), started to demonstrate higher order thinking skills. It was interesting to note that there were more Level 3 arguments than there were Level 2, but it was found that once students started in their discussions they tended to become more and more involved in the task at hand and demonstrated higher levels of argumentation. See section 4.3.1 for more discussion on this issue.

There were a number of typical examples. In the following example, the students have just decided that the gender of the astronaut may play any important role in balancing the diet and exercise requirements on the base. The decisions that are being made on the way through result in more or less indicator lights on the vertical scale on the screen (see Figure 3.8). There are different scales for each food constituent fat, carbohydrate, protein, as well as a number of key minerals:

ST2 One to three (the number of hours of exercise allocated in the day’s routine), why don’t we just try a female and see what happens there because they need time to exercise. (Claim)

ST1 Oh! That’s so good, we need more fat. (Claim)

ST2 Sodium. (relating to the lights that are flashing on the screen as a result of their last inputs)

ST1 We need less carbohydrates and we need more calcium, way more calcium. (Claim)

ST2 Carbohydrates, we need to have more. (Supporting Claim)

ST1 Potatoes have more carbohydrate. (Claim)

ST2 One of sodium. (Claim)

ST1 Salt. (Claim)

ST2 Soya and lettuce, we need less lettuce, or does he need more lettuce, I think he needs more lettuce for sodium. (Weak Rebuttal of the need for that amount of salt)
ST1: No, see that went, that made Vitamin A go up, look at it.  
   (Weak Rebuttal)
ST2: Yeah, I know.  
   (Comment)
ST1: Now have a look at it, you’ll have another green light there.  
   (Claim)
ST2: Sodium.  
   (Checking the balancing of the amount of salt required)
ST1: Run the simulator now.
ST2: I can’t.  
   (Referring to the current imbalance of salt)
ST1: What are you meant to do?  
   (Why can’t we run the simulator now?)
ST2: You’ve got to get all green lights, which means you need fat, carbohydrates, calcium, and sodium.  
   (Claim – before you can run the simulator)

The two students moved rapidly from the initial claim relating to the gender of the astronaut to the food required, to the mineral composition of the food types. The students used data derived from knowledge presented in a series of lessons before the use of the software and other data available within the software. They then used the calculator in the software to analyze this data to provide themselves with the knowledge required to balance the astronauts’ food requirements. There were a number of weak rebuttals in these dialogues for example:

ST1: Soya and lettuce, we need less lettuce, or does he need more lettuce, I think he needs more lettuce for sodium.  
   (Weak Rebuttal of the decision required to increase the sodium levels)
ST2: No, see, that went, that made Vitamin A go up, look at it.  
   (Weak Rebuttal from Data, there was not anything wrong with the decision in terms of sodium but it did have an effect on the Vitamin A)
Here, the second student realises that the effect of increasing the lettuce intake is to feed the astronauts too much Vitamin A. However, in the next dialogue, very little was expressed except that the student realised that the input data would not produce an acceptable outcome when the program was run:

ST2 Run the simulator now.

ST1 I can’t. (A simple statement which doesn’t refer to a physical inability to “run the simulator” but rather the settings will not produce an acceptable result)

These two situations gave the students an opportunity to disagree, rather than argue, but even these small sessions presented them with more opportunity for guided discussion and argument than is usually available in the everyday science lesson.

Yet another brief example of Level 3 argument occurred when the students came up with an unreasonable conclusion to their investigations that surrounded the age of the astronaut. It comes from the transcripts of the Average Academic Pair and expresses one student’s response to the ideal astronaut being a three year old weighing six kilograms:

SA2 What’s in this exercise? (I have lost track of what we are trying to achieve in this section)

SA1 So what are we doing now?

SA2 Maybe we could just try with a 3 year old kid…that would be easier. (Claim)

SA1 You can’t take a three-year-old on an international space station. (Weak Rebuttal)

SA2 Yeah you can, look crew, you can have a 3 year old who weighs 6 kilograms. (Weak Rebuttal using Data provided in the simulation)

SA1 Yeah but it’s not normal. (Weak Rebuttal)
Once again the software led the students to consider the reality of the situation and whether in fact the data presented in the table on the computer screen was plausible as well as accurate. It was interesting that this dialogue came from the members of the Average Academic Pair. This issue will be discussed further in chapter five.

4.2.4 Examples of Level 4 argumentation

Level 4 argumentation, “consisting of a claim with a clearly identifiable rebuttal with an argument having several claims and counter claims as well” (Osborne et al., 2001, p. 13), decreased in the number of arguments from Level 3 to Level 4. This appeared to be due to the fact that students often progressed from their initial argument to more general conversation once they had formed their point of view. There were therefore not many examples of Level 4. Three examples are given below.

In the first example, the students discuss an issue raised in the Human Requirements (HR) Simulator that is used to investigate human requirements, inputs/outputs, and how changes in nutrition and activity schedules affect human health and nutritional requirements. The conversation centres around the food types required to balance the mineral requirements for the astronauts:

ST2    Oh nothing is off the screen.  

        (Claim relating to the nutritional values on the gauges)

ST1    We need fat.  

        (Claim)

ST2    I reckon we need three things off the screen so like seven that’s all right.  

        (Claim)

ST1    Are we good with iron?  (Do we have enough iron in their diet?)

ST2    Not really.  

        (Weak Rebuttal)

ST1    Iron is still OK, oh I’m just getting rid of all of the potato. I’m going to leave one potato, no one likes the potato.  

        (Claim from personal preferences not Data)
ST2 Now it’s perfect, well getting close to perfect anyway.

(Counter Claim)

ST1 They’re not eating anything, like, they’re starving.

(Clearly Identifiable Rebuttal)

ST2 Okay let’s see Vitamin C, it increases the Vitamin C into that higher level, Vitamin C, there’s no such thing as Vitamin C in here.

(Counter Claim looking at food tables)

ST1 What’s Vitamin C? Dodgy, what is Vitamin C? There is no symbol for Vitamin C on here I don’t think.

ST2 A crew, make it a male, 1 to 3 years old weighing 6 kilograms, it’s a baby.

(Claim)

ST1 Baby sleeps 18 hours a day and then do 6 hours of nothing!

(Claim reading from Data table)

The whole dialogue focussed around the dietary needs of the astronauts, however, the outcome was rather surprising to the students. The students followed the logic of their argument to an illogical conclusion, the best age for this astronaut was a child between the ages of one and three years old. This is also discussed further in chapter five.

Another passage of Level 4 argumentation included some comments for the teacher that added an interesting slant to the argument. Again, the focus of much of the discussion and argument was around the issue of dietary requirements. The students here trying to relate the astronaut’s exercise requirements with what the astronauts were eating (T is the teacher).

SA2 We open this so you just put the values in and it tells you calcium.

(Claim describing what is happening on the screen at this point in the simulation)

SA1 It’s just starting to get a bit blown because you’re trying to do different things and it’s still not working, so you’ve tried
everything and it doesn’t work so you don’t know what to do next.

(Trying to adjust too many variables at once)

T So what do you two guys decide is the next thing to do?

(Comment to try to get the students back on task)

SA2 Give up!

T Some of you are giving too much carbohydrate aren’t you, just wait a minute, some of you to actually try and balance some of the vitamins have found that to do that you need more potato and more wheat, what does that do to the carbohydrates?

SA2 Sends it way up.

(Claim from Data learnt in previous science lessons)

T How could we get rid of carbohydrates?

SA2 More exercise.

(Claim from Data learnt in previous science lessons)

T More exercise.

SA2 But that gets rid of the fat that we’re trying to build up.

(Claim showing an understanding of the interrelationship between exercise and food types)

SA1 If you use more exercise you have to use more water which brings your water storage down which makes for more problems.

(Clearly Identifiable Rebuttal now also considering the extra restriction of water usage)

SA2 Which means you just need a little bit more lettuce which means the Vitamin A goes way up.

(Counter Claim)

The transcript does not clearly express the determination in the students’ arguments and the body language that accompanied this interchange. The video showed the students facing each other and gesturing at the screen. The voices became raised, and the students, once the teacher had re-engaged them with the task, became quite animated.
Yet another occasion where the students demonstrated Level 4 argumentation occurred as they sought to combine all the three aspects of the activity into the final module. They discussed a number of issues and eventually came to consensus on the length of days that their simulation will run successfully. Some of the apparently simplistic comments “No that will be over, yeah it’s just over” (transcript) hides an understanding of the underlying theory that has been learnt over the past seven lessons. The value in kilograms is the amount of waste product from the Lunar Base each day:

ST1  Let’s fix this, run 5,000 games.  
     (note the association of the software with a game! They actually wanted to run the experiment for 5,000 days)

ST2  No wouldn’t we want it to go up to the max cause the gas storage level is 20, I mean if we set our storage level to say 11, there we go it goes right to just about to the top, so that’s what we have to do.  
     (Rebuttal for ST1 who thinks their values in the computer are correct)

ST1  It’s 10.9, put 10.9 in.  
     (Claim based on the data on the computer screen, ST1 has realised that the number entered is too large and needs adjusting by a small amount)

ST2  You can’t change it by a decimal, try ten.  
     (Claim from Data, the student already understood that only whole numbers could be entered in this field)

ST1  No that will be over, yeah it’s just over.  
     (Rebuttal, student has realised that there is an inverse relationship between the values being entered and the results appearing on the screen)

ST2  No because when it goes over it goes off the screen, yeah have between eleven and ten kilograms every day.  
     (Rebuttal based on the Data from the screen)
ST1 They have big bowels, what do we do now we’ve finished this? (final agreement has been reached on all variables for the three parts of the simulation)

ST2 Just run it for 5,000 days.

T Just run it for 5,000, okay how do the three topics interrelate?

ST1 Well um the plant production one it’s all about the food for the human resource one and this one here is sort of comes off, they’re all around the human resource one.

T Right okay so can we actually run them all together into one?

ST2 Yep.

ST1 Um we did in that first one.

T Well how can we do the first one when we haven’t seen how the others work?

ST2 Oh well when we first got in the different type of simulator where we had to do all three areas like with soil and that and then we tested and it showed us all.

T Right.

ST2 Whereas with this one now we’re just dealing with individual sessions.

T Right so you’ve done the rest and this one is just working fine.

ST2 Yeah we figured out why too.

T Human resources we had all those, we had some big problems (recalling past conversations).

ST2 Mmm but we got pretty close when we had the six year old, oh the three year old that weighs six kilograms so that was the easiest way to do that.

