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**UNIVERSITY OF SUSSEX**

**An Investigation into Improving Scientific Literacy  
in Israeli University Students  
within an Academic English Reading Programme**

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**February 2016**

**Dissertation for the Degree of Doctor of Philosophy**

## **Declaration**

I hereby declare that this thesis has not been and will not be, submitted in whole or in part to another University for the award of any other degree.

Signature:.....

## TABLE OF CONTENTS

<b>Acknowledgements.....</b>	<b>vii</b>
<b>Abbreviations and Acronyms.....</b>	<b>viii</b>
<b>Glossary of Hebrew words.....</b>	<b>ix</b>
<b>List of Tables.....</b>	<b>x</b>
<b>List of Appendices.....</b>	<b>xiii</b>
<b>Summary.....</b>	<b>xiv</b>

### CHAPTER ONE

INTRODUCTION.....	1
1.1 Overview of my Action Research.....	1
1.1.1 Understanding scientific literacy.....	1
1.1.2 Groups of students studied.....	4
1.1.3 Challenges in the classroom and developing the intervention.....	5
1.2 Aims and Research Questions.....	10
1.3 Thesis Organisation.....	12

### CHAPTER TWO

CONTEXT OF THE RESEARCH.....	15
2.1 Introduction.....	15
2.2 The Israeli Education System.....	15
2.2.1 School system.....	15
2.2.2 Tertiary education.....	18
2.3 Why <i>mechina</i> students were chosen for this study.....	20
2.4 A brief personal biography.....	21

### CHAPTER THREE

LITERATURE REVIEW.....	24
3.1 Introduction.....	24
3.2 The normative view.....	25
3.3 Assessments based on the normative view.....	26
3.4 Complexities in conceptualization of scientific literacy.....	28
3.5 Scientific awareness and not scientific literacy.....	31
3.6 Different interest groups.....	34
3.7 Alternative approaches to assessment.....	36

3.7.1 Media related knowledge.....	36
3.7.2 Problems of comprehension.....	37
3.7.3 Scientific knowledge v critical thinking.....	39
3.7.4 Wider perspectives about literacy in general.....	41
3.8 Scientific literacy in secondary schools.....	44
3.9 Student learning-methods.....	48
3.9.1 Constructive alignment.....	48
3.9.2 Dialogic talk.....	49
3.10 Theories of learning.....	51
3.11 Critical thinking .....	53
3.12. Conclusion.....	58

## **CHAPTER FOUR**

METHODOLOGY AND METHODS.....	60
4.1 Introduction.....	60
4.2 Paradigms in Educational Research.....	60
4.3 Action Research: Problems and Solutions.....	61
4.4 Towards a Methodology.....	65
4.5 Ontological Issues.....	66
4.6 Epistemological Issues.....	68
4.7 Research Tools.....	71
4.7.1 Unstructured observation.....	71
4.7.2 Self-report techniques.....	71
4.7.2.1 Attitude scales.....	71
4.7.2.2 Questionnaires.....	72
4.7.2.3 Interviews.....	72
4.7.2.4 Projective techniques.....	73
4.7.3 Class discussion.....	73
4.8 Triangulation.....	74
4.9 Ethical considerations.....	74

## **CHAPTER FIVE**

### **RESEARCH PLAN**

Introduction.....	77
5.1 2009: Preliminary Reconnaissance.....	78

5.1.1 Getting to know my students.....	78
5.1.2 Student scientific literacy.....	79
5.2 2010: Further reconnaissance and piloting the intervention.....	83
5.2.1 Further reconnaissance.....	84
5.2.2 Piloting the intervention.....	84
5.3 2011: The Intervention.....	86

## CHAPTER SIX

<b>2009: Preliminary Reconnaissance .....</b>	<b>89</b>
Introduction.....	89
6.1 Getting to know my students.....	89
6.1.1 Personal essays.....	89
6.1.2 My students' views on Israeli education.....	90
6.1.3 What students want to learn.....	94
6.2 Scientific literacy in the context of a reading programme.....	95
6.3 Why is scientific literacy important? .....	97
6.3.1 Assessing attentiveness.....	99
6.3.2 Science literacy and superstitious belief.....	100
6.4 The study population.....	101
6.5 Data and analysis.....	103
6.5.1 Age and sex.....	104
6.5.2 Subject of study.....	104
6.5.3 Level of science education at school.....	105
6.5.4 Assessing interest and attentiveness.....	106
6.5.4.1 Index of issue interest.....	107
6.5.4.2 Attentiveness.....	109
6.5.5 Non-scientific and superstitious views.....	114
6.5.6 Specific issues of interest.....	118
6.5.7 Do students want to participate in decision making?.....	120
6.6 Conclusion.....	123
6.6.1 General comments on the reconnaissance.....	123
6.6.2 Moving forwards.....	126

## CHAPTER SEVEN

<b>2010: Further reconnaissance and piloting the intervention .....</b>	<b>128</b>
Introduction.....	128
7.1 Further reconnaissance.....	128
7.1.1 Getting to know my students .....	128
7.1.2 Comparing 2009 and 2010 classes.....	130
7.1.3 Comparison of my students with international data.....	135
7.1.4 Does studying science impact on interest? .....	135
7.1.5 Changing teaching style.....	137
7.2 Designing the intervention.....	142
7.3 Implementation and Monitoring the Intervention.....	145
7.3.1 The intervention: stage by stage.....	145
7.3.2 Feedback, analysis using an open-ended questionnaire.....	148
7.3.3 Other Research Methods.....	157
7.4 Evaluation and Areas for Improvement.....	161

## CHAPTER EIGHT

THE INTERVENTION.....	163
8.1 Introduction.....	163
8.2 Student profiles.....	164
8.3. Social scientific issues: student listings.....	169
8.4. Is scientific literacy important? Student opinions.....	171
8.5. Science education and scientific literacy: student opinions.....	173
8.6 The new intervention.....	179
8.6.1 The general context.....	179
8.6.2 Introducing ‘devil’s advocate’.....	180
8.6.3 The intervention: stage by stage.....	180
8.6.4 Student responses: data analysis.....	184
8.7 Conclusion.....	190

## CHAPTER NINE

DISCUSSION AND CONCLUSION.....	192
Introduction.....	192
9.1 Defining scientific literacy.....	193
9.2 Assessing scientific interest.....	193

9.3 The teacher-student dynamic.....	196
9.4 Outcomes of the intervention.....	198
9.4.1 Challenges of working with my students.....	198
9.4.2 The interventions.....	199

## **CHAPTER TEN**

FINAL REFLECTIONS.....	202
Introduction.....	202
10.1 Path taken.....	202
10.2 Contribution to knowledge.....	204
10.2.1 Scientific literacy as critical thinking.....	205
10.2.2 Method for developing open-mindedness .....	205
10.2.3 Comparing interest of my students with international data.....	206
10.2.4 Interest in science among humanities' students.....	207
10.2.5 Impact of school science on interest in scientific issues.....	207
10.3 Implications and future research.....	208
10.3.1 Impact of school science on interest in scientific issues.....	208
10.3.2 Redefining scientific literacy.....	209
10.3.3 Student feedback.....	209
10.3.4 Critical thinking and open-mindedness.....	209
10.4 Limitations of research design.....	210
10.5 Application of my research.....	214
10.6 Closing remarks.....	215
<b>REFERENCES.....</b>	<b>216</b>

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## Abbreviations and Acronyms

<b>AAAS</b>	American Association for the Advancement of Science. It describes itself as: an international non-profit organization dedicated to advancing science for the benefit of all people.
<b>CCTDI</b>	California Critical Thinking Disposition Inventory
<b>CE</b>	College of Engineering where I taught
<b>CT</b>	Critical Thinking
<b>EAP</b>	English for Academic Purposes.
<b>EFL</b>	English as a Foreign Language. This is the name given to all departments in universities and colleges in Israel that provide courses for students who do not have an exemption certificate ( <i>ptor</i> ) in English. The term 'English for academic purposes' describes the content of these courses but is not used as the department name in Israel.
<b>OECD</b>	The Organization for Economic Co-operation and Development.
<b>PISA</b>	The Programme for International Student Assessment. It is a worldwide study by the (OECD), in member and non-member nations, of 15-year-old school pupils' scholastic performance in mathematics, science, and reading.
<b>PUS</b>	Public understanding of science.
<b>SSI</b>	Socioscientific issues: controversial social issues which relate to science.
<b>SSSP</b>	Science for Specific Social Purposes
<b>STEM</b>	Science, Technology, Engineering and Mathematics
<b>STS</b>	Science and Technology Studies.
<b>TBSL</b>	Test of Basic Scientific Literacy, designed by Laugksch and Spargo (1996)
<b>U</b>	Israeli University where I taught
<b>VOSTS</b>	Views on Science-Technology-Society

## Glossary of Hebrew words

***bagrut*** (*pl. bagruyot*) matriculation exam taken in last year at high school.

***kibbutz*** (*pl. kibbutzim*) an agricultural co-operative community.

***Knesset*** the Israeli parliament

***mechina*** (*pl. mechinot*) the word means preparatory. It is used to describe a one-year programme of study, in a college or university, that prepares a student for tertiary education.

***Moed Bet*** The second sitting for an exam which students can take if they missed the first sitting, or if they want to try and improve the grade they received for the exam they took at the first sitting.

***ptor*** the term is used within an EFL department of an institution of tertiary education to mean an exemption from taking further courses in English. Students need a *ptor* in English to receive a first degree.

***yeshiva*** Jewish religious institution which focuses primarily on the study of tractates relating to ancient Jewish law.

## LIST OF TABLES

Table 5.1. 2009: The Preliminary Reconnaissance.....	81
Table 5.2. 2010: Further reconnaissance and piloting the intervention.....	85
Table 5.3. 2011: The Intervention.....	86
Table 6.1 Student suggestions of teacher qualities.....	93
Table 6.2 Students identify English skills they want to improve.....	94
Table 6.3 Data and analysis: age and sex.....	104
Table 6.4 Assessment of school science education showing numbers taking 4- or 5-point <i>bagruyot</i> in science subjects.....	105
Table 6.5 Mean Scores on the Index of Issue Interest for my classes. An average over all students is also given (Av).....	107
Table 6.6 Mean Scores on the Index of Issue Interest Scores. Miller and Pardo (2000, p.68). ....	108
Table 6.7 Percentage of attentive (A) or interested (I) in each class.....	109
Table 6.8 Percentage of attentive (A) or interested (I) in each class.....	111
Table 6.9 Percentages who are attentive (A), and who are interested (I) in scientific, medical or technological discoveries.....	112
Table 6.10 Percentages of 18-29 year olds who are attentive (A), and who are very interested (I) in sci., med. or tech. discoveries.....	113
Table 6.11 Views on astrology: numbers of students in each class.....	116
Table 6.12 Mean scores of Index of Interest.....	119
Table 6.13 Numbers of students choosing each statement in Q14.....	121
Table 6.14 Student opinion on public involvement in scientific/technological decisions.....	122
Table 7.1 Data and analysis: age and sex.....	130
Table 7.2 Assessment of school science education: numbers taking 4- or 5-point <i>bagruyot</i> in science subjects.....	131

Table 7.3. Mean Scores on the Index of Issue Interest for 2009 and 2010.....	131
Table 7.4 Percentage of attentive ( <b>A</b> ) and very interested ( <b>I</b> ) in science and technology in each class.....	132
Table 7.5 Percentages of 18-29 year olds who are attentive ( <b>A</b> ), and who are very interested ( <b>I</b> ) in sci. and tech. discoveries.....	132
Table 7.6 Scientific literacy knowledge test.....	133
Table 7.7 Comparison between the scientific literacy test scores in the US and in my classes.....	134
Table 7.8 Comparison of Index of Issue Interest at beginning ( <b>B</b> ) and end ( <b>E</b> ) of semester, and also compared with 2009.....	136
Table 7.9. Open-ended questions about the project/intervention.....	149
Table 7.10. Code letter, category and examples from U hum for Q A.....	149
Table 7.11. Code letter, category and examples from U sci for Q A.....	150
Table 7.12A. Analysis for responses from U hum and sci for Q A.....	151
Table 7.12B. Extracted from Table 7.12A.....	151
Table 7.13. Codes, categories and examples for positive responses for U hum, Q.B.....	153
Table 7.14. Codes, categories and examples for positive responses for U sci, Q.B.....	153
Table 7.15. Numbers (N) of students giving positive reactions.....	154
Table 7.16 Codes, categories and examples of negative reactions from U hum for Q.C.....	155
Table 7.17 Codes, categories and examples of negative reactions from U sci for Q.C.....	155
Table 7.18. Numbers (N) of students giving negative reactions.....	155
Table 8.1 Data and analysis: age and sex.....	166

Table 8.2. Question relating to language fluency.....	167
Table 8.3. No. of students in U sci (11) speaking each language, according to the order they listed them.....	168
Table 8.4. Assessment of school science education showing numbers taking 4- or 5-point <i>bagruiyot</i> in science subjects.....	169
Table 8.5 Question to find issues that interest students.....	170
Table 8.6. The issue of greatest interest.....	170
Table 8.7. Q 9. Student opinions on status of scientific literacy.....	172
Table 8.8 Data relating to Q.9 giving student opinions on importance of scientific literacy.....	173
Table 8.9. Question on science bagrut.....	174
Table 8.10. Data for Q.10 on science bagrut.....	174
Table 8.11. Q.11 on increasing scientific literacy.....	175
Table 8.12. Data for Q.11 on increasing scientific literacy, comparing U sci (11) and U hum (11).....	176
Table 8.13. Samples of topics chosen and statement of point of view (in students' own words).....	182
Table 8.14 Questions written on the board for student feedback.....	184
Table 8.15. The headings for content analysis.....	185
Table 8.16A. Comments on intervention. Responses to Q.A.....	185
Table 8.16B. Comments of intervention with data from 7.12B.....	185
Table 8.17A. Comments on intervention. Responses to Q.B.....	188
Table 8.17B. Comments on intervention with data from 7.15.....	188
Table 8.18. A selection of comments in response to Q.B., referring to the most useful part of the project.....	189

## LIST OF APPENDIXES

<b>APPENDIX A:</b> University approval.....	233
<b>APPENDIX B:</b> Essays on sources of influence.....	234
<b>APPENDIX C:</b> Why the <i>mechina</i> ?.....	240
<b>APPENDIX D:</b> Sample projects .....	241
<b>APPENDIX E:</b> Sample <i>peteks</i> .....	246

## SUMMARY

The commitment to improving scientific literacy is voiced by governments throughout the world. One of the main objectives is the development of an informed and active citizenry able to participate in decision-making processes concerning socio-scientific issues (SSIs).

There is a growing literature which suggests that engaging with the complexity of SSIs demands a high level of critical-thinking skills. These skills include: open-mindedness, independence, and scepticism. This three-year long study attempted to develop an intervention which will, in particular, provide subjects with an ability to be more open-minded, evaluate counter opinions, and respect those holding such opinions.

The importance of developing an ability to value the ‘other’ emerged from years of teaching academic English within an Israeli university, where initiating fruitful classroom discussion was problematic. The lack of dialogue resulted from individuals voicing strongly held opinions and seeming to be unable to acknowledge, and evaluate opposing views.

This project was designed as an action research study. Both quantitative and qualitative data was collected, and analysed within an interpretive framework. As both the researcher and researched, many of my teaching methods were modified during the course of this study, including the introduction of pair-work in class.

The study was conducted in three cycles over three consecutive years, primarily with two classes (one humanities and one science) in the pre-academic, *mechina*, program of an Israeli university. The *mechina* is a year-long programme and the students I taught had a single semester of English. This meant that three different cohorts of students were studied, (there were always 25-30 students in each class, so about 50 students were studied each year). The classes I taught were proficient in English, and were required to do a research project as part of the course. This project became my intervention.

I developed a project based on devil’s advocate which required them to choose an SSI that interested them, write a statement of their opinion, and then, much to their astonishment, find evidence to support the counter opinion. I gave a lesson on how to

evaluate sources available on the internet. Although the project was set up as a standard research exercise, which is what they expected, the majority of students identified that this project made them more aware of the value of counter opinions – more ‘open-minded’.

The primary method for collecting feedback on the project, and on other aspects of my course, utilized a projective technique – students wrote their views anonymously on a piece of paper; these are then analysed by coding the responses.

This study also employed questionnaires, which were given to all students. These showed that the majority had little or no science education in high school, and yet registered high levels of interest in science and technology on a three-level Likert item. These findings add support to research that shows the more science studied in high school the lower the interest in the subject. Furthermore, by including a standard VOSTS (Views On Science-Technology-Society) I was able to show that my students believed the general public should participate in governmental decisions relating to SSIs. Responses to open-ended questions showed that most students, including those in the humanities, believed everyone should take science courses at university, and should have science classes in school (though not the current curriculum).

In conclusion, this research indicated that interest in science was not related to studying the current school science curriculum. And feedback from the intervention demonstrated that students could be aware of a change in their cognitive skills, and independently acknowledge the importance of being open-minded – an important step towards promoting an active, informed, scientifically literate society.

# Chapter One

## Introduction

*From the place where we are right* by Yehuda Amichai (1986)

*From the place where we are right  
flowers will never grow  
in the spring.*

*The place where we are right  
is hard and trampled  
like a yard.*

In this introductory chapter I will give an overview of my action research in the first section. A further section will be devoted to the aims and research questions. And the final section will show how the whole thesis is organised.

### 1.1 Overview of my action research

There are three subsections here:

1.1.1 Understanding scientific literacy. The difficulty in ascribing meaning to the term scientific literacy is briefly discussed. The meaning I have adopted is introduced, and this provides the context of my action research.

1.1.2 The groups of students studied. I briefly introduce the students who became the focus of this study.

1.1.3 Challenges in the classroom and developing the intervention

#### 1.1.1 Understanding scientific literacy

Ever since my first job as a medical physicist in St Mary's Hospital Paddington I have been committed to promoting various aspects of scientific literacy. The prime motivation at that stage was to empower patients so they could become more active partners in the decisions relating to their healthcare options.

This commitment to improving scientific literacy has continued to be an important element throughout my working life. And my appointment, ten years ago, at an Israeli University as a teacher in of academic English in the Department for Pre-Academic

Studies offered a new opportunity to reconsider how I could best improve the scientific literacy of my students. This became the foundation of my action research.

Although I have freely used the term 'scientific literacy' here it should be noted that there is no agreed definition in the field of education. And Chapter Three in this thesis looks closely at the conflict of ideas that have evolved around this term. I shall cover them briefly here.

The term first appeared in the literature in the late 1950s (Hurd 1958) and has been widely identified with the goals of science education. The list below gives the guiding principles in science education identified by the US Government's National Science Education Standards (National Research Council, 1996, pp. 1-2). These principles encapsulate what has been adopted in many countries as the fundamental objectives of scientific literacy.

- a) Everyone needs to use scientific information to make choices that arise every day.
- b) Everyone needs to be able to engage intelligently in public discourse and debate about important issues that involve science and technology.
- c) Everyone deserves to share in the excitement and personal fulfilment that can come from understanding and learning about the natural world.
- d) More and more jobs demand advanced skills, requiring that people be able to learn, reason, think creatively, make decisions and solve problems. An understanding of science and the process of science contributes in an essential way to these skills.
- e) To keep pace in global markets, the United States needs to have an equally capable citizenry.

This list presents a considerable challenge to science educators and alludes to many different definitions of scientific literacy. The response by educators to this collection of diverse objectives has produced a tension between two approaches. The first regards school science as the preliminary preparation for a scientific or technical career, and the second sees the science classroom as having a more general educational purpose. This latter approach became the focus of those advocating teaching science within its social context. But even the limited introduction of a science-technology-society (STS)

curriculum drew strong criticism for failing to teach science (Kromhout and Good 1983).

However, even with a growing awareness of the importance of STS content, most school curricula continue to be heavily knowledge-based because students are subject to testing. Indeed, the commitment to prescribed standards, with its concomitant international comparisons, has encouraged teachers to maintain a test-content focus in the classroom. This has continued despite the fact that "there is considerable evidence, that although well-intentioned, standards-based education has the potential to inhibit the autonomy and creativity of classroom teachers and their students" (DeBoer 2000, p.599).

Lemke in the foreword to Wellington and Osborne's book *Language and Literacy* (2001, p.v) notes that "Too many pupils care less and less for science as a school subject the more of it they've taken." Another criticism of the current approach of knowledge-based school curricula rests on findings that this method of instruction is perhaps directly responsible for the decline in interest in these subjects during adolescence (Vedder-Weiss and Fortus 2010; Ebenezer and Zoller, 1993). The importance of critical thinking within the context of scientific literacy is discussed in Chapter Three.

When developing my intervention my aim was not to increase their scientific knowledge but to improve some aspect of critical thinking. Targeting students' ability to think critically is slowly becoming acknowledged as an essential goal for all educational practice, within school and university. Its importance is, for example, highlighted in a report from the Association of American Colleges and Universities (2005, pp.4, 6) which revealed that while 93% of college faculty considered analytical and critical thinking to be among the most essential skills students can develop, and, according to their own measures, only 6% of graduates showed proficiency in these skills. This is further supported by the work of Lujan and DiCarlo (2006) who found degree courses in physiology overlaid with factual material and failing to produce students capable of critical thinking. Lujan and DiCarlo suggest that "collaborative learning activities, interactive models, educational games, and establishing a culture of

inquiry/scholarship are critical" in order to develop "life-long skills such as critical thinking, problem solving, and communication." (Lujan and Carlo, 2006, p.21)

One of the goals of programmes of scientific literacy is to create an informed citizenry who can actively participate in decision-making processes relating to socioscientific issues. Critical thinking skills are of central importance in evaluating argument. For my intervention I carefully thought about what specific approach I would adopt in the context of the classroom experience in University pre-academic programme. It became clear through classroom experience that my students needed to be able to listen to and respect opinions different from their own. This is widely acknowledged as a critical thinking skill.

#### 1.1.2. The groups of students studied

Throughout this action research the main focus in each cycle are my students who were enrolled in the one-year pre-academic (*mechina*) programme at an Israeli university. There are three cycles to my action research (2009, 2010 and 2011). Each year is a different cohort of students. By giving the same questionnaires to all students throughout this action research I was able to show internal consistency in opinions and abilities across the years.

It should also be noted here that in the first cycle of my action research, see Chapter 6, I also collected data from two classes in an Israeli college of engineering. The classes I worked with were at the highest level (known as level 1) and required a single semester of English to gain an exemption in the subject. These college of engineering students were in the first year of their degree studies, and would not be able to get a degree without having passed the English exam at level 1 (it is passing this exam which gives them an exemption – a *ptor*).

The students at the university *mechina*, my main study population, had elected to take this one-year of intensive study in order to remedy a school experience that left them without the necessary qualifications to study at tertiary level. Many of these students self-identified as drop-outs from school, or came from regions of Israel where the school system is struggling to provide the basics of education. Others had been in schools on traditional *kibbutzim* (agricultural co-operative communities) where

agricultural needs (picking crops etc.) took precedence over formal classroom schooling. A few had come from the system of democratic schools where students are autonomous and determine their paths of study. I chose the two top classes who already had an exemption certificate (*ptor*) in English and had a good level of the language in all three modalities (speech, reading, and writing)

These students are a unique population to work with because they do not have good enough grades from school to get a place at higher education, but are studying within an academic institution. And the fact that I taught two classes, one in the humanities stream and the other in the science stream, meant I could also look at differences between these two streams when investigating interest in, and knowledge of, scientific issues.

I would throughout this action research be collecting feedback from my students to help evaluate and direct my teaching methods, and in particular those relating to the intervention I would introduce and subsequently modify.

There was much in my teaching style that changed during the years of this research. For example, I moved increasingly towards allowing my students to work in pairs and encouraging them to do so when working on the term's project. It was this project that became my intervention.

This change in teaching style was not only grounded in my observations of my class dynamic, but was also supported by my reading of the relevant literature. I was especially influenced by the growing body of evidence (Wallace 1996, Rudduck and McIntyre 2007) that shows that student motivation is fostered by increased student autonomy, with the classroom being a place where students can collaborate and have control over the pace and nature of learning. Much of this research is situated within the school classroom but it is important to consider its relevance for teachers in universities and colleges because it is here that the loss of enthusiasm for studying science, technology, engineering and mathematics (STEM) is most marked. In the US "fewer than 40% of students who enter college intending to major in a STEM field complete a STEM degree" (President's Council of Advisors on Science and Technology 2012). This report identified uninspiring teaching as a main demotivating influence and quotes

research (2012, p.11) that demonstrates that "critical thinking skills, long-term retention of information, and student retention in STEM majors" are all improved by active teaching methods. These methods include group work, and project work that students identify as relevant and meaningful.

The intervention I developed was the tool I used to improve the scientific literacy of my students. And although I knew that improving their knowledge of science was not the direction I wanted to go in, the exact nature of the interventions took time to formulate. Even the idea that I wanted to improve their 'critical thinking' lacked specificity. However, it was my classroom experience that ultimately enabled me to identify something that I felt I wanted to try and address.

### 1.1.3 Challenges of the classroom and developing the intervention

I had taught these groups of students each year since 2005, having moved to Israel in 2004. Arriving in a country that I had only visited for two weeks previously was challenging in many ways. But as a new arrival I experienced a heightened perception of the contrasts in my new life and those of the life I had left behind.

In Israel I had several teaching jobs in different institutions of tertiary education, and was always warned by the head of the department that Israeli students were unruly in the classroom. Negotiating a relationship with my classes required considerable care and reflection, especially as I did not want to make tertiary education feel in any way like an extension of their negative school experience. Fortunately, it only took a year to find a way to gain control of the class without adopting an authoritarian approach. Most importantly I allowed them to formulate and justify the rules of behaviour within the class.

I found that once I was engaged in action research I became more self-analytical of every aspect of my standard classroom practice. As with all other teachers in the *mechina*, I engaged in frontal teaching with students working individually. But it became clear that students much prefer working in pairs, and indeed work effectively like this, without the class degenerating into the bedlam we all feared.

However, class control was much more problematic when initiating class discussion, which is a mainstay of my teaching method. But it didn't take long for them to learn that only one person would speak so we could all hear what was being said. However, observing the dynamics of the activity soon revealed that the problem was not about maintaining some order in the classroom – that was easily done. The problem was the inability of the students to listen to each other, to acknowledge an idea that conflicted with their own strongly voiced opinion. This is, of course, not just a problem in the classroom.

The confrontational style of discussion that was present in the classroom is also found in Israeli radio phone-in programmes and television shows involving political discussion.

Students would often point out that their classroom behaviour was no different from that of the recordings on TV of debates in the *Knesset* (the Israeli Parliament). Indeed, research investigating the nature of Israeli debate and its relationship to the methods of religious debate (Blum-Kulka et al. 2002, p.1583) highlighted the fact that “high levels of topical involvement can come at the expense of ... interpersonal, dialogic involvement”. The analysis given of both political discourse and traditional religious dispute within a *yeshiva* (an institution of religious study) shows a preference for disagreement. Furthermore, they note (2002, p. 1576) that “the religious obligation to study the [Jewish] law is not goal-oriented ... Therefore, there is no incentive for reaching a particular conclusion, let alone an agreement”. This is seen as the model influencing Jewish political discussion and does much to explain why “disagreements... are conversationally favored” rather than normal western expectations for seeking agreement, (Hutchby and Woolffitt, 1998).

The notion that the conduct of discussion is rooted in cultural norms is further reinforced by a study where special methods were devised to help Asian students to engage in critical thinking (Chiu, 2009) because “many of the practices associated in the West with nurturing critical thinking are alien to the norms of students” from a Confucian Heritage Culture (CHC). This study engaged with students in an English as a Foreign Language class in Taiwan, and adopted an approach of ‘shepherd leadership’ as a means of encouraging student participation in a process of critical thinking – reaching out to students individually to overcome their reluctance to voice opinions

because the CHC “cultivates social harmony, reverence for teachers’ authority and silence to avoid confrontation” (Chiu, 2009, p.44)

It was clear that I would also have to consider the implications of the cultural disposition towards argumentation when designing an intervention that would promote a more critical discourse. In view of the discussion above, my intervention seems to be more than having an educational aim – it will also challenge a cultural norm.

The development of Western democracies, with their focus on the rights of the individual and the importance of citizen power, should demote the power and influence of single ‘authorities’. However, in the Far East and Middle East there remains a deference for ancestral and contemporary authorities. In Islam, the Imam, and in Judaism, the Rabbi. The modern day religious authorities have ultimate power over their followers, and claim their authority by deferring to revered ancestors, often claiming a direct patrilineal line (or occasionally, among rabbinic families, matrilineal links). As a Jew, with a great diversity of communal experience, I have some knowledge of the orthodox authoritarian structures. From Arab friends and students, I have been able to gain some insight into Muslim socio-religious life, and identify much commonality with that of Jews – the reverence for religious authority is pervasive in the Middle East. Also private discussion with Druze, in my class, showed a rigid hierarchy within their communities which means that their fathers, and communal elders, have ultimate authority over the decisions of young people, including what professions they pursue and who they marry. Christian Arabs I have taught, mainly from Nazareth, have strong patriarchal authoritarian figures within their church and families.

It should be added that in the midst of all this religiosity is a move towards secularism, especially among young Jews. For those coming from the ultra-orthodox community this means total separation from their families, who suffer considerable social stigma when a child goes ‘off the *derech*’. *Derech* loosely means ‘The way/path’, but refers to ‘The path that God has laid down for the righteous to follow’. Arab friends who are secular have a similar experience of being identified as ‘outsiders’ with all the religious and social disapprobation this brings. However, both secular Jews and Arabs often still participate in religiously-based events, and remain bonded to family through celebration and ritual.

This is a great simplification of a complex, multi-ethnic society which forms contemporary Israel. However, I feel it gives some context to the daily experience of confrontation and argument at every level of the society. Argument embedded in the voice of revered authority leaves no room for negotiation, and no room to even acknowledge the possibility of other opinions. To challenge this norm within the context of improving critical thinking became a focus of my intervention.

I had the possibility of introducing an intervention because the courses I taught at the university required me to give the students a project to work on. The design and content of the project was left up to the individual teacher, but it was assumed that it would contain a research element, which would include use of the university library databases. It was understood that it should not be very time-consuming (no more than a couple of lessons and a couple of homework sessions).

But I knew that I wanted to incorporate an element that would challenge their process of thinking about contentious issues. As with much of my course I wanted them to challenge themselves and recognise the inherent danger of assuming we are right. It would be an intervention that would fulfil some of the requirements of engendering critical thinking, this is further discussed within the literature review (Chapter 3) and during the description of my research.

In preparation for the term's project I give a detailed lesson on ways of accessing information on the internet, and challenging its bias and general validity. Working in pairs, the students then choose a controversial issue and find supporting evidence for their opinion. The twist comes when the students are asked to adopt the opposite opinion and find the evidence to support their 'new' opinion. They write a short piece showing the relevance of this evidence to their new position and give a short presentation in class. I collected anonymous written feedback from the students to assess their perception of the purpose of the project and their views, both positive and negative, on how it impacted on their learning.

The aims of this project are wholly consistent with the intention of improving scientific literacy when the definition focuses on the ability to think about issues in a critical and analytical way, not influenced by "assumptions and prejudice" (Devlin 1998, p.559). This project evolved out of my role as a teacher-researcher engaged in action research and is resonant with the underlying principles of the endeavours in that field. It is an approach expressed by McKernan (1996, p.53).

The goal is not only to emancipate practitioners but to allow such a strategy to empower students so that they are emancipated as learners. What this will mean is that students take the responsibility for thinking and learning, making rational choices, and so forth. If the students do not become involved in critical thinking and inquiry learning while they are at school, then it is highly unlikely that they will go on 'leaning' on authorities in their future lives – thus minimizing the chance of developing as autonomous individuals.

## **1.2 Aims and Research Questions**

This section brings together my overall aims and lists my primary and secondary research questions.

The primary aim of this research is to address how scientific literacy can be improved within an Israeli university student population. More specifically I consider whether it is possible to do this without making major curriculum changes. Instead, I look at the impact of a modest, self-contained project that targets a single learning outcome. In order to evaluate the effectiveness of the intervention, I collect qualitative data, analysed using a method of coding.

This action research project confronts some fundamental questions relating to the meaning of scientific literacy. It also endeavours to identify and challenge some of my own preconceptions of my role as teacher, and look more closely at the teacher-student dynamic with a view to promoting increased student autonomy within an academic framework.

In the literature review I consider the wide range of meaning given to the term scientific literacy and try to identify a definition that is appropriate to the focus of this research. But irrespective of the precise definition of 'scientific literacy' that is ultimately

adopted, my research questions remained relevant. I also include a discussion of critical thinking within the literature review and show its relevance to my research.

The main research question that this thesis attempts to address is:

How can the scientific literacy of Israeli university students be improved as part of an advanced academic English programme?

There are several sub-questions which I investigate; the four listed below probe some of the fundamental assumptions which underpin current global efforts to promote scientific literacy:

1. How can the term 'scientific literacy' be usefully defined in the context of my action research?
2. How can I endeavour to improve my students' scientific literacy (within the meaning I ascribe to scientific literacy)?
3. How do levels of interest towards science and technology among my students compare with those of similar groups in other countries?
4. Is the degree of interest in scientific issues associated with the field of studies students are pursuing at university: specifically, do science students show more interest than those on a humanities track?
5. Can I collect any data that will contribute to the discussion of the relevance, or otherwise, of science education in school and its impact on scientific literacy?

There are several other questions that I will investigate directly with my students, in order to get their perspective on the intervention and other aspects of my teaching. In order to implement the intervention effectively I will consider some general aspects of my teaching methods. Some of the questions I hope to ask students will include:

- What do the students perceive as the learning outcome of the intervention?
- What is the students' overall assessment of this project?
- What are their criticisms and comments on other teaching practices I implement during the semester? (these might influence the way I implement my intervention)

### 1.3 Thesis Organisation

Following the general overview of my research given in this chapter, the following chapters focus more closely on all aspects of my research, a synopsis is given below.

**Chapter Two: Context of the Research.** This chapter gives an overview of the Israeli education system to help understand the educational structure that my students are part of. There is detailed information about the classes of students chosen for my action research.

The chapter also includes a short personal biography helps identify the origin of my own pre-conceived ideas on education and how these ideas impacted on my formulation of my research.

**Chapter Three: Literature Review.** This chapter reviews the literature on scientific literacy. Throughout the other chapters in this thesis relevant research is cited, but I felt I needed to explore extensively the different ways the term 'scientific literacy' is conceptualised. Exploring the ideas on this subject helped me clarify the framework of my intervention, which became closely associated with ideas in critical thinking. Therefore, this chapter also includes a section on the literature relating to critical thinking.

As a teacher-researcher I became more reflective on my teaching style and student learning styles, this resulted in a review of the literature on constructive alignment, dialogic talk, and learning theories. Changes made in my teaching style might influence the way my intervention was implemented.

**Chapter Four: Methodology and Methods.** This chapter was an enormous challenge to write. I come from physics and research in allied fields. Researching and writing this chapter initiated an important change, not only in the way I approached action research, but in re-evaluating the assumptions underpinning research in the natural sciences. It became clear that my action research would be carried out within the framework of an interpretivist approach.

The final section in this chapter explores and critiques different research tools I could employ in my research. More details on the tools used in my research appear in the following three chapters.

**Chapter Five: The Research plan.** This chapter is an overview of the three years of my action research project and is a road map for the three action research cycles that took place in three successive years – 2009, 2010 and 2011. It forms a bridge between chapter 4 (which discusses the theoretical underpinnings of my action research) and chapters 5, 6 and 7, which detail the methods and data analysis for each of the three cycles of my research. A table showing the research done in each cycle accompanies the relevant section.

**Chapter Six: 2009: Preliminary Reconnaissance.** The reconnaissance provided me with the opportunity to explore the level of science education of my students, their level of interest in science and technology, and attitudes to participation in government decisions relating to matters with scientific or technological content. Questionnaires were used to collect data that was computed to generate values for 'Attentiveness' and an 'Index of Interest', both of which have a body of international data to compare with. Although my cohort has a unique profile in socio-cultural terms, international comparison is interesting to see whether there is a way of contextualising data in this way. Within this chapter are also my observations and reflections as a teacher-researcher on several aspects of the classroom dynamic.

**Chapter Seven: 2010: Further reconnaissance and piloting the intervention.**

This chapter continues the reconnaissance of my students with assessment of their interest in scientific issues. There is also a description of the criteria that determined the design of the intervention and the methods used to obtain student feedback. It also introduces the method used to monitor the success of the intervention – not in terms of a test scores but in terms of students own personal assessments. Ways that this piloted intervention could be improved were identified.

**Chapter Eight: The Intervention.** Basically the same intervention is used, but the instructions to the students were slightly modified. This chapter describes the implementation and student responses to my modified intervention. A questionnaire also explored student attitudes to scientific literacy.

**Chapter Nine: Discussion and Conclusions.** This chapter discusses my findings in the context of my main research question and the four sub-questions that I identify in Chapter One. I reflect on the changes introduced into my classroom and how these impacted on my students.

**Chapter Ten: Final Reflections.** Here I take a brief look back over the path taken through my research, and identify my contribution to knowledge. There is also consideration of the limitations of my research design. I have included how I have implemented what I learnt from research action into other educational settings, and I have made some suggestions for future avenues of study that might result from my action research.

## Chapter Two

### Context of the research

#### 2.1 Introduction

My research primarily focuses on two classes within an Israeli university's department for pre-academic studies, known as the *mechina*. Most universities and colleges in Israel now have a *mechina* to provide a route into higher education for post high-school students who fail to meet the entry requirements to study in an institution of higher education.

In order to situate my research I have given a brief overview of the Israeli education system in section 2.2., with sections (2.2.1) on the school system and (2.2.2) on tertiary education. It is an extraordinarily diverse system which is shaped by the nation's complex social, economic, and political realities. I have chosen to describe briefly some of the factors that impact on the cohort of students I have chosen for this action research.

In section 2.3 I elaborate on the reasons for selecting my *mechina* classes for this research. I have also included here some general research I did to improve my understanding of my students, which was especially important as I was a new arrival in Israel and needed to grasp aspects of the socio-cultural environment I was working in.

In section 2.4, I give a brief, selective, personal biography to help contextualise this research as part of my own continuing professional development. I also hope that this background information will help identify some of the things which have influenced my research, and helped me get a better understanding of my students.

#### 2.2 The Israeli education system

##### 2.2.1 School system

The Israeli education system consists of three tiers: primary education (grades 1-6, approx. ages 6–12), middle school (grades 7-9, approx. ages 12–15) and high school (grades 10-12, approx. ages 15–18). School attendance is free and mandatory from the age of 6-18; some students embark at the age of 16 on vocational studies with apprenticeships. School is usually followed, for Jewish Israelis, by 3 years in the army,

or a year and a half in the national volunteer service (where young people can for example be trained and work as paramedics, nursing assistants, classroom assistants). From Israel's Ministry of Foreign Affairs website there is a brief description of the structure of the education system:

The multi-cultural nature of Israel's society is accommodated within the framework of the education system. Accordingly, schools are divided into four groups: state schools, attended by the majority of pupils; state religious schools, which emphasize Jewish studies, tradition, and observance; Arab and Druze schools, with instruction in Arabic and special focus on Arab and Druze history, religion, and culture; and private schools, which operate under various religious and international auspices.

In the final two years at school, matriculation exams (*bagruyot*) are taken in a set of core subjects:

- Hebrew Bible or the Scriptures of Christianity or Islam, in the relevant sectors of the population
- Language
  - Hebrew or Arabic grammar
  - Hebrew or Arabic composition
- English language (written and oral)
- Mathematics
- Civics
- World History
- Hebrew/Arab literature
- At least one elective, such as geography, physics, chemistry, biology, computer science, Arabic, French, social sciences, music, art etc.
- Physical Education

These subjects can be taken at different levels (3 point, 4 point, or 5 point). Students need to pass the exams and accrue 21 points in order to get a certificate of matriculation. In 2013, 48% of Hebrew speakers (not including the ultra-religious *Haredim*) and 38% of Arabs received a certificate of matriculation. The certificate is one prerequisite to getting a place in tertiary education. High scores on psychometric exams (in mathematics, verbal reasoning and the English language) are also required.

Israel has been a member of the OECD since 2010 and now implements PISA exams for direct international comparisons of performance of school children. The results are poor. In the 2012 PISA exams, out of 70 OECD countries, Israel ranked 40th in math, 33rd in reading and 40th in science. But scores in mathematics showed some improvement over previous years' tests – perhaps as a result of teachers better preparing their students for these exams.

Test results continue to be the benchmark of success in education and the number of exams inflicted on school children varies according to the education policy of the Minister of Education. At tertiary level student testing is obsessive with termly exams in every topic covered. There is also always the option of retaking an exam, the *Moed Bet*, to edge the student's already inflated grade closer to 100%.

The most widespread complaint about education in Israel focusses on the highly disordered state of the school classroom. Lessons resemble riot control, and both students and their parents have no respect for teachers. Failure of the student is only attributed to failure by the teacher. Teachers are poorly paid and much abused. Teacher training colleges are highly variable in the quality of teachers they launch into schools, and there is a severe shortage of teachers in all subjects because few are attracted into the profession.

Although teachers' salaries are well under half of the OECD average, Israel's investment in education is roughly in-line with average OECD figures and there have been per capita increases over recent years. According to Ben-David (2010, p.78) increased expenditure has not brought improvement in test scores, and maintains that this has been observed worldwide:

The lack of an ability to utilize increased education spending for systemic improvements is not unique to Israel. Focusing on five European countries (Belgium, France, Germany, Italy, and the United Kingdom) as well as on Japan, Australia and New Zealand, McKinsey (2007) shows that substantial increases in real education expenditures per pupil were accompanied by almost no changes at all – just minute positive and negative changes – in student achievements...

This raises many important educational issues. It certainly challenges the fundamental premise that more investment has positive outcomes in terms of test scores. Surely some of the questions we should be asking are about how money can be best spent, and, more basically, what should be defined as desirable outcomes? These questions become all the more important in light of recent research which shows students become increasingly disaffected with a subject as they progress through years of school study (see overview by Osborne et al. 2003). An Israeli study compares student motivation in science classes in regular state schools with that in democratic schools where students have complete freedom about what they study. Vedder and Fortus (2010) chart a marked decline in all parameters relating to motivation in traditional teaching, whereas

the autonomous students within democratic schools retain their motivation. My research is, at its most fundamental, concerned with this issue.

### 2.2.2 Tertiary education

At the higher level of education there are seven universities, the Open University, 29 academic colleges, and 26 colleges of education. It is at this level that the education system is most successful.

An overview of the standing of tertiary education in Israel is given by the OECD report (2014):

A high level of education is particularly common in Israel. The country ranks fourth among OECD countries for tertiary attainment among 25-64 year-olds: 46% of adults held a tertiary degree in 2012 compared with 33% on average for OECD countries. In contrast, only 15% of 25-64 year-olds have not attained upper secondary education, compared with 24% on average for the OECD. This statement holds true especially among the older generations. Almost twice as many Israeli 55- 64 year-olds held a tertiary education degree than the average for OECD countries (47% compared with 25%). Unusually, holding a tertiary education degree is more common among this age group than in the younger generations in Israel: 47% of 55-64 year-olds have a tertiary degree, compared with 45% of 25-34 year-olds. Generally, in other OECD countries more young people have attained a tertiary degree than those in the older age group. (OECD, 2014).

For data on students in tertiary education, the latest figures I could access were from the Central Bureau of Statistics for the academic year 2007/2008 (Central Bureau of Statistics 2009). The data showed that around 74,000 students applied to study for a first degree with approximately half applying to universities and half to colleges. About 60% were accepted and commenced studying, 15% were accepted but didn't begin their studies, and 25% were rejected. (These figures exclude those students who study at the Open University and those at teacher training colleges). Of those entering higher education, 83% were Jews and 13% were Arabs (In the population as a whole the religious make-up is: 75.4% Jewish, 17.3% Muslim, 2% Christian, 1.6% Druze and 3.7% others. I have given the percentages by religious affiliation as this is very defining in Israel and is more meaningful than the simple two group designation of Arabs and Jews. Of the Jewish population 70% are Israeli born, 30% are immigrants. Other interesting data includes the fact that Israeli students tend to be older with the average age of all first year students at about 23. And the gender distribution among

Jewish students is male, 46% and female, 54%; in the Arab population the figures were 67% to 33% respectively.

According to a detailed and informative government report on pluralism in higher education in Israel, (Shaviv et al. 2013), the number of students entering a pre-academic programme in the academic year 2010/2011 was 12,250. About half of them move on to study for a first degree at a university or a college. But only 6% are Arab, and that is certainly true within the university *mechina* where I taught. Research quoted in this report identified several reasons for the low uptake in the Arab sector. I have paraphrased his conclusions below and added my own comment in *italics*.

- Lack of awareness of the option of pre-academic preparatory programmes.
- Negative reputation: preparatory programmes are seen as intended for weak students, who are later tagged in their home communities as less successful than the rest of the students who graduated on time. (*Not an attitude in Jewish Israeli society*).
- The teaching method in the preparatory programmes, which is the same as in academic programmes, results in a high dropout rate. The Arab school sector primarily teaches information-based learning, and a respect for authority.
- Financial cost: although most Arab students are eligible for funding, studying for a year meant the loss of wages for that year. And often the location of their home town means that they will have to move to dorms for *mechina* studies, yet another financial burden.

However, the report notes the success of recent initiatives to set up pre-academic courses specifically designed to help Arab students acquire study skills, and improve their Hebrew and English. It should be noted that for Arab students English is a fourth language (spoken Arabic, classical Arabic for reading literature, and Hebrew are the first three). Such programmes are being integrated into the *mechinot* of academic colleges and members of staff are visiting local Arab schools to encourage students to follow this option. Additional counselling support is being offered in the institutions with these programmes. It should be noted that having trained counsellors available to students is an integral part of the education system in Israel. Most schools have a dedicated counsellor and in university *mechina* we have two full-time counsellors available to our 400 students.

Students at the university's *mechina* fall into four groups:

- About 20% are sponsored by the army. These students are only 18 years old and usually come from socially, economically and educationally disadvantaged

communities but have been identified through psychometric testing as having academic potential. They include students from Ethiopian and Druze communities, and also students who come from the periphery of Israel where education standards are especially low. If successful in the *mechina* the army will fund their first degree studies (in STEM subjects or medicine) and then employ them when they have completed their studies.

- There are some students who want to improve their grades so that they have a better chance of being accepted into medical school where the number of applications can be up to five times the number of places available.
- Many students have failed in the *bagruyot* at school and need improvements in grades to get a place to study for a degree.
- A small group of students were school dropouts and had done all sorts of other jobs before deciding they want to study for a degree.

### 2.3 Why *mechina* students were chosen for this study.

In this section I explain why my *mechina* students were a really interesting group to study for my action research. The students selected were in two classes that I teach English for Academic Purposes (EAP).

Students in the *mechina* are divided into five levels of English proficiency. The standardised psychometric score in English determines which level class students are assigned to when they enter the *mechina*. Students who gain more than 132 points in this exam are given an exemption from English – they are known as *ptor* (exempted) students. Those with lower scores are divided into four levels according to the points awarded in the psychometric.

Each course consisted of two 90-minute lessons throughout one 13-week semester. It was a high level EAP course with many challenging texts (which I chose) across a wide range of subjects. Both classes had one *mechina* exam in English at the end of the first semester which included some grammar questions, and a few lessons were devoted to preparing them for this exam. The science students averaged about 96% in this exam and the humanities class had a class average of about 94%. The whole *mechina* takes this exam but it is the *ptor* students who shine – those attempting to enter medical school will need at least 98% on this exam.

Since 2005, when I began teaching at the *mechina*, I taught *ptor* students, as well as students in two top levels who had not gained a *ptor*. I also taught English for Academic Purposes in several other academic colleges in Israel. But it was my *ptor*

students who seemed the best group for me to work with. Firstly, these students had excellent English and I wanted them to be able to work with information on the internet and academic material – all available primarily in English. Secondly, I taught two parallel classes: a science stream and a humanities stream. This would allow me to compare these two groups of students. And thirdly, typical of most *mechina* students, they have a poor educational record and minimal, if any, teaching in science at high school.

There is always an issue over poor class discipline among Israeli students which I want to briefly address here. Even before I entered my first classroom at the university I was warned that Israeli students are hard to control and I must be strict from the first encounter or all would be lost. It was good advice, but I would want to add that once the ground rules are laid the student-teacher relationship, regardless of whether the students are Arab, Christian or Jewish, quickly becomes deep and sensitive. Rules of the classroom were tempered with understanding about the range of difficulties students were experiencing in their private lives. These difficulties would mean they were unable to concentrate within the classroom, had to miss classes, and completed assignments weeks late. Making myself available for one-on-one time with students throughout each teaching day was essential. These were not designated office hours. If I was in the teacher's room, or seen anywhere around the *mechina* I was always available. I did not give my cell phone number to students but they could contact me via email.

## **2.4 A brief personal biography**

There are various elements of my life that make this action research especially important to me. I would like to outline them briefly here.

My first degrees were in physics and following research, I began my working life as a medical physicist at St Mary's Hospital, Paddington, London. I was shocked by my encounters with patients who felt that the process of diagnosis and the ensuing treatment was something beyond their understanding. The doctors remained aloof and the patients uninformed. I felt that some scientific knowledge would empower these patients to become partners with the clinicians treating them.

I left the hospital to become a science journalist. I joined the editorial team of a US company publishing material for the international pharmaceutical industry. I wrote and edited a weekly newsletter about developments that affected pharmaceutical companies. A close encounter with the drug industry showed that it was only concerned with financial success; patient welfare was only important because it could impact on the bottom line. Their responsibilities of supplying patient information were driven by the necessity to comply only with minimal government regulations, and they kept information on drugs veiled in esoteric language. This situation has deteriorated further as drug information has moved to the internet (Schommer and Glinert 2014).

I left and joined the Science Unit at the BBC World Service as a producer and scriptwriter for science programmes. These were interesting years but also brought some upsetting insights. In this job I was endlessly shocked by the misreporting of scientific and medical discoveries in the popular press – especially in medicine where the results of research were distorted to give a great headline. For the average reader newspapers and news in general has the status of authority. Even more disturbing was the fact that many of the scientists were compliant with the hyped misreporting because it was what suited their funders' objectives.

These were some of the contributing factors that led me to believe that the general public needed to be empowered to ask meaningful and challenging questions on those scientific matters that directly impact on their lives. And at a more global level, the public needs to be an active citizenry with a voice that can influence government decisions on many controversial issues that shape the society we live in.

I went on to write several books on popular science designed to promote wonder and interest among adolescents. I then set up my own publishing company, New Look Books. I wrote and published a series of books designed to entice and fascinate young children in a world of learning. Another series that I translated from Italian, and then published, called *Never Ending Stories*, were designed to challenge young readers in an imaginative way. I still work as a science journalist, for the Israeli university where I teach. I write about the scientific achievements of the university and believe that no matter how complex the scientific ideas there are meaningful and informative ways of communicating them to a lay population.

In the education of my own three sons I tried to adopt an open and enriching environment. I had, since my own school experience, been deeply disturbed by the content and approach of school education and decided to home-school my sons to varying degrees. The two youngest never entered a traditional school. They all have university degrees (Chinese, microbiology, music) and continue to be highly creative, open-minded thinkers.

In 2004 I moved to Israel to teach English in both the Arab and Jewish sectors of the society. I deal with my experience as a teacher in Israel throughout this thesis as it is closely woven with the development of my action research. I have found myself challenging my embedded assumptions about every aspect of my teaching. I have tried to deal with issues such as: how I can improve the learning experience for my students; how to keep informed of students' classroom experience; what learning outcomes can better equip my students for a role of as active, participatory citizens. My intervention enabled me to develop a simple project that could meet some of my objectives and opened the way to further investigation.

## **Chapter Three**

### **Literature review**

#### **3.1 Introduction**

Much of this chapter closely follows the evolution of my thinking on the subject of scientific literacy. It is laid out in the order in which I read and critiqued the literature. The chapter includes a final section where I critique the literature on dialogic talk, critical thinking, and theories of learning. This review is far ranging and gave me the opportunity not only to evaluate the current understanding of the term 'scientific literacy', but also to meet ideas on the value of dialogue in teaching practice, and some important ideas in understanding teacher/student education.

The sections on scientific literacy provided me with a wide perspective on how the term scientific literacy is used, and led me to reject current views that focus primarily on the acquisition of scientific knowledge. I found the discussion of the conceptualization of scientific literacy formulated by sociological researchers compelling. This resulted in my formulating an intervention based on the investigation of a socioscientific issue. And furthermore, the literature helped me recognise the importance for students to select a topic of particular interest to them.

There is a complexity in this thesis because it also contains a development in my own understanding of how the term scientific literacy can best be interpreted in the context of the educational environment in which I teach. Each stage of my developing understanding is followed in each section within this chapter. It is an attempt to capture the reflexive process that I engaged in during my reading of the literature. However, once I embarked on the research my findings and experience initiated further reading, especially in the field of critical thinking, and this is also included here.

The literature on critical thinking highlighted the importance of attempting to focus on certain basic skills so that students were able to critically evaluate arguments. I had already observed the difficulty students had in participating in discussion in a meaningful way and found analysis of this phenomenon in the literature (see section 1.1.3). Consideration of the literature led to my developing an intervention loosely

based on 'devil's advocate'. The details of which are discussed in the chapters on the interventions introduced during my action research cycles.

My reading on the literature on critical thinking and theories of learning, appear in the final sections of this chapter. This follows the model of the construction of the thesis as a whole, which is an attempt to reconstruct the chronologically development both in my practice and thinking.

### **3.2 The normative view**

The term 'scientific literacy' is problematic because it does not have a single definition that is widely accepted. However, the term has been generally conceptualised within a definition of 'civic scientific literacy' which primarily emphasises the importance of the understanding of the vocabulary and the processes of science (Miller 1997). It is this knowledge-based definition that forms the basis of much of the international testing. Yet by every measure, public surveys show ignorance of basic scientific knowledge (for example: Ziman 1991; Durant 1989; Miller 1997, 2006). The public is therefore deemed scientifically illiterate. Despite this general consensus that scientific literacy is desirable and that the public doesn't measure up, there still remain fundamental problems in the conceptualization of the term 'scientific literacy'.

This section looks at what has become the normative understanding of the term, mainly due to the work of Miller (1983, 1997) and also looks at other interpretations which are more useful to the approach I am adopting in my research. The conceptualization of scientific literacy necessarily determines the methodology and methods employed in assessment. Furthermore, it is this understanding that guides the form of appropriate interventions.

The currently accepted definition of scientific literacy owes much to the work, over forty years ago, of Shen (1975). He suggested that the public understanding of science could be divided into three categories: practical scientific literacy; cultural scientific literacy; and civic scientific literacy. Shen wrote:

Familiarity with science and awareness of its implications are not the same as the acquisition of scientific information for the solution of practical problems. In

this respect civic science literacy differs fundamentally from practical science literacy, although there are areas where the two inevitably overlap. Compared with practical science literacy, the achievement of a functional level of civic science literacy is a more protracted endeavor. Yet, it is a job that sooner or later must be done, for as time goes on human events will become even more entwined in science, and science-related public issues in the future can only increase in number and in importance. Civic science literacy is a cornerstone of informed public policy. (Shen 1975, p.49)

The term 'civic scientific literacy' has subsequently been widely adopted, notably by those who attempt to quantify the level of scientific literacy within different countries and use the data comparatively. At the forefront of this work is that of Miller (1983) who suggested that civic scientific literacy should be conceptualised in terms of three related dimensions:

(1) a vocabulary of basic scientific constructs sufficient to read competing views in a newspaper or magazine, (2) an understanding of the process or nature of scientific inquiry, and (3) some level of understanding of the impact of science and technology on individuals and on society.

Miller (1997) noted that the third dimension, which focuses on utilizing the social impact of science in conceptualizing civic scientific literacy, has remained a subject of disagreement among those working in the field and so he resorted to only using the first two dimensions for cross-national analysis (Miller 1997, 1998). And yet it is perhaps this third dimension that is the most important aspect of scientific literacy when considering the role of literacy as empowerment within a democracy. It is interesting to note here that Shen's initial concern with the "awareness of implications" has not generally been carried forward by those working and testing in the field. It may be its somewhat abstract nature that has proven problematic in quantitative research, but this makes it more appropriate to use qualitative methods.

### **3.3 Assessments based on the normative view**

Miller was concerned to construct a means of assessing civic literacy which would have "durability" and not become out of date as scientific issues changed. To this end he selected a set of basic constructs that were perceived to be the "intellectual foundation for reading and understanding contemporary issues, but which will have a longer

durability than specific terms.” (Miller 1998, p.206). These so-called basic constructs have formed the core of almost all recent surveys.

A similar instrument used in the UK, sometimes known as the Oxford Survey (Durant et al. 1991) included items that overlapped with Miller’s US national survey. The general conclusions had much in common, especially with regard to measures of basic scientific knowledge (Evans 1990). There have been similar surveys with comparable results in Australia (Schibeci 1990). Schibeci raised the question about whether we should be concerned about the observed, and universal, lack of scientific knowledge among adults. He concurred with Lucas (1987) that if we wish to develop a community with “a sympathetic understanding of the scientific world view, then we need to increase the level of knowledge in the adult population beyond that which currently exists.” This belief in a link between scientific knowledge and a “sympathetic scientific world view” is challenged by the work of Evans and Layton (1995) and is expanded on in section 3.7 below.

Over the years Miller has maintained a constant core of scientific constructs but has included recent developments in science and technology, for example “Miller’s 2003, 2004, and 2005 studies of the American public have included new open-ended measures of stem-cell, nanotechnology, neuron, genomic, and neuroscience and new close-ended knowledge items concerning the genetic modification of plants and animals, nanotechnology, ecology, and infectious diseases.” (Miller 2006).

Laugksch and Spargo (1996) extended Miller’s work and derived a pool of 472 true-false items based on the American Association for the Advancement of Science’s (AAAS) Project 2061’s publication *Science for all Americans* (Rutherford 1990). Project 2061, was first initiated in 1985, with the objective of identifying what was needed to make all Americans scientifically literate and is primarily focused on the needs of science education. For more information on Project 2061 see Laugksch (2000, pp.78-80).

Laugksch’s Test of Basic Scientific Literacy (TBSL) consists of 110 test-items selected from the pool of 472 (Laugksch and Spargo 1996). It should be noted that the TBSL differs from Miller’s testing by including 16 items that explore Miller’s third dimension

of scientific literacy, namely: the impact of science and technology on society, thereby returning to Shen's (1975) statement on the conceptualization of civic scientific literacy (quoted above). (In the TBSL 22 items focus on the nature of science and 72 on science content knowledge). The TBSL was specifically designed for high-school leavers in South Africa going on to tertiary education. It was based on the goals recommended in *Science for All Americans* (AAAS 1989). I am grateful to Laugksch for providing me with the complete TBSL and giving permission to use it. However, the 100 questions make it a very long test and it has not been generally adopted. I decided to employ a widely used standard-test that only had ten questions. This test is further discussed in Chapter 6 and the results from test given internationally are shown in Table 6.9 in that chapter. This gave me the means of comparing scientific knowledge of my students with those at various levels of education in the U.S. This, and other international comparisons in this thesis, enable me to challenge the idea that scientific knowledge, and scientific interest, are primarily derived from studying science in school. These comparisons allow me to raise questions that perhaps should be further researched.

### **3.4 Complexities in conceptualization of scientific literacy**

The complexity of conceptualizing "scientific literacy" becomes especially clear when methods for communicating science to the public are discussed (Silverstone 1991). Here Silverstone challenges four main assumptions that emerge from the literature in the field:

1. There is no such thing as the communication of science. Neither science nor the media environment is a unified phenomenon. Scientists disagree; the media present different accounts; receivers of scientific communication interpret each set of them in different ways, which may result in distinct, even disjointed, understandings.
2. There is no such thing as the public. There are many publics for science: the specialist and the lay, the interested and the disinterested, the powerful and the powerless; young and old; male and female. While these publics will share much, they will also understand or misunderstand, remember or forget, in different ways.
3. In the modern communication environment, science cannot claim any privileged status... The knowledge claims of science will not necessarily (nor even very often) float to the surface of media, professional, or public understanding of the world.

4. The omnipresence of the media does not equal omnipotence. ... Local knowledge, practical understanding, common sense: these can translate, transform, or resist scientific communication. (Silverstone 1991, p.106).

These assumptions, while acknowledging the diversity and the interests of the target audience, make it clear that any simplistic conceptualization of scientific literacy is profoundly flawed. It is essential to identify the limits of meaning and relevance of any conceptualization.

Fundamental questions in formulating a useful literacy concept could include: what motivates people to seek scientific knowledge, and how do they relate this information to everyday experience? It was these questions which were at the heart of the projects initiated to explore the relationships between members of the public and those individuals and organizations which represent the world of science (Wynne 1991). The answers could guide us to what sort of scientific literacy people themselves would perceive as useful. It seems extraordinary that the dominant normative descriptions of civic scientific literacy and the methods of assessment fail to acknowledge what people surveyed actually regard as useful or interesting. The notion that knowledge can be imposed where neither usefulness nor interest are considered might do much to explain the failure of institutions, both governmental and educational, to improve 'civic scientific literacy' even by their own measures. Indeed, Wynne himself notes that his research "indicates that the current institutional structures within which science is organised and projected may be part of the problem in public understanding and uptake of science" and that there is a basic assumption that science is "unitary and coherent" and is "central to everyday beliefs and practices" and that ignorance "indicates a deficit of democratic capability". (Wynne 1991, p.112)

The papers by Ziman (1991), Silverstone (1991) and Wynne (1991) cover the findings of a series of projects initiated by the UK Science Policy Support Group, a research initiative sponsored by the UK Economic and Social Research Council (ESRC) and the Advisory Board for the Research Councils.

Ziman (1991, pp.101-102) clarified some of the broad principles that emerged from this series of research projects. I include them here because of their importance to anyone

working in this field and should form an essential part of any conceptualization of scientific literacy, its assessment and resultant interventions.

**Incoherence.** People do not draw on stable, if fragmented or ill-conceived, “models” of the world, along the lines of textbook accounts of scientific knowledge. The little they retain of what they were taught at school is overlain and supplemented by the diverse representations of science that they meet in the media and in many other aspects of life. What they pick up is not simply a filtered version of formal scientific knowledge: its meaning is actively constructed by the processes and circumstances under which it is communicated and received.

**Inadequacy.** The use that people make of formal knowledge in any particular situation depends on the needs of the moment and represents only one element in a complex and varied response. They not only rely heavily on the tacit, uncodified, but highly expert and rational knowledge that is shared in most work communities: they also engage with, select, or construct the scientific elements according to their own interests, involvement, personal and social histories, and other circumstances.

**Incredibility.** People do not accept passively the knowledge presented to them by scientific “experts”. The credibility of a source depends strongly on its perceived interests in a particular context. This applies to individual scientists, scientific institutions, public bodies, and private enterprises.

**Inconsistency.** Public conflicts on social issues between scientific experts inevitably downgrade the privileged position of scientific knowledge. But public and private discussion helps people combine their scientific knowledge, ethical views, and tacit understanding of life into personal positions on controversial matters. In effect, they resolve the contradictions that arise by incorporating items of formal science into the whole knowledge complex and making them “disappear” as such.

These conclusions direct us towards the value of qualitative methods of assessing scientific literacy, and cast doubt on the value of the cross-national surveys based on the deficit model of scientific literacy.

It is interesting to include here a specific illustrative example cited by Wynne (1991) to show the difficulty of measuring scientific understanding in a standardised way. It arose from the Bradford project on familial hypocholesteremia.

The standard question, used in a national public understanding of science survey, asked whether eating a lot of animal fats can contribute to heart disease. The public involved with familial hypercholesterolemia operates with a more sophisticated distinction of saturated, mono-, and polyunsaturated fats. Thus the binary animal/nonanimal-fat distinction was insufficient for this part of the public. The qualitative and interpretive approaches thus allow insights that are excluded by standardized questions and analytical methods, especially concerning the complexities of beliefs, understandings, and responses.

There is considerable evidence of the highly specialised knowledge of local communities which can have significant influence on the ecological well-being of those localities. The research of Chhatre and Agrawal (2009) has shown that, contrary to prevailing official doctrine, carbon sequestration increases when forest ownership is transferred from governments to communities. These findings cast serious doubt on the UN's plan to pay governments to protect forests. It is feared that this UN policy will result in local communities losing control of their forests with an accompanying negative impact on carbon emissions and forest preservation. This suggests that there is much to be learned here from interested communities with local knowledge.

### **3.5 Scientific awareness and not scientific literacy**

The essential role of “scientific awareness” was highlighted in a brief paper by Keith Devlin (1998).

I think it is pointless to define scientific literacy in terms of any particular body of scientific knowledge. I neither know nor understand most of present day science. And yet I am a dean of science at a private four-year college, an active researcher, and the author of several mathematics textbooks and science books for the general reader.... In fact hardly any of us is sufficiently well informed to be able to reach a sustainable, independent conclusion on a single scientific issue, whether it is global warming, ozone depletion, or genetic engineering. (Devlin 1998, p. 559)

But Devlin doesn't despair, he maintains that all adults should be scientifically aware and should

base their opinion on fact and observable evidence rather than on prejudice or assumptions; they should be willing to change their opinions based on new evidence, understand cause and effect relationships, and appreciate how science is done – in particular understand the role played by observation and experiment in establishing scientific conclusion and they should know what the words “scientific theory” and “scientific fact” mean. (Devlin 1998, p. 560)

Devlin notes that not even graduates, or college professors, who have taken science courses, meet these standards of scientific awareness. But his description of scientific awareness fails to incorporate “awareness” of the social context of science, which includes not only public perception of science but also the impact of social considerations on the production of scientific knowledge. He does however make an important shift away from evaluating scientific knowledge to considering assessment of some of the basic scientific principles which underpin all scientific research.

This opinion has echoes of that expressed by Shamos (Shamos 1995). In this book the history of interest in scientific literacy is carefully documented. This well-respected professor of physics and science educator also identifies three levels of scientific literacy: cultural, functional and true scientific literacy. It is only the last form that he regards as conferring the essential highly specialised knowledge that is needed to participate in the process of scientific decision making. But for Shamos this can only be done by the experts. His view is rooted in his disillusionment in the whole process of promoting scientific literacy. He identifies the failure to have some sort of agreement on what scientific literacy actually means. And he points out that despite many educational programmes there has been a total failure to promote even low levels of scientific literacy in the American population. He is especially disturbed by the fact that much of the population actually identify themselves as having scientific and technological knowledge, but basic testing shows this faith in themselves is totally misplaced! For example, (p. 74) he cites a study in Denmark where 89% thought themselves well informed on biotechnology, but in fact in a test on the subject 89% “failed completely”. Comparable figures are given for the US.

Shamos feels it impossible to improve current levels of American scientific literacy, which stand at 5%. However, there is a real logical chasm in his argument. On the one hand he accepts there is no satisfactory definition of scientific literacy, and therefore, I would argue, it follows that the methods of assessing levels of scientific literacy are flawed. And yet he uses this data to demonstrate a failure in increasing the levels of scientific literacy – all of this based on definitions of scientific literacy that he rejects.