T Okay and you’ve got all your exercise in?
The final comments from the teacher reinvigorated the conversation and resulted in the students going back and making some more attempts at completing the simulation with values that are more realistic for the ages of the astronauts.

4.2.5 Examples of Level 5 argumentation

Level 5 argumentation, “consisting of an extended argument with more than one rebuttal” (Osborne et al., 2001, p. 13), occurred only once in all of the transcripts. The model for argument made no comments about any norms that would be experienced by students of any particular age, but it would appear that greater skills in argument would be required from students before Level 5 argument occurred with any regularity. The fact that the students were also involved in a computer simulation may also have given them a momentum to move on to the next part of the simulation without necessarily resolving the issue at hand or rather than continuing their discussion at a greater depth. The one clear example demonstrated a distinct clarity of argument:

ST1 I shall try it again, okay. Is what we’re eating, fresh or dry food? I think it’s dry food. (Claim)
ST2 Yeah.
ST1 Put an A in the vitamin box. (Claim)
ST2 This is impossible! Maybe do less exercise? (Counter Claim - the large range of variables being adjusted made it very difficult to balance and the students were finding the solution very difficult)
ST1 Were you just trying to change the food around?
ST2 It’s not going to work, you need nine units, that’s a lot of potato serving, carbohydrate is good, sodium is good, protein is good, fat is bad, still too much exercise. (Counter Claim)
ST1 No, make him do more exercise! (Clearly Identifiable Rebuttal)
ST2 Yeah I know but we don’t want him to burn off a lot of fat.  
(Clearly Identifiable Rebuttal)

ST1 Mmm, lots of consequences, what are the consequences?  I don’t 
think the Vitamin A is good and sodium is good, Vitamin C is bad 
so, Vitamin C is bad so let’s see what happens to him.  
(Counter Claim)

ST2 Nothing!  Vitamin C prevents you getting colds.  Niacin whatever 
that is?  
(Claim)

ST1 It’s very nice.  

ST2 It is, it lowers his blood cholesterol level, riboflavin whatever.  
(Claim from a closer examination of available Data)

ST1 Riboflavin?  

ST2 That’s the one, there is no known consequences, that’s good so 
he’s not going to die yet.  
(Claim - based on data available through a Internet site)

ST1 Why don’t we just run the simulator and see what happens?  

ST2 We can’t run the simulator I don’t think, iron and C, iron help us 
play.  
(Claim due to the number of data items not currently balanced)

ST1 Okay now.  

ST2 (Reads aloud from Internet site) -Your iron consumption is above 
the recommended daily intake range.  The body cannot eliminate 
excess iron easily; high iron stores have been linked with increased 
risk of coronary heart disease.  Excess iron consumption is a major 
concern in space flight because the changes in blood indicate 
lesser need for iron, so he’s going to die, plus your phosphorous 
consumption is above the recommended daily intake range, high 
amounts of phosphorous in the blood can lead to tandy, that’s the 
one, okay calcium, excessively high intake of calcium can lead to 
soft tissue bones and increase risk of urinary stones and not going
to go from that, carbohydrates, Mmm your fat consumption is below the normal range, retinol are not produced in the body must be consumed in fat.

ST1 So the only thing you’re dying from is iron, so let’s have a look what iron is in, what is the iron symbol? Fe, that’s soya bean, like put up everything else, see what his iron level is now, iron levels too huge, it’s 140 too much, 130, 130 divide by seventeen is about seven, now get rid of five, five and three look at it now, you have 182 grams of lettuce. (Claim based on calculations)

ST2 Have a look at what it says (the scale on the screen), it didn’t do anything. (Claim from observed data)

ST1 Yeah it did look, now we’re like good. (Counter Claim based on an alternative opinion of the screen data)

ST2 Not really. (Counter Claim)

In this session, the students remained very much on-track and the occasions where clear argument occurred resulted in good decision making. Both students felt confident and competent in “having their say” and directing the conversation to achieve their goals. This session also demonstrates the detail to which the program took the students and the combinations required in order to achieve an acceptable solution to the task. Some of the dialogue is the students reading from an on-screen help and this in itself is useful in understanding the facility with which such software can assist learning.

Table 4.2 reports on the total number of arguments at each level for both pairs of students given as a total and a percentage by level both within pairs and for the pairs combined. The data shows a decrease in the percentage of arguments at each level of argumentation except between Level 2 and Level 3 where the increase is discussed in section 4.3.1.
### 4.3 Frequency of argument by level

The collation of identifiable arguments from both pairs and for each pair individually is reported in Table 4.2. The table also indicates the percentage of arguments at each level for the pair and for each pair separately.

**Table 4.2**

<table>
<thead>
<tr>
<th>Level</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Combined Pair</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>29</td>
<td>19</td>
<td>26</td>
<td>5</td>
<td>1</td>
<td>80</td>
</tr>
<tr>
<td>%</td>
<td>36.3</td>
<td>23.8</td>
<td>32.5</td>
<td>6.3</td>
<td>1.3</td>
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<tr>
<td><strong>Top Academic Pair</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>14</td>
<td>11</td>
<td>15</td>
<td>2</td>
<td>1</td>
<td>43</td>
</tr>
<tr>
<td>% (within pair)</td>
<td>32.6</td>
<td>25.6</td>
<td>34.9</td>
<td>4.7</td>
<td>2.3</td>
<td>100.0</td>
</tr>
<tr>
<td>% (within combined group)</td>
<td>17.5</td>
<td>13.7</td>
<td>18.7</td>
<td>2.5</td>
<td>1.3</td>
<td>53.8</td>
</tr>
<tr>
<td><strong>Average Academic Pair</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>15</td>
<td>8</td>
<td>11</td>
<td>3</td>
<td>0</td>
<td>37</td>
</tr>
<tr>
<td>% (within pair)</td>
<td>40.5</td>
<td>21.6</td>
<td>29.7</td>
<td>8.1</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td>% (within combined group)</td>
<td>18.7</td>
<td>10.0</td>
<td>13.7</td>
<td>3.7</td>
<td>0.0</td>
<td>46.2</td>
</tr>
</tbody>
</table>

Note: Percentages are rounded to one decimal place and don’t always sum to 100.0%.
4.3.1 Data analysis for individual pairs

The data for the Top Academic Pair, showed that most arguments occurred in the Level 1 to Level 3 range and tended to decrease in number of arguments with increasing level of argumentation except between Level 2 and Level 3. It appears that once students started in their discussions they tended to become more and more involved in the task at hand and demonstrated higher levels of argumentation, hence moving naturally from Level 2 to Level 3.

The data from the Average Academic Pair, showed a similar pattern with most arguments occurring in the Level 1 to Level 3 range and a decrease in number of arguments with increasing level of argumentation except between Level 2 and Level 3.

The two pairs exhibited similar skills in argument with the Top Academic Pair accounting for 53.8% of the total responses. This figure rose to 56.8% of the responses in Levels 2 to 5. However, a closer examination of the comments did not reveal any sizeable differentiation in the type of comments between the two pairs.

Observations of the Top Academic Pair indicated they spent a greater amount of time in a synergetic relationship whereby they seemed to “feel” the response from their partner. Thus much of the Level 1 communication that occurred in the Average Academic Pair was absent in their work. The video showed the Top Academic Pair pointing at the screen to emphasise issues and even at times to argue about points until a resolution could be found. The Average Academic Pair expressed their issues more vocally and at times engaged in extensive Level 1 argument without appearing to resolve anything.

A good example of this comparison at Level 1 argument is included below. The Average Academic Pair of students expressed their knowledge of the data required
to complete the simulation in discussions that included basic claims that were often
derived from facts that the students recalled from their previous lessons, therefore
merely using one claim to support a previous claim (claim versus claim):

SA1  We need fuel cells, BioBLAST® needs fuel cells or else we won’t
be able to live for more than six years.  (Claim)
SA2  It’s the three things near there, that’s them there, that’s it there.  
  (Claim)

Whereas, even at this simple Level (1), the Top Academic Pair were already using
counter claims to proceed at a quicker rate through the software (claim versus
counter claim):

ST1  Nutrition from edible biomass, where do we go to get that?  That's
what we need, potato is the most edible biomass.  Potatoes mass is
fourteen and twenty-four for wheat.  (Claim)
ST2  Huh?  Oh.  Change that, it needs more light
  (Counter claim)

Even the content of these arguments pointed to evidence of higher order thinking
skills and the underlying achievement of the Average Academic Pair; “edible
biomass” demonstrates concept formation unusual in many Year 9 students.

Similarly, if we compare examples of Level 4 argumentation, we notice that the Top
Academic Pair develops a great depth of argument in their rebuttals and counter
claims:

ST1  We need fat.  (Claim)
ST2  I reckon we need three things off the screen so like seven that’s all
right.  (Claim)
ST1  Are we good with iron?
ST2  Not really.  (Weak Rebuttal)
ST1 Iron is still OK, oh I’m just getting rid of all of the potato, I’m going to leave one potato, no one likes the potato.
(Claim)

ST2 Now it’s perfect, well getting close to perfect anyway.
(Counter Claim)

ST1 They’re not eating anything, like, they’re starving.
(Clearly Identifiable Rebuttal)

ST2 Okay let’s see Vitamin C, it increases the Vitamin C into that higher level, Vitamin C, there’s no such thing as Vitamin C in here.
(Counter Claim)

SA2 We open this so you just put the values in and it tells you calcium.
(Claim)

As opposed to this, the Average Academic Pair, who whilst also using Level 4 arguments, were much less focussed in them and in this case required the teacher prompt them to keep them on task.

SA1 It’s just starting to get a bit blown because you’re trying to do different things and it’s still not working, so you’ve tried everything and it doesn’t work so you don’t know what to do next.
T So what do you two guys decide is the next thing to do?
SA2 Give up.
T Some of you are giving too much carbohydrate aren’t you, just wait a minute, some of you to actually try and balance some of the vitamins have found that to do that you need more potato and more wheat, what does that do to the carbohydrates?

SA2 Sends it way up. (Claim)

T How could we get rid of carbohydrates?
SA2 More exercise. (Claim)

T More exercise.

SA2 But that gets rid of the fat that we’re trying to build up. (Claim)
SA1  If you use more exercise you have to use more water which brings your water storage down which makes for more problems.  
   (Clearly Identifiable Rebuttal)  
SA2  Which means you just need a little bit more lettuce which means the Vitamin A goes way up.  
   (Counter Claim)

A similar observation came from observing and filming the other groups that formed the rest of the class. The higher achievement groups were more able to focus on the task at hand and consider issues with higher level arguments although this difference in Level I and II argument was not evident: “…these (top ability) students had related well to the activity with the nutritional requirements and the age and sex” (Teacher, December 2002).