However, he does suggest that the situation can be remedied by focusing on technology and increasing “scientific awareness” with a syllabus that would focus on the meaning of scientific “facts” and “truths”, the method of scientific experimentation and some understanding of the importance of statistics. He has been widely criticised in the scientific academic community for demoting the importance of learning science (Wolpert 1995). And I believe that scientific 'facts' and 'truths' might not so easily be defined as Shamos seems to think – except for some trivial items.

Shamos' work does help clarify the problems defining scientific literacy and then constructing a curriculum to fulfil the requirements of meeting the constructed definition. Aims and goals need to be more carefully considered. I can't help but wonder that if 89% of Danes felt themselves to be well-informed in bio-technology, as Shamos quoted, did at least feel connected and interested in the subject, which is in itself highly significant. Perhaps the testing of some form of absolute knowledge was misplaced!

The focus on 'science awareness' is also seen as an important element in developing a means of assessing scientific literacy in China (Chen 2009). Chen identifies Miller's methods based on the deficit model as culturally inappropriate for China.

Chen presents the definition of scientific literacy as formulated by the State Council of the People's Republic of China:

Citizens must have the ability to understand the necessary knowledge of science and technology, to know basic scientific methods, to keep thinking scientifically, to advocate scientific spirit, to use the above in making decisions in personal life and to participate in public affairs involving science and technology (Chen 2009, p611).

He points out that the term 'keep thinking scientifically' was subsequently replaced by 'scientific awareness', and that this term, and the reference to “advocating a scientific spirit”, are much more abstract and less easily quantified than those found in Miller(1998) and in the OECD's Programme for International Student Assessment, PISA (OECD 2000).

The OECD PISA programme explains its remit as follows:

Are students well prepared for future challenges? Can they analyse, reason and communicate effectively? Do they have the capacity to continue learning throughout life? The OECD Programme for International Student Assessment (PISA) answers these questions and more, through its surveys of 15-year-olds in the principal industrialised countries. Every three years, it assesses how far students near the end of compulsory education have acquired some of the knowledge and skills essential for full participation in society. (OECD 2000).

Chen (2009) divides scientific literacy into three dimensions but stresses that in China where the level of scientific knowledge is low, it is perhaps most important to target instilling scientific awareness.

- a) scientific knowledge including basic scientific terms, concepts and processes;
- b) scientific awareness meaning appreciating science, explaining natural and social phenomena by scientific rationales rather than supernaturalism, arguing with superstitions, and understanding the impact of science on society and individual life;
- c) scientific abilities to use scientific and technological knowledge and methods in personal and public decision-making involving science, and to conduct innovation activities.

I wrote to Chen requesting a copy of the questionnaire but his research group declined to give permission for me to have a copy. The article did reference a few of the questions including a section which directly looked at superstitious belief. The eradication of superstitious belief was seen as important in establishing scientific literacy. This raised an interesting question about the influence of religious and superstitious belief on the assessment of scientific literacy among my own students. In my own investigations I should perhaps consider how different belief systems might impact on the answers students recorded.

### **3.6 Different interest groups**

Another means of identifying different interpretations of scientific literacy is to consider how different interest groups approach the subject. Laugksch identified three basic groups: sociological researchers; public opinion researchers; and science educators. (Laugksch 2000)

Taking Laugksch's classification I have drawn on other sources to expand on the interpretation of the values and commitments of each group.

a) *Sociological researchers*. In this field researchers recognise that the general public has life experiences and real personal interest which connect them to specific scientific matters. Layton et al. (1993, p.46) cite specific case studies where the knowledge of a specific group was better, in the sense of more useful, than that offered by professionals, for example: parents of children with Down's syndrome, and a case study concerning toxic water disposal revealed that "some of the local population appeared to possess a deeper understanding of the changing patterns of underground water courses than technical experts who came to solve the problem." (Layton et al. 1993, p.47).

Layton et al. do not overstate the value of lay knowledge but are identifying a partnership in the acquisition of scientific literacy where the needs of the audience are considered. Their concluding comments include the statement that:

if science is to be returned to the people to assist their empowerment in relation to problems with a science dimension, then it will need to be structured in ways that relate to the interests of specific groups of adult.

Furthermore, Layton et al. (1993) cite the work of Chavis et al. (1983) with reference to the acquisition of functional scientific literacies and note that there is an obligation for "a reconsideration of the tensions between the needs, methods and values of scientists and citizens" (Chavis, Stucky and Wandersman 1983, p.424).

Sociological research of scientific literacy within this conceptualization necessarily focuses on identifying people's existing understanding of scientific issues. It should be "context related" and is termed "science for specific social purposes", SSSP (Layton et al. 1993) It must relate to specific issues and uses qualitative methods for obtaining information including case studies, interviews and questionnaires (Wynn 1991)

b) *Public opinion researchers*. Social scientists working in this field are often involved in cross-national comparisons of scientific knowledge and attitudes towards science. There are standardised surveys used (Miller 2006). It depends on the so-called "deficit model" (Ziman, 1991) because it is primarily seen as investigating what people do not

know. The decision about what is regarded as the “essential” knowledge rests with scientific experts.

c) *Science educators*. This group is primarily focused on the scientific content of the standard science education packages within the framework of school and tertiary education. It is concerned that science education should be disseminated as widely as possible and will be designed primarily to provide the future scientists required for national prosperity. There is also a belief among scientists that what is perceived as an “anti-Science” view within society will be eradicated with increasing knowledge of science. There is no evidence of such a correlation and indeed it has been suggested by Layton et al. (1993, p.36) that the contrary might be true and that a scientifically informed public might subsequently demand greater control of science. Indeed subsequent research (Evans and Layton 1995) showed that while “more knowledgeable members of the public are more favourably disposed towards science in general, they are less supportive of morally contentious areas of research than those less knowledgeable” with clear implications for areas of research concerning, for example, human embryology.

My research can be identified with the aims and conceptualization of sociological researchers. It is also useful in this context to consider Prewitt’s use of the phrase “scientifically savvy” (Prewitt 1983) to describe the sort of scientific knowledge base he feels the public should have, noting that scientific literacy begins at “the point of interaction between science and society” and not with science itself.

### **3.7 Alternative approaches to assessment**

#### **3.7.1 Media related knowledge**

The tests described in 3.2 rely on experts deciding what particular items of scientific information everyone should know. In order to circumvent this problem Brossard (2006) shifted the focus from what “should” be known, to what people can be expected to know in the context of what is published in the media (Brossard 2006). This is not a totally novel approach and had been adopted by Koelsche in 1965, when he surveyed three thousand science-related news items and identified 175 basic scientific principles and 693 vocabulary items that a scientifically literate person would need to understand

(Koelsche 1965). Indeed this approach has the value of surveying the popular press which has been shown, unsurprisingly perhaps, to be one of the essential sources of scientific knowledge in the general population (Nisbet 2002).

Brossard did not initially sample the media but took every tenth word, as a random selection of words, from the Oxford Dictionary of Science. This sample of 896 scientific and technical terms was then analysed according to the frequency they appeared in major newspapers. The top five per cent were then selected and a cloze exercise based on the dictionary definition was generated as a media scientific literacy test. (In a cloze test students are required to fill in missing words in a text. Also known as a 'gap-fill exercise').

A conventional scientific literacy questionnaire was also given for comparison. The overall conclusion was that the method could be developed "to assess civic scientific literacy without the biases associated with a selection of terms based solely on experts' views" (Brossard 2006, p.57). Looking at the exercise that Brossard constructed it is clear how problematic it is to use a cloze based on dictionary definitions. Brossard herself describes it as "dry". However, it is perhaps worth considering whether access to a relevant, well explained glossary of terms relating to specific issues should be made available to facilitate understanding.

### 3.7.2 Problems of comprehension

All the standardised instruments for assessing views and knowledge about science are primarily based on true/false statements with occasionally a 'don't know' option.

Aikenhead and Ryan (1992) raise the important issue that it is an "erroneous assumption that students perceive and interpret the test statements in the same way researchers do".

Aikenhead and Ryan are primarily interested in content relating to the 'nature of science' and have "empirically" derived a new testing instrument based on written answers students gave to open-ended questions over a six-year period. The tests deal with "Views on Science-Technology-Society" (VOSTS) (Aikenhead et al. 1992). VOSTS is a pool of 114 multiple-choice items that address a broad range of STS topics. Each VOSTS is extremely long as it attempts to cover a range of different opinions

An example is given here:

**40216 Scientists should be the ones to decide what techniques will be used with unborn babies in Canada (for example, analyzing chromosomes of the fetus, altering embryo development, test-tube babies, etc.) because scientists are the people who know the facts best.**

**Your position, basically:** (Please read from A to J, and then choose one)

Scientists and engineers should decide:

- A. because they have the training and facts which give them a better understanding of the issue.
- B. because they have the knowledge and can make better decisions than government bureaucrats or private companies, both of whom have vested interests.
- C. because they have the training and facts which give them a better understanding; BUT the public should be involved — either informed or consulted.
- D. The decision should be **made equally**; viewpoints of scientists and engineers, other specialists, and the **informed** public should all be considered in decisions which affect our society.
- E. The **government** should decide because the issue is basically a political one; BUT scientists and engineers should give advice.
- F. The **public** should decide because the decision affects everyone; BUT scientists and engineers should give advice.
- G. The **public** should decide because the public serves as a check on the scientists and engineers. Scientists and engineers have idealistic and narrow views on the issue and thus pay little attention to consequences.
- H. I don't understand.
- I. I don't know enough about this subject to make a choice.
- J. None of these choices fits my basic viewpoint.

VOSTS have been used in the UK (Botton 1997) with pre-service science teachers and comparisons drawn with results from Canada. The overall conclusion was that the results in the two countries were much the same for the 27 items selected by the UK researchers. The teachers tested in the UK were divided into different groups and the results were compared across the groups to gain a measure of reliability of the test. It was found by this criterion to be reliable.

Looking at the sample question above I feel that the length and complexity of the answers mean that students can't be expected to answer many of them with care and concentration. I do wonder how many students just opt for answers, such as D, which have a sense of fairness. I would much prefer to use qualitative methods such as

interviews and discussions to elicit this type of information from students and feel it would provide a more valuable insight into some of the issues being investigated here.

The ideology that motivated this work on VOSTS does however focus on an important issue: do students understand the questions posed in the same way as those who formulated them? It is surely through discussion and interview that these issues are clarified.

### 3.7.3 Scientific knowledge v critical thinking

Much of the literature I have reviewed has focused on traditional views of scientific literacy and is primarily concerned with ensuring that the public having a certain prescribed knowledge of scientific 'facts' and 'truths'.

A case for giving instruction in critical thinking skills instead of scientific knowledge was given by philosopher Grayling (2008, Aug 6) when discussing the ease of accessing “information through the internet” (he might have added the general availability of information through all media outlets). He explained that with so much indirect knowledge now available, (i.e. not from reliable academic sources), then “knowing how to evaluate information, therefore, is arguably the most important kind of knowledge that education has to teach.” He continued “critical thinking should be right at the centre of the education system”.

Grayling (2008, Feb 9) had previously attacked the definition of scientific literacy given by the US National Academy of Sciences namely, that it is "knowledge and understanding of the scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic productivity". He felt that this had a serious omission by not acknowledging the importance of “the kind of healthy skepticism that asks for good evidence and good argument, that applies critical scrutiny to propositions or claims, that suspends judgment while the evidence is pending, and accepts what the evidence says once it has arrived, independently of prior wishes or partisan beliefs.”

Grayling's focus on "skepticism" is important but he seems to ignore several important things associated with understanding science: the complexity of the "evidence" with which the public is bombarded and the difficulty in evaluating it in a particular socio-political context; the importance of recognizing the writer's purpose; the interpretative act of reading. There is much written that presents itself as evidence, and that too must be subjected to reader consciousness of the complexity of the reader-author relationship. A good example where a reader might feel in safe hands and in receipt of some form of pure evidence is in the plethora of books published as 'popular science'. Information between hardcovers, or soft covers, has a worth and weightiness which could prevent a reader from pursuing important questions in the reader-writer interactive. Books that present themselves as a highly reliable source of information can be problematic, for example Zimmerman (1995). He wrote his book to promote environmental literacy, and in it deals with many dilemmas where different information from 'reliable' sources seriously conflicts. He noted that his aim was to help us make decisions not based on facts and not on "superstitious drivel". One of his examples is perhaps worth noting. When working with certain chemicals an increased risk of cancer was identified. A US company using those chemicals decided that fertile women would be most at risk and so allocated only low-paid, menial jobs to women aged 16 to 50, "protecting" them from the higher paid, higher risk jobs. It has subsequently become clear that not only was there a risk of cancer but many of these toxic chemicals also adversely affect male fertility, severely reducing sperm count. The active reader, the critical thinker, will be teeming with questions: Why initially were certain hazards investigated and not others? Is testing influenced by a socioeconomic agenda? Is identifying a high risk for cancer in one group not indicative of potential toxicity in other areas? Were the workers kept fully informed of the risks? Would men have accepted being demoted to menial jobs or would they have demanded that other chemicals be used?

A different approach by Graham and Wiener (1995) attempts to promote scientific literacy by analysing the trade-offs and consequences of decisions based on issues such as "is it healthier to eat fish than beef?" There is a simple calculation which compares the risk of getting a heart attack from eating beef or getting cancer from the carcinogenic pollutants that accumulate in fish. (By the way the fish wins). The critical thinker should surely ask: Why is there a risk from eating fish, and what processes have

made fish a doubtful source of nourishment? Why is there so much beef eaten in modern society? These questions are a small step away from questions such as: What is a healthy diet? Does a healthy diet need to be manufactured and labelled as 'health giving' before we can buy it with confidence? How do we evaluate labels? Are labels agenda-free? What are the forces driving the food manufacturing industry?

Perhaps what is needed as part of a scientific literacy programme is not only to develop the consciousness of the reader-author interactive but also to engender the confidence to confront authorities and ask probing questions.

There are now university programmes, especially within the US, which have developed a cross-curricular approach to address the challenges facing the modern citizen confronted with the impact that science and technology has on society. These STS (Science and Technology Studies) courses are multi-disciplinary and are designed to promote critical thinking. They not only focus on the ethical, legal and social implications of science and technology, but also “examine the relationship between science and other forms of epistemic or cultural authority (e.g. law, religion, politics.)” (Harvard, 2009). An important discussion on an integrated social constructivist approach to explaining 'scientific knowledge and technological artefacts' is found in the work of Pinch and Bijker (1984). Their approach of having a more integrated, cross-curricular approach could be more widely applied in tertiary education. However, I would still argue that Pinch and Bilker have overlooked the importance of identifying text as discourse, requiring reader awareness of their role in constructing meaning.

#### 3.7.4. Wider perspectives about literacy in general

This section considers the challenge of constructing meaning from any text, and is therefore intrinsic to all literacies. It is perhaps better addressed with a cross-curriculum approach within educational institutions at both secondary and tertiary level.

The idea of presenting a curriculum that integrates science and humanities into a general education programme is gaining interest, for example it was addressed at a Carnegie Corporation meeting in 2000 (Barker 2000). “How many college graduates today” asked Barker “have an understanding of the meaning and value of history or science or

the humanities sufficient to make sense of the forces unleashed by the combination of technological innovation, the free market, and globalization?”

We might ask an even more fundamental question: “How many college graduates have sufficiently developed literacy skills to critically evaluate any text – let alone one with scientific content?” This was basically the question investigated by Norris and Phillips (1994) and although they used texts relating to scientific topics they were primarily testing fundamental skills of interpreting 'pragmatic' reading. Their texts were all from popular science written for laypeople and were given to top science students at Grade 12. The students were considered to have much more scientific knowledge than was required to understand the scientific aspects of these articles, but half the students failed to make appropriate inferences from the text or even assess the degree of certainty with which the writers expressed their views. To read at this level, students need to be able to read analytically. But this leads to even more profound issues concerning the nature of reading and the relationship of reader and writer.

We are forced to confront the fundamental issue about the nature of reading: whether reading is a repetitive or constructive process? In the words of Haas and Flower (1988): “*meaning* does not exist in a text but in readers and the representations they build. This constructive view ... is complemented by work in rhetoric which argues that reading is also a discourse act.” These authors raise two questions which relate to this constructive, rhetorical view of reading. “The first is, how does this constructive process play itself out in the actual, thinking process of reading? And the second is, are all readers really aware of or in control of the discourse act which current theories describe?” As Haas and Flower note “they read for information”.

To get an insight into how students construct meaning from their reading, Haas and Flower (1988) observed and analysed the strategies used by ten readers (including both college and graduate students). The researchers designated three distinct strategy groups: content strategies; feature strategies and rhetorical strategies. In the study described regular students only utilised rhetorical strategies as one per cent of all strategies used, in experienced readers this rose to thirteen per cent.

Some of the range of rhetorical strategies identified included comments concerned with author's purpose, context or source, intended audience, and actual effect.

The question arises as to whether it is always essential to employ rhetorical reading strategies. Haas and Flower (1988) identify that it has an important role for decoding complex texts and also when dealing with propaganda, where recognizing the author's intention is crucial. Texts relating to material with scientific content fall into both of these categories. It is worth noting here that texts written for the general reader, especially those in the popular press have undergone several stages of metamorphosis and invariably emerge as blatant propaganda or at least support a particular agenda. Basic skills in rhetorical analysis enable the reader to identify some of the manipulative and affective elements within the text.

The role of rhetorical devices in science writing has been identified in the work of Fahnestock (1986). She writes referring to the "accommodators" of science who communicate the work of scientists to lay readers as often presenting the work more elegantly than the scientists themselves but raises the fundamental question about what happens in the course of adaptation? Is the discourse transformed? I would include another question: What if the accommodators have a particular agenda and the transformations are directed towards a particular propaganda goal. Can we identify those transformations?

The ubiquity of rhetoric and its role in the formation of opinions was put forward by Nietzsche when he wrote:

"No such thing as unrhretorical "natural" language exists that could be used as a point of reference; language is itself the result of purely rhetorical tricks and devices ... Language is rhetoric, for it only intends to convey doxa (opinion), not episteme (truth)"  
(de Man 1979, p.107)

The necessity to understand reading as much more than a linear progression of decoding strings of words is stated by Norris and Phillips (2003) who identify the importance of "active construction of new meanings, contextualization, and the inferring of authorial intentions". For them these interpretive tasks "transcend scientific knowledge and knowledge about science". For them the current quests for civic scientific literacy all

fail to ensure that students acquire literacy in its “fundamental” sense. They list eleven different ways that the term scientific literacy is used and note that hardly any reference is made, by any of the authors they cite, to the importance of reading analytically or critically.

### **3.8 Scientific literacy in secondary school education**

There is a great deal of research published relating to science literacy in the context of secondary school science curricula and pedagogy. I have selected some twenty first century work that is relevant to my action research project.

A serious concern for all science educators is the failure of much current school science to engage pupils in a positive and meaningful way. Wellington and Osborne (2001, p.2) identify that “language is the major barrier (if not *the* major barrier) to most pupils learning science” and insist that teachers should regard every science lesson as a language lesson. While their book focuses on methods to improve the teaching of scientific language within the school classroom, it has relevance within a university setting, and especially within an EFL program. Wellington and Osborne (2003) examine ways of improving reading in science education, and suggest strategies. These authors also highlight the importance of pupil-teacher dialogues within the classroom, noting that “the opportunity to engage in *reasoned* discussion with others is central to any education devoted to fostering rationality and critical thinking” (2003, p.84). This is surely as important at tertiary level as within the school environment. And these ideas have shaped my own approach to the intervention in this thesis. I have endeavoured to develop a particular thinking skill that will facilitate the process of meaningful dialogue.

The essential role of reading and writing skills as fundamental to scientific literacy has also been stressed by Norris and Phillips (2003). They note that in their search of the literature on scientific literacy, the role of reading and writing are scarcely perceived as functionally important, whereas their research has supported the view that “reading and writing are constitutive parts of science’. (2003, p. 226). Much of their discussion

references science teaching within the school system but is pertinent to tertiary education. Indeed, their own research (Norris, Philips and Korban, 2003) highlighted the fact that the failure of school education in this area leaves university students without the skills to accurately analyse contemporary texts that appear in the popular media. This work is wholly consistent with their earlier research (1994) focusing on final year high-school students. They note that at the failure to develop higher-level reading skills has much to do with the prevailing simple view of the nature of reading – namely, a basic ability to know words, identify and locate information. What is missing is the ability to analyse and interpret, and these are strategies that are addressed in the teaching of critical thinking. Thus, the definition of scientific literacy, within a school framework, and beyond should include higher level reading skills than are ordinarily addressed within a school framework.

Despite decades of discussion about changes in school science curricula, little seems to have changed, according to Osborne (2007, p.179). He maintains that science is still presented as “a body of authoritative knowledge which is to be accepted and believed.” And furthermore, contemporary science curricula, are what Osborne terms ‘foundationalist’, and are primarily designed to provide the essential knowledge for future scientists, and do not provide for the needs of future citizens. In his discussion on the meaning of scientific literacy, Osborne, firmly aligns himself with Norris and Phillips and emphasises the importance of being able “to interpret and critically evaluate writing in science and writing about science” (Osborne, 2007, p.177). He also notes that it is not enough to transform a curriculum, “we must also transform a teacher’s pedagogy”, and, ultimately, practice is a ‘triumvirate of curriculum, pedagogy *and* assessment” (Osborne, 2007, p.182). Furthermore, he identifies a failure in developing useful means of assessing student understanding.

A recent attempt to meet this challenge, and find new ways to assess the understanding of science in 15-year old school children in OECD and non-OECD countries has been undertaken by the PISA project. The PISA 2006 science survey was the first time science was a major assessment domain in PISA, “and the definition of scientific literacy was expanded to include aspects of individuals’ attitudes towards science” (Bybee and McCrae, 2011). The assessment of attitude was achieved with items designed to assess students’ *Interest in learning about science*, and their *Support for scientific enquiry* embedded in many of the test units. Student “*Interest in learning*

*science topics*” and their “*General interest in science learning*” was scaled. The findings showed “a negative correlation between student science topic interest and science performance at the country level” (Bybee and McCrae, 2011, p. 23). Another intriguing finding was the fact that students from developed countries had lower levels of interest than those from developing countries. Recognising the importance of making some sort of assessment of attitude towards science, I incorporated methods for assessing interest and attentiveness in my own questionnaires, these assessments were not based on PISA items but used other internationally applied methods of assessment.

The PISA assessments were designed to assess scientific literacy according to four interrelated features that involve an individual’s:

- Scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomenon (*sic*), to draw evidence-based conclusions about science-related issues.
- Understanding of the characteristic features of science as a form of human knowledge and enquiry.
- Awareness of how science and technology shape our material and intellectual, and cultural environments.
- Willingness to engage in science-related issues, and with the ideas of science, as a constructive, concerned, and reflective citizen. (OECD, 2006)

Bybee et al. note (2009, p.8) that PISA adopts a definition of scientific literacy that emphasises the model put forward as Vision II by Roberts (2007, p. 732), which prepares students for “*science-related situations* in which considerations other than science have an important place at the table” (2007, p. 731).

PISA’s description of the elements of scientific literacy are given a curriculum context by Bybee and Van Scotter (2006), who identify three guiding principles for the development of effective science curricula. The principles, derived from recent developments in research in cognitive science on processes involved in student learning, are:

- Students come to class with preconceptions about how the world works. The science curriculum must engage students in a process of conceptual change.
- Competence in science includes a foundation of factual knowledge, a conceptual framework, and a means to organize scientific knowledge. The science curriculum must include all three.

- Students can learn to take control over their own learning by defining goals and monitoring their progress in achieving them. The science curriculum must include experiences that require metacognition and provide opportunities for students to engage in metacognitive practices, such as think-aloud problem solving and group work. (Bybee and Van Scotter, 2006, p.43-44)

These principles together with the OECD definition of scientific literacy present much of the current thinking about content and method in school science teaching.

Unfortunately, there is a failure here to identify elements relating to moral and ethical considerations that Roberts (2007) views as central to any definition of scientific literacy. Furthermore, there is no attempt to address the essential core skills identified by Osborne, Wellington, Norris and Phillips, namely: the ability to analyse and interpret text in a critical and meaningful way. My academic reading course at the university addresses both these concerns, with extensive engagement in critical, analytical reading of popular science texts and the introduction of texts relating to pressing ethical issues within science. I acknowledge them to be central to any framing of a definition of scientific literacy.

I have tried to develop a course where the selected texts and much of the work, and discussion, is based on SSIs. A thought-provoking approach to an issues-based curriculum in a school setting is presented by Hodson (2003) and is derived from his earlier work (Hodson, 1999). He argues that this approach can be regarded as comprising of four levels of sophistication:

*Level 1:* Appreciating the societal impact of scientific and technological change, and recognizing that science and technology are. To some extent, culturally determined.

*Level 2:* Recognizing that decisions about scientific and technological development are taken in pursuit of particular interest, and that benefits accruing to some may be at the expense of others. Recognizing that scientific and technological developments are inextricably linked with the distribution of wealth and power.

*Level 3:* Developing one's own views and establishing one's own underlying value positions.

*Level 4:* Preparing for taking action. (Hodson, 2003 p. 655)

Hodson acknowledges that making these kinds of changes in the curriculum is not easy and is “unlikely to be achieved by conventional strategies of curriculum reform.” He continues:

A curriculum that aims to achieve a critical scientific and technological literacy must, in my view, be based on a model of curriculum development that seeks to encourage and support teachers in becoming critically literate about their own educational practice. Action research is probably the only coherent and viable way of addressing curriculum evaluation, curriculum development and professional development/teacher education that are central to the implementation of this radically new form of science education.  
(Hodson, 2003 p.665)

The problems of introducing substantial changes in a curriculum led me to recognise the advantage of introducing a small self-contained intervention. Such an intervention could easily be integrated by other teachers into their classrooms if felt to be useful. Hodson’s suggestion does encourage all teachers to consider embarking on action research to develop and evaluate novel elements that could shift their teaching methods, and content, towards a greater socio-political awareness of subject content.

### **3.9 Student learning-methods**

#### **3.9.1 Constructive alignment**

An important focus of my action research is to improve the way my students learn. I have wanted to shift away from the conventional model of students as recipients of the knowledge imparted by teachers – the declarative model. A totally student-centred approach at the tertiary level is offered by Biggs (2003a).

He insists that learner activities should be central to the student learning experience, and the activities must be designed to fulfil the educational aims of the course/teacher/final assessment. His term ‘constructive alignment’ enables courses to be designed so that required learning outcomes are aligned with learning-focused activities. For Biggs the key questions are: “what should the student be able to understand/perform at the end of the learning experience? What activities would the student have to undertake in order to learn this? And how can the tutor find out if the student has learned successfully?” (Walsh 2007, p.80). For Biggs sees teaching and assessment as synergistic. It is the content of the assessment which often drives both the teaching and learning processes. Teachers prepare students to succeed in the assessment, and the students themselves are

often primarily motivated to work towards the objectives of the assessment.

Furthermore, an assessment that only tests surface knowledge can fail to encourage students to higher levels of learning (Ramsden, 2003).

Biggs identifies two main categories that assessment can be carried out: the first is the traditional approach where a student is tested and rated on a scale, usually by giving them a percentage score which places them within a class hierarchy; the second is *criterion-referenced*, where “the score an individual obtains reflects how well the individual meets preset criteria, those being the objectives of teaching.” (Biggs, 2003b, p.5). The *criterion-referenced* method of assessment allows the focus to be on process, and this becomes the method I adopt in assessing student projects. When assessing the project/intervention that I introduce I am concerned if students met the criteria specified at each stage.

Furthermore, my intervention/project in this action research also assesses its impact on student learning by asking the students to identify what they discerned as their own learning outcomes. This could be seen as another element in ascertaining whether there is constructive alignment between the outcome and the teacher’s objectives, and is consistent with Biggs’ system of constructive alignment.

### 3.9.2

#### Dialogic talk

For Biggs creating appropriate learning contexts is a key element in his system of constructive alignment and he notes “that students can get away with being passive, whereas high level learning requires them to be active in their learning.” (Biggs, 2003b, p.4). Dialogic talk is an important way of encouraging students to participate actively within the classroom. This term is familiar to school teachers, where its role is well established as an important teaching tool (Simpson, Mercer and Majors, 2010; Webb and Treagust, 2006). Understanding the theory underpinning the use of dialogic talk has relevance in my classroom, where it can achieve the same sort of development in thinking as seen in young children.

Piaget and Vygotsky have made important contributions in describing the role of dialogic talk in the development of children’s thinking. Mercer (2003) notes that

Vygotsky “suggested that using language to communicate helps us learn ways to think.” And both Piaget and Vygotsky see the development of thinking as a logical process. For Piaget thinking develops from the more concrete towards the more abstract. Vygotsky also sees progress in development in thinking in this way but attributes a greater role to culture and education than Piaget does.

These models are challenged by Wegerif (2011), who argues for a new theory of learning in light of recent research in cognitive development and neuroscience. Wegerif challenges the prevailing description of dialogue in terms of epistemology – that is, as a form of ‘shared inquiry’ which promotes collaborative construction of knowledge. He suggests it is “also useful to think of dialogues in terms of ontology” so that dialogue is “not only treated as a means to an end but also treated as an end in itself” (Wegerif 2011, p.184). His work with Mercer (Wegerif and Mercer, 1997) led to the introduction of the term the ‘space of dialogue’, or ‘dialogic space’ to locate the standpoint from which children are able to challenge their own thinking. Wegerif goes on to describe this Dialogic Space as functionally equivalent to “openness to the other and openness to the other” (Wegerif 2011, p.189). Furthermore, he notes that “both disputational talk and cumulative talk involved identification with limited images, one an image of self and the other an image of the group”. However, dialogic talk is characterized by openness and respect for difference.

Mercer has developed a sociocultural theory built on the foundations of Vygotsky’s work to help explain “not only how individuals benefit from interaction with others, but also how collective understanding is created from interactions among individuals”. (Mercer, N., and Howe, C., 2012, p.14). The importance of the nature of these interactions has been extensively researched by Alexander through international studies (Alexander, 2001). His work highlights the importance of the structure of the exchanges in promoting learning and thinking. Within a classroom much dialogic talk is mediated by teacher questions. Alexander’s work suggests that open questions, as opposed to the prevailing method of closed questioning, lead to dialogic talk and discussion, and encourages high-level learning.

Although most of the research and discussion I have cited in this section is framed within studies of primary school children (Simpson, Mercer and Majors, 2010; Webb

and Treagust, 2006)., it seems to have relevance for evaluating the processes of ‘talk’ within adult settings, and especially among students. There is now a growing body of research confirming the usefulness of dialogic talk within university education (Hardman 2008). The intervention developed within my action research project was specifically designed to encourage students to have greater openness to the other – to be able to have discussion within a dialogic space.

Within my classroom, dialogic or exploratory talk is an important part of developing an interactive learning environment. As Roberts (2007, p.272) states “Discourse is the basis for creating meaning in classrooms”. His comments are made within the context of developing scientific literacy and he notes that the essential nature of discourse is independent of which of his two definitions of scientific literacy (Vision I or Vision II) are being pursued. Vision I focuses on scientific subject matter and Vision II, emphasises life situations in which science plays a key role. (2007, p. 254). He also notes that discourse in science, particularly framed within moral and ethical considerations are not part of the education of science teachers, and might not even be an area in which teachers feel “competent or comfortable” to teach. However, the importance of this approach is stressed by Zeidler and Lewis who state:

Arming our students with improved understandings of nature of science and scientific enquiry does not provide a complete picture of the scientifically literate individual. Moral development and ethical reasoning play an important role as students consider what is best for the common good of society or whether the ‘common good is relevant to the issue at hand. (Zeidler and Lewis, 2007, p.290)

It is worth reiterating here that for dialogic talk to take place at an individual or collective level the ability to listen, evaluate, and integrate other people’s opinions is absolutely central. It is this aspect of dialogic talk that my intervention addresses.

### **3.10 Theories of learning**

An important understanding of the process of learning is provided by Sternberg’s work on thinking styles (Sternberg, 1994, 1997). By identifying different learning styles he also provided a framework for the development of different teaching styles. His model of intelligence as mental self-government, formed the basis of this theory of intellectual

styles. Sternberg's work, both theoretical and empirical, seeks to "explain individual differences in performance that are not explained by abilities" (Zhang and Sternberg). According to Sternberg, intellectual styles can be considered as governmental in:

- a) function (legislative, executive, judicial).
  - b) form (monarchic, hierarchic, oligarchic, anarchic).
  - c) level (global, local)
  - d) scope (internal, external)
  - e) leaning (conservative, progressive)
- (Sternberg, 1988, p. 197)

In recent years, Sternberg has worked collaboratively with Zhang at the University of Hong Kong, and investigated within a Chinese context the link between learning approaches and thinking styles. Their work adopted a simplified categorization of thinking styles into Type I (legislative, judicial, hierarchic, global and liberal) and Type II (executive, local, monarchic, and conservative). Subsequently Zhang (2002) showed correlations between: Type I and a relativistic level of cognitive development (associated with critical thinking); Type II and dualistic cognitive development (thinking in right-wrong, black-white terms). Concluding that "students who reasoned at a higher cognitive developmental level tended to use a wider range of thinking styles than students who reasoned at a lower cognitive level" (2002, p.179), and that "the use of the judicial style is most conducive to cognitive development" (2002, p.191).

Sternberg sees the judicial student in the following terms:

The judicial student has a predilection for tasks, projects, and situations that require evaluation, analysis, comparison–contrast, and judgment of existing ideas, strategies, projects, etc. The judicial person tends to like evaluative essays, commenting on other people's ideas, and assessing others' strengths and weaknesses.