4.4  Data analysis for arguments in various topics

The four topics that covered the duration of the task have been labelled Topics A to D for ease of identification.

4.4.1  Rationale for the categorisation of argument by topic

Whilst the students were accustomed to using computer software as an aid to their learning, there was very little software in the school of the high educational calibre of BioBLAST®. As the lessons had actually been in pairs and the students covered one of the four sections in each pair of lessons, for the purpose of this analysis, the transcripts are divided into the discourses associated with each of the four topics each representing the pair of lessons.

4.4.2  Data analysis of argument by topic
Table 4.3 reports on the total number of arguments at each level recorded in the topics. Results are given as a total number and a percentage of the total of number of arguments.

Table 4.3

Frequency of Argument Units of Level of Argument for Combined and Individual Pairs across topics given as Total Number and Percentage

| Level N(%) | Combined Pairs | | | | | Total |
|-----------|----------------|---|---|---|---|---|---|
|           | I   | II   | III | IV | V |     |
| Topic A   | 10(47.6) | 3(14.3) | 6(28.6) | 1(4.8) | 1(4.8) | 21(100.0) |
| Topic B   | 12(80.0) | 1(6.3) | 3(18.8) | 0(0.0) | 0(0.0) | 16(100.0) |
| Topic C   | 3(20.0) | 5(33.3) | 5(33.3) | 2(13.3) | 0(0.0) | 15(100.0) |
| Topic D   | 4(14.3) | 10(35.7) | 12(42.9) | 2(7.1) | 0(0.0) | 28(100.0) |
| TOTAL     | 29(36.3) | 19(23.8) | 26(32.3) | 5(6.3) | 1(1.3) | 80(100.0) |

Within Pairs

<table>
<thead>
<tr>
<th>Level N(%)</th>
<th>Top Academic Pair</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>Topic A</td>
<td>4(40.0)</td>
<td>1(10.0)</td>
</tr>
<tr>
<td>Topic B</td>
<td>7(70.0)</td>
<td>0(0.0)</td>
</tr>
<tr>
<td>Topic C</td>
<td>0(0.0)</td>
<td>3(50.0)</td>
</tr>
<tr>
<td>Topic D</td>
<td>3(17.6)</td>
<td>7(41.2)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>14(32.6)</td>
<td>11(25.6)</td>
</tr>
</tbody>
</table>

Average Academic Pair

<table>
<thead>
<tr>
<th>Level N(%)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
</tr>
<tr>
<td>Topic A</td>
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<td>5(83.3)</td>
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<tr>
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<td>3(33.3)</td>
</tr>
<tr>
<td>Topic D</td>
<td>1(9.1)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>15(40.5)</td>
</tr>
</tbody>
</table>
Note: percentages are rounded to one decimal place and don’t always sum to 100.0%

4.4.2.1 Argument in the first topic

These eight lessons were in pairs and the students tended to work through each of the three area-specific simulations (topics) in one of the double lessons. In the first topic students commenced with a short exercise in balancing inputs and outputs, *Tons O’ Tyns*, part of Part A, before moving on to the first of the three area-specific simulations, the Plant Production (PP) Simulator which is used to investigate plant lighting requirements; seed-to-harvest schedules; and water, oxygen, and biomass production rates. Within this section students were able to select variables which included: crop type, growing area, the planting and harvesting schedule, the period of each rotation and the total time over which they wanted to test their variables. There were no identifiable arguments in the *Tons O’ Tyns* introduction due to its purely instructional nature but as soon as the students started the Plant Production (PP) Simulator, a range of identifiable argument was recorded.

Eight of the ten Level 1 arguments occurred at the beginning of the Plant Production (PP) Simulator. One of the earliest was recorded in the Average Academic Pair and related to the first issue that required solution, what area was to be planted with each crop.

SA1  You’re only allowed nine square metres.

(Claim referring to the total area)

SA2  We need more than one square metre wouldn’t you? There is a nice seven day soya beans (quick growing variety), oh this tells you everything, (observing the hints on the screen), I really don’t know what I’m doing, we need more than one crop, go away.

(Claim based on Data – note SA1 tries to enter his own data without consultation at this point)
Whilst the students were only just starting the project, it is evident that they were being forced to consider a number of alternatives on a continuum that was encouraging the argumentation indicative of higher order thinking skills.

Later in the first topic, we see the other pair of students (Top Academic Pair) examining the relationship between the area planted and the ability to store the resultant biomass. They were nearing the end of the session and were already being encouraged by the software to make decisions that would effect the length of time that the Lunar Base would survive:

ST1 It doesn’t matter though if you have anything left over.  (Claim)
ST2 No because we used one bioreactor a day, because look if we had ten we do it every ten days but if we have ten and only do it every 50 days.  (Counter Claim)
ST1 But it doesn’t matter though, that really doesn’t matter.  (Weak Rebuttal)
ST2 Every eight days, look at that, it screws up.  That’s why this has to equal that because that’s just what we’ve set it at.  Just say we increased the storage to maybe 100.  Look at that!  (Student runs the simulation, uses the Data to Rebut the previous claim, then enters the Data that he now suspects is correct and proves his point)

4.4.2.2 Argument in the second topic

The second topic involved the students in the Human Requirements (HR) Simulator that is used to investigate human requirements, inputs/outputs, and how changes in nutrition and activity schedules affect human health and nutritional requirements.
Whilst the activities in each pair of lessons appeared to be similar in structure, the content varied widely and the Human Requirements (HR) Simulator in particular produced some interesting argument units such as this one that led to the best age and sex for the astronauts. This was categorised as a Level 3 argument because the “argument consists of a series of claims or counter claims with either data, warrants or backings with the occasional weak rebuttal” (Osborne et al., 2001, p. 13, repeated from section 4.2.4):

ST2  Now it’s perfect, well getting close to perfect anyway.  
     (Counter Claim)
ST1  They’re not eating anything, like, they’re starving.  
     (Clearly Identifiable Rebuttal)
ST2  Okay let’s see Vitamin C, it increases the Vitamin C into that 
     higher level, Vitamin C, there’s no such thing as Vitamin C in here.  
     (Counter Claim)
ST1  What’s Vitamin C?  Dodgy, what is Vitamin C?  There is no 
     symbol for Vitamin C on here I don’t think.

However, this topic was unusual, with a total of 16 identifiable arguments being recorded and 12 of these being ascribed to Level 1. A typical Level 1 argument which examined how the astronauts used their 24 hours in each day:

SA2  No because it has to be twenty-four hours.  
     (Claim)
SA1  And we got only twenty-three.  
     (Claim totalling the time allocation to tasks they had devised)
SA2  Now it’s twenty-four hours, now for the oxygen available what is 
     the balance and how much water do you need.

Another Level 1 example that related to the amount of food being consumed by the astronauts and again reflected a very simplistic understanding of this section of the program.
SA1 Well, why did you ask?
SA2 Cause he’s not eating enough hey or he’s doing too much exercise.  
   (Counter Claim from Data)

A slightly more developed argument related to a discussion which related food that was required to balance the astronauts exercise in the construction of the Lunar Base:

ST2 1 kilogram every hour.          (Claim from Data)
ST1 I don’t think.                 (Rebuttal)
ST2 Every day, okay every day.     (Counter Claim)
ST1 Oh every day, three kilograms a day not a 100.     (Counter Claim)
ST2 What am I meant to do? Oh my parents don’t care.  (Aside)
ST1 Storage capacity twenty, slow reactions.        (Claim)
ST2 Twenty!                          (Counter Claim)
ST1 No the answer is.               (Counter Claim)
ST2 Just put twenty.                (Counter Claim)
ST1 Twenty-five.                   (Counter Claim)

Whilst the second topic could have demonstrated an improvement in the higher order thinking skills it appears that the concepts involved in this simulation appeared to be of a more complex nature and reduced the opportunities for either pair to demonstrate these skills.

4.4.2.3 Argument in the third topic

The third topic involved the students working on the Resource Recycling (RR) Simulator which is used to test and compare oxygen, water, and nutrient production rates based on different settings for the bioreactors and the incinerator.
At this point in the simulation, the half way mark, students appeared to have started to understand the issues of the simulation and discussing underlying principles of the activity rather than merely trying to successfully navigate what they may have perceived to be a game. This change was apparent in the rapid decrease of the number of Level 1 arguments from 34.5% of the total arguments in the first topic to 41.4% in the second to 10.3% in the third. Conversely, Level 4 arguments were up to 40.0% in the third topic as opposed to 0.0% in the second and 20.0% in the first.

Whilst the students were using higher levels of argumentation, the materials that they were discussing were not better known to them or in fact facts that they had experienced at a greater depth. This might have been because they had realised the importance of teamwork and were in the process of developing a need to vocalise their thoughts in determining a solution to the simulation but there was no clear evidence on this speculation. The following two Level 3 arguments involved the students working on the issue of appropriate balances required for the incineration of waste product and how that waste product could be recycled in gaseous form, certainly concepts far from the everyday science classroom.

ST2  See look, you have to do it every four days or do it every six days  
(Claim relating to how often the incinerators required lighting)

ST1  Look at this, look at that.  
(Observing the results of the firing of the incinerators on the gauges on the screens)

ST2  Oh cool.  
(Claim of success)

ST1  See exactly!  
(Claim of success)

ST2  Yeah because we used a kilo.  
(Claim relating to the inputs they had used)

ST1  It doesn’t matter though if you have anything left to burn.  
(Weak Rebuttal related to the perception that ST2 had that it was completely successful)
ST2  No because we used one bioreactor a day because look if we had 10 we do it every 10 days but if we have 10 and only do it every 50 days.

(Warrant from the logical extension of Data given)

ST1  But it doesn’t matter though, that really doesn’t matter.

(Weak Rebuttal)

ST2  Every eight days, look at that. It screws up. That’s why this has to equal that because that’s just what we’ve set it at. Just say we increased the storage to maybe 100, look at that.

(Weak Rebuttal)

ST1  So? Are they killing up? NO!

(Weak Rebuttal from observations on the screen)

The second argument from a similar point of view indicates the improvement in the argument of the students as they further considered the issue of just how the incinerators worked. At the same time, they had started to consider how they would integrate all components of the simulation, to see the disparate parts would successfully integrate.

ST1  Yeah the incinerator.

ST2  What is that, it goes up and then down? (Discussing the process over time as the gauges indicate the incineration process)

ST1  No that’s one of the incinerators. (Claim)

ST2  Yeah but it goes right up and then down and then it will go right up again, see and all of a sudden it will shoot down see.

(Claim as the students start to see the relationship between the activity and the gauges)

ST1  Does it matter? (Weak Rebuttal – as the student starts to question the relationship)
ST2 Yes it does! (Weak Rebuttal – the student is now convinced that he understands the relationship but doesn’t appear to be able to explain it in words)

ST1 There’s no, we haven’t got solid weight, we don’t, that’s the thing. (Weak Rebuttal – again unable to express his concerns about what is happening with in incineration process)

ST2 It looks like it’s working because before we had five of the reactors working correctly and four of the five were going like this and the fifth one was empty and so we got rid of the fifth one and now we only need four but they’re still working. (Weak Rebuttal which ends the unit of conversation)

4.4.3.4 Argument in the fourth topic

Once each of the previous sections was completed the students spent the final pair of lessons working on the BaBS Simulator that “ties together the components of the three area-specific simulators” (Center for Educational Technologies, 1999, p. 16).

The number of examples on higher Level arguments increased again in this topic to 43.8% as the students demonstrated the skills that they had developed over the eight lessons. At the lower Levels of argumentation there were a marked decrease in the number of arguments with only 13.8% Level 1 arguments compared with the average of 37.9% in the previous two sessions, 52.6% of the Level 2 arguments compared with an average 16% in the previous three sessions. In the higher Levels of argument the percentages compared to the other three topics increased with 46.2% of all Level 3 arguments as opposed to an average of 17.9% in the previous sessions and 40.0% of Level 4 which is exactly double the average of the other three sessions.
An example of how the students were combining the three parts together is given in a passage where the two students, with the subtle directing of the teacher, try to balance the food production module with the other two modules:

T  Right. Now what have you done to make the 10,000 come up? Have you started pressing a button? Do we know how to produce it?

(Discussion centres around the amount of food and calorie units required for the length of time)

ST1  No, not really. See, now we have 4.65 people.

(Data given by the previous result is calculated as a decimal number – students need to adjust this to a whole number)

T  Right. What about that total biomass?

ST1  I'm not sure what that is at this point. Is that all, because it's not available in other types but if you come back to the example here, it's the same as edible biomass – they're both out of 762?

(Claim from the Data available)

T  However, there's very little there, isn't there? Are you getting enough water?

ST1  Oh yeah, we're getting enough water for about 50 people.

(Claim from the Data and calculations – comes very quickly as they have now some experience with the outcomes)

ST1  But I think this here – the edible biomass is a portion of the biomass that's edible. That's why it's, they're both out of the 762 that we're producing. But this is all that we can eat. And it's enough for four and a half people.

(Weak rebuttal includes the Warrant that the edible biomass is a portion of the biomass that's edible)

ST2  So what's the point. You've got to try and get it so that people can get supplies.  

(Weak Rebuttal without any substantiation)
ST1 Yeah, so you can get more people supplied for a year and we can get four people at the moment, because that's the smallest amount. (Claim from Data)

The two students have come to a number of successful conclusions as they rehearse issues previously discussed in the first topic of the software.

Another example of Level 4 argumentation occurred as the students in the Top Academic Pair sought to combine all the three aspects of the activity into the final module. This was previously discussed in section 4.2.4, the discussion on Level 4 arguments but bears repeating as it demonstrates how the students have improved their skills in argument as they reach the end of the simulation and as they combine a number of issues to eventually come to consensus on the length of days that their simulation will run successfully. The value in kilograms is the amount of waste product from the Lunar Base each day:

ST1 Let’s fix this, run 5,000 games.

(actually, run the experiment for 5,000 days)

ST2 No wouldn’t we want it to go up to the max cause the gas storage level is 20, I mean if we set our storage level to say 11, there we go it goes right to just about to the top, so that’s what we have to do. (Rebuttal for ST1 who thinks their values in the computer are correct)

ST1 It’s 10.9, put 10.9 in. (Claim based on the data on the computer screen, ST1 has realised that the number entered is too large and needs adjusting by a small amount)

ST2 You can’t change it by a decimal, try ten. (Claim from Data already understood by the student)

ST1 No that will be over. Yeah it’s just over. (Rebuttal, student has realised that there is an inverse relationship between the values being entered and the results appearing on the screen)
ST2 No because when it goes over it goes off the screen, yeah have between eleven and ten kilograms every day.

(Rebuttal based on the Data from the screen)

ST1 They have big bowels, what do we do now we’ve finished this.

(final agreement has been reached on all variables for the three parts of the simulation)

ST2 Just run it for 5,000 days.

T Just run it for 5,000, okay how do they interact with the three topics?

ST1 Well, um the plant production one. It’s all about the food for the human resource one and this one here is sort of comes off. They’re all around the human resource one.

T Right okay so can we actually run them all together into one?

ST2 Yep.

ST1 Um we did in that first one.

T Well how can we do the first one when we haven’t seen how the others work?

ST2 Oh well when we first got in the different type of simulator where we had to do all three areas like with soil and that and then we tested and it showed us all.

T Right.

ST2 Whereas with this one now we’re just dealing with individual sessions.

T Right so you’ve done the rest and this one is just working fine.

ST2 Yeah we figured out why too.

T Human resources we had all those, we had some big problems.

(recalling past conversations)

ST2 Mmm but we got pretty close when we had the six year old, oh the three year old that weighs six kilograms so that was the easiest way to do that.
Okay and you’ve got all your exercise in?

Observation by the researcher and teacher comments supported the contention that the confidence of the students improved by this stage of the simulation and tends to indicate that some learning of argumentation has occurred over the time that the students explored the simulation.

4.4.4 Argument by pair across the four topics

This chapter ends with a brief analysis of the ways in which the argumentation of the two pairs was spread across the time of the recording of data. It was difficult to know if the fact that the Top Academic Pair produced a greater variation in the percentages or if this was a normal result that could be expected by studying two pairs of similar abilities.

4.4.4.1 Argument in the Top Academic Pair across topics

An examination of the Top Academic Pair appeared to show a more even distribution of argumentation during the first two topics followed by a reduction in the number of arguments in the third topic as they appeared to become more at ease with the skills of their partner. The effect of that was to allow the partner to try what they wanted in the knowledge that they had enough time to try as many alternatives as they required to complete the task. The passage below indicates such an effect and the lack of any argumentation that occurred over quite a substantial period of time:

ST1  It’s on about this part of the game, that is program.
ST2  Yeah that’s it.
ST1 (Reading) The resource recycling simulator makes you use some of the processes that are being investigated in NASA’s lunar lander program.
ST2  Is that spelt correctly?
ST1  No that’s spelt right.
ST2  Whoops where were we?

(As they move from one part of the simulator to another)

ST1  How many incinerators do we have here, we only need four, now
     watch when we run, see we only need to use four incinerators.
ST2  Why don’t you run it for 1,820 days and see what happens, that’s a
     few years.
ST1  I’ll just finish these.            (Entering other Data items)
ST2  Just put in like three years, no put in five years.
     (It doesn’t really matter – we’ve got plenty of time)
ST1  What was it, 1860?
     (The approximate number of days in five years)
ST2  No I’ll do it five times, they’ll work it out, no that’s not right.
     (A very relaxed attitude)
ST1  It is?
ST2  That’s going to take a while, oh well.
     (The while was less than a minute!)
ST1  I thought it would help for Maths and the hundreds of answers.
     (That is, let the computer do the calculation, don’t worry about the
      Maths)
ST2  I don’t think its working.
ST1  Let’s check out our incredible results.
     (Incredible? The computer is doing the work!)
ST2  Nothing is happening at all. (So, they now proceed to try
     again)

Once the Top Academic Pair worked their way through to the last topic, they found
it very easy to combine the previous three simulators but in the process engage in
many in depth discussions as they sought to get the best results.
4.4.4.2 Argument in the Average Academic Pair across topics

On the other hand, the Average Academic Pair engaged in more argumentation in the first topic (29.7%) and once they moved into the second topic spent more time on the successful manoeuvring through the simulation. They did, however, steadily increase the percentage of recorded arguments in each of the successive topics ending up with 29.7% again in the fourth topic.

These results would again speak of learning that was taking place over time and especially in the fourth topic when they were combining the knowledge and facts learnt in the previous three topics. However, this could only be advanced tentatively at it is confounded by the difficult nature of contexts in the various topics.

4.4.5 Summary of argument across topics

There appears to be some tentative indication that the simulation may have developed skills in argumentation over the duration of the activity (Topics). The combined number of arguments in both pairs in Topic D was 35.0% of the total number of arguments and 50.0% of these were Level 3 to 5 arguments. The Top Academic Pair in particular demonstrated this increase in the number of arguments with 40.0% occurring in Topic D. Whether this would happen so quickly or at a similar rate in a “normal” Science classroom is really only a matter for speculation without a more controlled experimental model. This could be including into any further study.

4.5 Conclusion

The chapter has given scripts representing the five levels proposed by Osborne et al. (2001), and found these levels to be adequate to represent the complexity of argument evident. Frequency tallies of the levels of argument showed that the
majority of arguments were of lower levels, levels I and II, and frequency decreased across the full range except between Levels II and III which was discussed in the text.

The variation in the tally between the two pairs of differing academic achievement was also analysed and possible reasons or that variation proposed.

Some tentative comments were also made about the analysis of tallies across the four topics but these were not conclusive due to the different nature of contexts in these four topics that may be confounding this finding.
CHAPTER 5
DISCUSSION

5.1 Introduction

The initial section in this chapter discusses the level of argumentation as it relates to the total number of arguments during the lessons, that is, the number of arguments that could be categorised at each of the five Levels. The chapter then proceeds to examine the variation between the two pairs in their use of argumentation. The chapter continues by examining the types of argumentation that are identified in the conversations, categorised by their chronological position in the transcripts. The final section of the discussion presents a comparison of the two pairs across the four topics of the simulation.

5.2 Discussion of argumentation as it related to the various levels

The nature of the software and the manner in which it was employed encouraged argumentation and forced students to consider their responses to their partner’s comments. The argumentation ranged across the five levels proposed by Osborne et al. (2001) and varied in the length of unit of argumentation.

The approach adopted by this simulation fulfils the criteria of the “thinking curriculum” approach as discussed in the Introduction (section 2.1; Dori et al., 2003). It required the students to evaluate the knowledge they were constructing and to connect and integrate that knowledge. Throughout his interview the classroom teacher commented that the work with the simulation seemed to give the students a deeper understanding of the material than was normally gained in standard lessons, “it is a refreshing change to have a program which allows them (the students) to apply and go beyond the general run of the mill classroom work” (Teacher, December 2002). He believed this was due to the different way the students worked
with the knowledge. This is in accord with Mazarno and Pickering’s (1997, p. 113) observation that a deeper understanding is achieved by an approach that causes the learner to “change, extend and refine the knowledge.” The development, connecting and integrating of this knowledge is reflected in both the content and level of argumentation employed by the students.