(Sternberg and Zhang, 2005, p.247)

My intervention could be seen as best suited to students with a judicial style of learning. A question that Sternberg and his colleagues do not seem to address is whether styles of learning always remain intrinsic and fixed or can be modified. Transformative learning theory suggests that change is indeed possible even in adult populations (Mezirow, 1981), for requires critical self-reflection. Furthermore, he identifies some sort of trigger that provokes the transformation. I see the moment that I ask my students to

change their deeply held opinion into the opposite, as such a trigger. The process of validating it with evidence initiates a process of critical self-evaluation.

However, Sternberg's work suggests that some students will be better suited to this project than others. And indeed, his work helped me understand why different students respond differently to some of the teaching strategies I use. His theory asks for an acknowledgment of the diversity of learning styles among our students and the imperative for teaching styles to have a corresponding diversity. It gives another framing for the reflexive teaching practice associated with my action research.

### **3.11 Critical thinking and studying socioscientific issues.**

The link between critical thinking and scientific literacy is perhaps most clearly expressed by those researchers who have investigated the role of discussing socioscientific issues (SSIs) within classes designated for teaching science (Zeidler and Nicholls 2009). The role of discourse and debate are seen as promoting core critical thinking skills, such as analysis, inference, explanation, evaluation, interpretation, and self-regulation.

However, the definition of critical thinking itself is problematic, and there is much discussion about what should be the focus in an educational program designed to enhance the critical thinking of its students (Mulnix 2012). Several explanations of the term are inclusive of so many intellectual qualities and cognitive skills that it is daunting for any teacher to consider integrating critical thinking within their classroom. For example:

Critical Thinking is that mode of thinking – about any subject, content, or problem – in which the thinker improves the quality of his or her thinking by skilfully analysing, assessing, and reconstructing it. Critical thinking is self-directed, self-disciplined, self-monitored, and self-corrective thinking. It presupposes assent to rigorous standards of excellence and mindful command of their use. It entails effective communication and problem-solving abilities, as well as a commitment to overcome our native egocentrism and sociocentrism. (Scriven and Paul, 2008)

An earlier, but important, contribution to the discussion on critical thinking skills has been made by Ennis. He gives a useful, brief definition of critical thinking as “reasonable reflective thinking that is focused on deciding what to believe or do” (Ennis, 1991, p.6) Implicit within this definition is the process of decision making. He lists twelve dispositions, as well as sixteen critical thinking abilities and maintains all twelve dispositions and the first twelve of the abilities are “offered as constitutive of the ideal critical thinker” (Ennis, p. 8). This comprehensive list is given below:

A. *Dispositions* of the ideal critical thinker:

1. to be clear about the intended meaning of what is said, written, or otherwise communicated.
2. to determine and maintain focus on the conclusion or question.
3. to take into account the total situation.
4. to seek and offer reasons.
5. to try and be well informed.
6. to look for alternatives.
7. to seek as much precision as the situation requires.
8. to try to be reflectively aware of one’s own basic beliefs.
9. to be open-minded: consider seriously other points of view other than one’s view.
10. to withhold judgment when the evidence and reasons are insufficient.
11. to take a position (and change a position) when the evidence and reasons are sufficient to do so.
12. to use one’s critical thinking abilities.

B. *Abilities* of the ideal critical thinker:

(The first five items involve *clarification*.)

1. to identify the focus: the issue, question, or conclusion
2. to analyse arguments
3. to ask and answer questions of clarification and/or challenges
4. to define terms, judge definitions, and deal with equivocation
5. to identify unstated assumptions

(The next two involves the *basis* for the decision.)

6. to judge the credibility of a source
7. to observe, and judge observation reports

(The next three *inference*.)

8. to deduce, and judge deductions
9. to induce, and judge inductions
  - a. to generalizations
  - b. to explanatory conclusions (including hypotheses)

10. to make and judge value judgments.

(The next two are *metacognitive* abilities -involving *supposition* and *integration*.)

11. to consider and reason from premises, reasons, assumptions, positions, and other propositions with which one disagrees or about which one is in doubt – without letting the disagreement or doubt interfere with one’s thinking (“suppositional thinking”)
12. to integrate the other abilities and dispositions in making and defending a

decision.

(The next four are *auxiliary critical thinking abilities* – having them is not constitutive of being a critical thinker.)

13. to proceed in an orderly manner appropriate to the situation, for example,
    - a. to follow problem solving steps
    - b. to monitor one's own thinking
    - c. to employ a reasonable critical thinking checklist
  14. to be sensitive to the feelings, level of knowledge, and degree of sophistication of others.
  15. to employ appropriate rhetorical strategies in discussion and presentation (orally and in writing)
  16. to employ and react to "fallacy" labels in an appropriate manner.
- (Ennis, 1981, 8-9)

I have extracted from Ennis' list above those elements which are relevant to the course I teach. They are listed below. This list uses the same numbering as in Ennis' list and for each item I have added a brief comment indicating how each are addressed in the course I teach..

- A.1. form part of the reading program
- A. 4, 5, 6, 8, 9, 10, 11, 12 (form key elements within my intervention)
- B. 1, 2, 3, 4, form part of the reading program
- B. 6 (a key element within my intervention)
- B. 8, 9, 10 form part of the reading program
- B. 11, 12 (elements within my intervention)

An attempt to gain consensus for the conceptualization of critical thinking was pursued by Facione with a cross-discipline Delphi study with 46 experts on critical thinking from across the United States and Canada. The project lasted two years and was conducted on behalf of the American Philosophical Association (Facione 1990). As a result of this work the study defined "approaches to life and living which characterize critical thinking", these 'approaches' include:

- inquisitiveness with regard to a wide range of issues
- concern to become and remain well-informed
- alertness too opportunities to use critical thinking
- trust in the process of reasoned inquiry
- self-confidence in one's own abilities to reason
- open-mindedness regarding divergent world views
- flexibility in considering alternatives and opinions
- understanding of the opinions of other people

- fair-mindedness in appraising reason
- honesty in facing one's own biases, prejudices, stereotypes, or egocentric tendencies
- prudence in suspending, making or altering judgments
- willingness to reconsider and revise reviews where honest reflection suggests that change is warranted. (Facione 2015, online)

An instrument, California Critical Thinking Disposition Inventory (CCTDI), was developed, validated and used to assess students' disposition toward CT. It consisted of 75 statements, divided into seven subscales: Truth-seeking, Open-mindedness, Analyticity, Systematicity, Self-confidence, Inquisitiveness, and Maturity. (Facione and Facione 1992). It has been used widely, including in Israel where it has been applied to assess the impact of teaching higher-order thinking skills within science education (Barak, Ben-Chaim and Zoller, 2007). This study which looked at the effects over two years of having critical thinking as part of a high-school science program for one class, while leaving other classes with the usual syllabus and no critical-thinking component. The study showed marked improvement in the class with critical thinking activities on the four subscales: Truth-seeking, open-mindedness, CT self-confidence, and maturity. The researchers concluded that:

Although in this study the teaching strategies for the promotion of higher order thinking skills were applied in the context of science teaching, the students' success in the CT test suggest that they were capable of transferring across domains, since the CT tests include generic non-disciplinary questions and statements. (Barak et al. 2007, p.367)

Most teachers would claim to teach their students to think critically 'indirectly' or 'implicitly' within the normal teaching of their specific subject. But "increasingly, educators have to doubt the effectiveness of teaching 'thinking skills' in this way, because most students do not pick up the thinking skills in question. The result is that many teachers have become interested in teaching these skills directly" (Fisher, 2001). He also makes the important point that these skills are considered transferable, so that if taught in the context of one subject area they can benefit the student's thinking processes in other fields.

There is a large body of published literature to assist teachers in the classroom— as books and journal articles (Costa, 1991; Fisher, 2001; Swartz, 2001; Swartz, 2008). Swartz stresses the importance of having of teachers explicitly teach thinking strategies (2008, p.26). He cites research by Beyer (2001) that shows that the most effective of these programs “combine thinking techniques and strategies within a rich, multi-faceted framework. Swartz has repeatedly demonstrated to teachers that by using a metacognitive strategy important thinking skills and habits of mind can be taught (Swartz et al., 2007). This approach requires students to identify the kind of thinking they have used, and asks them to evaluate it and then consider modifying the approach. This stresses the importance of students reflecting on the cognitive processes they have employed. At the end of each cycle of my intervention, I ask my students to suggest what they learned from the processes involved the intervention/project. This enables me to evaluate what the students’ perceived as the learning objective, and also encourages the students to be self-reflective about the critical thinking process they have, hopefully, been developing.

All the definitions of critical thinking have common elements, which can perhaps be most easily given by this simple summary of what constitutes critical thinking. It is given in the textbook which accompanies the Cambridge syllabus for A and AS Level Thinking Skills (Butterworth and Thwaites 2013, p. 9).

Critical thinking ... should always be:

- fair and open-minded
- active and informed
- sceptical
- independent

The discussion of SSIs meets many of the criteria which appear as key to the promotion of critical thinking. There is mutuality here, between enhancement of critical thinking skills and discussion involving SSIs.

CRITICAL THINKING  DISCUSSION OF SSIs

I see the way forward in improving scientific literacy as being focused on this interrelationship, with both of these elements being used in the development of the necessary skills for critical reading and decision-making.

[Mention should be made here about the distinction that is made between the term SSI and STS (science, technology and society). Both seem to have much in common but those working in the field identify SSI as a broader term that "subsumes all that STS has to offer, while also considering the ethical dimensions of science, the moral reasoning of the child, and the emotional development of the student" (Zeidler et al. 2002, p. 344)].

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### 3.12 Conclusion

This review of the literature has shaped my action research in several ways.

My interpretation of the term 'scientific literacy' has been influenced by the work of sociological researchers (see: Ziman 1991, Wynne 1991, and Silverstone 1991). They have highlighted the complexity of the partnership between citizens and the institutions formally in control of the decision-making processes relating to socioscientific issues. These studies, and others mentioned in this chapter, stress the individuality of interaction with SSIs; certain groups within the general public having specialised knowledge and particular interests that direct their focus of engagement in discussion. This underlined the importance for me of allowing students to choose their own SSI for the project intervention I introduced.

The association of discussion about SSIs with critical thinking skills has helped me move away from a definition of scientific literacy that is heavily weighted in favour of constructs of scientific knowledge. In considering the range of critical thinking skills that were most appropriate to focus on with my students I concluded, as a result of experience, that I would try to help my students acknowledge the value of counter opinions. Hoping that it might also lead to respect for 'the other'. My approach would hopefully enhance many of the qualities listed by Ennis, Facione and others (quoted above) which characterise those engaged in critical thinking.

Understanding the construction of meaning from any text, the implicit and explicit bias, its affective rhetoric, are important elements within any program teaching critical thinking, and is already part of the academic reading courses I teach. For this action research I extended the study of text to include internet sources, so that students would be able to discover and evaluate the wide range of material available on Google, Google Scholar, and Google Books – this ability to critically evaluate a source is also a key element within the teaching of critical thinking.

## **Chapter Four**

### **Methodology and Methods**

#### **4.1 Introduction**

This chapter will open with an overview of the main paradigms in educational research. This is followed by sections on action research (its role in education research and responses to the problems it presents); the issues involved in developing a methodology; ontological and epistemological considerations; the research methods/tools employed.

#### **4.2 Paradigms in Educational Research**

Broadly there are two major research paradigms in social research which Hitchcock and Hughes (1995, p.21) term 'positivist' and 'qualitative'. Usher (Scott and Usher 1996, pp. 12, 18) identifies them as 'positivist/empiricist' and 'hermeneutic/interpretive'. Other writers choose different descriptions: Denzin and Lincoln (2011, p.102) write of 'Constructivism (or Interpretivist)'. For the purpose of this thesis I am using the terms 'positivist' and 'interpretivist'.

Positivism is associated with the natural sciences where the researcher is seen as external to the experiment so that findings are viewed as objective. The elimination of the subjectivity of the researcher is epistemologically “taken as ‘good grounds’ for considering the knowledge claim to be valid or true.” (Scott and Usher 1996, p.12). For those social scientists adopting this paradigm, the underlying ontological assumption is that the social world is like the natural world: it follows sets of rules, and is predictable. These ontological assumptions lead to the epistemological assumptions that these rules can be uncovered in an objective manner and can be expressed as generalisations. These generalisations can then be predictive.

Usher (Scott and Usher 1996, pp.16-17) cites Kuhn’s work (Kuhn 1970) to argue that scientific research can be “examined and critiqued in the same way as other social practices because, research, contrary to dominant philosophical understandings, is a social not a logical process” The positivist belief in knowledge leading to some ultimate truth is challenged by Kuhn’s approach, because ultimately “what constitutes ‘knowledge’, ‘truth’, ‘objectivity’ and ‘correct method’ is defined by the community

and through the paradigm of normal science which shapes its work.” (Scott and Usher 1996, p.17).

What has emerged following Kuhn’s work are new methodologies. Carr and Kemmis (1986, p.83) describe those methodologies that have been developed in educational research, as seeking “to replace the scientific notions of explanation, prediction and control, with the interpretive notions of understanding, meaning and action.” This promotes the view that educational research should not merely be data collection but should be specifically aimed at understanding and transforming education. However, a positivist tradition has remained in social research in general, and specifically in educational research. Here positivist researchers show a desire for “the precision and level of understanding characterised by the physical sciences” (Hitchcock and Hughes, 2001 p.22). There has also been an attempt to ensure that this research conforms to Popper’s ideas that the validity of the scientific method depends on the possibility of demonstrating the falsifiability of the hypothesis. This has according to Carr and Kemmis (1986) ensured that the methods employed by these researchers are primarily quantitative, as this is the form of data that can be most easily falsified.

However, in the last thirty years there has been a growing commitment to qualitative research in the social sciences, and in a method of research known as action research. In education research that uses the action research model, the teacher is placed in a pivotal role in the implementation and assessment of educational practices. Action research has been generally envisaged as a collaborative effort on the part of teaching colleagues and students. Carr and Kemmis argued that action research would give “form and substance to the idea of a self-reflective critical community committed to the development of education.” (1986, p.5)

#### **4.3 Action Research: Problems and Solutions**

Carr and Kemmis were not the first to use the term 'action research'. It seems to have been introduced by social psychologist Lewin (1948, pp.202-203) who described the research needed for improvements in social practice as “a type of action-research, a comparative research on the conditions and effects of various forms of social action, and research leading to social action.” He went on to describe an approach that involved a

spiral of steps "each of which is composed of a circle of planning, action and fact-finding about the result of the action".

Cycles of action, reflection, followed by modification of action have become a defining part of an action research project. Nowadays meaningful reflexive practice includes cycles of modification and improvement in response to experience. However, this method of conducting research does not define action research. It is much more than cycles of action, reflection and response. It is important to recognise that action research is, as Pine (2009, p.29) explains: "a paradigm and not a method. As a paradigm, action research is a conceptual, social, philosophical, and cultural framework for doing research, which embraces a wide variety of research methodologies and forms of inquiry."

Indeed, much of positivist empiricism follows a similar path; although sometimes described as a linear path, this doesn't reflect the process that the experimenter is involved with on a day-to-day basis. Laboratory work follows recursive paths of action and modification of action. But of course one of the sharpest distinctions between positivism and non-positivist paradigms is the status of the researcher. Within the positivist (and postpositivist) tradition the researcher's presence is seemingly annihilated as an influence on the outcome of the research. The research is seen as being ultimately distilled into a simplified linear representation within published papers. Positivist research is presented there as an orderly progression from hypothesis, method, and results to a conclusion which at best will support some current theory. Not only is the research not perceived as part of a socio-cultural fabric but the target end-point is solely the publication of a text, often without any consideration of its contribution to knowledge within its own field. This text is highly formalised in structure and does not even permit any record of negative findings or false trails that formed part of the recursive nature of the research.

But all academic writing imposes its own strictures. Even the highly personalised, reflexive nature of action research is, in the end, recorded in a text that is formalised and selective, written to tell a narrative as clearly, meaningfully and honestly as possible. This thesis itself has a template that dictates the order and style of presentation. It is a

form that attempts to bring order and comprehensibility to a process that has multifaceted, recursive complexity.

But action research is more than a text which might be written. It can also impact of individual practice. McNiff and Whitehead (2006, p.7) define it as “a form of enquiry that enables practitioners everywhere to investigate and evaluate their work”. The practitioner and the researcher become one as an insider researcher. It is this self-reflexive, transforming practice of the practitioner that is unique to action research. However, this should not be seen as an isolating, self-indulgent form of research – ultimately a researcher can have goals for improvement of society at some level. The improvement can be within one’s own approach to teaching, or can aspire to have more far-reaching consequences, as Reason and Bradbury (2008, p.1) explain: “Action research is a family of practices of living inquiry that aims, in a great variety of ways, to link practices and ideas in the service of human flourishing.”

But action research has posed a challenge to the general research community by removing research from the professional, academic forum and handing it into the hands of those at the chalk face. McNiff and Whitehead (2011, p.37) summed up the dilemma: “Action research is such a common-sense approach to personal and professional development that, when people first meet the idea, they often say, That’s what I do in any case. What’s different?” The authors proceed to explain that action research justifies its claims to knowledge by “the production of authenticated evidence” that are then “subject to critical evaluation to test their validity”.

Herein lies a major criticism of action research, namely, that much of the critical evaluation is in the hands of the practitioner-researcher. Traditionally evaluation has been placed in the hands of outsiders, who are viewed as more objective, more reliable. Positivists would argue that the system of peer review of papers in the natural sciences provides the highest level of evaluation. And yet the flaws in that system have been revealed by a series of scandals in recent years with high-profile papers being retracted after being peer-reviewed and published in prestigious journals.

It is perhaps relevant to mention a recent scandal about false stem-cell research where the research paper was retracted following publication in the prestigious journal *Nature* (Jan 30, 2014). It prompted the *New Scientist* (March 29, 2014) to conduct a poll of

scientists working in the field of stem cell research. Among those who responded to the poll, 5% answered yes to the question asking whether they or a colleague had ever falsified or augmented data that appeared in a published paper.

There is no doubt that action researchers require, as do all researchers, a high level of integrity and honesty. But the issue of the validity of research claims in action research does have to be addressed. What can replace the positivist reliance on generalizability and replicability? As in all research, being open to the comments and criticisms of colleagues is one important avenue for assessing validity but action research has generated new ideas and concepts to deal with the problem of claiming validity for research findings. McNiff and Whitehead (2011, p.163) list some of the most common and I am reproducing their complete list here because it shows the innovative approaches that are being developed to meet the challenge of new paradigms of research:

Catalytic validity – This term, coined by Patti Lather in 1991, expresses the idea that the experience of the study would enable people to move to new, more productive positions.

Construct validity – Refers to the idea that a researcher already has ideas and models (constructs) about the topic they are researching. It is therefore important to use multiple ways of establishing that what they are investigating really is going on, and is not just them imposing their existing constructs on the reality they are observing.

Face validity – An issue appears as basic common sense; you recognize its truthfulness at face value.

Ironic validity – The researcher does not take things simply at face value but interrogated underlying assumptions.

Rhizomatic validity – Another term coined by Lather that refers to the interconnected nature of human enquiry and the power of a study to have influence in multiple directions.

At this stage of my research I can see different concepts of validity being applicable to my research. Certainly 'ironic validity' and 'rhizomatic' or 'catalytic' validity would seem to have relevance. I have tried to challenge underlying assumptions in several aspects of my research, and in the couple of years since completing my last intervention, other members of staff have adopted the method I employed in that intervention. Methods of evaluation are another set of challenges facing any paradigm that breaks with the positivist tradition. While traditionally empiricists have understood evaluation to mean calling upon some absolute proof for verification, there is a shift towards the

“idea of reasonable evidence” McNiff and Whitehead (2011, p.79). There is the important question about who actually does the evaluation, and in action research it is the practitioners themselves who claim the right to self-evaluate, though as McNiff and Whitehead (2011, p.81) point out practitioners must make their “evaluation processes visible” and “show that these are rigorous and robust, and produce strong evidence to show that they as practitioner-researchers are competent and capable”. This is a serious injunction which must be a guiding principle throughout my research.

#### **4.4 Towards a Methodology**

At the basis of all research are the fundamental assumptions that there is something knowable to be discovered, and it can be communicated in some meaningful way to others working in the field. However, research in education poses particular challenges because of the problems of identifying what is knowable, and establishing ways by which it can be uncovered. These difficulties are made even more complex due to the fact that the processes being studied in a classroom are dynamic: there is a feedback loop involving teachers and students, which can impact of both parties in many important ways. As Yates (2004, p.3) notes “education research is a human, situated practice” which is itself “directed at, as well as located in, a field of activity (education) that changes form over time and place.” She continues to explain that because research is “contextually located” it cannot be approached in the same way as the experimental sciences. This does not mean that there is any lack of rigour in the methods employed to investigate questions relating to educational practice. But it does necessitate that the initial premises, including those which relate to epistemology (what the researcher can find out) and to ontology (the nature of reality) need clarification by the research practitioner at the outset of a project.

According to Carr (1995, p.1)

Research always conveys a commitment to philosophical beliefs even if this is unintended and even though it remains implicit and unacknowledged. Researchers cannot evade the responsibility for critically examining and justifying the philosophical ideas that their enquiries incorporate. It follows that philosophical reflection and

argumentation are central features of the methods and procedures of educational research.

But the elements that constitute the researcher's position are difficult to define as there is constant flux as Hitchcock and Hughes (1995, p.21) explain:

...ontological assumptions will give rise to epistemological assumptions which have methodological implications for the choice of particular data techniques. The significance of the interplay of all these aspects cannot be over-estimated.

The complexity of this mix is further compounded by the fact that these assumptions are constantly in interaction with my changing perceptions concerning my teacher identity, which is in part subject to my understanding and experience of the power relationships within my classroom, within the educational institution I work in, and under the influence of broader societal influences.

In conceptualising my methodology, I have found it helpful to use Pryor and Ampiah's topographical representation of an "elastic plane" (2004, p.162), with its shape determined by 'forces' tugging at the edge of this 'rubber sheet'. The 'forces' include, most importantly for me, epistemological and ontological assumptions, and also micropolitical issues. The problem remained on where to situate my researcher-teacher identity within this framework: was it a force pulling outward on the elastic plane or was it situated within the plane, influenced by all the peripheral forces that act on the methodology itself? I found it particularly helpful to adopt the suggestion given by Dunne et al.(2005, p.168) that in the topographical representation of Pryor and Ampiah, "it might be possible to substitute for 'Methodology' the words 'Researcher Identity'". This concept of the centrality of researcher identity within the context of research, how it is transformed and transforming, is resonant with my own experience. Moreover, I find it helpful to acknowledge that it is impossible to exclude it from the heart of my perceptions and understanding of the wider epistemological and ontological issues which are shaping the methodology of my research.

#### **4.5 Ontological Issues**

Fundamentally an ontological stance attempts to answer the question: "What is the form and nature of reality and, therefore what is there that can be known about it?" (Guba and Lincoln 1995, p.108).

In 1995 Guba and Lincoln (1995, p.105) analysed four paradigms that were competing to be accepted as “the paradigm of choice in informing and guiding inquiry, especially qualitative inquiry”. I have listed them here and included in brackets the ontological position that each adopt, (adapted from the table in Denzin and Lincoln (2005, pp.102-115):

1. positivism (with 'real' reality that is deterministic and therefore predictable)
2. postpositivism ('real' reality but accepting that our understanding is imperfect because of the nature of the phenomena. Our understanding is often given in terms of probability with reliability determined by methods of statistical analyses)
3. critical theory (which gives rise to a 'reality' that has been shaped by a whole range of socially related factors such as those affected by local politics, culture, and gender).
4. constructivism (reality is constructed by individuals situated within specified locations; a self-reality that is gained through interpretation of situated perceptions)

Guba and Lincoln first identified these four paradigms in 1995 and then, ten years later, added a fifth (2005, p.195); they termed it “participative reality – a socially constructed reality, similar to constructivism but created by mind and surrounding cosmos”. This seems like a specific case of constructivism and Mertens (2010, p.8) does not accept that it is another paradigm, she describes it as “a methodology that can be applied to various paradigms depending on the beliefs that guide the researcher” and does not include it alongside the other four. However, it does appear as a fifth paradigm in Denzin and Lincoln (2005, pp.102-115) extensive table detailing: Themes of Knowledge: An Heuristic Schema of Inquiry, Thought, and Practice. This table is a rich resource for understanding many aspects of the different paradigms. As I have identified my research as interpretivist/constructivism, I shall only use this table to extend my understanding of this particular paradigm.

Interpretivist and constructivism seem, for my purposes, interchangeable terms. As Schwandt (1994, p.118) explains with reference to these terms:

Proponents of these persuasions share the goal of understanding the complex world of lived experience from the point of view of those who live it...The world of lived reality and situation-specific meanings that constitute the general object of investigation is thought to be constructed by social actors.

A description of constructivism ontology is given by Guba and Lincoln, (1994, p.113):

Knowledge consists of those constructions about which there is a relative consensus (or at least some movement towards consensus) among those competent (and in the case of more arcane material, trusted) to interpret the substance of the construction. Multiple 'knowledges' can coexist when equally competent (or trusted) interpreters disagree, and/or depending on social, political, cultural, economic, ethnic, and gender factors that differentiate the interpreters. These constructions are subject to continuous revision..."

This ontological stance requires me to be aware that the social/educational reality that I describe is locally and specifically constructed, and unique to those factors which influence that knowledge. Unlike the positivist I do not acknowledge the existence of an objective world but recognise that my research is bound within a specific context dictated by many constraints, some more easily recognised than others. While my findings do not automatically lead to generalisations and predictive outcomes, I would argue that the outcomes of interpretivist research can be an important stimulus that provokes other researchers bound by different local conditions to explore similar questions within their own environmental context. (I use the word 'environmental' loosely here to imply all those factors which make a piece of research situated within a particular context).

#### **4.6 Epistemological Issues**

The ontological view I am taking necessitates that the epistemological question: "What is the nature of the relationship between the knower or would-be knower and what can be known?" (Guba and Lincoln 1994, p.108) should be answered in an appropriate way. Guba and Lincoln (1994, p.111) expand on this and explain that:

The investigator and the object of investigation are assumed to be interactively linked so that the 'findings' are *literally created* as the investigator proceeds. The conventional distinction between ontology and epistemology disappears..."

This description is especially helpful because it deals with the crisis I have felt of the intertwining of ontology and epistemology. My relationship with what can be known

meshes intimately with the reality within which I am situated. And both my ontological and epistemological assumptions are affected by my researcher identity, which holds centre stage in the rubber sheet image mentioned earlier. There it was suggested that it could be situated as the central elastic plane succumbing to the other influences, but this should be seen as a two-way interaction. The elasticity of the sheet has its own interactive effect on the tensions being applied to its edges. Ultimately, the whole complex of these interactions falls within the influences of reflexivity; it is through the prism of critical reflexivity that concepts and assumptions are formulated, and reformulated.

Furthermore, it is reflexivity that will inform the text I write describing and interpreting my research. A text is always a subjective selection of information that employs a certain rhetoric (even subconsciously) to expound and explain its claims. There are issues of contextuality and intertextuality to be explored here to understand the epistemological status of a research text. Dunne et al. (2005, p.143) explain the relevance of intertextuality, stating that “our texts do not stand alone but are inevitably imbued with the presence of those absent texts that have been part of our experience and have influenced us one way or another as researchers”. And, of course, we sometimes give them a nod by actually quoting from them, while others have influences unacknowledged even subconsciously. This quote from Roland Barthes (1977, p.146) gives a meaningful description of the problematic nature of text:

a text is not a line of words releasing a single ‘theological meaning’ (the ‘message’ of the Author-God) but a multidimensional space in which a variety of writings, none of them original, blend and clash. The text is a tissue of quotations drawn from innumerable centers of culture.

Although he is primarily writing about literature and literary criticism, his words have relevance to all text. Empiricists often think of their texts as standing apart from those written in the humanities, and believe that it is easier for them to achieve transparency of meaning. But I am fortunate to have experience as a rewriter and editor of texts and research papers relating to current research in physics to know first-hand how problematic it is to discern unambiguous meaning from those texts. The writer perceives clarity of meaning but readers deciphering meaning will often come to sharply different interpretations. And the scientists do find the process of writing problematic because the ideas and concepts they are playing with at some level of mind do not

comfortably translate into communicative text. Scientific writing resorts to metaphor and imagery to create impressionistic textual correlates to the ideas that the writer is attempting to convey. It also adopts conventions from its own community which can also impact on the integrity of a text. Every writer, in all subject areas, confronts the same problems: creating meaningful text and acknowledging the factors influencing 'authentic' text production, whatever readers understand that to mean.

In action research the researcher is acknowledged as an 'insider' and so the text could be termed an 'insider text' which seems to give it an authority which perhaps an outsider author cannot claim. However, the notion that this somehow privileges the result is dismissed by MacLure (2003, p.103-104) who discusses the notion of “*textual innocence*” (her italics) derived from perceptions of insider knowledge. She points out that “the view from the inside is never, in any case, ‘enough’ in research terms: something else is always needed to complement or complete it...The researcher always acts as some kind of broker between the inside and outside, however minimally she envisages that role.” Indeed, it could be argued that the 'insider' is a product of both the inside and the outside, and any written text is subject to those forces, the forces that are at work in contextuality.

Contextuality is seen as an important influence on the way we construct written text. It can be understood to be those elements which influence us, and in a profound and meaningful sense actually make us who we are. There needs to be an awareness of those factors which can most directly influence our construction of a text. Usher particularly highlights (Scott and Usher 1998, p.45): “the socio-cultural subjective, the contextual self or, to put it another way, the embodied and embedded self”. He stresses that this does not give rise to biases that need to be identified and somehow eliminated but these biases are “ineliminably part of us, which can be recognised but not willed away”. He adds, powerfully and meaningfully for this researcher: “they are the marks of the trajectory of our desires and emotional investments in the research act.” Ultimately it is reflexivity as part of constructive epistemology that results in the written text forming “part of the flux of social meanings” (Dunne et al.2005, p.139).

## **4.7 Research tools**

Before embarking on my action research I read extensively and explored the methods of data collection that could be used for my research (e.g. McKernan, 1996; Cohen et al., 2010). I selected those ways that seemed appropriate to investigating my particular research questions. This resulted in a blend of quantitative and qualitative methods. Details of the success and failures of each method are discussed more fully in the relevant chapters that focus on the different phases of my research. Here I am giving an overview of the research tools I employed with some reflections both on their usefulness and their limitations. The section headings are drawn from those used by McKernan (1996).

### **4.7.1 Unstructured observation**

Throughout my research I tried to be sensitive to the factors influencing my collection and interpretation of data. But the highly subjective observations of the teacher-researcher can shine a light on student experiences within the classroom. This opportunistic collection of feedback is useful in giving spontaneous glimpses into student reactions to the learning activities and curriculum content provided by the teacher. The unsolicited comments following a class or the discussion resulting from chance encounters at the coffee bar were recorded in my daily diary, and quoted within this thesis.

### **4.7.2 Self-report techniques**

#### **4.7.2.1 Attitude scales**

I used attitude scales within my questionnaire to assess interest using a three-point Likert-scale. The information collected was then used to calculate an 'index of interest' and a measure called 'attentiveness' (see Chapter Six for an explanation of how these were calculated). By calculating these values, I was able to make comparisons with similar data from other countries. This was not just inherently interesting in terms of situating my research in a more general context, but it also revealed, surprisingly, that there seemed to be some elements that seemed to be shared with some of the international data. Despite the problems of making international comparisons which are detailed where I have made them, it was perhaps important that my data fell within international

values. Data that fell well outside these ranges might have indicated a failure in the way the method was applied or in the detailed computations.

#### 4.7.2.2 Questionnaires

My questionnaires were given at the beginning of class. They were anonymous and I reminded students that this was part of my educational research project and they had no obligation to fill one in or answer any question that they didn't feel comfortable with. All questionnaires were always returned fully answered. I always tried to keep my questionnaires short so that students could complete them in about 10 minutes. The questionnaires mainly used fixed response (closed) questions but wherever relevant I provided extra lines for students to give free responses.

The questionnaires had different purposes: they gave general data on the level of high-school science education of the students; they identified levels of interest in socioscientific issues (SSIs); they allowed students to show the level of involvement they felt the public should have in the decision-making processes relating to SSIs.

#### 4.7.2.3 Interviews

Initially I thought interviews, especially semi-structured, would be a valuable research tool. During my reconnaissance I formed focus groups, each of five or six volunteer students who committed to meet every few weeks throughout the semester. We met twice and I then abandoned the process. There were several problems. Firstly, I was acutely aware that my students thought of me as in a position of power – marking their assignments, marking their exams, giving them a class grade that determined their final grade (a score that determined which degree courses they could gain admission to). Even the act of volunteering to participate was probably viewed as a way of optimizing the class grade that I give them. The teacher's class grade is 20% of their final grade. But I had announced at the beginning of the semester that I give everyone 100% as long as the student participates actively in the course. I also told them that I would inform them during the semester if I thought they were at risk of getting less than 100%. The students didn't seem to believe me and asked about their

class grade on a regular basis. They even came to plead for a higher class grade once they got their final grade after taking the final exam – even though they already had 100% from me.

Being aware of the way they perceived my power in the teacher-student relationship made me sensitive in all exchanges I had with students, particularly in any formalised face-to-face setting.

I was aware that getting reliable, honest responses in an interview setting was highly problematic because the teacher might be perceived as being in a position of power, someone to please.

#### 4.7.2.4 Projective techniques

This research tool is described by McKernan (1996, p.134) as providing an opportunity for a respondent to 'project' themselves by, for example, completing incomplete sentences or answering open-ended questions. The method I devised, which I called the *petek* (Hebrew for 'note'), falls under this category. Students were given a half piece of coloured A4 paper and asked to write, anonymously, a response to a question that I wrote on the board. The papers are then folded and placed in a plastic bag that is handed round. This method could give me a snapshot of student opinion on something we had been doing in class, or provide a more reflective response on aspects of the course (details are given throughout this thesis). But analysing them was painstaking and time-consuming. I used a standard method of content analysis and coding. The method was based on descriptions of the process in the literature (e.g. Cohen et al. 2010 pp. 476-483). I redid the analysis on all these slips of paper a year later to check that I got the same results.

#### 4.7.3 Class discussion

The use of discussion was an important part of my teaching strategy. It was the problems associated with these class discussions – dogmatism and unwillingness to consider or listen contrary opinions – which helped me formulate the intervention I chose.

#### 4.8 Triangulation

Within action research triangulation has become a method of demonstrating validity and reliability of research carried out by a practitioner researcher. It also is a way of ensuring that the complexity of a topic is being investigated from different standpoints to give depth and greater understanding. In its first format Elliot (1977, p.10) described it as "gathering accounts from three quite different points of view". As I did not have a participating observer, I could not carry out this procedure of validation. However, Denzin (1997) outlined three types of data triangulation: time, space and person. All of my questionnaires were given to different classes in three successive years in two different institutions of higher education. I was therefore able to look at the data collected from 8 different classes in total over the years 2009, 2010, 2011. The fact that this data showed internal consistency with different classes over successive years could be considered as a method of triangulation verifying some of the data sets from my questionnaires. The similarity in responses helped confirm that there was a more general validity to my research – the responses from a single class could have been determined by many local considerations, and not representative of a wider student body.

My research would, of course, benefit from being pursued in a wider context and with a longitudinal study over several years with the same students to explore longer term effects of the intervention.

#### 4.9. Ethical considerations

Throughout my research I tried to maintain an awareness of any ethical issues that might arise. Sometimes one can fail to recognise where there might be an ethical issue. For example, in discussing my first questionnaire with my head of department, she pointed out that while it was fine to ask whether the students had a specific science *bagrut*, it would not be regarded as ethical to ask them to give the number of points they got on the exam, even though the questionnaire was anonymous. It could cause them discomfort to have to write down a low grade. This response made me realise that even when responses are given anonymously I must maintain sensitivity to the way my students might feel at the moment of writing their reply. The emotional and psychological well-being of the student remains paramount throughout the research.

On the other hand, the anonymous feedback I regularly asked for in the form of a *petek* was welcomed by the students. An opportunity to give their opinion on the quality and meaningfulness of an element of the course was something that they appreciated.

In the first lesson of the semester in which I taught my classes at the university, I told my students that I was doing educational research that I hoped would improve the way I taught. I explained that I was especially interested in scientific literacy, and briefly gave an outline of what this term can mean, namely being able to participate in discussions on social scientific issues.

I explained that I would be giving them a questionnaire and gathering feedback throughout the semester on their opinions on the content of the course and the way I was teaching it. It was made clear that their comments and the questionnaires they filled in would be anonymous. I also explained exactly how long any questionnaire I gave them would take to fill in. No more than a total of about one hour of the whole semester was taken up with the questionnaires or feedback *peteks*. A single questionnaire was typically not more than 10-15 minutes to fill in.

Before giving them questionnaires I made it clear to the students that they were under no obligation to answer all, or any, of the questions. And there was always a note at the top reminding them that this was part of my research and should not have their name written on it, and that they were not obligated to answer all, or any of the questions.

I also explained that as part of this *mechina* course there was always a project and the one I would be giving them was of special interest to my research. The students would be required, as in every other course, to do the project. But if I used any part of their project in my research it would remain totally anonymous. They were not obliged to return their written work to me at the end of the semester after I had seen it and they had used it as the basis of a presentation.

I also notified them that none of their work, including the project would affect their class grade and introduced them to the fact that they would all get 100% class grade from me for actively participating in the course. This was a policy I had adopted years

before this research began. (This class grade constituted 20% of their final grade). I stressed that making mistakes did not matter, and in fact they should be valued as the place where learning begins. This novel concept of not losing marks for getting things wrong was not a concept that the students grasped easily (see section 4.2.3 above). The 100% class grade was at risk if they did not participate actively in the whole course throughout the semester. I explained that I would always warn them if there was any chance they would lose marks from the class grade. I met and talked informally with any student who did not seem engaged with the course; they invariably bounced back and secured their 100% grade. Those who didn't return to being diligent students were usually about to drop out of the *mechina* completely.

I informed my classes that I was in the *mechina* on three days a week (and gave my hours) so that they could come and ask about my research, or raise any other issues relating to the classes. They were also given my email address. A few came to me during the semester to ask about my research. Everyone filled in all questions on the questionnaires, and gave detailed and informative feedback on the *peteks*.

I also told all students that if they ever wanted to read my doctoral thesis they could contact me by email and I would make a copy available to them. I have one student who followed up, but he didn't realise it would take so long to complete!

The university where I taught was informed of my research and raised no problems. Their signed consent form is in Appendix A.

## **Chapter Five**

### **Research Plan**

#### **Introduction**

This chapter provides an overview of my action-research project. It deals with my research year by year, showing exactly what happened at each stage. It provides a map that will help a reader navigate through the rest of this thesis.

The theoretical underpinnings of this research are discussed in detail in Chapter Four, where my interpretivist approach throughout this action research is established. Chapter Five forms a bridge between the theoretical discussions of Chapter Four and Chapters Six, Seven and Eight, each of which is dedicated to one year of my action research project. Each of these chapters (6,7 and 8) give details of: the implementation of the research methods; data analysis; and conclusions.

The nature of action research with its recursive cycles, and the cycles within cycles, makes a linear description from the beginning of the research to the end extremely problematic. I have tried to capture this dynamic process in chapters 6,7, and 8. They are written so that the reader can follow the path of experience of both myself and my students. This approach retains some of the authenticity and spontaneity of the experience of being a teacher-researcher. It tries to reflect the fact that I am engaged in “constructions that are subject to constant revisions” (Guba and Lincoln 1994, p.113), and attempts to capture some of the complexity associated with the multi-layered nature of my research. This approach can at times seem confusing and dense. It is hoped that this chapter, my research plan, shows how the threads weave together and complement each other. It prepares the reader for the twists and turns that lie ahead.

There are three sections in this chapter, each is dedicated to one of the three years over which this action research was conducted namely: 2009, 2010 and 2011. It should be noted that both 2009 and 2010 constitute reconnaissance. It is in 2011 that my intervention, in its final form, was implemented and evaluated. Each section in this

chapter is followed by a synoptic table which can be referred to if a quick overview is needed when reading subsequent chapters of this thesis.

### 5.1. 2009: Preliminary Reconnaissance

This section provides an overview of the research I did in the first semester of the academic year 2009-2010. It is discussed in detail in Chapter Six. It followed extensive reading on action research, classroom practice, and scientific literacy, which is discussed in Chapter Three, Literature Review. A synopsis of this cycle of my action research is given in Table 5.1.

I used the 2009 reconnaissance to gather general information about my students using essays, open-ended questions, and questionnaires. This stage allowed me to pilot each of these methods and decide if they needed to be modified. (All information received was anonymous).

My preliminary reconnaissance had two threads:

**Getting to know my students:** this includes autobiographical essays that they wrote about themselves and also views they had on specific aspects of education.

**Student scientific literacy:** this includes discovering the level of school scientific education they had received, assessing general interest in science and technology, and identifying interest in specific SSIs.

#### 5.1.1 Getting to know my students

As a teacher-researcher I was aware that my classroom style was, on the whole, teacher-centric. And although I did try to encourage class discussion, it was not successful. I recognise that I come from a teaching tradition which does not gather student feedback on the content and style of what is being taught. Much of my teaching has been based on assumptions about what should be taught and how it should be done. The voice of the student went unheard.

For this thread of my preliminary reconnaissance all my research was done with a single class in the university *mechina*. They were a top class who already had an exemption in English. I focused on either the class in the science stream, designated 'U sci', or the

class on the humanities track, designate 'U hum' chose to focus on a top class at the university *mechina* who already had an exemption in English.

U sci (N=27) were given two homework assignments within the first two weeks of the first semester and asked to write short essays entitled: "Something interesting about myself", and "How to improve the Israeli education system". They are generally never given essays to write in English because it is assumed that their level of writing is too low. I needed to know how well they could write, as I wanted to make written feedback a regular means of 'hearing' the voice of my students. The majority were able to write clearly and communicate ideas effectively.

I also gave the U sci students a simple questionnaire in which they had to identify the English skills that they felt needed improvement (from a list of seven). I wanted to know how well this matched with the skill content that was required to be taught by the university.

A single open-ended question was given to the humanities stream, in the university *mechina*, U hum (N=34), it read: "What are the two most important qualities a teacher should have?" The importance of this question is discussed in section 6.1.2 (p.92). In the literature there is no indication that student opinion (especially at tertiary level) has ever been collected.

I tried to identify my own expectations of student responses prior to collecting and analysing them. This was an important element in the "construct validity" of McNiff and Whitehead (2011, p.163). The various forms of student feedback gave me the authentic experience of my students against which my own assumptions could be tested. For example, I had notions of what makes a good teacher, would my students have the same ideas? If not how would I integrate their judgements into my own teaching practice.

#### 5.1.2. Student scientific literacy

There is a great deal of discussion elsewhere in this thesis (see Chapter 3) on the meaning of the term 'scientific literacy', and how my research is situated within a particular framing of current ideas relating to scientific literacy. I acknowledge the

fundamental importance for students to have the ability to interpret meaning and infer author intention from texts (Norris and Philips, 2003). However, this is what most of my class time is devoted to. My research focuses on the importance of critical thinking skills as a focus of improving scientific literacy, and for my action research I focus on a particular critical thinking skill – “open-mindedness regarding divergent world views” (Faccione, 2015). It is improving this ability that became the focus of my intervention, and it is the means I use to improve scientific literacy.

In 2009, I investigated the level of interest in science and technology, the amount of school science education part of my reconnaissance was conducted with four of the classes that I was teaching in the first semester. In the university *mechina* I selected the two top classes who already had an exemption in English, one in the humanities stream and one in the science stream. They are designated U hum (N=34) and U sci (N=27), respectively. I also chose the two top classes that I taught at the college of engineering; they were already studying in their first year of their engineering degrees; both of these college classes needed to pass my one-term course in order to gain an exemption in English. One class was taught Monday and Wednesday and is designated CE M, (N=29), and the other class was taught Tuesday and Thursday and is designated CE T (N=27).

I used the same questionnaire (QNR A) with all four classes (U sci, U hum, CE M, CE T). It asked their age and gender, and the subject (or proposed subject) of their degree course. It also had a section for them to identify any science bagriot they had taken (and the level taken), as this would enable me to assess the level of school science education they had received.

QNR A also had questions on interest in science, technology, sport, politics etc. It was assessed with a three-level Likert scale that allowed me to compute ‘Index of Issue Interest’ and ‘Attentiveness’ scores. The scores were averaged over all four classes (N=117). This method of scoring is widely used and provides a single score from a three-level Likert scale. I compared my data with that of several other countries. International comparisons are somewhat problematic within an interpretivist framework, and I acknowledge the unique socio-cultural context in which all my assessments are done. However, the international comparisons are useful in indicating

how the levels of interest in science and technology among my students (with negligible science education) compare with that in other countries where there is considerable emphasis on teaching science in school. This research was done to help explore my research question on the relationship between level of school science education and degree of interest in the subject.

These four classes (N=117) were also given questions with open-ended responses to investigate their views on astrology. Throughout the western world and in China, the prevailing definition of scientific literacy is knowledge-based, and astrological belief is identified as anti-scientific (Miller, 1983, 1987a, and Chen, 2009). Instead of asking ‘do you believe in astrology?’ I provided open-ended questions which allowed much more nuanced responses. I hoped that the students’ responses might give me an insight into their views on astrology and perhaps show that there is not a simple yes/no choice here. A more complex range of views would enable me to challenge the idea that a declared belief in astrology should immediately preclude someone from being identified as scientifically literate (regardless of the definition of scientific literacy being adopted).

The four classes were also given a questionnaire to assess their interest in a wide range of SSIs. Instead of assuming what might interest my students and selecting texts that related to those topics, I decided to design a course that, at least some of the time, would provide texts on topics that the students identified as of interest to them. The students were also able to suggest any socio-scientific issues that they would like to study during the semester.

All efforts to promote scientific literacy assume that the general public want to participate in decision-making processes relating to SSIs. By taking a single question on a ‘hot’ topic in Israel, namely the construction of a nuclear reactor, and providing it in the form of a VOSTS (Aikenhead et al. 1989, p.33), I was able to investigate whether my students thought there should be public involvement in this decision. VOSTS are discussed in Chapter Three. This VOSTS was given to all four classes, but not all students were present (N=96).

Table 5.1. **2009: The Preliminary Reconnaissance.** This Table gives a synopsis of all the research described in sections 5.1.1 and 5.1.2.

**Abbreviations used in this table.**

QNR = Questionnaire

U sci = University *mechina* class, science stream, exemption for English (N= 27)

U hum = University *mechina* class, humanities stream, exemption for English (N= 34)

CE M = College of Engineering, top level English class (Mon and Wed class) (N= 29)

CE T = College of Engineering, top level English class (Tues and Thurs class) (N= 27)

When given	Class	Research tool	Description	Objectives
2009 Beginning first term	U sci	Essay	Title: Something interesting about me	To get some insight into my students.
2009 Beginning first term	U sci	Essay	Title: How to improve the Israeli education system.	To learn about student perceptions of the education system.
2009 Beginning first term	U sci	Single question	Which language skills students want to work on? Choice includes, grammar, reading writing, speaking.	To discover what students want from the course.
2009 Beginning first term	U hum	Single question	‘What are the two most important qualities a teacher should have?’	Did the students have the same view as I did, namely, that expertise in the subject matter was most important? Discipline rather than pedagogic qualities.
2009 Beginning first term	U sci U hum CE M CE T	QNR A	Questions: Age; sex; science bagrut studied; 3-point Likert scale for interest in politics, science etc.	To discover number of students with science education in school. To compute Index of Interest and Attentiveness for each class, and compare with

				international scores.  To see how lack of school education in science impacts on interest in science.
2009 Beginning first term	U sci U hum CE M CE T	Question	Related to the value of going to an astrologer	An attempt to assess the prevalence of superstitious belief in students.
2009 Beginning first term	U sci U hum CE M CE T	Question	List of SSIs with 3-point Likert scale showing interest in each issue.	To discover the SSIs which interested my students. Introduce texts on the most popular subjects.
2009 Beginning first term	U sci U hum CE M CE T	VOSTS question on QNR A	A question relating to the construction of a nuclear reactor and who should make the decision.	A tool for identifying if students feel they should be part of the decision-making in an SSI.

## 5.2. 2010: Further reconnaissance and piloting the intervention

This section gives an overview of the action research done in the first semester of the academic year 2010-2011. All the students I work with each academic year only have a single semester of English, so the groups I worked with each year are a completely new intake. A synopsis of this cycle of my action research is given in Table 5.2.

For my action research in the academic year 2010-2011 I decided to concentrate my research on the two top classes I teach in the university *mechina*. These students have an exemption in English, and not only read well, but can also express themselves clearly both in speech and in written work. They are designated U sci (10) and U hum (10). The previous year's students are now designated U sci (09) and U hum (09)

There are two threads running through my action research in this second cycle are:

5.2.1. **Further reconnaissance**, which parallels that of the reconnaissance of 2009 and extends it.

5.2.2. **Piloting the intervention**, where the project relating to devil's advocate is introduced for the first time.

#### 5.2.1. Further reconnaissance

There are several elements here that exactly parallel the reconnaissance of 2009. By comparing results across the years I could see if there was any internal consistency between the study populations of each year.

The two classes in the university are given the same questionnaire as used in 2009 (QNR A). The questionnaire provides data for assessing an index of interest and attentiveness. This data allows for international comparisons. These are useful in indicating how my students (with negligible science education) levels of interest compare with that in other countries where there is considerable emphasis on teaching science in school. This research was done to help explore my research question on the relationship between level of school science education and degree of interest in the subject.

The university science stream is given at the beginning of the semester the same list of SSIs with a 3-point Likert scale as used in 2009. These students are given this same list at the end of the semester. They have had a whole semester of intensive science teaching, and in my English class we have read texts and had discussions on many of these SSIs. This was designed to see if education in science affects interest in science.

I also set up focus groups and semi-structured interviews but was unable to use a mediator other than myself.

#### 5.2.2. Piloting the intervention

Having identified from the literature that an important way to improve scientific literacy is to improve critical thinking skills, I design a project which focuses on the critical thinking skill 'open-mindedness'. The decision to focus on this particular ability came directly from my classroom experience, which I found was shared by other teachers I

knew within secondary and tertiary institutions of education. The project I designed, based on devil's advocate, might also help other attributes of the critical-thinker, namely: scepticism and independent learning (Butterworth and Thwaites 2013, p.9).

This stage of my action research was conducted with my two classes in the university *mechina*. The process from method to data analysis is described in detail in Chapter 7.

Table 5.2. **20010: Further reconnaissance and piloting the intervention.** This

Table gives a synopsis of all the research described in sections 5.2.1 and 5.2.2.

**Abbreviations used in this table.**

QNR = Questionnaire

U sci = University *mechina* class, science stream, exemption for English (N= 27)

U hum = University *mechina* class, humanities stream, exemption for English (N= 34)

CE M = College of Engineering, top level English class (Mon and Wed class) (N= 29)

CE T = College of Engineering, top level English class (Tues and Thurs class) (N= 27)

When given	Class	Research tool	Description	Objectives
2010 Summer course	U hum Level 1	Essay	Title: Write about a person, a book, or event that was a major influence in your life.	To get to know my students a little better.
2010 Beginning first term	U sci U hum	QNR A	Questions: Age; sex; science bagrut studied; 3-point Likert scale for interest in politics, science etc.	To discover number of students with science education in school. To compute Index of Interest and Attentiveness for each class, and compare with international scores.  To see how lack of school education in science impacts on interest in science.  To compare with data I got in 2009

2010 Beginning first term	U sci U hum	Science Literacy Test	Widely used US test used to assess scientific knowledge.	The conventional approach to measuring scientific literacy. Allows international comparisons, and also comparison between science and humanities track students.
2010 Beginning and end of term	U sci	Question	List of SSIs with 3-point Likert scale showing interest in each issue.	Many of the SSIs would be discussed during the semester. Did this impact on interest?
2010	U sci U hum	the <i>petek</i>	For snapshot feedback	Using discourse analysis, I would be able to use this as anonymous and immediate student feedback.
2010 following intervention	U sci U hum	Open-ended questions	Feedback on project to identify what students felt was purpose of intervention, and their interactions.	This feedback shapes the intervention for the following academic year.
2010	U sci U hum	Focus group and semi- structured interviews	Feedback on course and intervention	

### 5.3. 2011: The Intervention

In this cycle of my action research I continue to study only the two university *mechina* classes (designated in all tables as U sci (11) and U hum (11)). They are given the same questionnaire as used in 2009 and 2010 (QNR A). They are also given new open-ended questions relating to their attitude towards scientific literacy and the importance of science *bagruyot* in their school science education.

The intervention is still based on devil's advocate but is modified slightly as a result of the feedback from piloting the intervention in 2009. The main research tool for feedback on the intervention is the *petek*.

Table 5.3. **2011: The Intervention.** This Table gives a synopsis of all the research described in sections 5.3.1 and 5.3.2.

**Abbreviations used in this table.**

QNR = Questionnaire

U sci = University *mechina* class, science stream, exemption for English (N= 27)

U hum = University *mechina* class, humanities stream, exemption for English (N= 34)

CE M = College of Engineering, top level English class (Mon and Wed class) (N= 29)

CE T = College of Engineering, top level English class (Tues and Thurs class) (N= 27)

When given	Class	Research tool	Description	Objectives
2011 Beginning of semester	U Sci U Hum	Profile QNR	Age; sex; and languages spoken with mother tongue identified.	Basic information and indication of ethnicity from mother language.
2011 Beginning of semester	U Sci U Hum	QNR A	Questions: science bagrut studied; 3-point Likert scale for interest in politics, science etc.	Comparison across the years and also compare science and humanities students in 2011.
2011 Early in semester	U Sci U Hum	Open-ended question	Students list SSIs they are aware of from the media and identify one that they are most interested in.	Open-ended so that students can give what interests them.
2011 Early in semester	U Sci U Hum	Question	Question asks students if they think scientific literacy is important, and allows them to state whether they think they are scientifically literate.	To ascertain whether students perceive themselves to be scientifically literate, and whether they think scientific literacy is important.
2011 During semester	U Sci U Hum	QNR	Questions on how important students think science <i>bagruyot</i> are in helping them	To assess whether <i>bagruyot</i> per se are regarded as important in engaging with SSIs.

			engage with SSIs	
2011 During semester	U Sci U Hum	QNR with space for student comments	Questions on various ways of becoming scientifically informed.	To gain some insight into students' views on getting science education (not <i>bagruyot</i> ) in school/university/th e community.
2011 mid semester	U Sci U Hum	Instructions for project/inter vention		Intervention given in stages with detailed instructions.
2011 end of semester	U Sci U Hum	<i>petek</i>	Feedback on intervention	To ascertain what students perceived as purpose of intervention and gather feedback on what they found useful. Did their perceptions reflect my intentions?

## Chapter Six

### 2009: Preliminary Reconnaissance

#### Introduction

This chapter presents the reconnaissance phase of my research which took place during the first semester of the academic year 2009-10. The structure of the chapter integrates the questions I was addressing, the methods I employed, and the data I collected. As with the following chapters, it follows the path of my thinking. I have used subheadings to help a reader readily identify the role of each section.

This chapter is divided into the following sections:

**6.1 Getting to know my students.** This is a major part of the reconnaissance and provided an opportunity to get to know a little more about them at a personal level and also their views on education, teacher qualities, course content.

**6.2 Scientific literacy in the context of a reading programme** Here I revisit some general issues surrounding the term ‘scientific literacy’ in order to contextualise my reconnaissance. By looking at the discussion of the ‘derived’ and ‘fundamental’ definitions of scientific literacy, I explain why my research on science literacy is appropriately situated in an academic reading programme.

**6.3 Why does scientific literacy matter?** Here I clarify the goals of the quest for scientific literacy and look at some of the measures that have been surveyed. This helps contextualise some of the questions I include in my questionnaire. Each subsection here relates to a question included within my questionnaire.

**6.4 The study population.** This includes an explanation of why my student groups are particularly useful and interesting to work within the context of this research. A more detailed overview of my students and the Israeli education system is given in Chapter Two.

**6.5 Reconnaissance data and analysis.**

**6.6 Conclusion**

#### 6.1 Getting to know my students

##### 6.1.1 Personal essays

My action research made me realize how little I knew about my students, especially as I had arrived in Israel only four years before I commenced this research project, and had no prior experience of the country. I had begun teaching almost as soon as I arrived in

Israel, initially Arabs in East Jerusalem. Eleven years later I am still unravelling the complexities of living in a multi-ethnic society embedded within a Middle Eastern culture. It is of considerable importance to understand the socio-cultural influences within a classroom in order to teach appropriately, and build mutual understanding between student and teacher.

From the outset of my research I prompted classroom debate wherever appropriate and also gave brief writing assignments on topics that gave some insight into my students' lives and the issues that concerned them. The freedom to choose the subject of the intervention project was also an opportunity for them to identify a subject that was important to them.

I used open-ended questions to gain insight into my students' lives and opinions. The students provided anonymous written responses of any length. I rarely got less than two paragraphs. The essays were usually one- or two-pages long. It was always surprising how much was written, and how much thought and effort had been invested in this non-compulsory assignment. All the essays were totally anonymous and the students were given the same preamble as I used when giving them questionnaires more closely related to my research, i.e. they had no obligation to answer all or part of them. I also explained the nature of my research. I explained that I might extract a few illustrative sentences for use in my thesis. But if any student wanted to do the essay but not to make it available for quoting they could write 'private' on it and no part of the content would be shared with anyone. I reminded them of this before the essays were handed in at the beginning of the next lesson.

In October 2009 I asked them to write a few paragraphs entitled "something interesting about me". 8 out of 26 essays that were given to me, were labelled as private. And the majority of students found this title very problematic, and wrote at length about how hard it was to think of themselves as interesting in any way. They felt that they hadn't achieved anything in their lives that would be of interest to me.

#### 6.1.2 My students' views on Israeli education

Arriving in a new country there was a great deal for me to learn. I had committed to working in education, and specifically teaching academic English. From the beginning I

have taught at a university and other institutions of tertiary education. More recently I have been co-opted into work at the Ministry of Education that relates to the teaching of English within high schools.

But when I commenced my action research project in 2009, I realised that I had a rather limited knowledge of the Israeli education system as a whole, and wanted to understand how my students perceived its somewhat notorious failings – the complaints about rowdy classrooms, and disaffected teachers abound. But was this my students' experience? I decided that a negative personal question, such as “what didn't you like about school” would probably produce a great deal of personal narrative whereas I wanted a more general view, but from their own perspective. I therefore asked one of my classes at the university to write about ‘How to improve the education system’.

It is important to reflect on what answers you anticipate before reading their responses. I certainly expected some of them to implicitly have a criticism of teachers. I also expected that most of them would want the amount of material included in the syllabus to be reduced and less homework. The essays I got did not match these expectations, but did provide the overview I wanted.

There were 25 essays handed in. Each essay focussed on one main issue and sometimes added some additional subsidiary comments. There were basically two issues that concerned the students. Firstly, the inadequacy of the current teaching staff, and secondly, the failure of the curriculum to include a creative or value-based education. Out of the 25 responses, 15 emphasised the importance of having “higher quality” teachers. All students suggested that higher salaries would bring “better”. “brighter”, “more qualified” teachers. Several suggested some sort of personality testing to identify suitability for entering the teaching profession. One suggested that all high achieving professionals should be given a tax break if they committed to some school teaching. Two others related their experience as “soldier teachers” and expressed the value of using soldiers as teachers.

In the second category, eight focussed on changes to the taught curriculum, with three of these expressing dissatisfaction with the current highly competitive system, and suggesting that “success” needs to be redefined to produce a less competitive, “less

corrupt”, less “money hungry” society. Five of this second category stressed the importance of teaching open-mindedness as a priority. The other curriculum changes suggested included the introduction of creative subjects such as “music, dancing, philosophy”, or something practical, for example “handling money”.

It is worth noting that most of these comments refer to pedagogical issues within teaching.

Another class was given a page with a question that asked:

‘What are the two most important qualities a teacher should have?’

Research in this area is of interest because of the current debate on whether teacher training should focus on disciplinary education, namely content relating to the subject being taught, or pedagogical education, which relates to the art of teaching. In Israel the preference is on disciplinary education, despite the fact that current research shows that students of education place greater emphasis of the importance of personal development (Arnon and Reichel, 2007). Identifying the qualities of good teacher is seen as important with the shift from factual-based learning to problem-based learning (PBL) which includes “encouraging critical thinking; fostering self-directed learning and curiosity” (Azer, 2005, p.67). Lists of “good qualities” appear in the literature, and seem to be exclusively drawn from feedback, in various forms, from teachers or student teachers. My approach to ask students provides yet another approach to this important question.

As always, I feel it is useful to think about the answers that I expect before evaluating student responses. At the top of my list would be: Teachers should understand the material they are teaching, and should be able to explain it in a way that interests the students, namely, primarily focussed on course content.

Twenty-seven students gave responses to this question. Using the method of analysis using coding, the following categories were used. Most students gave two qualities, as requested, a few gave only one.

Table 6.1 Student suggestions of teacher qualities. (N=25)

Key words	No. of students
patient	11
ability to teach students at an appropriate level/understanding students' difficulties	10
deep understanding of subject	5
listen to students/care for students	6
love the subject	3
love teaching	5
charisma	1
interesting	2
organized	1
open-minded	1

This can be reduced to two categories: Category A, which relates to pedagogy, i.e. the art of teaching and includes personal qualities in the teacher; and Category B, which relates to subject, or disciplinary, knowledge.

Category A includes: patience, ability to teach, listening to students and caring for them, love of the subject, love of teaching, charisma, interesting, organized, open-minded.

Category B consists of deep understanding of the subject.

This means the table above produces 40 in category A and 5 in category B. The actual numbers are not particularly important but the overall perception that students want teachers to be patient and caring is unmissable. The fact that few of them mention the importance of a teacher's knowledge about the subject being taught does not mean that students don't regard this as important. This list could be interpreted as the qualities the students have experienced and valued, or the qualities they feel were needed but didn't receive. Using either interpretation it is clear that students want teachers to relate to them individuals and not merely be purveyors of knowledge. This is contrary to the emphasis that the education system places on the training of teachers, and is also contrary to the teacher values I held prior to this study. It impacted on my whole approach and made it more student-centric.

### 6.1.3 What students want to learn

Having a more reflective approach to my teaching also made me think about the course content, and I decided to find out how well the course matched what my students wanted to learn.

I presented my science *ptor* class at the university *mechina* in October 2009, at the beginning of the academic year, a simple questionnaire that asked four questions. The first question asked their age, the second what they were hoping to study, the third appears below and relates to the skills they felt needed to improvement.

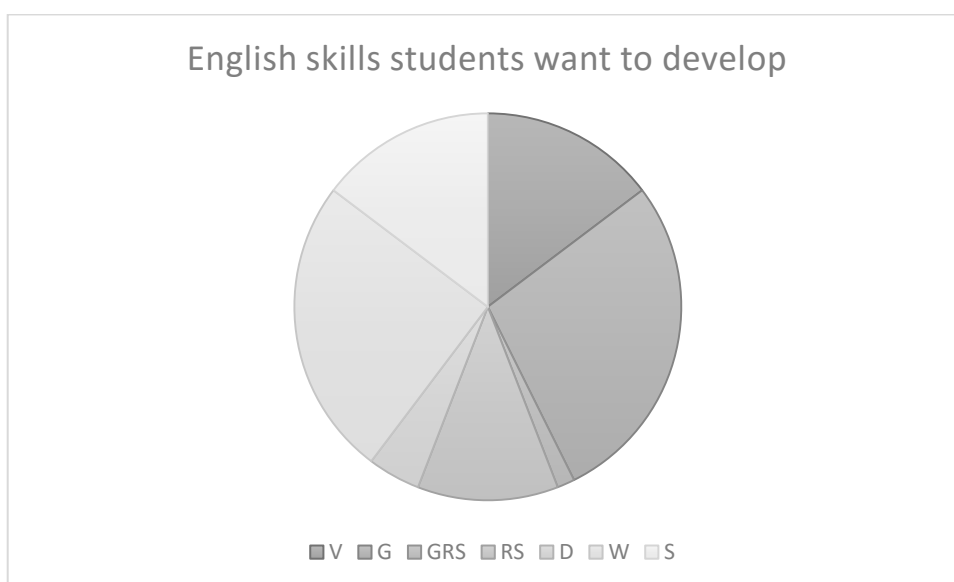
Question 3.

3. Which of the following do you need to develop? (circle as many as you want to).  
**vocabulary / grammar / general reading skills / reading speed /  
 using a dictionary / writing skills / speaking**

Table 6.2 Students identify English skills they want to improve (N=25) Shown as Table and pie chart below.

<b>V</b>	<b>G</b>	<b>GRS</b>	<b>RS</b>	<b>D</b>	<b>W</b>	<b>S</b>
<b>10</b>	<b>19</b>	<b>1</b>	<b>8</b>	<b>3</b>	<b>17</b>	<b>10</b>

**vocabulary (V) / grammar (G) / general reading skills (GRS) / reading speed (RS) /  
 using a dictionary (D) / writing skills (W) / speaking (S)**



**vocabulary (V) / grammar (G) / general reading skills (GRS) / reading speed (RS) /  
 using a dictionary (D) / writing skills (W) / speaking (S)**

It is interesting to note that the course I was teaching was defined by the university as focussed almost exclusively on improving reading skills. We are required to teach some very minor and general grammar which is tested (e.g. identifying verb, noun and adjective), but there is absolutely no content relating to writing in English within the *mechina* courses – even though all these students will have to write papers in English for masters’ degrees, and are increasingly being expected to write essays in English in first degree courses. In very few subject areas does the university offer English writing courses. I initiated, four years ago, the first writing course on the science campus, and it is designed exclusively for doctoral students. An attempt to set up one for masters’ students has so far been unsuccessful.

There is also no speaking component to the course. Although students are encouraged to present opinions in class, and give a 3- or 4-minute end-of-semester presentation, there is no requirement for teachers to address issues surrounding speaking or presentations.

It is clear that the course we provide does not meet what students self-identify as their English needs.

## **6.2 Scientific literacy in the context of a reading programme**

The term ‘scientific literacy’ is a shorthand for a complex idea. In Chapter Three, Review of the Literature, I have explored the diversity of meanings ascribed to the term since it first seems to have been used in 1958 by Paul deHard Hurd (Hurd, 1958). An important analysis of the meaning was addressed by Norris and Phillips (2003) when they drew a distinction between the *fundamental* and *derived* senses in which the term can be used. I am including some details of their arguments here because it helps explain why I feel that an academic reading programme is the ideal context for promoting scientific literacy.