Level 1 argumentation, “a simple claim versus a counter claim or a claim versus claim” (Osborne et al., 2001, p. 13), was found in 36.3% of the discourse units analysed (Table 4.2). These usually focused around discussions about the basic facts used in the program and were often derived from facts that the students recalled from their previous science class lessons or from working with the simulation.

Level 2 argumentation, “consisting of claims with either data, warrants or backings but not containing any rebuttals” (Osborne et al., 2001, p. 13), occurred in 23.8% of the identified argument units (Table 4.2) and were distinguishable from Level 1 by their use of appropriate data from the BioBLAST® program. The students became very adept at sourcing this data using the on-line videos and even the Internet at times.

At this level, issues about which the students’ knowledge was minimal, such as nutritional facts, were explored and as the students’ conversations were examined, it was interesting to observe the argumentation developing. In a particular segment of conversation (see section 4.2.3), the first student was exploring vitamin and mineral inputs and made a claim about the use of Vitamin A. His partner immediately related the existing intake to that claim and used the data found elsewhere in the program to advocate the reduction of the amount of food eaten at that time. In what then appeared to be an aimless series of claims, the two students independently thought their way through the finer details of exercise programs and food intake to see if the decisions that they had already made would produce an acceptable solution.
to living in the Lunar Base. The interactions caused by the software and the thought processes expressed through argument demonstrated just how the software was assisting in the development of higher order thinking skills by enabling the students to use the information meaningfully (Engle, & Conant, 2002) in a “real-life context” (Jimenez-Aleixandre, & Pereiro-Munoz, 2002).

Level 3 argumentation, “consisting of a series of claims or counter claims with either data, warrants or backings with the occasional weak rebuttal” (Osborne et al., 2001, p. 13), occurred in 32.5% of the identified argument units (Table 4.2). It was interesting to note that there were more of these than there were Level 2. It was found that once students started in their Level 2 discussions, they tended to become more and more involved in the task at hand and built the discussion to demonstrate higher levels of argumentation. There were a number of typical examples such as when the students decided that the gender of the astronaut might play an important role in balancing the diet and exercise requirements on the base. The two students moved rapidly from the initial claim relating to the gender of the astronaut to the food required, to the mineral composition of the food types. The students used data derived from knowledge presented in a series of lessons before the use of the software and other data available within the software. They then used the calculator in the software to analyse this data to provide themselves with the knowledge required to balance the astronauts’ food requirements. The students were able to use the variance in data between genders to demonstrate that it was better to use female astronauts to complete this section of the task. In a normal science classroom, it would not have been usual for this question to be asked and the boys would certainly have no reason for pursuing an answer.

So, the students’ responses to this simulation indicate that it also met the definition of scientific reasoning as the “formulation of theories and models with consideration of the evidence that supports them” as advanced by Stephens et al. (1999, p. 189).
These situations gave the students an opportunity to disagree, rather than argue, but even these small sessions presented them with more opportunity for guided discussion and argument than is usually available in the everyday science lesson: “I really believe the opportunity is there for it to be used as an excellent tool particularly in the higher order thinking skills” (Teacher, December 2002). It was interesting that only 42.3% of the Level 3 dialogues came from the members of the Average Academic Pair. The teacher commented on the variety of responses and how they related to the ability of students in the class:

better students listened, copied down notes and used those notes to actually work out what they were supposed to do, so I found that the actual type of conversation that went on varied greatly depending on the abilities of the students. (Teacher, December 2002)

Level 4 argumentation, “consisting of a claim with a clearly identifiable rebuttal with an argument having several claims and counter claims as well” (Osborne et al., 2001, p. 13), occurred only 6.3% of the time. The sharp decrease from the number of Level 3 arguments appeared to be due to the fact that students often progressed from their initial argument to more general conversation once they had formed their point of view, “as we worked … from the very capable to the capable to the ones that are less capable and need more concrete information to work with, those students struggled once they got past the basics, they became bored reasonably quickly” (Teacher, December 2002). Students were accustomed to spending only short blocks of time “on-task” in many of their subjects and this was reflected in the way they approached the lessons. Despite this problem, they did seem to be more involved for longer periods of time whilst using the simulation than often in normal class work: “…the better students listened, copied down notes and used those notes to actually work out what they were supposed to do” (Teacher, December 2002).

There were, therefore, not many examples of Level 4 argument. Most of the examples occurred as a result of the students exploring the interaction of a number
of variables across two or more of the three simulators. In some of these dialogues the students followed the logic of their argument to an illogical conclusion, for example when they “discovered” that the best age for this astronaut was a child between the ages of one and three years old. The program presented the students with an opportunity to discuss illogical outcomes, a situation that certainly would not have arisen in the classroom. The students spent some time discussing these surprising outcomes before deciding that the important thing was to make the game work and therefore moved on to the next aspect of the simulation: “…most of them didn’t see those discussions and those arguments as important as the issue of what they actually did, the numbers they fed in and I think that’s probably a characteristic of boys of that age, they focus very much on, well we put it in 11 there and put in two here and then described that in their notes” (Teacher, December 2002). This focus on just making the game work may have reduced the possible level of argument in the Average Academic Pair and on some occasions resulted in argumentation not occurring.

So in the Top Academic Pair the students, by engaging in discussion and taking more responsibility for their own learning, showed some development as critical thinkers. Totten et al. (1991) concluded that this would result from the “shared learning situation” (cited in Gokhale, 1995, p. 1). However, in the Average Academic Pair the students found it harder to work collaboratively and tended to resort to “playing the game” rather than working on their hypotheses.

Another example of Level 4 argumentation occurred as the students tried to relate the astronaut’s exercise requirements with the food that the astronauts were eating. The voices became raised, and the students, once the teacher had re-engaged them with the task with: “So what do you two guys decide is the next thing to do?” (transcript) became quite animated. It is interesting that this need for the teacher to re-engage the students with their task occurred a number of times through the lessons and once again emphasises the importance of the role of the teacher in the
use of the simulation: “I found, as the teacher, I had to put more and more input in to get the weaker students on the right track”. (Teacher, December 2002)

Yet another occasion where the students demonstrated Level 4 argumentation occurred as they sought to combine all the three aspects of the activity into the final module. They discussed a number of issues and eventually came to consensus on the length of days that their simulation would run successfully. Some of the apparently simplistic comments, “No that will be over, yeah it’s just over” (transcript) hides an understanding of the underlying theory that has been learnt over the past seven lessons. Comments from the teacher often reinvigorated the conversation and resulted in the students going back and making more attempts at completing the simulation with more realistic values for the ages of the astronauts. This was noted by the teacher in his interview: “…more advanced students were actually able to see the whole, the big picture and they’re looking at, there’s humans, there’s activity, here’s food, we’re going to be there isolated” (Teacher, December 2002) and therefore want to complete the simulation with useful data rather than just succeed in the game. So, the development of the students’ argumentation in at least some instances demonstrates the deepening of the students’ understanding of the topic (Dori et al., 2003).

Level 5 argumentation, “consisting of an extended argument with more than one rebuttal” (Osborne et al., 2001, p. 13), occurred only once (1.3%) in all of the transcripts. The model for argument made no comments about any norms that would be expected from students of any particular age, but it would appear that greater skills in argument or more time would be required from students before Level 5 argument occurred with any regularity. It did not appear that the students were lacking in maturity for their age. In fact the teacher indicated that these groups were at least as good as their peers in previous Year 9 classes: “…they got more out of the program … because they had more background to be able to draw on” (Teacher, December 2002). He noted that it was quite usual for the discussions
between students to move on to the next issue without a reasonable conclusion being reached on the current issue:

some of these students had related quite well the activity with the nutritional requirements and the age and the sex and they ascertained that it was actually easier for them to change their activity than it was to change and balance the food so they worked out what they considered a reasonable diet and then changed the activity of the people to suit it. (Teacher, December 2002, repeated from section 4.3)

This attitude in the students probably precluded the development of Level 5 argument. The fact that the students were involved in a computer simulation may also have given them a momentum to move on to the next part of the simulation without necessarily resolving the issue at hand or rather than continuing their discussion at a greater depth. At times the students appeared to see the simulation as a game. Therefore, their pre-conditioning to the “timing-factor” in many computer games may have cause them to hurry on to the next stage. This is an issue that needs to be considered if simulations are to be used successfully in education.

In the session in which Level 5 argumentation occurred, the students remained very much “on-track” and the occasions where clear argument occurred resulted in good decision making. Both students felt confident and competent in “having their say” and directing the conversation to achieve their goals. The Level 5 session of argument also demonstrated the detail to which the program took the students and the combinations required in order to achieve an acceptable solution to the task. Some of the dialogue recorded in the passage was the students reading from an on-screen help and this in itself was useful in understanding the facility with which such software can expedite learning.
5.3 Discussion of argumentation as it related to the individual pairs

The data showed that for both pairs most arguments occurred in the Level 1 to Level 3 range and tended to decrease in number of arguments at each level of argumentation except between Level 2 and Level 3. It was interesting to note that there were more identifiable examples of Level 3 argumentation than there were Level 2, but it was found that once students started in their discussions they tended to become more and more involved in the task at hand and demonstrate higher levels of argumentation, until Level 3 was reached when it dropped off again. This could be age related with Level 3 argumentation being the peak level of argumentation to be expected most of the time in Year 9 boys, however, examples of Levels 4 and 5 did occur.

These results generally confirm Kuhn’s (1991, 1993) finding of an apparent lack of skill in argumentation among learners of all ages. It would appear that at least the academically more able students possessed argumentation skills but they needed more developing. According to Kuhn (1997), these skills need to be developed by methods such as engaging students in thinking about topics in a critical and structured manner.

There was some evidence to support the contention that the argumentation skills of the students had showed some improvement over time on task and had improved by the end of the simulation. This appeared to be related to the students’ increasing ability to think through the topics under consideration in this critical and structured manner.

The final exercise that required integration of the knowledge gained from individual topics showed an increase in both the percentage and levels of argumentation. This may have been a result of the practice the students had been receiving, or of their increased experience in working collaboratively, or may possibly have just been
associated with the varying context and complexity of the task. However, when the students were able to move into the higher levels of argument, their knowledge and understanding of the biodiversity concepts were greatly enhanced as evidenced in the transcripts (eg, see section 4.2.5).

The two pairs exhibited similar skills in argument with the first (Top Academic Pair) accounting for 53.8% of the total responses. This figure rose to 56.9% of the responses in Levels 2 to 5. However, a closer examination of the comments did not reveal any noticeable difference between the pairs in what was being said in the arguments.

The Top Academic Pair appeared to spend a greater amount of time in a synergetic relationship whereby they seemed to feel” the response from their partner and thus much of the Level 1 communication that occurred in the Average Academic Pair was absent in the work of the Top Academic Pair. The video showed them pointing at the screen to emphasise issues and even at times to argue heatedly about issues until a resolution could be found. The Average Academic Pair expressed their issues more vocally and at times engaged in extensive Level 1 argument without appearing to resolve anything. They often expressed their knowledge of the data required to complete the simulation in discussions that included basic claims that were only derived from facts that they recalled from their previous lessons. They, therefore, merely used one claim to support a previous claim. Whereas, even at this simple Level (1), the Top Academic Pair were already using a counter claim to proceed at a quicker rate through the software.

Even the content of these Level 1 arguments pointed to the higher thinking skills and underlying ability of the Top Academic Pair, using expressions such as “edible biomass” to demonstrate concept formation unusual in a Year 9 student (Teacher, December 2000).
Similarly, if we compare examples of Level 4 argumentation, the Top Academic Pair developed a greater depth of argument in their rebuttals and counter claims. This was not evidenced in the Average Academic Pair, who whilst also using Level 4 arguments, are much less focussed in them and in most examples required teacher intervention.

In some cases, when the students were “confronted with different interpretations of the given situation” (Bruner, 1985), greater debate and further development of their hypothesis occurred, (eg, section 4.2.4). In other cases, however, the students did not seem to have the skills or the knowledge to follow through the debate and argumentation stalemated.

This seems to have influenced the level of argumentation that developed. If the students were able to debate the different interpretations of the data, then higher levels of argumentation developed. However, if they were unable to accept, or even understand, these different interpretations, then the argumentation stayed at a lower level.

There would seem to be a complexity of variables involved in this situation. First, it could be that the students lacked the original content knowledge of the subject matter that is needed before argumentation can take place displaying higher order thinking skills (Gatto, 1993; Hanks, 1994). Alternatively, if they had the knowledge, they may not have been sufficiently fluent with it to use it in a discussion of this nature.

On the other hand, maybe they did not have the higher order thinking skills necessary to develop and argue their hypotheses in the first place. If this was the case, then it may have been that the simulation helped them to develop this basic scientific skills of formulating “theories and models with consideration of the
evidence that supports them” (Stephens et al., 1999, p. 189) as their argumentation had improved by the end of the series of lessons.

Yet another interesting observation came from recording and filming the other groups that formed the rest of the class. These groups included students achieving at a lower level and it was these students that appeared to benefit the least from the use of the software:

I also found that perhaps there needed to be a little bit more guidance for the weaker students in the actual introduction of what they’re trying to achieve there because I found as the teacher I had to put more and more input in to get the weaker students on the right track. So, it’s a matter of using it as a game, press this button, press that button, and let’s see what happens here. “Oh okay, we’ve done that now.” Whereas the groups that contained higher ability students were able to proceed by themselves. (Teacher, December 2002)

The attention of the students achieving at a lower level, recorded on a moveable hand-held camera, waned very quickly and whilst the two pairs in the study found it relatively easy to keep on task for the 90 minutes of each double period, students achieving at a lower level soon lost interest and wanted to “know the answer” or to do something else on the computer: “…these students play games on the computer, well a lot of them play games, that’s one of their favourite pastimes and if the instructions are not clear cut they get bored very easily” (Teacher, December 2002).

These initial findings provide some support for the contention that students with a higher than average academic achievement benefit more from the use of this type of software and that those who experience difficulty in the traditional science classroom also may experience difficulties in using this type of computer software: some of our best students got over that by opening up browser software and going onto the Internet and opening up a periodic table or go into another
resource so they could go between the two but the weaker students found that a little bit too much for them. (Teacher, December 2002)

Indeed, the pedagogy and methodology used when using computer simulations may prove to be similar to that which students perceive to be those of a “traditional classroom” and hence the weaker students may experience the same feelings of rejection. A solution to this may be in placing computers in the science laboratories, around the walls, and using them much as one would in performing a science experiment.

However, having said that, the class teacher indicated that all students of whatever academic achievement demonstrated an improvement in their willingness to undertake a discovery based learning task:

they were in the better more able students probably around the B-A level students rather than the other ones…although I must admit I was quite pleased with some of our less able students and their persistence, they were determined to get somewhere even if it took them the whole time. (Teacher, December 2002)

Moreover, at later testing, the teacher considered that an improvement in both knowledge and knowledge application had occurred across the whole class as a result of the simulation.

Overall, the teacher’s comments indicated that he felt the students were achieving a higher level of understanding than was attained in a normal classroom lesson. Further, he felt that the kind of debate the students were engaging in did not normally develop in the standard science classroom. This would indicate that working with a simulation in collaborative teams had lead to higher levels of scientific processing by the students. Whether this was the result of working collaboratively which causes the learners to “achieve at higher levels of thought and retain information longer than students who work quietly as individuals“ (Johnson, & Johnson 1986, p. 31, cited in Gokhale, 1995, p.1). On the other hand, is it the
“more sophisticated reasoning” Hennesy et al. (1995) found resulted from using interactive simulations and relevant practical activities? Further research will be needed to determine the actual interaction between the two types of learning situations.

5.4 Discussion of argumentation as it related to the topics

It was decided to attempt to examine the change in the types and Levels of argumentation that were identified in the conversations across the four topics of the simulation. Whilst the students were accustomed to using computer software as an aid to their learning, there was very little software in the school of the investigative educational genre of BioBLAST® and it was expected that the software itself might promote the development of argumentation skills. The ability of the software to promote the learning of the higher order thinking skill of argument was measured and analysed in terms of the position of the arguments in the transcripts. As the lessons had actually been in pairs and the students covered one of the four sections in each pair of lessons, it seemed logical, for the purpose of this analysis, to divide the transcripts into four topics each representing the pair of lessons.

The simulation required students to acquire factual information and then move into the realm of reasoning about the causes and consequences (Dori et al., 2003; Engle, & Conant, 2002; Flage, 2004; Hakkinen, 2003; Jimenez-Aleixandre, & Pereiro-Munoz, 2002; Pontecorvo, & Girardet, 1993) of applying that factual information, using argumentation as they worked collaboratively on the task in hand. The consequences of students’ decisions were immediately evident to the students. However, they needed to determine the causes of those consequences in terms of the data they had input into the simulation.

In the first topic, students commenced with a short exercise in balancing inputs and outputs, Tons O’ Tyns, before moving on to the first of the three area-specific
simulations: the Plant Production (PP) Simulator which is used to investigate plant lighting requirements; seed-to-harvest schedules; and water, oxygen, and biomass production rates. There were no recorded or identifiable arguments in the Tons O’ Tyns introduction but as soon as the students started the Plant Production (PP) Simulator a range of identifiable argument units were recorded.

The frequencies of argument levels for the first topic of the simulation for each of the five argumentation levels range from being close to the expected value of 25.0% in the case of Level 3 (23.1%) to the only example of Level 5 (100.0%). It was interesting to note that the only example of Level 5 argument was in the first topic but did in fact did occur at the very end of the session in a section where the students in the Top Academic Pair had both expressed prior knowledge in their explorations.

Eight of the 10 Level 1 arguments occurred at the beginning of the first topic, the Plant Production (PP) Simulator, as the students started to understand how the software was going to work. Whilst the students were only starting the project, it was evident that they were being forced to consider a number of alternatives on a continuum from easy to difficult, that were encouraging the argumentation indicative of higher order thinking skills. Later in this topic the Top Academic Pair of students were examining the relationship between the area planted and the ability to store the resultant biomass. They were nearing the end of the session and already being “encouraged” by the software to make decisions that would effect the length of time that the Lunar Base would survive. As noted in the previous paragraph, it was at this point that the only example of Level 5 argumentation was recorded.

The second topic involved the students in the Human Requirements (HR) Simulator that was used to investigate human requirements, inputs/outputs, and how changes in nutrition and activity schedules affect human health and nutritional requirements. Whilst the activities in each pair of lessons appeared to be similar in structure, the content in each topic aroused a variety of interest and hence produced different
numbers and ranges of argument. The Human Requirements (HR) Simulator in particular produced some fascinating arguments such as the one that led to the best age and gender for the astronauts.

However, this topic did not appear to be as interesting to the students judged by the total number of arguments and resulted in only 16 identifiable arguments being recorded and 12 of these being ascribed to Level 1. Comments such as:

T So what do you two guys decide is the next thing to do?

SA2 Give up!

were recorded on a number of occasions. Whilst the second topic could have demonstrated an improvement in the higher order thinking skills as a result of practice, it appears that the concepts involved in this simulation were of a more complex nature and reduced the opportunities for either pair to demonstrate these skills. All through the simulation the students demonstrated a reticence to argue issues that they did not fully comprehend unless the felt that they had data to support their point of view.

Venville et al.’s (2003) results which demonstrated that even quite young children can become involved in in-depth arguments about familiar topics. Therefore, familiarity with the topic seems to be an influence on the level of argumentation achieved. Although the students in this study had some knowledge of biodiversity and all necessary information was readily available in the simulation package, they were not fluent in the knowledge as it had probably not yet been fully acquired and internalised. Further research would demonstrate whether this kind of exercise allows student to internalise knowledge or what degree of basic content knowledge is needed to maximise the effects of the teaching/learning model used in this study.

The third topic involved the students working on the Resource Recycling (RR) Simulator which was used to test and compare oxygen, water, and nutrient
production rates based on different settings for the bioreactors and the incinerator. At this point in the simulation, the half way mark, students appeared to have started to understand the issues of the simulation and were discussing underlying principles of the activity rather than merely trying to navigate successfully the “game.” This change was apparent in the decrease of the number of Level 1 and Level 2 arguments from 27.1% of the total number of Level 1 and 2 arguments in the first topic and 27.1% in the second to 16.7% in the third. Conversely, Level 4 arguments were up to 40.0% in the third topic as opposed to 0.0% in the second and 20.0% in the first.