According to Norris and Philips (2003) the fundamental sense of scientific literacy is more closely related with what is more generally understood as the “essential nature of reading” whereby meaning is inferred from text. The derived sense refers to being “knowledgeable, learned and educated in science” (2003, p.224). They reflect on the inadequacy of limiting the meaning of scientific literacy to this derived sense. It is,

however, this sense which is still the prevalent understanding of the term. Norris and Phillips (2003, p.225) illustrate its widespread use by compiling a list (with references, which I have not included) identifying eleven ways in which the term ‘scientific literacy’ is used in the literature:

- a) Knowledge of the substantive content of science and the ability to distinguish science from nonscience.
- b) Understanding science and its applications.
- c) Knowledge of what counts as science.
- d) Independence in learning science.
- e) Ability to think scientifically.
- f) Ability to use scientific knowledge in problem solving.
- g) Knowledge needed for participation in science-based social issues.
- h) Understanding the nature of science, including its relationship with culture.
- i) Appreciation of and comfort with science; including its wonder and curiosity.
- j) Knowledge of the risks and benefits of science.
- k) Ability to think critically about science and to deal with scientific expertise.

They note that, in almost all of the papers associated with these definitions of scientific literacy, the term is being associated with acquisition of scientific knowledge. Testing of scientific literacy strongly relies on the derived sense with its focus on knowledge, especially defining terminology. Many assessments of scientific literacy do little more than test familiarity with jargon terms (see for example the recent Pew Report (2013), commissioned by the magazine of the Smithsonian Institute. Also, similarly, the Australian Academy of Sciences: Science literacy report (2013). Other examples are given in Chapter Three: The Review of the Literature).

In their own research, Norris, Phillips, and Korpan (2003) investigated how university students interpreted a media report about movement of ice on the Jovian moon of Europa. They showed that the students were unable to identify the wide range of degrees of certainty and doubt expressed in the text. The students were unable to make interconnections between different information in the text, but at the same time 95% of them judged the text as easy or very easy to read – they knew the words but were not able to interpret the meaning. This experience is something that teachers of EFAP (English for Academic Purposes) often encounter. My own colleagues regularly report students who complain when failing the final exam “I understood every word of the

text”. The students have not recognised that understanding the words is insufficient for grasping meaning.

For Norris and Phillips it is the failure to address the fundamental sense of the term scientific literacy which results in educators neglecting to integrate certain essential reading skills as part of a science literacy programme. They expand on the nature of this fundamental sense (2003, p.228):

Inferring meaning from text involves the integration of text information and the reader’s knowledge. Through this integration, something new, over and above the text and the reader’s knowledge is created – an interpretation of the text. It is crucial to understanding this view to recognize that interpretations go beyond what is in the text, what was the author’s intent, and what was in the reader’s mind before reading it...The possibility of more than one good interpretation exists for all text types...Thus, the essential nature of reading – inferring meaning from text – is the same no matter what is being read, even though there may be variations in reading purposes and strategies across text types and reading contexts.

The academic reading programmes I teach are committed to this purpose: to enable students to infer meaning from a wide range of texts. Furthermore, I recognise that it is essential that students are aware of how interpretations are affected by prior knowledge, assumptions, expectations and prejudgements – all of which can be affected by socio-cultural context. It is this emphasis on the importance of the fundamental sense of scientific literacy which justifies incorporating my research with a teaching programme providing skills for academic reading. I was not interested in testing for the derived sense of scientific literacy but I did want to ascertain the level of school science education my students had received. I therefore included a question about whether they had taken any science exams in the *bagrut* (baccalaureate) and at what level. (See Chapter Two for more information on science teaching in the Israeli school system).

### **6.3 Why is scientific literacy important?**

The importance of scientific literacy is seen as two-fold according to Ayala, former President of the American Association for the Advancement of Science (2004):

Two increasing demands of modern nations establish the universal need for scientific literacy. First is the need for a technically trained labor force. Second is the requirement that citizens at large pass judgment on the promises and

actions of their governments and on the claims of advertisers of consumer goods.

Governments closely link scientific literacy with interest in science, and the resultant likelihood of students choosing to study the STEM (science, technology, engineering and mathematics) subjects. Reports of declining science literacy do mirror the decline in the numbers of students studying those subjects at an advanced level (Osborne et al. 2003). This overall decline in interest in science has deeply concerned governments of industrialised countries because the level of scientific literacy is perceived as directly linked with economic productivity. Walberg (1983), referring to the work of Schultz and Simon, Nobel Prize winners in Economics, identifies that there is “a considerable amount of plausible and consistent evidence on the pecuniary and other benefits of literacy” and Wahlberg states that this is particularly relevant to scientific literacy. Osborne (2003) expresses it succinctly “the low uptake of mathematics and science (*for study at university*) and the negative attitudes towards these subjects pose a serious threat to economic prosperity.”

However, DeBoer (2000) points out that the poor performance of US students in international science tests might not be heralding a “national crisis”. He comments that “In fact, people with extremely limited understanding of science function very well in society, many of them at the very top levels of their professions.” He continues with an extract from Shamos (1995, p.5), where Shamos quotes Audrey Champagne (1986):

“The perception of crisis is partially a product of hyperbole employed in the many national education reports...The rhetoric notwithstanding, there is no reason to believe that the national security, economy, democratic way of life, and science prominence are threatened by the low level of scientific and mathematical literacy in the general population.” (Shamos 1995, p.5)

But Shamos does not reject the whole concept of scientific literacy, what he questions is whether “any science is needed at all except as a way of discussing the nature of science” (DeBoer 2000). It is a radical approach and in Shamos (1995) “highly influential book” (DeBoer 2000), *The Myth of Scientific Literacy*, he suggests that the goal of a scientific literate citizenry is impossible, and that decision making should remain in the hands of the experts.

In the past twenty years there has been a growth in the movement for social responsibility in science and technology, much of this focuses on the scientists and the institutions themselves, but there are implications for a partnership in decision-making with the general public. Ramsey (1993) details the extensive literature on science education which presents social responsibility as a goal of the promotion of scientific literacy. He insists (1993, p.235) that “Science education cannot be sequestered in the laboratory; it must, to some critical extent, be an active part of our social milieu.”

I think it important to ascertain whether my students feel they should be part of the decision-making process that relates to scientific and technological issues, or whether they believe these decisions should be left with the experts. For this reason, I selected one of the VOSTS questions to include within my initial questionnaire. (VOSTS are discussed more fully in Chapter Three: The Review of the Literature)

#### 6.3.1 Assessing Attentiveness

Independent of what is regarded as the purpose or usefulness of scientific literacy, there is an underlying assumption that scientific literacy (in all its meanings) is associated with interest in scientific and technological issues. One of the prime objectives of the reconnaissance was to ascertain levels of interest in scientific issues and associated knowledgeability (whether students chose to read about the subject in the popular press). A combination of both these elements gives rise to a measure of ‘attentiveness’. This concept of an attentive public was put forward by Almond (1950) and has been identified as of considerable importance in all polling of public opinion (Adler, K. 1984).

According to Miller and Kimmel (2001, p.176) the term ‘attentive public’ as used in Almond’s model (Almond 1950) is “composed of those individuals who are interested in a given policy area, are knowledgeable about that area, and are regular consumers of relevant information. To be classified as attentive to a given policy area, individuals must indicate that they are very interested in a given issue area, report that they are very well informed about it, and be a regular reader of a daily newspaper or relevant national magazines”. This attentive public is at the third level in Almond’s model of public participation in the formulation of public policy. In every country, the proportion of

adults interested in a public policy issue is far higher than the proportion who report that they are well informed about that issue.

(Almond's model. Diagram of triangle with layers going up from bottom Residual public, Interested public, attentive public, policy leaders, decision makers.)

In this model "citizens who display a high level of interest in an issue area, but who do not think they are well-informed about it, are classified as the interested public. "It is possible that some of the individuals in the interested public would become attentive during a particular controversy if they became convinced that they knew about the issue." (Miller and Kimmel 2001, p.176)

But note that in Miller's study (1987), he found that in the case of the explosion of the space shuttle Challenger "virtually no members of the interested public for space exploration moved into the attentive public for that issue as a result of the accident or during the six months after the explosion in which numerous public hearings and investigations were held" (quote from Miller and Kimmel 2001, p.177). Miller and Kimmel recommend more studies of the 'interested' public, as it is important to see if there are ways of moving them into the group that is defined as 'attentive'. It is the attentive public who are also informed on a particular issue and are those who are best placed to engage with democratic decision-making processes relating to that issue.

In Miller and Pardo's work (2000) data has been compiled from national studies relating to scientific literacy in the European Union, Japan, the United States and Canada. This comparative study provided me with detailed data of the percentage of attentive public for medical, scientific and technological issues. The questions in my questionnaire parallel a small selection of those asked in these international studies. This enables a direct comparison, for the first time, of Israeli data with corresponding international studies for the same age group and educational status.

### 6.3.2. Science literacy and superstitious belief.

It is interesting that Miller (1983, 1987a) disqualifies individuals from being scientifically literate if they have a belief in astrology, which could be characterised as a superstitious belief and the antithesis to scientific thinking. It is not clear to me that this

value-judgement is appropriate. Furthermore, living in a country where religious and superstitious beliefs are widespread and diverse, the idea of distinguishing between religious belief and superstition is highly problematic. People seem able to compartmentalise scientific beliefs and religious/superstitious beliefs; religious people do not abandon rationale thought and argument because of non-scientific beliefs. In fact, belief in astrology has, in the past, been part of religious practice in the three Abrahamic faiths. There could be here, as with any belief (religious or political), an inhibiting factor to open-minded, critical thinking in assessing SSI issues. However, we all come with some baggage, consciously or subconsciously, which taints our judgement. My intervention would perhaps help address this.

Interestingly, longitudinal national surveys in China of scientific literacy monitor superstitious belief (belief in lucky numbers for example) as a means of ascertaining trends towards greater scientific thinking. (Chen 2009). And it is interesting to note that one of the reasons the spiritual sect known as the Falun Gong has been outlawed in China is because it is regarded as fostering superstitious beliefs.

I decided to incorporate a question on belief in astrology to see what sort of responses I got and see if this belief was associated with lack of interest or ‘attentiveness’ in science. I embedded this question among others, similarly worded, which looked at views on using homeopathy, applying graphology, the dangers of using mobile phones, and video games as a source of violence. All of these issues are unsupported by scientific evidence.

Each of these questions provided space for students to explain/justify their answers if they so wished.

#### **6.4 The study population.**

The study population for this reconnaissance cycle are drawn from four classes that I teach – two classes at a university *mechina* and two at a college of engineering. All four classes form the study population for most of 2009, though there are some investigations only done with the two classes at the university.

It is the two classes at the university that become the focus of my research for the years 2010 and 2011.

I am fortunate to have complete responsibility for the content that I teach in the various departments where I work. I teach academic reading in English and can select the texts and implement any methods that I feel will enhance the reading performance of my students. Interventions designed around promoting scientific awareness and higher level analysis will not conflict with the general goals of my course and will only constitute a small element of it.

The students at the university who form part of my study population are within the pre-academic department of the university. These students are given a year's intense instruction in a wide range of subjects to prepare them for their first degree studies. They all take English. They are streamed according to ability in each subject and are then subdivided into specific subject areas according to the degree courses they are applying for at the university. I take one class designated as Science and one designated as Humanities. Both classes usually do a project in the first semester and my interventions will form that project work; the interventions are wholly consistent with the objectives of the projects that I normally give.

Each group of students is taught for 4 hours a week, for 14 weeks – the length of a single semester in a two-semester academic year. Most semesters I teach six courses of top level students. There are between thirty and forty students in each class, ranging in age from 19 to about 25 years old. Although predominantly Jewish Israeli students, the classes are ethnically mixed with Arab Israelis, Ethiopians and Druze students. The usual breakdown, which changed little in the university *Mechina*, in the ten years I have taught there, was 97% Jewish Israeli (of whom about 10% were Ethiopian). The remaining 3% were Druze and there was occasionally an Arab Israeli. Arab Israeli students are found in other *mechinot* in the University, where there is pre-academic teaching for students with poor Hebrew and very low/or no psychometric score.

At the university the classes I have chosen for this research already have exemption certificates in English, called a *ptor* in Hebrew, but are still obliged to take the high level course I give. The two classes I teach at CE are top level (Level 1) students who have not yet received their *ptor*. Getting a pass in my course will provide them with the *ptor*, 'exemption certificate' that will qualify them to receive a first degree. Without a *ptor* students cannot receive a degree in any subject studied in university or

college. The exemption certificates received at the university and CE are valid throughout Israel's institutions of higher education and are also accepted for study for a master's degree in all subjects.

I teach in total about 200 students in the first semester. Around 120 of them were given the first questionnaire in the first lesson of the first semester. The questionnaires were totally anonymous, and I explained that they formed part of a doctoral study programme I was doing. The students were under no obligation to answer a questionnaire, and could leave unanswered any questions they didn't wish to answer. I was available to clarify anything they didn't understand. In fact, all students took a questionnaire, completed all questions, and none raised any problems or difficulties. It took approximately 20 minutes out of this first lesson.

To protect my students' anonymity none of these questionnaires was looked at until months after I had finished teaching them. This meant there was no likelihood of identifying a student by their handwriting. I never identified any of the respondents.

### 6.5 Data and analysis

The data and analysis is given for each question in the questionnaire. There is a separate subsection here for each question. The questions are in the order they appeared in the questionnaire. Each group of questionnaires had a printed code on the top so that I can quickly identify the year and group they belong to.

Here is the heading for a questionnaire given to one of my groups at CE .

#### Questionnaire (QCE 109) M

This questionnaire is part of a research project.

I would be grateful if you could answer it as honestly as possible.

There are no right or wrong answers!

If you don't understand anything, please ask.

**CE** refers to the institution; **1** means first semester; **09** is the year 2009, **M** is the class I teach on Mondays and Wednesdays, as oppose to **T** which I teach on Tuesdays and Thursdays. My two CE classes are therefore designated CE M and CE T in this thesis.

The other classes are designated as follows.

U sci (University science stream, *ptor* class)

U hum (University humanities stream, *ptor* class)

The questionnaire was divided into three sections. Section A (questions 1-6). Section B (questions 7-11). Section C (Questions 12 -14) It was laid out so that each section occupied one full page. The questionnaire was therefore three pages long. A lot of thought went into the design so that it didn't have a lot of dense print for the students to read.

#### 6.5.1 Age and sex. Q1 and Q2

The questions below gave me information about the age and sex of my students.

**Q1. How old are you? \_\_\_\_\_ years old**  
**Q2. Male/female (please circle)**

I used this information to calculate averages of their age. For each group I found the mean, and median. I also give the range. See Table 6.3.

I use the male/female ratio in Table 6.7.

Table 6.3 Data and analysis: age and sex

Place	Class	Class size	M	F	Averages of students' ages
HU	Sci ( <i>ptor</i> )	27	15	12	Average ages: Mean: 22 years    Range: 18-25    Median: 23
HU	Hum ( <i>ptor</i> )	34	18	16	Mean: 23 years    Range: 21-25    Median: 23
CE	M (level 1)	29	17	12	Average ages: Mean: 23 years    Range: 18-30    Median: 23
CE	T (level 1)	27	20	7	Average ages: Mean: 24 years    Range: 21-31    Median: 24

#### 6.5.2 Subject of study

For my students on the university pre-academic programme they were asked:

**Q3. What do you want to study at university?** \_\_\_\_\_

And at CE the students were asked:

**Q3. What are you studying?** \_\_\_\_\_

I have all this information on file but I haven't analysed it because I am unclear how valuable it is. I thought it might be useful because there are courses at CE and in U

which are regarded as having less scientific and technological content. I thought I might want to separate out the questionnaires from these students at some point.

### 6.5.3 Level of science education at school.

Science subjects are not required in the *bagrut* (baccalaureate) and few schools offer them. Biology, physics and chemistry as separate subjects are taken by small numbers of students. The *bagrut* can be taken at one of three levels: 3 point; 4 point; and 5 point. Most students who recorded taking science *bagrut* (plural of *bagrut*) took them at the four or five-point level. The three-point level is basic. There is only person who took a 3-point *bagrut* (in biology) recorded in my data. I have chosen only to list those who took 4- or 5-point as these do show a reasonable (but not high) level of science teaching. The number of points is not a score, it just shows the level of exam they took (perhaps 4-point would approximate to GCSE, and 5-point to AS level in the UK).

#### Q4. Did you take a *bagrut* in any science subject?

Subject	How many points?
Biology	
Physics	
Chemistry	

Table 6.4 Assessment of school science education showing numbers taking 4- or 5-point *bagrut* in science subjects.

Class	Class size	Biology no. of students	Physics no. of students	Chemistry no. of students	Total no. of students with at least one science <i>bagrut</i> .	% of class with at least one science <i>bagrut</i>
U sci	27	11	2	3	11	40
U hum	34	5	1	2	7	21
CE M	29	9	5	6	15	52
CE T	27	3	2	1	6	22

This table shows that the level of school science education is low. The majority of students taking science take only one science *bagrut*, namely biology; there is very poor uptake of physics and chemistry at school.

The marked difference between CE **M** and CE **T** results probably reflects that CE **T** classes are students retaking English in their second year of study at the college, and they are generally known to be weaker students across all subjects and not just English. CE **M** students are those in the first semester of their first year.

The first year of science and engineering degrees in the Israeli education system has much in common with the syllabus of 'A' levels in mathematics, physics and chemistry in the UK.

#### 6.5.4. Assessing interest and attentiveness.

Below are the next questions on the questionnaire, Q5 and Q6.

The data and analysis follows, and a comparison with similar international data.

#### **Q5. How interested are you in the following subjects?**

**Please put a check in the appropriate box for each item.**

<b>Subject</b>	<b>Very interested</b>	<b>Moderately interested</b>	<b>Not at all interested</b>
Sports news			
Politics			
New medical discoveries			
New films			
New scientific discoveries or inventions			

**Q6. How well informed do you think you are about these subjects?**

Please put a check in the appropriate box for each item.

<b>Subject</b>	<b>Very well informed.</b> I always look for the latest news on this subject.	<b>Moderately informed.</b> When I see an article on this subject I usually read it.	<b>Not at all informed.</b> I never read about this subject.
Sports news			
Politics			
Medical discoveries			
Films			
Science and technology			

#### 6.5.4.1 Index of Issue Interest

Miller and Pardo (2000, 68) computed mean scores for an ‘index of issue interest’. This was done by giving a 100 when a respondent declared they were very interested, 50 when they were moderately interest, and zero points when they were not interested at all. The grand total for each issue is then divided by the total number of respondents in that class. This index is a useful way for calculating a single score for a three-level Likert item and enables me to make a direct comparison with the international data assembled by Miller and Pardo (2000).

I have computed values for this Index (Table 6.5) for each of my four classes, and an average over all the classes.

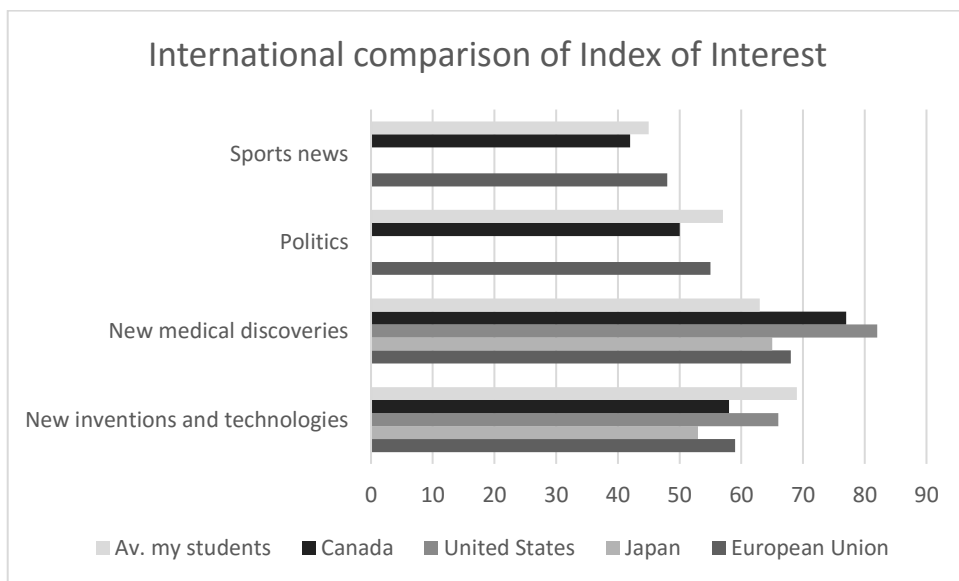
Table 6.5. Mean Scores on the Index of Issue Interest for my classes. An average over all the students is also given (Av).

<b>Issue area</b>	<b>U sci</b>	<b>U hum</b>	<b>CE M</b>	<b>CE T</b>	<b>Av.</b>
New inventions and technologies	83	69	69	56	<b>69</b>
New medical discoveries	76	56	71	50	<b>63</b>
Politics	52	74	48	50	<b>57</b>
Sports news	37	49	50	43	<b>45</b>

I have reproduced part of the table that Miller and Pardo (2000, p.70) compiled from international data and have added a last column with my own average data (Av.) for Comparison (see Table 6.6)

Table 6.6. Mean Scores on the Index of Issue Interest Scores. From Miller and Pardo (2000, p.68). The last column is the average (Av.) for all my students.

Issue area	European Union	Japan	United States	Canada	Av. my students
New inventions and technologies	59	53	66	58	<b>69</b>
New medical discoveries	68	65	82	77	<b>63</b>
Politics	55	-	-	50	<b>57</b>
Sports news	48	-	-	42	<b>45</b>



It is important to notice that my values for the Index of Issue Interest for Sports and Politics are in close agreement to those recorded for Europe and for Canada. This helps add confidence to the other values, which are of more relevance to my research.

#### 6.5.4.2. Attentiveness

To be categorised as attentive (A), individuals must be ‘very interested’ in a subject and also categorise themselves as ‘very well informed’.

The assessment of how well informed students regard themselves is important.

To assess the degree of self-perceived knowledgeability, national studies in Canada, Europe, Japan and the United States asked respondents to categorise themselves as being well informed, moderately well informed, or poorly informed about the same set of subjects as used to assess interest. In every country, the proportion of adults interested in a subject is far higher than the proportion who report that they are also well informed about that subject.

I have analysed the data I collected. The category of interested (I) individuals is computed by taking the numbers of students who marked that they are ‘very interested’. A percentage is calculated for each class. To identify students as attentive (A) I took the students who were ‘very interested’ and checked if they also marked that they were ‘very well informed’.

The data for (A) and (I) are given in Table 6.7.

A male/female ratio is calculated for each class from data shown in Table 6.3.

Table 6.7 Percentage of attentive (A) or interested (I) in each class.

Subject	U sci		U hum		CE M		CE T	
	A%	I%	A%	I%	A%	I%	A%	I%
Sports news	19	33	21	29	17	21	33	37
Politics	15	19	32	63	7	10	19	22
New medical discoveries	15	59	24	32	17	48	11	22
New films	15	37	26	29	10	17	15	22
New inventions and technology	26	74	21	44	17	38	22	33
<b>Male to female ratio in each class (to 1 d.p.)</b>	1.3		1.1		1.4		2.9	

There are several comments to make about the data in Table 6.7

- The percentage of students who show ‘attentiveness’ is less and often much less than those who are only ‘very interested’. These figures show the importance of also asking about how informed individuals perceive themselves to be, and not

just assessing the level of interest. According to Miller and Pardo (2000) it is only those identified as attentive who are likely to participate actively in issues relating to science and technology.

- There are high levels of **(A)** for science and technology across all classes, including the humanities class.
- Looking down a column for any single class is interesting. In column **(I)** there is a range in each class (except CE T, which I will deal with separately). But when viewing values for **(A)** the values are more uniform.
- **(I)** and **(A)** for science and technology have high ranking in all classes, even if not always the highest.
- Two **(A)** values break the overall pattern of the table. Politics in U hum and sports news in CE T. It is perhaps worth noting that the male to female ratio in CE T is higher than in the other classes, with almost three times as many males as females, this could perhaps account for the high level of **(A)** value for sports.
- With the exception of sports in CE T the male to female ratio does not seem to affect other **(A)** and **(I)** values.
- U hum shows high values for **(A)** and **(I)** across all subjects. The uniformly high values of **(A)** are especially interesting, and perhaps reveal that students who are generally engaged with the world around them are also interested in medical, scientific and technological issues.

The table below (Table 6.8) extracts from Table 6.7 the information relating to scientific topics. I have also averaged **(A)** and **(I)** for medical, scientific, and technological subjects as do Miller and Pardo (2000). This provides a single figure for comparison with international data in Table 6.9.

Table 6.8 Percentage of attentive (A) or interested (I) in each class.

Subject	U sci		U hum		CE M		CE T	
	A%	I%	A%	I%	A%	I%	A%	I%
New medical discoveries	15	59	24	32	17	48	11	22
New inventions and technology	26	74	21	44	17	38	22	33
Average over both subjects	21	63	23	39	17	43	17	28

It can be readily seen that the levels of students stating that they are very interested in medical discoveries and science and technology is high. The percentage drops markedly when calculating those who are ‘attentive’ (i.e. consider themselves very interested and very well informed on a subject) but is still high.

These values can be compared to those in the table compiled by Miller and Pardo (2000, 70). Their table (Table 6.9) shows the percentages of the public who are attentive (A), and those who are interested (I) in scientific, medical or technological discoveries. The data was collected and computed in a similar way to mine. It can be seen by the lower levels of attentiveness that the proportion of respondents internationally who identify themselves as interested is far higher than those who also regard themselves as well informed. Miller and Pardo (2000, p.68) point out that “the perception of not being well-informed deters individuals from engaging in overt efforts to influence public policy” by for example writing a letter or contacting a public official.

I have extracted the relevant sections, of Miller and Pardo’s table so that my students can be compared either with high school graduates or those in the age category 18-29. See Table 6.9. This table is taken directly from Miller and Prado’s publication on the comparisons they made from internationally recorded results.

Table 6.9 Percentages of the public who are attentive (A), and those who are interested (I) in scientific, medical or technological discoveries. (Miller and Pardo 2000, p.70)

This table is taken directly from Miller and Prado's publication on the comparisons they made from internationally recorded results.

<b>variable</b>	<b>EU (A)</b>	<b>EU (I)</b>	<b>Japan(A)</b>	<b>Japan(I)</b>	<b>US (A)</b>	<b>US (I)</b>	<b>Canada (A)</b>	<b>Canada (I)</b>
Education								
Less than high school	5	25	1	9	4	37	9	37
High school graduate	9	33	2	18	8	48	11	45
18-29 years	13	35	2	19	7	52	8	38
Male	13	36	3	24	12	49	14	44
Female	7	30	1	11	8	45	7	47

By combining the information in Tables 6.6 and 6.7 I am able to make a direct comparison with international data. The values for high school graduates and 18-29 year olds are similar, and either could be chosen for a comparison with my first year students. There are, however, intrinsic problems of comparing my data with that collected internationally. Firstly, my sample size is small – although the data collected over three years was internally consistent which meant that it was representative of almost 200 students. And secondly, international comparisons are problematic because they ignore all the parameters that shape individual nations. However, international comparisons do appear in the literature relating to research in scientific literacy. I therefore think it is useful to include them here but with the caveat that it might not be clear what the comparison actually shows. However, I do think that the fact that my data has values falling within the range of international data perhaps indicates that I didn't make any major errors in the methods of analysis I adopted. If my values

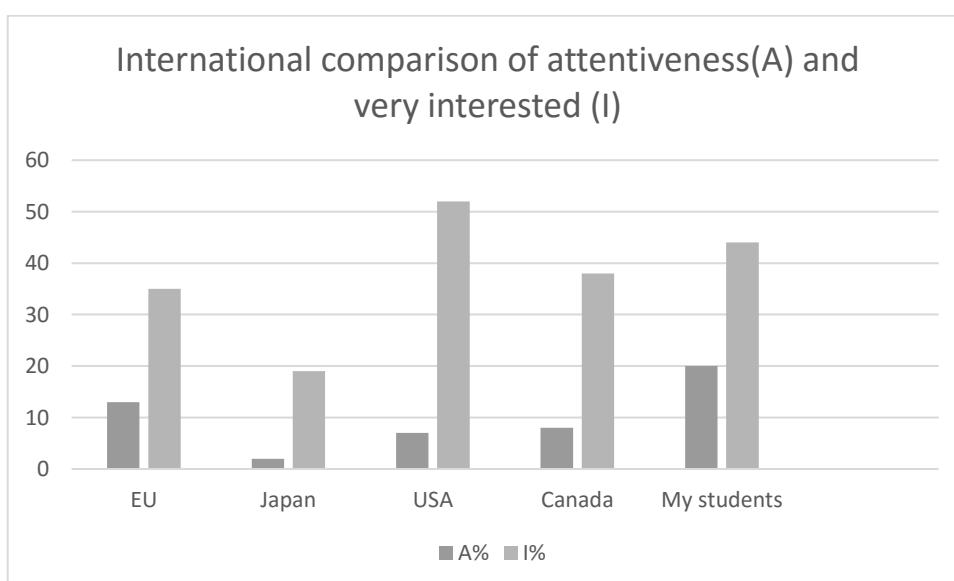
had been outside the range seen globally I would have checked back on my methods of data collection and the details of computation.

Furthermore, the international comparisons are useful in indicating how my students' levels of interest (with negligible science education) compare with that in other countries, where there is considerable emphasis on teaching science in school. This research was done to help explore my research question on the relationship between level of school science education and degree of interest in the subject.

By constructing Table 6.10 vertically only for the group 18-29 years old I have made comparison easier. I have added my figures at the bottom of this table (Table 6.10) for direct comparison.

Table 6.10 Percentages of 18-29 year olds who are attentive (A), and those who are very interested (I) in scientific, medical or technological discoveries. Given in two formats: as a table, and as bar chart (below).

<b>Location</b>	<b>Attentiveness (A) %</b>	<b>Very interested (I)%</b>
European Union	13	35
Japan	2	19
United States of America	7	52
Canada	8	38
My students in Israel (N= 117)	20	44



#### 6.5.5 Non-scientific and superstitious views

Because there is a view that scientific literacy is incompatible with superstitious belief, particularly astrology, I decided to see how prevalent this particular belief was among my students. I also included other issues that are regarded as not having any scientific evidence supporting their validity. I thought it might be useful to see how these views changed at the end of the semester. Especially as there would be class discussion relating to some of them.

These questions (Q7-Q11) are reproduced below. Students were not obliged to give reasons for their answers but were given the space to write anything they felt appropriate. This was explained in class. Many answers were very interesting.

## SECTION B.

Please read the following statements. Put a check in the box closest to your opinion.

7. Graphology is the study of handwriting. It is used by some companies to decide if they should employ someone.

- ☐ I think this is a good idea, because \_\_\_\_\_
- ☐ I think this is a bad idea, because \_\_\_\_\_
- ☐ I don't know.

8. Astrology is the study of how the position of stars and planets influence our lives. Some people go to an astrologer to help them make important decisions.

- ☐ I think this is a good idea, because \_\_\_\_\_
- ☐ I think this is a bad idea, because \_\_\_\_\_
- ☐ I don't know.

9. There is a lot of research on how dangerous cell phones are. Some parents don't allow their children to use cell phones.

- ☐ I think this is a good idea, because \_\_\_\_\_
- ☐ I think this is a bad idea, because \_\_\_\_\_
- ☐ I don't know.

10. Some people want to reduce the violence on television and in video games.

- ☐ I think this is a good idea, because \_\_\_\_\_
- ☐ I think this is a bad idea, because \_\_\_\_\_
- ☐ I don't know.

11. Some people use homeopathy to treat illnesses. Some people think homeopathy should be available as part of your health care insurance.

- ☐ I think this is a good idea, because \_\_\_\_\_
- ☐ I thinks this is a bad idea, because \_\_\_\_\_
- ☐ I don't know.

Subsequent discussion with the class when we had a text on the dangers of cell phone use revealed that most of them thought that the dangers were about crossing roads while using a cell phone, or perhaps becoming addicted to playing games on them. This

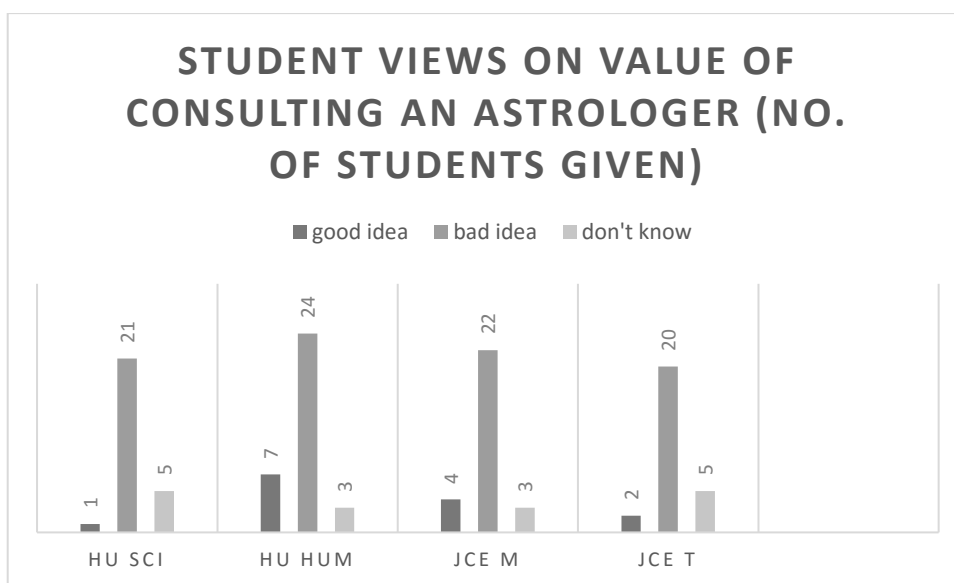
question was intended to address the (scientifically unfounded) belief that cell phones cause cancer. A good illustration of the problems of conveying meaning.