Whilst the students were using higher levels of argumentation, the materials that they were discussing were not better known to them, nor were they facts that the students had experienced before. An example of Level 3 argument recorded in this time period involved the students working on the issue of appropriate balances required for the incineration of waste product and how that waste product could be recycled in gaseous form, concepts far from the everyday science classroom. A second argument from a similar point of view indicated the improvement in the argument of the students as they further considered the issue of just how the incinerators worked. At the same time they started to consider how they would integrate all components of the simulation, to see how the disparate parts would successfully interrelate.

Once each of the previous sections was completed the students spent the final pair of lessons working on the BaBS (Build a BLISS System) Simulator that “ties together the components of the three area-specific simulators” (Center for Educational Technologies, 1999, p. 16).

The number of examples on higher level arguments increased once again in this topic as the students demonstrated the skills that they had developed over the eight lessons. At the lower levels there were a decrease in the number of arguments with
only 13.8% Level 1 arguments compared with the average of 28.7% in the previous three sessions, 52.6% of the Level 2 arguments compared with an average 15.9% in the previous three sessions. In the higher Levels of argument the percentages increased with 46.2% of all Level 3 arguments as opposed to an average of 17.9% in the previous sessions and 40.0% of Level 4 which is exactly double the average of the other three sessions.

An example of how the students were combining the three parts together is given in a passage where the two students, with the subtle directing of the teacher, try to balance the food production module with the other two modules (section 4.2.4). The two students come to a number of successful conclusions as they rehearse issues previously discussed in the first section of the software. It was logical that these final two lessons would contain such an increased number of these arguments as the concepts have already been discussed and decided upon. All that was left in this section was to combine them.

One of the best examples of Level 4 argumentation occurred in this section as the students in the Top Academic Pair sought to combine all the three aspects of the activity into the final module. This was previously related in section 4.4.3.4 and demonstrates how the students had honed their skills in argument as they reached the end of the simulation and as they combined a number of issues to eventually come to consensus on the length of days that their simulation would run successfully.

The confidence of the students was evident and would indicate that learning had indeed occurred over the time that they explored the simulation.

The activities the students engaged in during this simulation were activities aimed at giving the students the knowledge they needed on the subject but also at developing the kinds of scientific processes required by the Queensland science syllabuses. As such they are activities “whose purpose is to develop, interpret, or evaluate
explanatory models for the phenomena being investigated” (Raghavan, & Glaser, 1995, p. 38). The content of the argumentation as the students tried to refine their biologically sustainable environment on the moon demonstrated that the students’ scientific thinking was improving.

5.5 Discussion of comparison of two pairs across the topics

This chapter ends with a brief analysis of the ways in which the argumentation of the two pairs were “spread” across the eight lessons in which data was recorded. It is difficult to know if the fact that the pairs were from different achievement cohorts produced the variation in the frequency of argument levels or if this is a random result that could be expected by studying any two pairs of students.

An examination of the Top Academic Pair, showed a more even distribution of argumentation during the first two topics followed by a reduction in the number of arguments in the third topic as they appeared to become more at ease with the skills of their partner. The effect of that was to allow the partner to try what they wanted in the knowledge that they had enough time to try as many alternatives as they required before completing the task. Once this reached the last topic, they found it very easy to combine the previous three simulators and in the process engaged in many in depth discussions as they sought to get the best results.

On the other hand, the Average Academic Pair engaged in more argumentation in the first topic (29.7%) and once they moved into the second topic spent more time on successfully manoeuvring through the simulation. They did, however, steadily increase the percentage of recorded arguments in each of the successive topics ending up with 29.7% again in the fourth topic.
The results again speak of learning taking place over time and especially in the fourth topic when they were combining the knowledge and facts learnt in the previous three topics.

The results present some support for the contention that the simulation achieved its goal of developing skills in argumentation over time. However, the differences observed might also have been confounded by the differing subject knowledge required and the types of activities inherent across the topics. Whether this would happen so quickly or at a similar rate in a normal Science classroom is really only a matter for speculation without a more controlled experimental model. This could be included in any further study.

Although the study demonstrated that the students evidenced a range of argumentation and that they may have shown an improvement in level of argumentation, the question remains, “In what way did the learning model cause them to develop these argumentation skills and how can they be even more successfully developed in students in the junior high school years so that they are more readily available for use in the senior years when the demands of the curriculum are even greater?”

5.6 Summary

The chapter presents the results of the analysis of argument in students as they used a computer simulation to develop a Lunar Base. The analysis used the definitions of the five levels of argument proposed by Osborne et al. (2001, p. 13). It then related the levels of argument to the academic achievement of the students and the topic they were studying at the time of the argument.
CHAPTER 6
OVERVIEW, CONCLUSIONS, AND EDUCATIONAL IMPLICATIONS

6.1 Introduction

This final chapter provides an outline of the study and draws some general conclusions from its findings. It concludes with an examination of the educational implications of the results of the study.

6.2 Overview of study

The study investigated the argument structures engaged in by students as they used a piece of educational software. In this study, the higher order thinking skill examined was the use of argumentation. Four students in a Year 9 class were video recorded and their dialogue examined. Their use of argumentation was analysed by level according to Osborne et al. (2001) and by the number of occurrences. The teacher and the students were also interviewed and video recorded and observation were also made of the activities of the whole class by both teacher and researcher.

6.3 Objectives

The object of the study was to investigate the context and situations which give rise to argumentation strategies and hence examine and analyse higher order thinking skills, in particular dialogic argument used by Year 9 students engaged in a computer simulation requiring the application of skills and knowledge already learnt in their science course.
6.4 Results and findings

The two pairs of students both demonstrated some use of the higher Levels of argumentation with the Top Ability Pair demonstrating half of their arguments in the Levels 3 to 5 in the final topic. There was some evidence that the simulation did encourage some of the students in the pairs observed to think in greater depth about the materials and to argue their convictions in an improved manner as a indicated by the argument level based on Osborne et al. (2001).

The Top Academic Pair provided a higher amount of argument at a higher level than the Average Academic Pair (Table 4.3) did. Other students in the class identified by the teacher as being of achieving at an even lower level, generally found the simulation to be difficult to take advantage of and when recorded on the hand-held recorder, demonstrated low levels of argumentation.

As well as the students appearing to increase in competency in argument over the period of time, the four students in their final interviews, spoke of feeling satisfied with the results of the lessons and that they and the rest of the class agreed that the experience was both interesting and worthwhile. Students were able to access materials of interest from the software and from references on the Internet which encouraged further learning. The teacher indicated that the majority of the students were more engrossed in their task and continued “on-task” for longer periods of time than in their standard classroom.

The pedagogy provided in the task was appreciated by many of the students who saw these lessons as a great improvement to the rote learning that so often had occurred in their previous science topics. It gave meaning to why they were required to learn scientific materials but it also presented them with ways to find the knowledge for themselves.
6.5 Limitations of the research

The background research and findings examined showed that much of the research into argument structures had been performed overseas and some of their comments may not be appropriate for Australian conditions. This was one of the first Australian studies and demonstrated the advantages of using an appropriate computer simulation to improve skills in argument. It was however, limited in size and time and it is expected that further Australian research will be needed to support these results.

There are also a number of variables that could not be controlled within this study. Whilst students had studied the same subject and content over the past years, the way in which their past and present teachers had taught them may have affected their attitudes to freely express their argumentative skills. At one end of the continuum, teachers take their students to the computer room and let the students approach their tasks on their own whilst at the other end, teachers guide their students through a very lock step learning process. Any discrepancy in this aspect of the study could in itself be the source of a research project. The current changes in pedagogy in Science Education are moving towards a more “hands-on” and inquiry based approach. The teacher whose class was used in this study is one of those who had adopted this new approach and thus the students were already accustomed to following through their own investigations.

It would be interesting to study how students from classes whose teachers were more traditional would cope with this simulation.

The objective of the study was to analyse the argumentation of the students in the two pairs studied. These students may not be typical of a broader range of students. Hence, further studies on a wider range of students and their argumentation levels would add to the trustworthiness of the findings in terms of other classes.
were also only a limited number of lessons available for the study; the educators who prepared the software recommend a longer period of time.

There was not enough known about the students' use of computers and specifically computer games. It appeared that students, who saw the simulation as a game, expected that there would only be one “correct” choice in each situation and thus failed to enter into as much argument as those who realised that there were a multitude of pathways through the activity. It would be interesting to determine the degree and type of exposure to such games students had experienced.

There were no pre- and post-tests of argument undertaken, if in fact such a test exists. It can not be asserted accurately whether the students developed skills in argument as they worked through the activity or were they using already attained abilities. However, the results in Table 4.3 show some support for the contention that the development did occur.

No consideration for gender issues was taken into consideration in the study, as only boys were available. The current emphasis on boys’ education is for problem solving in a real-world environment. Students in this study were able to learn in such an environment without needed to leave to school grounds. Their ability to “speak” to an expert or even e-mail them proved to be an exciting change to their usual classroom methodology. It would be very interesting to see how gender would affect the results and if in fact, girls did not find the material as stimulating although they tend to have better verbal ability at this age.

The positioning of lessons in the day may have adversely affected the results. Four out of the eight lessons occurred in the afternoon and the other four between 10.30 am and 12.00 noon. In a boys’ school, teachers are constantly aware of the attention factor in presenting their students with a positive learning environment. The experimenter was aware of the improved attentiveness and the students’ ability to
focus on the task at hand in the lessons that occurred early in the day. The converse was true for the lessons at the end of the day when the boys were tending to spend more time “off-task.”

The current emphasis and availability of computer hardware and software has not always produced the positive educational results that the vast amount of spending would predict. It would be interesting to correlate the development of higher order thinking skills and the expenditure on information and communication technology. It would also be interesting to study the methodology used when employing this technology. There has been a long running argument about the use of computers in laboratories or integration into the classroom. This study as completed in a computer laboratory could just as easily been applied in the science classroom. Which environment would have been better, or if there would be any differences, is unclear.

6.6 Implications

The study suggests that the use of this software has the potential to enhance the development of and the engagement of students in higher order thinking skills and is an encouragement to continue to engage students in computer based learning. When a school has budgeted for extensive expenditure in computer hardware, software, and staffing, it is important to know that there can be some positive returns resulting from the investment.

It is important that students have access to appropriate software as so much of what is available in the marketplace is trivial and only caters for low level skill and knowledge development. It is also important that students are educated to understand that there is rarely only one way to solve a problem and that much of their game software is of that genre. Students need also to be given some
fundamental instruction in the logic of argument using structures discussed in this report.

By using observations of argumentation, it is expected that teachers will be able to point their students towards more appropriate learning techniques than they may be currently using. This may include the use of good quality scientific software, the use of Internet activities and even the availability of scientists on-line for e-mail access.