As my main interest was to ascertain whether it is important to know about people's superstitious beliefs I am focussing on the data from Q8, on astrology. This question was not a simple 'do you believe in astrology?' I have found in class discussions in previous years that it is important to leave room for students to give more nuanced answers. And indeed the answers I got here were much more interesting than a simple dichotomous choice. Their answers reveal complexity.

I have collected the data that shows how many students in each class thought it a 'good idea', a 'bad idea' or said 'don't know'. I have also identified how many students who expressed that they were 'very interested' (I) or were designated attentive (A) also thought astrology 'a good idea'. The analysis is shown in Table 6.11.

Table 6.11 Views on astrology (numbers of students in each class) and chart below.

Class	Good idea	Bad idea	Don't know	(I) plus 'good idea'	(A) plus 'good idea'
U sci	1	21	5	0	0
U hum	7	24	3	2	1
CE M	4	22	3	2	0
CE T	2	20	5	0	0



U sci class comments that astrology was a 'bad idea' did not have any religious reference. A number of them said it was "not proven" and a few said it was "not accurate".

U hum class comments among those who thought is a 'good idea'. "I believe the stars influence our behaviour" "It works" "If it makes your life easier, why not?" "Everybody needs to believe in something". "It helps decide what you want" "It helps people overcome their problems" "It can give an interesting perspective." These don't all demonstrate belief in astrology but they do indicate that these students felt some value in it, and the question gave them room to express that.

On the other hand, those who thought it a 'bad idea' were more direct. "It is crap", "it is not scientific". Several wrote "it is not science". One person described it as "superstition". Most stated in some form "I don't believe in it".

**CE M students.** Those choosing it is a 'good idea' added: "It is always nice to get advice", "It is helpful to hear an objective opinion". "For those who believe it can change their life in a good way". "Usually true and really helpful."

Bad idea. "Only God knows the future". Only one student wrote "It is not scientifically proven" The rest gave versions of "I don't believe in it". One student wrote "It gives them something to blame if things go wrong."

**CE T students.** Those choosing it as a 'good idea' added: "It can help someone feel good about his decisions", "It can help someone make decisions". Among those regarding it as a 'bad idea' they noted "it contradicts my religious belief", "they should talk to a rabbi if they have a problem". Most who answered 'it was a bad idea' added "I don't believe in it", "It is a lie", "It is nonsense"

I pulled out the questionnaire of the single person who was 'attentive' and thought astrology was a good idea, noting that they had written "I believe that the stars influence energy and through that a person's behaviour". This individual was in U hum, 25 years old and planning to study PPE (philosophy, politics and economics) at university. In the questionnaire he/she declared being very interested and very well informed in everything except films. He/she was either very interested or moderately interested in the scientific issues listed in Q12. He/she suggested in Q.13 "looking at ways for conserving water and energy at home" – one of the few people out of the 117 students

to make any suggestion. He/she thought graphology a good idea and so was homeopathy, and mentioned that her mother is homeopathic pharmacist. Do the non-scientific/superstitious beliefs disqualify this student from being designated 'attentive'? Her questionnaire was lively and engaging. I did not attempt to identify who he/she was.

I am convinced from my every encounter with many religious students (Jewish and Muslim) that their religious beliefs do not compromise their ability to deal with scientific issues in a meaningful and useful way. This does not mean that there aren't religious individuals for whom there are conflicts between science and religious belief/superstition. But if there is a move to regard superstition as contrary to the ability to engage with scientific issues then religious belief might also have to be included. And indeed as mentioned earlier, all our opinions are influenced by beliefs (religious and political) and perhaps modified by life experiences.

#### 6.5.6 Specific science issues of interest

I wanted to know how much interest there was in specific scientific issues among my students and intended to select one to focus on for a mini project. This would perhaps be the focus of my first intervention.

Questions 12 gave students a chance to express how interested they were in a range of contemporary issues and Question 13 was open ended.

**Q12** How interested are you in discussing these in class during this semester.

Issues	Very interested	Moderately interested	Not at all interested
1. Alternative therapies are useful/useless			
2. Causes of violence in society.			
3. Graphology and astrology are useful/useless			
4. Cell phones are dangerous.			
5. Animal welfare issues.			
6. Pollution problems worldwide.			
7. Global warming is/is not a serious problem.			
8. Genetically modified food is/isn't dangerous.			
9. Nuclear power is/isn't dangerous			
10. Fluoridation of water is/isn't a good idea.			

These are all issues regularly covered in the media and newspapers in Israel.

Graphology is widely used by major companies. The causes of global warming are still discussed – a senior physicist at the university has online lectures advocating solar activity as the prime driver of global warming. The fluoridation of water remains a live issue here.

**Q13.** Please write about any issues that have scientific or technological content that you would like us to cover this semester. \_\_\_\_\_

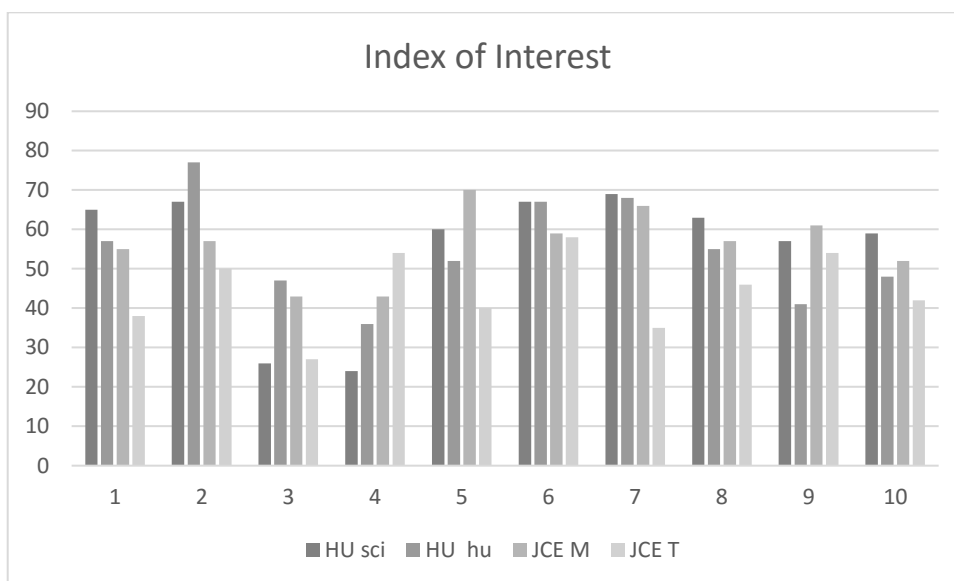
This question produced almost no contributions from the students.

In assessing the responses to Q.12 I have calculated the mean scores of the Index of Issue Interest. This gives 100 to those who are very interested, 50 to those who are moderately interest and no points to those who are not at all interested. The total is then divided by the number of students in the class. The results of this analysis are shown for each class in table 6.12.

Table 6.12 Mean scores of Index of Interest

Issues	U Sci	U Hum	CE M	CE T
1. Alternative therapies are useful/useless	65	57	55	38
2. Causes of violence in society.	67	77	57	50
3. Graphology and astrology are useful/useless	26	47	43	27
4. Cell phones are dangerous.	24	36	43	54
5. Animal welfare issues.	60	52	70	40
6. Pollution problems worldwide.	67	67	59	58
7. Global warming is/is not a serious problem.	69	68	66	35
8. Genetically modified food is/isn't dangerous.	63	55	57	46
9. Nuclear power is/isn't dangerous	57	41	61	54
10. Fluoridation of water is/isn't a good idea.	59	48	52	42

Students in U sci, U hum and CE M show a wide range of interest in scientific issues that they want to discuss. The bar chart shows the information from Table 6.10



Students in CE T show overall less interest in most subjects but do show greater interest in the issue relating to cell phones than all the other classes. It is perhaps interesting to note that this is the only issue that can be seen as having direct personal relevance to the students. It is also worth noting here that this class is known as a weaker class overall, being a second year class that is retaking exams in many subjects that were failed in their first year. A fellow teacher who also teaches CE M and CE T at level 1 (parallel classes to mine) complains weekly about their failure to work, to stop talking in class. These classes often have disruptive students in them and students who find independent working impossible. They are always a challenging bunch of students to teach and I have various strategies to defuse the most disruptive elements so that the rest of us can get on.

#### 6.5.7 Do students want to participate in decision-making?

The last question, **Q14**, was item **40215** taken from the publication Views On Science and Technology (Aikenhead et al. 1989, p.33). In Table 6.11 is the data collected for each class for Q14. The raw numbers are given for each statement.

**Q14** Please read this and think what your position on it is. Then read from A to J and circle the one closest to your opinion.

**Scientists and engineers should be the ones to decide whether or not to build a nuclear reactor and where it should be built, because scientists and engineers are the people who know the facts best.**

**Your position, basically:** (Please read from A to J, and then choose one.)

Scientists and engineers should decide:

A. because they have the training and facts which give them a better understanding of the issue.

B. because they have the knowledge and can make better decisions than government bureaucrats or private companies, both of whom have vested interests.

C. because they have the training and facts which give them a better understanding; BUT the public should be involved — either informed or consulted.

D. The decision should be made **equally**; viewpoints of scientists and engineers, other specialists, and the informed public should all be considered in decisions which affect our society.

E. The **government** should decide because the issue is basically a political one; BUT scientists and engineers should give advice.

F. The **public** should decide because the decision affects everyone; BUT scientists and engineers should give advice.

G. The **public** should decide because the public serves as a check on the scientists and engineers. Scientists and engineers have idealistic and narrow views on the issue and thus pay little attention to consequences.

H. I don't understand.

I. I don't know enough about this subject to make a choice.

J. None of these choices fits my basic viewpoint.

Table 6.13 Numbers of students choosing each statement in Q14.

Statement	U SciP	U HumP	CE M	CE T
A	1	2	3	2
B		2	1	2
C	5	9	4	3
D	7	7	4	4
E	3	2	6	4
F	3	2	1	1
G				
H				
I	1	2	1	1
J		1	2	

Comments. This was a lengthy question involving careful reading and not all students chose to do it. However, there was a high percentage in each class who did it and did it carefully. This can be seen by the fact that everyone rejected G and H. G states the decision should be solely made by the public and all students rejected this. Overall 74% of all the students answered this question.

C and D both give the public an important role in the decision making process and these each got consistently high scores. F gives the public a stronger role but, scientists and engineers are still involved in the decision-making process.

A and B gives sole responsibility to scientists and engineers without any public involvement.

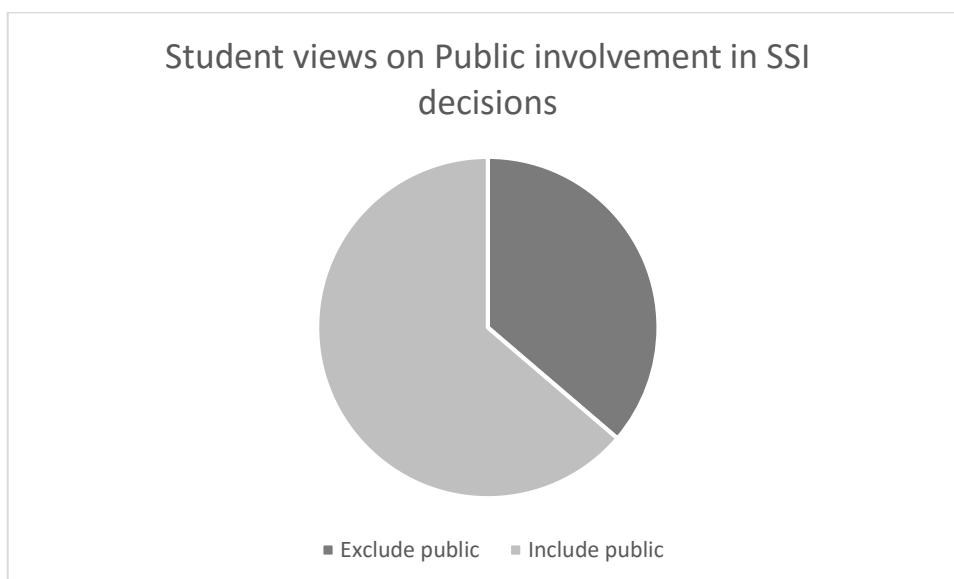
E gives the responsibility to government, with advice from scientists and engineers but excludes the public.

Basically A, B and E exclude the public. C, D and F include the public.

I have presented the sum values for A, B and E (called 'public excluded') and the sum values of C, D and F (called 'public included') in Table 6.12. These categories are also summed across all classes. The data are given as raw numbers and as a percentage of the students who answered this question (i.e. 86 students). All data is taken from table 6.13.

Table 6.14 Student opinion on whether there should be public involvement in scientific/technological decisions. Also see pie chart below (N=96)

A+B+E (public should be excluded)	A+B+E as a % of students who answered Q14.	C+D+F (public should be included)	C+D+F as a % of students who answered Q14.
28	33%	50	58%



A clear majority do want public participation in a decision relating to the building of a nuclear reactor. This means that for those of us in education there is a responsibility to give our students the tools so that they can participate in this type of decision-making in a useful and meaningful way.

## 6.6 Conclusion

### 6.6.1 General comments on the reconnaissance

This reconnaissance produced a wealth of data which gave me considerable insights into my study population. I also produced data in a form that meant I was able to directly compare it with international data. This has allowed me to draw some tentative conclusions about Israeli students in comparison to those in other countries.

My students provided a particularly interesting group to study because of their limited experience of higher level science education at school. I knew that few high school pupils studied a science *bagrut*, and if they did it was almost exclusively biology. The absence of such study does not preclude students from studying STEM subjects at tertiary level (university or college). It is worth noting that Israel highly values education, perhaps not in terms of investment, but certainly in social status. Almost half of all 25-64 years olds have tertiary education. The inadequacies of the school system are compensated for by intensive foundation programmes in all subjects for the first year or two of tertiary education. University and college students will often attend eight hours of lectures a day and then continue with private study.

My first questionnaire investigated the level of science that students had achieved in school, (see Table 6.2). A 4- or 5- point *bagrut* is about the level of a single science subject at GCSE in the UK. 11 of the university science class of 27 had one science *bagrut*, and 7 in the humanities stream. Results from the two classes I teach at a college of engineering were comparable.

Overall this showed, what I had anticipated, namely a low uptake of school science. And it should be stressed that for most students the option of taking science *bagrut* is not available in the majority of schools. This is not a case of students turning away from the sciences, but primarily not having the opportunity to study them at *bagrut* level.

My questionnaires at this stage were only given within the first week of the first semester at university or college so their exposure to science education was within their new institution of study was negligible. Would their lack of school science education affect their interest or their willingness to engage in science issues of social, economic or environmental importance?

Although it could be argued that many of these students had already declared an interest in STEM subjects by electing to study them at tertiary level, I did have one class of students studying humanities. For most of my research I would be looking only at the science and humanities streams at the University, and I would be looking for differences in the attitudes of these two groups towards topics relating to science literacy.

However, for the reconnaissance I included two classes from CE in order to be able to compare the University students and students at a general college level (not such an academically demanding environment, and more vocationally oriented).

By computing an Index of Issue Interest for my data I was able to compare my findings directly with published international data, (see Table 6.4). Taking an average across all my students their interest in sports news and politics was exactly comparable with a similar cohort in the European Union. Their level in new inventions and discoveries was somewhat higher than other industrialised nations, and their interest in new medical discoveries lower. Particularly interesting is the data from the humanities students; it showed a high level of interest in new inventions and technologies, higher than any of the comparable international data.

Here perhaps was evidence that interest in science and technology might be independent of science education.

The international measure of 'attentiveness' also produced an interesting comparison with my students (see Table 6.8). Taking an average of all my students the percentages showing 'attentiveness' and those who declared themselves 'very interested' are higher than any of the international assessments. Referring back to Table 5.5, it can be seen that humanities students show a great deal of 'attentiveness' in all fields of declared interest. They score especially highly on new medical discoveries and only slightly less than science students on new inventions and technologies. Attentiveness is an important measure because it indicates motivation to actively learn about a topic. And here the indication is that this quality is independent of school science education.

I had interspersed some questions investigating superstitious belief among some general questions on opinions (see section 6.5.5). This had been prompted by mention in the literature (Miller, 1983, 1987a) that superstitious belief was seen as the antithesis of scientific thinking. According to Table 6.9 about two thirds of each class thought consulting astrology was a bad idea. This left a third who either didn't know or thought it was a good idea. Furthermore, the students' comments made it clear that those who might be termed 'believers' in astrology, and therefore designated superstitious, often seemed to regard astrology as opening up another point of view during a decision making process. They were not bound to it as an ideology.

In a country full of religious beliefs, it would be hard to separate superstition from religious faith, and I am not convinced that it will distort scientific thinking on issues of social and communal importance. I did not make any further enquiries about student belief in the rest of my research, but continued to explain the role of evidentially based argument when discussing scientific issues.

The final part of the questionnaire showed that students were interested in many scientific issues. And the majority (in a ratio of almost 2:1) felt that public involvement was important in a decision relating to the construction of a nuclear power reactor.

The last part of my questionnaire included a question identifying specific scientific issues in which my students could declare an interest. I used the results of this question (see Table 6.10 and Fig. 6.1) to inform my selection of a topic that we focussed on at the University during the semester. The topic I chose was violence society. It showed

primacy of interest in both classes at the university (see Fig 6.1). It” offered the opportunity for lively classroom discussion and included a rhetorical analysis of a related text. The text was two pages from Steven Pinker’s *Blank Slate*, (it was used with the author's permission). I felt that by helping students to read more critically I would be giving them an essential tool in promoting the critical thinking that they needed to be active participants in activities requiring scientific literacy. I studied more systematically in the first intervention the impact of studying a specific topic had on student interest in that topic.

However, it didn’t take more than one lesson to discover that what students really enjoyed was the opportunity to put forward their opinions. Many spontaneously approached me at the end of the lesson and asked why we didn’t have more classroom discussion. But what had happened was not a ‘discussion’. I struggled to get one person to speak at the time – the cacophony of multiple speakers shouting each other down bothered them little; one student even pointed out that this is what went on in the *Knesset* (the Israeli parliament). We set some ground rules about the importance of hearing what someone else has to say. But what was clear, even when each opinion was given its own space to be clearly expressed, they didn’t listen to each other. There was no interest in anybody else’s opinion. Even when I worked hard to mediate the discussion the students resolutely refused to consider another viewpoint – it was almost as if they regarded negotiating a position as losing face. Discussion was pointless, it was no more than soapbox oratory.

In order to have a vibrant democracy there needs to be meaningful discussion. In my first intervention I developed a project that I hoped would shift my students’ into more thoughtful participants in discussion – an essential for anyone being labelled ‘scientifically literate’ within the context of civic scientific literacy.

#### 6.6.2 Moving forwards

As well as collecting lots of data something much more fundamental was happening within my classroom. As a teacher-researcher, I became more aware of teacher-student dynamics. I saw how my teaching style resulted in structured lessons and that some of the things that I had cared so deeply about when home educating my own children had not reached the classroom – namely, student autonomy.

My university students were all fluent English speakers and they relished the opportunities to express their point of view on any of the topics which emerged from the texts we were studying. But it was chaos. They loved expressing their opinion but they never listened carefully to what anyone else said, even if I managed to enforce the rule that only one person spoke at the time. This made me formulate an intervention within the framework of critical thinking that would specifically address this issue. The critical thinking ability I wanted to target with my intervention was ‘open-mindedness’- a key component of courses in critical thinking. In developing a project based on the principles of devil’s advocate, I felt that I might also be enhancing what are sometimes given as the fundamental attributes of people engaged in critical thinking:

Critical thinking ...should always be:

- fair and open-minded
- active and informed
- sceptical
- independent

(Butterworth and Thwaites 2013, p.9)

## Chapter Seven

### 2010: Further reconnaissance and piloting the intervention

#### Introduction

In this year of the cycle there are two main elements: I carry out a similar reconnaissance to 2009; and I develop, implement and monitor my intervention. This cycle of the research is only with the two top classes in the *mechina*, one in the humanities stream and one in the science stream.

The sections in this chapter:

7.1 Further reconnaissance. This includes changes in teaching style that resulted from class observations and feedback.

7.2 Development of the Intervention

7.3 Implementation and Monitoring of the Intervention.

7.4 Evaluation and Areas for Improvement.

#### 7.1 Further Reconnaissance

##### 7.1.1 Getting to know my students a little better

The essay title I had given in 2009, in which I asked the students to tell me something interesting about themselves, was not successful. Most students wrote that they thought there was nothing interesting. So in the following academic year, October 2010, I changed the question and asked for a few paragraphs on a book, person or event that had influenced them. Most wrote over a page. It was insightful and moving, and gave me a glimpse into what it means to be a young Jew, or Druze, in Israel today. Only three people labelled their work private, though the information everyone gave was very personal.

This approach gave me a rich body of information about my students and made me reflect on how intimidating the students had found my initial question in October 2009. In Appendix B I have typed an extract from all of the student essays, except the three marked private. They are typed ad verbatim with spelling and grammar mistakes intact. The sections omitted are generally lengthy descriptive passages. Many of their essays revealed a strong bond with their families, and with their ethnic group. Students used

the opportunity to identify a source of hope and courage to help them maximise their own potential. A few illustrative extracts from the samples are given below:

(The letter and number is the way the extracts are coded in the Appendix. The normal Times New Roman Font is my synopsis. The handwriting font is the student's own words.)

A2. Following her mother's recovery from cancer., she wrote: *I think it made me stronger...I became more mature and responsible. I can face every obstacle.*

A3. Reflecting on the inspiration of his cousin becoming the first Druze pilot, he wrote *Being a minority kid didn't affect him at all, unlike myself my cousin didn't let anyone bring him down, he always stayed focused on his target, not letting anyone stand in front of it.*

A4. An Ethiopian student reflected on a school counsellor *She was the one that helped me believe in my self.*

A5. An Ethiopian student explaining why he was inspired by the success of an Ethiopian runner: *he is from a poor country like Ethiopia he still find the time and the power to move on with his dream.*

A6. This student explained that he wanted to be a combat doctor because his brother lost his leg as a soldier. He added: *I come from a family of survivors and I strive for victory.*

A7. Writing about his hero, Franklin D. Roosevelt this student wrote: *"The only thing we have to fear is fear itself" – this goes to show that this was a man who feared nothing and I admire him for that.*

C11. Writing about a biography of Israeli politician David Levi: *I learned that if you want something in your life its only in your hands, if you really want something you should work hard – but in the end you will succeed...*

C12. With reference to an article on Martin Luther King: *every time I feel weak or disturbed I go back to the article to fill my soul with inspiration.*

Reading this collection gives a sense of the strong ethnic identity students have. This could affect many aspects of the class dynamic. Though not specifically the focus of my research, ethnicity might also affect learning style and the contributions made in class. It is essential to keep an alertness to the socio-cultural influences within my classroom and how these might impact on the students' class participation and learning experience.

### 7.1.2 Comparing 2009 and 2010 classes.

The classes I focussed on for the intervention were the two classes that I teach at in the *mechina* at the university. I chose these classes because these students already have an exemption from English having gained a high mark in reading, as tested by the psychometric exam. One class was on a science track and the other on the humanities. Both these classes always had a project as part of their semester programme in English. And in the academic year 2010-2011, the project that would be my intervention, was similar to the different types of projects I had implemented in previous years.

The 2010 classes were designated U hum (10) and U sci (10) to distinguish them from the classes of the previous year designated U hum (09) and U sci (09).

Having demonstrated the usefulness of the questionnaire I had developed for the 2009 class, I felt I should use it again and compare the results of the two groups (humanities and science) across the two years to assess whether there was any consistency. The 2010 classes were given the same questionnaire as I gave in 2009 and the analysis showing comparison with the classes of 2009 appears in the tables below. Table 7.1 shows that the mean ages of the class and the range of ages was comparable across the two years.

Table 7.2 shows that the number of students having one bagrut in science was small. Most students with a science bagrut have it in biology, and only two or three students in each class have more than one science bagrut (this can be seen by looking at the total number of different students with at least one bagrut and seeing how close it is to the total number of *bagruyot* registered for the whole of that class).

The low number of students in my classes with any high school science education, as indicated by their receipt of a bagrut, is typical of the experience of high school students throughout Israel. This is discussed in some detail in Chapter Two.

Table 7.1 Data and analysis: age and sex

Class	Class size	M	F	Averages of students' ages
U sci (09)	27	15	12	Average ages: Mean: 22 years      Range: 18-25      Median: 23
U hum (09)	34	18	16	Average ages: Mean: 23 years      Range: 21-25      Median: 23
U sci (10)	25	15	10	Average ages: Mean: 23 years      Range: 19-25      Median: 23
U hum (10)	27	20	7	Average ages: Mean: 23 years      Range: 21-24      Median: 23

Table 7.2 Assessment of school science education showing numbers taking 4- or 5-point *bagrut* in science subjects.

<b>Class</b>	<b>Class size</b>	<b>Biology no. of students</b>	<b>Physics no. of students</b>	<b>Chemistry no. of students</b>	<b>Total no. students with at least one science bagrut.</b>	<b>% of class with at least one science bagrut</b>
<b>U sci (09)</b>	27	<b>11</b>	<b>2</b>	<b>3</b>	<b>11</b>	<b>40</b>
<b>U hum (09)</b>	34	<b>5</b>	<b>1</b>	<b>2</b>	<b>7</b>	<b>21</b>
<b>U sci (10)</b>	25	<b>9</b>	<b>3</b>	<b>3</b>	<b>14</b>	<b>56</b>
<b>U hum (10)</b>	27	<b>3</b>	<b>3</b>	<b>3</b>	<b>8</b>	<b>30</b>

I calculated the Index of Interest for the two classes (Table 7.3) and compared it to the data for 2009. Using this Index solves the problem of how to get a single figure when the question provides trichotomous answers: very interested; moderately interested; and not at all interested. The first answer is scored 100, the second 50, and the third zero. The mean score is obtained by adding them and dividing them by the number of students. This method is used internationally and allows direct comparison with international data.

I also calculated the percentage who were ‘very interested’ (**I**) and the percentage that could be identified as attentive (**A**), shown in table 6.4. These figures are then compared to those recorded internationally (Table 7.5).

Table 7.3. Mean Scores on the Index of Issue Interest for my classes for 2009 and 2010.

<b>Issue area</b>	<b>U sci (09)</b>	<b>U hum (09)</b>	<b>U sci (10)</b>	<b>U hum (10)</b>
New scientific discoveries or inventions	83	69	90	71
New medical discoveries	76	56	76	56
Politics	52	74	50	70
Sports news	37	49	26	44

The values for the humanities classes for the two years are almost a complete match for each issue area. The same is true for the Index of Interest for medical discoveries and politics. The interest in science and technology is higher (90 compared to 84) but both are well above the figures given for groups in other nations (see Table 6.4). The

closeness of values when comparing classes from 2009 and 2010 helps give further confidence in the reliability of the questionnaire.

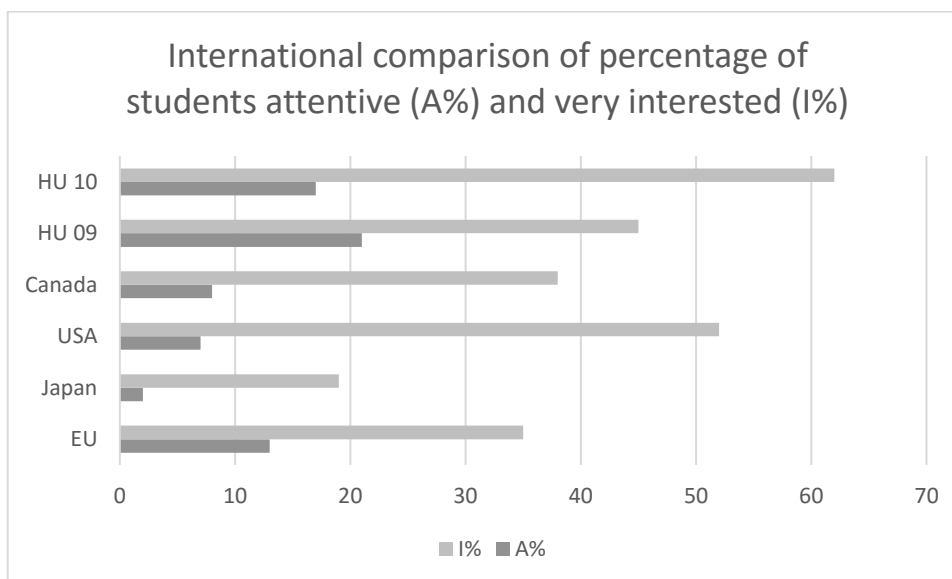
Table 7.4 Percentage of attentive (**A**) and very interested (**I**) in science and technology in each class.

Subject	U sci (09)		U hum(09)		U sci(10)		U hum (10)	
	A%	I%	A%	I%	A%	I%	A%	I%
Science and technology	26	74	21	44	20	80	15	48

The values in Table 7.4 between the two years are comparable, although the attentiveness values were a little lower and the numbers of those who were very interested were up a little. The numbers are close enough to show the similarities in the student body from year to year, within a subject track. From the two classes for 2010 I calculated a single figure and listed it on the table of national data (see Table 7.5). The values of **A%** and **I%** put my students at the top of the international table.

Table 7.5 Percentages of 18-29 year olds who are attentive (**A**), and those who are very interested (**I**) in scientific and technological discoveries. The data are shown in both the form of a table and a bar chart (below).

Location	Attentiveness ( <b>A</b> )%	Very interested ( <b>I</b> )%
European Union	13	35
Japan	2	19
United States of America	7	52
Canada	8	38
My students in Israel, 2009 (N=61)	21	45
My students in Israel, 2010 (N=62)	17	62



I have argued strongly against the value of standard scientific literacy tests because they adopt the deficit model and are based exclusively on knowledge. I have adopted a different approach in defining scientific literacy. However, I did give the standard test to my students. The fact that I do compare my data to that of other countries does not represent any shift away from interpretivist position. I am aware that even the questions given in this, so-called, standardised test fail to acknowledge socio-cultural differences between the different countries using this method for evaluation of scientific literacy. However, if my students fared well (which was not to be expected considering their negligible school science education) it would challenge the value given to these tests. It would add to the argument that perhaps science education and scientific literacy should be decoupled, and it would help throw doubt on the value of these tests as a measure of the success of school science education in promoting scientific literacy (even when a deficit model is being employed).

Below in Table 7.6 are the standard questions given to test scientific literacy.

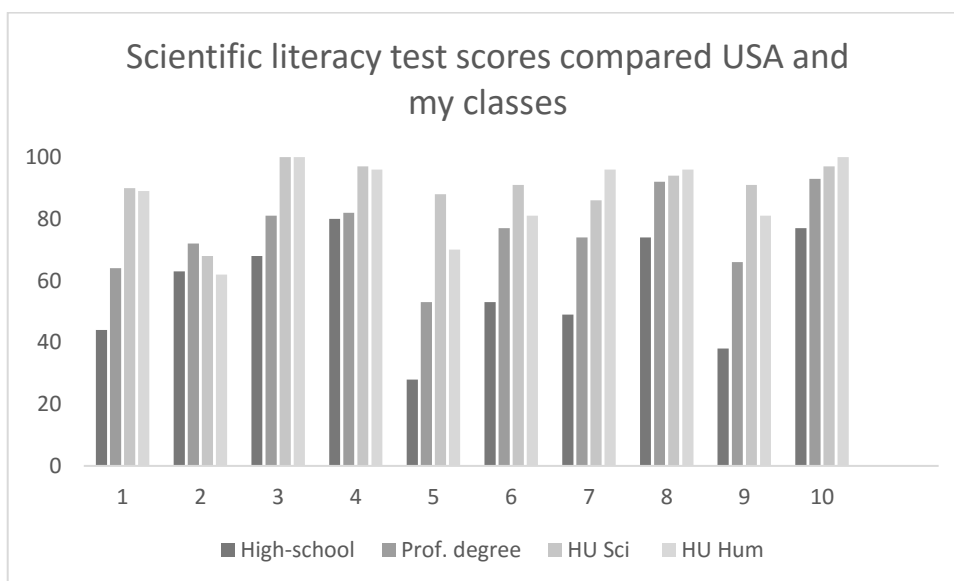
Table 7.6 Scientific literacy knowledge test.

<p><b>A. Please read the following statements and circle if they are true or false.</b></p> <ol style="list-style-type: none"> <li>1. Lasers work by focusing sound waves. <b>true / false</b></li> <li>2. It is the father's genes that decide whether a baby is a boy or a girl. <b>true / false</b></li> <li>3. All radioactivity is man-made. <b>true / false</b></li> <li>4. The center of the Earth is very hot. <b>true / false</b></li> <li>5. The universe began with a huge explosion. <b>true / false</b></li> <li>6. Antibiotics kill viruses as well as bacteria. <b>true / false</b></li> <li>7. Electrons are smaller than atoms. <b>true / false</b></li> <li>8. The Earth goes round the Sun. <b>true / false</b></li> <li>9. Human beings developed from earlier species of animals. <b>true / false</b></li> <li>10. The continents have been moving their location for millions of years and will continue. <b>true / false</b></li> </ol>
--

I calculated the percentage of correct responses for each question and have added them beneath the US data for 2006 (Table 7.7). The US data was prepared by the University of Chicago National Opinion Research Center (National Science Board 2008, pp.7-6) The questions are not given in the table in the same order as in my literacy test. In table 7.7 the number of the question appears along the top row of the table. The numbers correspond to the number of my question.