6.7 Future research

There are a number of issues that lead directly from this study, all of which would be worthwhile pursuing. These include:

1. What is the interaction between academic achievement and ability to work collaboratively?
2. What is the influence of the “computer games” mentality on the use of computer simulations in the classroom?
3. What is the relationship between academic achievement and argumentation or critical thinking?

Other issues have been raised in section 6.5 under limitations of the current research study.
APPENDIX 1
Science Content Charts from workbook (Center for Educational Technologies, 1997, pp. 41-44)

These charts are not available online. Please consult the hardcopy thesis available from the QUT Library
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APPENDIX 2
Five Sample BABS Runs (Center for Educational Technologies, 1997, pp. 50-54)

<table>
<thead>
<tr>
<th>BABS SETUP FILE: MIXED CROP – 5 YEAR RUN</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Male Crew members:</strong> 3</td>
</tr>
<tr>
<td><strong>Female Crew members:</strong> 3</td>
</tr>
<tr>
<td><strong>Crops</strong></td>
</tr>
<tr>
<td>Lettuce Soybean Potato Wheat</td>
</tr>
<tr>
<td><strong>Number of 100-gram servings per day</strong></td>
</tr>
<tr>
<td>1.220 1.980 3.162 1.950</td>
</tr>
<tr>
<td><strong>Light cycle - hours on 24</strong></td>
</tr>
<tr>
<td>14 14 24</td>
</tr>
<tr>
<td><strong>First planting day</strong></td>
</tr>
<tr>
<td>1 1 1 1</td>
</tr>
<tr>
<td><strong>Harvest/planting period</strong></td>
</tr>
<tr>
<td>28 97 90 85</td>
</tr>
<tr>
<td><strong>Plant growth chambers</strong></td>
</tr>
<tr>
<td>3 @ 35 cm 3 @ 55 cm 3 @ 100 cm 2 per chamber (6 per chamber) (4 per chamber) (2 per chamber)</td>
</tr>
<tr>
<td><strong>Total planting area (sq. m)</strong></td>
</tr>
<tr>
<td>90 180 90 90</td>
</tr>
<tr>
<td><strong>Resource Recycling</strong></td>
</tr>
<tr>
<td>Bioreactors Incinerator</td>
</tr>
<tr>
<td><strong>Inedible biomass storage capacity (kg):</strong></td>
</tr>
<tr>
<td>Solid 700</td>
</tr>
<tr>
<td><strong>Solid waste storage capacity (kg):</strong></td>
</tr>
<tr>
<td>44</td>
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<tr>
<td><strong>Liquid waste storage capacity (kg):</strong></td>
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<tr>
<td>1500</td>
</tr>
<tr>
<td><strong>Incinerate how often (days):</strong></td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td><strong>Gray water storage capacity (kg):</strong></td>
</tr>
<tr>
<td>1000</td>
</tr>
<tr>
<td><strong>Maximum amount to incinerate (kg):</strong></td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td><strong>Number of bioreactors</strong></td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td><strong>(10.9 kg dry &amp; 16.4 kg liquid each):</strong></td>
</tr>
<tr>
<td><strong>Bioreactor retention time (days):</strong></td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td><strong>Storage</strong></td>
</tr>
<tr>
<td><strong>Startup (kg) Capacity (kg)</strong></td>
</tr>
<tr>
<td>Lettuce 200 250</td>
</tr>
<tr>
<td>Soybean 300 350</td>
</tr>
<tr>
<td>Potato 470 500</td>
</tr>
<tr>
<td>Wheat 300 350</td>
</tr>
<tr>
<td><strong>Energy</strong></td>
</tr>
<tr>
<td><strong>Energy source:</strong> Nuclear</td>
</tr>
<tr>
<td><strong>Energy output (kW):</strong> 450</td>
</tr>
<tr>
<td><strong>Type of lights:</strong> Fluorescent</td>
</tr>
<tr>
<td><strong>Food Processing</strong></td>
</tr>
<tr>
<td><strong>Items Weights (kg)</strong></td>
</tr>
<tr>
<td>Soy Oil Press 292.0</td>
</tr>
<tr>
<td>Hand Blender 6.4</td>
</tr>
<tr>
<td>Electric Mixer 1.4</td>
</tr>
<tr>
<td>Toaster Oven 4.5</td>
</tr>
<tr>
<td>Flour Mill 3.6</td>
</tr>
<tr>
<td>Bread/Dough Maker 6.8</td>
</tr>
<tr>
<td>Pasta Maker 8.2</td>
</tr>
<tr>
<td>Microwave Oven 22.7</td>
</tr>
<tr>
<td>Food Processor 9.5</td>
</tr>
<tr>
<td>Dehydrator 2.7</td>
</tr>
<tr>
<td><strong>Light output per sq.m (kW):</strong></td>
</tr>
<tr>
<td>Lettuce: 300</td>
</tr>
<tr>
<td>Soybean: 600</td>
</tr>
<tr>
<td>Potato: 850</td>
</tr>
<tr>
<td>Wheat: 1500</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BABS SETUP FILE: ALL WHEAT – 5 YEAR RUN</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Male Crew members:</strong> 3</td>
</tr>
<tr>
<td><strong>Female Crew members:</strong> 3</td>
</tr>
<tr>
<td><strong>Crops</strong></td>
</tr>
<tr>
<td>Lettuce Soybean Potato Wheat</td>
</tr>
<tr>
<td><strong>Number of 100-gram servings per day</strong></td>
</tr>
<tr>
<td>0.000 0.000 0.000 6.513</td>
</tr>
<tr>
<td><strong>Light cycle - hours on 24</strong></td>
</tr>
<tr>
<td>0 0 0 24</td>
</tr>
<tr>
<td><strong>First planting day</strong></td>
</tr>
<tr>
<td>0 0 0 1</td>
</tr>
<tr>
<td><strong>Harvest/planting period</strong></td>
</tr>
<tr>
<td>0 0 0 85</td>
</tr>
<tr>
<td><strong>Plant growth chambers</strong></td>
</tr>
<tr>
<td>0 @ 100 cm 0 @ 100 cm 0 @ 100 cm 2 per chamber (2 per chamber)</td>
</tr>
<tr>
<td><strong>Total planting area (sq. m)</strong></td>
</tr>
<tr>
<td>0 0 0 300</td>
</tr>
<tr>
<td><strong>Resource Recycling</strong></td>
</tr>
<tr>
<td>Bioreactors Incinerator</td>
</tr>
<tr>
<td><strong>Inedible biomass storage capacity (kg):</strong></td>
</tr>
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<td>Solid 900</td>
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<td><strong>Solid waste storage capacity (kg):</strong></td>
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<tr>
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<td><strong>Liquid waste storage capacity (kg):</strong></td>
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<tr>
<td>1500</td>
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<tr>
<td><strong>Incinerate how often (days):</strong></td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td><strong>Gray water storage capacity (kg):</strong></td>
</tr>
<tr>
<td>1000</td>
</tr>
<tr>
<td><strong>Maximum amount to incinerate (kg):</strong></td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td><strong>Number of bioreactors</strong></td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td><strong>(10.9 kg dry &amp; 16.4 kg liquid each):</strong></td>
</tr>
<tr>
<td><strong>Bioreactor retention time (days):</strong></td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td><strong>Storage</strong></td>
</tr>
<tr>
<td><strong>Startup (kg) Capacity (kg)</strong></td>
</tr>
<tr>
<td>Lettuce 0 0</td>
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<tr>
<td>Soybean 0 0</td>
</tr>
<tr>
<td>Potato 0 0</td>
</tr>
<tr>
<td>Wheat 1300 1500</td>
</tr>
<tr>
<td><strong>Energy</strong></td>
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<td><strong>Energy source:</strong> Nuclear</td>
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<td><strong>Energy output (kW):</strong> 565</td>
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<td><strong>Type of lights:</strong> Fluorescent</td>
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<td><strong>Food Processing</strong></td>
</tr>
<tr>
<td><strong>Items Weights (kg)</strong></td>
</tr>
<tr>
<td>Hand Blender 6.4</td>
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<tr>
<td>Electric Mixer 1.4</td>
</tr>
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<tr>
<td>Food Processor 9.5</td>
</tr>
<tr>
<td>Dehydrator 2.7</td>
</tr>
<tr>
<td><strong>Light output per sq.m (kW):</strong></td>
</tr>
<tr>
<td>Lettuce: 300</td>
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<tr>
<td>Soybean: 600</td>
</tr>
<tr>
<td>Potato: 850</td>
</tr>
<tr>
<td>Wheat: 1500</td>
</tr>
</tbody>
</table>

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These articles are not available online. Please consult the hardcopy thesis available from the QUT Library
BABS SETUP FILE: ALL SOY - 2 WEEK

Crew
Male Crew members: 3
Female Crew members: 3

Crops
Lettuce Soybean Potato Wheat

Number of 100-gram servings per day
Light cycle - hours on 0 14 0 0
First planting day 0 1 0 0
Harvest/planting period 0 97 0 0
Plant growth chambers 0 @ 35 cm 10 @ 55 cm 0 @ 100 cm 0 @ 100 cm
(6 per chamber) (4 per chamber) (2 per chamber)
Total planting area (sq. m) 0 600 0 0

Resource Recycling
Bioreactors Incinerator
Inedible biomass storage capacity (kg): 800 Solid waste storage capacity (kg): 45 Liquid waste storage capacity (kg): 1500 Incinerate how often (days): 1 Gray water storage capacity (kg): 1000 Maximum amount to incinerate (kg): 4 Number of bioreactors 7 (10.9 kg dry & 16.4 kg liquid each): Bioreactor retention time (days): 11

Storage
Startup (kg) Capacity (kg)
Lettuce 0 0 Soybean 1300 1500 Potato 0 0 Wheat 0 0

Energy
Energy source: Nuclear Energy output (kW): 465
Type of lights: Fluorescent

Food Processing
Items Weights (kg)
Soy Oil Press 292.0 Hand Blender 6.4 Electric Mixer 1.4 Toaster Oven 4.5 Flour Mill 3.6 Bread/Dough Maker 6.8 Pasta Maker 8.2 Microwave Oven 22.7 Food Processor 9.5 Dehydrator 2.7

Light output per sq.m (kW):
Lettuce: 0 Soybean: 600 Potato: 0 Wheat: 0

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APPENDIX 3
Contents page from NASA Wheat Production Document of 55 pages
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REFERENCES


Australian College of Education. (2001). *Celebrating the past shaping the future, outcomes from the educational assembly*. Deakin, ACT: Paragon Press.