Table 7.7 Comparison between the scientific literacy test scores in the US and in my 2010 classes (and chart below)

Question number	4	3	1	7	5	10	8	2	6	9
High school grad.	80	68	44	49	28	77	74	63	53	38
Professional degree	82	81	64	74	53	93	92	72	77	66
U sci (10)	97	100	90	86	88	97	94	68	91	91
U hum (10)	96	100	89	96	70	100	96	62	81	81



The results of my students are higher than those of the groups listed for the US. (I chose the US groups with the highest scores). The only scores that are comparable with US students (with a professional degree) are for question 2 (It is the father's genes that decide whether a baby is a boy or a girl). Since biology is the most widely taught science in school it is perhaps surprising that so many of my students got this basic question wrong. Among my students who got question 5 and question 9 wrong, one

Muslim and two Jewish students wrote the unsolicited comment that they were religious.

### 7.1.3 Comparison of my students with international data: Conclusions

The overall positive results from the students I tested with regard to knowledge and interest in science were independent of the fact that they had little science education. Even those students who were planning to study in the humanities produced impressive figures in all the areas I investigated. These figures have to be seen as supporting the idea that scientific literacy in its derived meaning is independent of school science education.

The question must be asked: what is responsible for these results? The answer is perhaps indicated in one item of data collected in a survey done in Israel in 2006 (Yaar, 2006). Quoted in 'Science and Engineering Indicators 2014', (2014, pp.7-35), the survey shows: "In 2006, the majority of Israelis said they would be pleased if their children became scientists (77%), engineers (78%), or physicians (78%)." These were the top ranked jobs in Israel (Yaar, 2006). There was little international data to compare this with although it was noted that in a survey in Korea in 2010 "overall, 24% said they would "strongly support" their children in pursuing an S&E (science and engineering) career". Furthermore, there is "nearly a total consensus (96%) about the importance of maintaining a high level of S&T in Israel. This consensus is related to the common belief that the advancement of S&T (science and technology) is vital for Israel's economic development (94%), needs of security (90%) and quality of life (90%)." (Yaar 2006). All this data indicates that the information collected from my students probably reflects the overall cultural standing of science and technology in Israel, as opposed to educational input.

### 7.1.4 Does studying science impact on interest?

Scientific curricula worldwide have undergone many changes in order to promote scientific literacy. However, the overall impact on student interest is not investigated. Having shown that measurement of interest levels is consistent across cohorts in two separate years, I feel there is value in looking at what happens after a semester of intensive science education in a university programme.

The students in the U sci class experience a rich input of science during the first semester, studying physics, chemistry and biology. Also in the English programme most of the texts studied relate to SSI. There were specifically texts relating to issue 2 (violence in society), 4 (risks of using cell phones), and 5 (animal welfare issues). There was extensive classroom discussion on each of these issues and at least one lesson was dedicated to the subject.

During my intervention many of the students work closely on a scientific issue.

The question I wanted to answer is whether engaging with these issues effects their interest in them in particular. And more generally, I wondered if there declared interest in specific issues was stable, or perhaps just a whim of the moment.

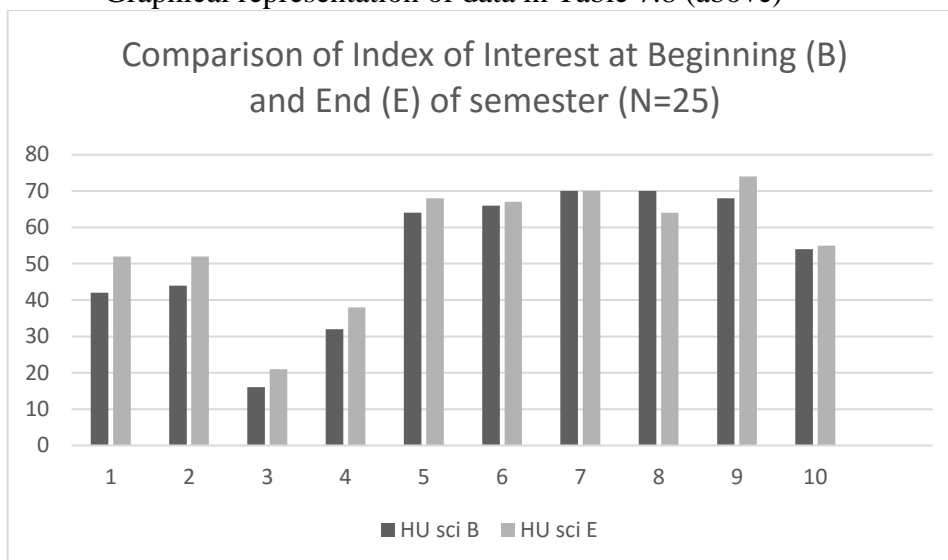
Furthermore, all these students had intense programs of study in science subjects (usually for the first time in their educational experience). Did studying science have an impact on their overall interest in SSIs? If there was any major shift in interest in SSIs it would be difficult to ascertain the precise reasons for such a shift. The absence of any change would in fact be more interesting and easier to comment on.

To assess any change in their interest in SSIs I gave them same table of issues (see table 7.11) at the beginning (**B**) and end (**E**) of the semester and calculated the Index of Issue Interest. The chart below the table shows the results.

Table 7.8 Comparison of Index of Issue Interest at beginning (**B**) and end (**E**) of first semester 2010, and also compared with 2009 (same information shown graphically below)

Issues	U sci (09) N=27	U sci (10) <b>B</b> <b>N=25</b>	U sci (10) <b>E</b> <b>N=25</b>
1. Alternative therapies are useful/useless	65	42	52
2. Causes of violence in society.	67	44	52
3. Graphology and astrology are useful/useless	26	16	21
4. Cell phones are dangerous.	24	32	38
5. Animal welfare issues.	60	64	68
6. Pollution problems worldwide.	67	66	67
7. Global warming is/is not a serious problem.	69	70	70
8. Genetically modified food is/isn't dangerous.	63	70	64
9. Nuclear power is/isn't dangerous	57	68	74
10. Fluoridation of water is/isn't a good idea.	59	54	55

Graphical representation of data in Table 7.8 (above)



It should be noted that in a class of 25 a student changing from ‘Not at all interested’ to ‘Very interested’ produces a shift of (100/25) points in the mean score i.e. an increase of 4 points. The chart shows that there is no dramatic shift overall in interest between the beginning and the end of the semester in any issue. There are a few issues where more than two students or more had to shift from “not at all interested” to “very interested”, notably issue number 1 and number 2.

The overall picture is of little change and this consistency is interesting for two reasons. Firstly, students show that they decide in a reliable way what interests them, and secondly, their opinion of what interests them is not easily changed, in a positive or a negative way, even after a subject has been the focus of teaching. It might be that a single semester’s exposure is insufficient to impact on these points of view held by students. But that in itself is interesting because it indicates that these students have developed their interest in specific SSI over a long period of time. Socio-political influences and media coverage, might be influential factors in making some issues of more current interest than others.

#### 7.1.5 Changing teaching style.

This section looks at how I developed a different teaching style which impacted directly on the way I implemented my intervention in 2010, and then in 2011.

The standard method of teaching in the Department of Pre-Academic Studies is text based. Each teacher has complete freedom to choose whatever texts we want to use. There is a book of texts available, or we can each assemble our own. There is a university book of texts for Level 1 (top level) students in the humanities, and a separate one for Level 1 (top level) students in the sciences. I use the published books of texts, and supplement them with other material that I feel will interest the students. All students are required to purchase a copy of the book of texts and bring it to each lesson. The usual pattern of teaching adopted by the majority of teachers of EFL reading programmes in the University is to take a text, discuss what it is about in general terms, and use it to teach particular reading strategies. The students are then given a question page and expected to quietly complete it during class time. The students are always carrying a great burden of homework from all the other subjects they study so most of us try to keep homework to a minimum.

I primarily work with classes of high-level students; this makes classes lively because they have the skills to contribute to class discussions. While all classes at all levels at the University encourage class discussions much of the class work is done by students working individually. This is standard practice among my colleagues. There are good practical reasons for this:

- Teachers always complain that students do not have good class discipline and it can be hard work to keep students focussed and prevent endless, random social exchanges between students in the classroom. This problem begins in school where teachers often describe their job as “riot control” (quote from a friend teaching in my son’s high school.) There is a feeling that it will be hard, if not impossible, to keep students focussed if the class is fragmented into a dozen or more separate pairs or groups.
- The classrooms we teach in at the university are often packed beyond capacity. This leaves little physical space for arranging groups. Furthermore, the groups would be so close to each other that the level of competitive noise would escalate rapidly.

However, I felt forced one day to try pair/small group work in rather unusual circumstances. The experience and the student feedback triggered an investigation into

the research literature on working in pairs, and resulted in a change in my teaching style.

I would like to relate how it happened: One day in a cramped, stifling classroom in the University (temperatures over 90° F, with no air-conditioning) I realised we were achieving little so I suggested that the students organise themselves in pairs or small groups and took the work outside. This was the first time I had even suggested co-operative work. I gave them a question page that related to a text we had already discussed in class, and they left with the text and question sheet. I told them I wanted them back in twenty minutes. I remained in the classroom available to anyone who wanted to come back in and talk to me about any aspect of the assignment. Twenty minutes later they returned and gave me their worksheets. Partly because they came back in dribs and drabs, resettling them took some time, but eventually we were able to carry on for a short while before the end of the lesson. A couple of students approached me afterwards and said how much they enjoyed working together. My immediate comment was that I couldn't keep sending them outside to work! These students suggested that I could push my desk into a corner, and we could rearrange the chairs so that they could get some space to work inside in pairs or in a small group. And that made me think about whether this was in fact a possibility.

They had each done their own worksheet and when I went through them in the evening the work was well done. And it made me think more about this as a method of teaching. I read some of the literature on the subject and decided to get feedback from the students themselves at the next lesson.

There is a body of literature about working cooperatively in pairs “regardless of the discipline or level of instruction” (Garfield, 1993). And there is evidence that students working in pairs or small groups can benefit in several different ways. It appears that some students actually assume a ‘teaching role’ when they understand the material better than the other students, and that in this role they not only help other students but also get better understanding themselves. Johnson et al. (1991, 36) state that “The likelihood of success is perceived as greater, and success is viewed as more important in cooperative than in competitive or individualistic learning situations”; this is supported by their own research (Johnson and Johnson 1989). An interesting overview of cooperative learning is given by McKeachie et al. (1986).

I had envisaged that it might be a problem if a strong student and a weak student were partnered. I supposed that the stronger student might do all the work. But there is also a problem if two weak students partner each other because they would be of less help to each other. Research has found (Cumming 1983) that it is preferable to have mixed ability groups rather than groups which are more homogeneous. Although some of this research relates to the teaching of statistics it was noted that co-operative learning is desirable because “College courses in statistics involve concept learning, problem solving, and the development of higher level thinking skills” (Keeler and Steinhorst, 1995); there is a commonality here with the teaching of higher level reading/critical thinking skills and HOCS (higher order cognitive skills) in general.

I gathered the feedback next lesson by using the method I have called the *petek*. I gave each of the students a blank half-page of A4 paper (each time I did this I chose a different colour for the paper, because it made it easy for me to separate them from other work I collected in during the lesson – all on white paper. It also marked the activity as something different from the general work related to the course. It seemed more fun to be writing on yellow or lilac coloured paper). The question I posed was: “Normally I ask you to work by yourselves. What do you think about the last lesson when you worked with a partner or in a small group?” I told them I wanted any feedback, positive or negative. The question alone was written on the board. Their comments were totally anonymous. The value of using open questions is clear. Cohen et al. (2010, p.330) explain that an open-ended question can “catch the authenticity, richness, depth of response, honesty and candour which ...are the hallmarks of qualitative data.” However, they also note that “open-ended also carries problems of data handling.” I used content analyses to categorise the responses received. I have read and reread the responses, and have identified useful, umbrella categories. I have not forced all responses into the categorisation; the authentic, individual voice can be of great importance. It is time-consuming to do this sort of analysis rather than to use rating scales (the problems with rating scales is described in Chapter Four under Methods) but this method gave me more insight than a rating scale.

For this class (U hum 2010) I categorised the replies into three groups, and have given the number of responses in each group:

**Group A positive (no details): 13**

(The comments in group A contained a single positive word e.g. “splendid”, “good”, “productive”. There were no additional comments.)

**Group B positive plus (these comments were positive but also identified the importance of cooperative learning): 10**

(The comments in group B revealed a cooperative learning experience e.g. “it helped to see things in a different way”; “opens the mind and allows new ideas to come up”; “we can talk about things more deeply”; “we learn a lot from each other”)

**Group C ambivalent: 9**

(These comments in group C were ambivalent e.g. “sometimes good, sometimes it is not”: “it depends on the students”; “it depends on the partner”; “it is nice, although people are not concentrated afterwards”; “I believe studying in a group will help my understanding but I prefer studying alone”).

There were no totally negative comments. There was one comment totally off the point. (The student wrote: “The article was mind-opening...”).

And there was one comment that I have not categorised. This was the only student who focussed on the fact they were outside, but the comment has wider application and is thought-provoking. I quote it here in full: “Doing work outside showed you have confidence in us, making us want to do the best job we can.” This prompted me to reflect on the issues of trust within the student-teacher dynamic. Promoting student autonomy is a demonstration of teacher trust in empowering students to have greater control over their own learning. There is increasing evidence (see Section 1.1.2, p.4) that student control over their learning is associated with high levels of motivation.

I was surprised by the number of students (10) who referred to the benefits of cooperative learning - a totally unsolicited idea. I had expected nothing much more than comments like “it was a good idea”, or “I didn’t like it”. The fact there were no totally negative comments was also encouraging.

On the strength of this I decided to introduce more pair/small group work both in class and for homework assignments. In class, my desk was shoved up against the wall and chairs were moved around; huddles of students were created, and, with a few reminders,

they spoke quietly! I always asked if they wanted to work on an assignment in pairs and gave the option for anyone to work alone; almost everyone worked in pairs or in a group of three or four. I have extended this practice to all the classes I teach in different institutions with excellent results. I can't demonstrate that they got better grades; most of my classes are pass/fail courses and my students almost always pass. The main point was that they generally expressed real willingness to work hard in class in a focussed way, and enjoyed the process. The class environment created is always one of engaged students, even at 6pm in the evening after a day that begins at 8.30a.m.

I decided that the intervention project would not be, as I had planned, worked on individually, instead the students would be given the option to work in pairs. This was the format for 2010 and for 2011.

The experiences described in this section illustrate the way observation of student activity and opinion can influence a teacher-researcher and help improve the learning experience of students. The combination of observation, accessing student opinion, and literature research, became an integral part of my teaching practice.

## **7.2 Designing the intervention**

The final design of the 2010 design could only be done at this stage, when I could reflect on the conclusions of the reconnaissance of 2009 and the other investigations carried out early in the 2010 semester. To select my approach, I need to reflect on the three general ways that scientific literacy can be improved, namely:

**A. Improving fundamental literacy skills.**

**B. Teaching nature of science.**

**C. Decision-making.**

Each of these approaches is discussed in detail below.

### **A. Improving fundamental literacy skills.**

There is for all readers, L1 or L2, the need to be able to distinguish between reliable and unreliable information. This presents a particular challenge when much of the information comes from the media, both written and spoken. In order to be media literate, Hodson (2011, p.51) states that we need to "understand that those skilled in producing printed, graphic and spoken media use particular vocabulary, grammar,

syntax, metaphor and referencing to capture our attention, trigger our emotions, persuade us of a point of view and, on occasions, by-pass our critical faculties altogether". He continues

Overall, research paints a pretty depressing picture of the ability of students, at both school and university level, to read media reports with the kind of understanding encapsulated in the notion of critical scientific literacy. (Hodson 2011, p.51)

For example, research with Canadian university students (English speakers) by Norris et al (2003) showed them unable to interpret meaning in media reports, i.e. popular non-academic texts. Important issues in the teaching of literacy (namely, basic reading skills) are raised by this and other work in the field. However, the methods I employ in the academic reading courses I teach do attempt to address many of the issues raised by Norris et al. (2003). My students are helped to develop the following skills: understanding inference; interactively questioning the text throughout the reading; evaluating relative levels of certainty expressed by the writer; contextualising text socially and politically; identifying vocabulary and rhetorical devices that are affective and impact emotionally on the reader. However, improving fundamental literacy is not a focus of my intervention.

## **B. Teaching nature of science.**

The traditional commitment to increasing the scientific knowledge input in school science teaching has been eroded in recent years. Reformers of science education agree that "less emphasis should be placed on teaching isolated scientific facts and concepts and more emphasis placed on broad, overarching themes, including scientific inquiry and the nature of science." (Bell and Lederman 2003). The desirability for the public to have an understanding of the "characteristics of scientific knowledge and the way it is constructed" is regarded as the essence of the 'nature of science' (Bell and Lederman 2003). Driver et al. (1996, p.18) argue that instruction in the nature of science is essential: "The democratic argument for promoting public understanding of science focuses on the understanding needed to participate in the debates surrounding [science and technology] issues and in the decision-making process itself" However, I feel the question remains: is it knowledge or thinking skills that lie at the heart of what is needed for a democratic citizenry to engage in SSI debates?

A fascinating study by Bell and Lederman (2003) looked at SSI (socio-scientific issues) decisions made by university professors from both science and humanities faculties. The study showed that when the respondents from both faculties used 'nature of science' factors in making their decisions, those factors consisted only of "superficial references to evidence". Bell and Lederman (2003) also noted that "developing better decision-making skills – even on science and technology based issues - may involve other factors" such as personal values, morals/ethics and social concerns. Decisions on SSI are not and should not be exclusively decided by consideration of scientific data – there are socio-economic, political and personal factors to take into account. High order cognitive skills (HOCS) are needed to synthesis all these factors when making a decision.

### **C. Decision-making.**

Irrespective of the definition of scientific literacy its ultimate goal is: "to improve citizens' ability to make reasoned decisions in a world increasingly impacted by the processes and products of science" (Bell and Lederman, 2002).

However, we need to acknowledge that the general population have little opportunity to make an essential contribution to most major decisions made by governments or large corporations. And even where the voice of the public might have some influence, the debate is often polarised so that a range of opinions goes unheard. Furthermore, the issues that reach the public arena are pre-determined by those vested with power and authority. But this does not diminish the imperative to encourage the wider public to assume a role of influence – in fact, it makes it even more important. There are ways for the individual to gain leverage by joining a collective of similar minded individuals, for example, by joining specific interest groups such as rights groups or environmental lobbyists.

It is perhaps the internet that will offer greater opportunities for the democratisation of decision-making and the increasing use of the internet platform [www.change.org](http://www.change.org) shows one way concerns of individuals can gain a voice by petitioning online. It is also conceivable that the Swiss model of referenda on topics initiated by members of the public could gain wider application through the use of the internet. In many ways, we stand at the threshold of increased public empowerment with the aid of internet tools.

However, even if the general public is at present muted by the existing power structures, there are decisions to be made at a more personal level which are related to socioscientific issues. Furthermore, as detailed in Chapter Three section 3.8, the study of SSIs brings many benefits to students including increasing social awareness and empathy, and developing the skills associated with decision-making and debate. Much of the decision-making relating to SSI has been identified as being based on informal reasoning because of the complexity of the issues (Wu and Tsai, 2007). However, research has shown that people often failed to integrate scientific evidence into their decision-making process relating to SSI that directly affected their lives (Sadler, 2004; Tytler et al. 2001). I have noticed something similar with my own students. They were given a text to read and then asked to write their opinion on the subject. Hardly any students drew on any of the evidence/information contained in the text. Their opinion existed independently and unaffected by what they had read – there seems to be no ‘natural’ process of synthesis. It is a learned skill.

At a more fundamental level, I have found myself dealing with a more basic problem related to decision-making within the classroom, namely: the failure of students to allow that there might be opinions other than the ones they so tenaciously express. This is not exclusively an Israeli problem. In a study done by Phillips and Norris (1999), they looked at the stance students took on various topics before and after reading popular science reports. They noted that “students expressed definite views, but rarely considered there might be alternative viewpoints”.

High-level decision-making requires an ability not only to understand a counter-argument but also to construct a rebuttal to confirm the validity of one’s own position (Kuhn, 1993). But preceding the development of counter-arguments and rebuttals there must be the recognition that a meaningful counter-argument exists.

### **7.3. Implementation and Monitoring of the Intervention**

#### **7.3.1 The Intervention**

The main objective of my intervention was to use a method of ‘active learning’ to encourage students to recognise that counter-arguments exist, and can be evidentially based. To put this objective another way: my intervention had the more general aim to

move my students towards hearing the voice of the other and acknowledging its validity. An essential and fundamental step in the decision-making process. In designing the intervention, I was influenced by reforms in STES (science-technology-environment-society) education where there is a paradigm shift from “disciplinary knowledge (LOCS) {low-order cognitive skills} to interdisciplinary evaluative, system thinking (HOCS) {high-order cognitive skills}” (Zoller and Scholz 2004).

The paradigm shift required by these programmes involves totally redesigning courses both for content and approach. The evaluation of attempts to do this (Nahum et al, 2010, and Zoller& Scholz, 2004) suggest that “long-term persistence in teaching for “HOCS learning” and transfer does have the potential to develop “competent and responsible decision-makers, problem-solvers, professionals and citizens.” This approach was not something I could consider embarking upon.

I am interested in looking at whether I can introduce one simple intervention over two or three lessons which can make my students more reflective about their own thinking in the context of formulating an opinion. A modest, but important objective.

By making the intervention part of the term’s project I would encounter no objection from the university authorities. I always had complete freedom over the project I introduced.

The students were arranged in pairs (see sections 7.4 and 7.6.1).

They were asked to choose an issue that they held an opinion on. They were encouraged to choose an SSI, but could suggest anything that interested them. Both members of the pair could hold the same opinion or have opposite opinions. They had to write a statement of the issue, and also each had to write their opinion with a simple explanation of why they held that position. This page was to be put in my box before the following lesson.

Lots of them came to discuss their choice of issue with me. I hadn’t given examples because I didn’t want to influence them. I didn’t mind if a few felt a bit lost and came to talk to me. There were, of course, ‘issues’ listed in the questionnaire given on the first day of the semester, but these had long since been forgotten. Students often came to me full of enthusiasm for what interested them; sometimes they could find important ‘issues’ associated with those subjects and sometimes they couldn’t. Defining an issue

clearly, and writing their opinion in simple terms with a sentence of explanation, was part of the project.

I gave the pages, with comments (mainly explained corrections) back to them in class and then asked them to write the counter opinion – the ‘con’ to their ‘pro’, or ‘pro’ to their ‘con’. I walked round the class and checked they had expressed themselves clearly and simply.

In all the higher level classes, the teachers use one lesson to introduce students to the library databases, especially the Web of Science, and show the students how to use them. This is done in a computer lab. I gave my students this introductory lesson. The next stage of the project was to use the Web of Science database and find one or two academic articles that supported the ‘con’ position. I knew that for some issues this would be difficult and made it clear that if they wanted to change the issue they were exploring they could. Once they found an article they copy-pasted the reference and the abstract on to the page and handed it in.

In order to evaluate the impact of my intervention it was introduced without any mention of the objectives I hoped it would achieve, namely recognising the status and validity of counter-arguments.

I was sure from my experience earlier in the semester (see section 6.4) that I wanted the students to work in pairs. I was worried that if I asked them to organise themselves in pairs certain individuals would be left out. And although I didn’t have any Arab students in these classes this is really uncommon. The absence of Arabs, Ethiopians and other minorities has been explained in Chapter Two (in the section about my students) as due to the exceptionally high level of the University classes I teach, with some of the students native speakers of English. I wanted a system that would avoid any possible difficulties and so I introduced a method of allocating pairs by lottery. I wrote two sets of numbers from 1 to 11, for a class of twenty-two students. (For an odd number of students one number was written as a triple.) The numbers were mixed in a bag and distributed among the students. I called out each number and took the names of the students with the same number.

I explained that in the workplace we often find ourselves working with people we don’t know. On the whole it was a reasonably successful arrangement except that it threw

together a male student, who turned out to be problematic, with a rather withdrawn female. She came to me in tears one day because he had pushed her over when he had become irritated with her. I took the matter to one of the fulltime counsellors we have in our department. She spoke to him and he did apologise to the student he had pushed. He continued to come my classes but later in the semester he voluntarily decided to leave the *mechina*. I spoke to the counsellor, to check that his experience in my class was not the cause. She said it had been his own decision because he had decided not to continue to a university degree course.

It was an awful experience. He came to me after the assault on the student and explained that he should never work with anyone because he loses his temper easily. I met him three years later working as a security guard at a museum in Israel. He came up to me in a friendly way and told me he was completing his degree through the Open University where he could work in complete isolation.

I realised that I hadn't made it clear enough that any student could work alone if they wanted to. Furthermore, in my next round of the intervention (2011) I would allow students to choose whom they partnered, and see how that worked out.

This event made me keenly aware of how sensitive I must be as a teacher, and researcher, to ensure that none of my course content and associated activities might cause any discomfort or psychological harm to any of my students.

It is worth noting that in other lower-level classes that I teach there are substantial numbers of ethnic minorities (about quarter of the class in many cases), mainly a mixture of Christian and Muslim Arabs. They usually partner by faith. I now realise that it was misguided for me to think I could successfully socially engineer a class. Handing out random partnering is not a respectful way to relate to the sensibilities of my students.

### 7.3.2 Feedback, analysis using an open-ended questionnaire

The students were given a series of open-ended questions to get feedback at the end of the semester. There are prompts written under the questions to try to illicit as much information as possible. Table 6.9 shows the three main questions: A, B, C, which are discussed below. Please note that under each question I numbered the lines given for

writing answers (1, 2, 3, 4) in order to encourage the students to give more than a single answer.

Table 7.9 Open-ended questions about the project/intervention.

- A.** Why do you think you were asked to do the project?  
(List as many reasons as you can think of)
- B. Positive reactions**  
(Include: what you enjoyed about doing it; what you learned; how it might help you in the future etc.)
- C. Negative reactions**  
(Include: anything you didn't enjoy; how it failed etc.)
- D.** Do you think everyone should present their project in class?  
**Yes / No (please circle) and explain your reason below:**
- 

#### Analysis of Data on Question A

The students did write fully and the problem has been how to do content analysis on their comments. I have forms from U hum (20 students) and U sci (27 students) and initially dealt with the two classes separately. Reading and rereading the student replies produced some clear categories, which received a code letter that could be written by each response on the questionnaires.

I analysed the responses for each question separately. For question A I placed a category for the reason given on each response.

In table 7.10 the code letter, category and examples are given for the questionnaires from U hum.

Table 7.10. The code letter, category and examples from U hum for question A.

CODE	CATEGORY	EXAMPLES
<b>R</b>	To improve research skills	"to learn how to use database" "to learn how to find articles"
<b>T</b>	To improve thinking skills	"to develop new thinking method" "to expand my views" "to improve our way of thinking"
<b>C</b>	To check on English skills	"to check level of writing" "to examine our ability to understand/read"
<b>G</b>	To give a grade	"to grade us creatively"
<b>E</b>	To improve English skills	"to improve..." reading/writing in English.
<b>TW</b>	To encourage teamwork	Stated explicitly
<b>GK</b>	To improve general knowledge	Stated explicitly
<b>V</b>	Vague	"to help us in our degree"

I carried out the same process for U sci and the categories are shown for that class. U sci produced the same categories as U hum with the addition of one extra category ‘to study something interesting’. The results are given in table 7.11.

Table 7.11. The code letter, category and examples from U sci for question A.

<b>CODE</b>	<b>CATEGORY</b>	<b>EXAMPLES</b>
<b>R</b>	To improve research skills	“to practise gathering resources” “to practice digging up the right articles that we can refer to” “to learn how to use sources of information”
<b>T</b>	To improve thinking skills	“to think ‘out of the box’” “to use our heads in an unconventional way” “to practise an ability to give argument for something we don’t necessarily believe in” “to make us ask questions about ‘facts’” “to experience a ‘mental’ academic debate”
<b>C</b>	To check on English skills	“to examine my capabilities in writing”
<b>G</b>	To give a grade	
<b>E</b>	To improve English skills	“to improve...” reading/writing in English.
<b>TW</b>	To encourage teamwork	“to experience co-working”
<b>GK</b>	To improve general knowledge	Stated explicitly
<b>V</b>	Vague or uncertain meaning	“to prepare us for uni” ‘A chance to interest with English articles’
<b>S</b>	To study something interesting	“to study something we find interesting”.

I have tabulated the categories and given the number of statements (T) made in each category and also the number of people (N) in each category. In some cases, the same person makes two or more separate statements that fall under the same category (this will be shown under the column for number of statements) but they will only be counted once in the number of people column for each different category of statement they make. This has been done for U hum and U sci (see table 7.12A)

Table 7.12A. Content analysis for the responses from U hum and U sci for Q.A (the purpose of the project)

<b>CODE</b>	U hum total (T)	U sci total (T)	U hum (N) No. of people	U sci (N) No. of people
<b>R</b>	15	25	12	23
<b>T</b>	8	10	6	10
<b>C</b>	7	1	5	1
<b>G</b>	2	0	2	0
<b>E</b>	8	13	8	13
<b>TW</b>	2	1	2	1
<b>GK</b>	1	4	1	4
<b>V</b>	1	2	1	2
<b>S</b>	0	4	0	4

There are several comments I would like to make about table 7.12A. It is really surprising that anyone thought this was to do with grading as my students are told repeatedly that my grade does not depend on their work, they only have to show commitment to get 100% from me. I also find it rather worrying that so many in the humanities class thought I was “checking their writing” when it is made clear that the course is not designed to teach writing in English. The only thing we did was to look at how to write simple statements defining an issue, and expressing a pro or a con position on an issue. This was done both in class and individually with students.

For greater clarity, I have extracted the top three categories from Table 7.12A. and tabulated them below as percentages in Table 7.12B.

Table 7.12B. Extracted from Table 7.12A and given as percentages.

<b>CODE</b>	U hum (N)	U sci (N)	U hum %	U sci %
<b>R</b> (improve research skills)	12	23	44	85
<b>T</b> (improve thinking skills)	6	10	22	40
<b>E</b> (improve English skills)	8	13	30	52

### Evaluation of Findings on Question A.

A large number of the students in both classes thought of this as a research project with many sure that it was about developing skills in using the Web of Science Database. This is something I wanted to shift away from. Many of them needed help in using the database and some came to me in despair during the semester needing one-on-one time to locate suitable articles. Some students changed the topic of the project because they couldn't find academic articles relating to it. This research could be seen as a valuable part of the process but many found it very time-consuming to use the database to find relevant articles, and this was the main complaint that I got about the project.

It became clear to me that it was actually more important for them to access material that is more readily available on the internet. This would also be quicker and more like a real world scenario experienced by the majority of people accessing information. This would be a major change in the intervention in 2011. I also hoped this would shift the emphasis away from seeing this purely as an exercise in working with the database. By insisting on using only the Web of Science I was still pursuing a university agenda rather than liberating my students to access information more widely.

It was encouraging to have around a third in each class explicitly homing in on the idea that their method of thinking was being challenged. No mention, even obliquely, of 'thinking' had ever been made in class with reference to the project. They are only given a few simple instructions about what they have to do. It is interesting that without any prompting they perceive that their usual ways of thinking are being challenged and, as can be seen from the examples given in Tables 7.10 and 7.11, they often find rather lively ways of expressing this.

### Analysis of question B. Positive reactions.

I carried out a similar content analysis for their answers to question B (positive reactions). The code, categories and examples are given below for U hum in Table 7.13 and for U sci in Table 7.14

Table 7.13. Codes, categories and examples for positive responses for U hum for Q. B

<b>CODE</b>	<b>CATEGORY</b>	<b>EXAMPLES</b>
<b>A</b>	Autonomous activity. Specifically mentions the freedom of choice of subject.	"I liked looking into a subject that interests me"
<b>R</b>	Specifically mentions enjoying the research.	"I liked the challenge of looking for the most appropriate article.
<b>P</b>	General positive comment.	"I enjoyed the project"
<b>O</b>	Specifically mentions enjoying forming counterarguments.	"Helped me work with people I disagree with." "Fun exercise thinking about the way the other side thinks." "Learned to find the things that are against my opinion." "I learned how to find the good in things that are against my opinions.
<b>E</b>	Helped with English skills	
<b>U</b>	Helped prepare for university studies	Explicitly stated
<b>TW</b>	Specifically mention value of teamwork/working in pairs	"Fun working in pairs". "working in pairs was good for our project"

Table 7.14. Codes, categories and examples for positive responses for U sci for Q.B

<b>CODE</b>	<b>CATEGORY</b>	<b>EXAMPLES</b>
<b>A</b>	Autonomous activity. Specifically mentions the freedom of choice of subject.	"Nice to be able to choose the topic myself." "I enjoyed the fact we can choose the topic since it makes the whole thing much more interesting and really creates a chain of events leading to a fun activity overall."
<b>R</b>	Specifically mentions enjoying the research.	"Learned to use the database". "I loved looking for articles."
<b>P</b>	General positive comment.	"I was exposed to an interesting subject." "I enjoyed the freedom that was given to me in this process"
<b>O</b>	Specifically mentions enjoying forming opinions.	"I enjoyed reading different opinions." "I liked giving the opposite opinion" "I enjoyed working with a subject that is hard to be a 'con'". "I feel like I won't forget the big picture."
<b>E</b>	Helped with English skills	"It helped me learn how to write."
<b>U</b>	Helped prepare for university studies	"It will help with university"
<b>TW</b>	Specifically mention value of teamwork/working in pairs	"Working in groups is good".

Tables 7.15 shows the numbers of students giving positive reactions in each category in the U hum class and the U sci class.

Table 7.15. Numbers (N) of students giving positive reactions and as percentages of each class.

<b>CODE</b>	<b>U hum (N)</b>	<b>U sci (N)</b>	<b>U hum %</b>	<b>U sci %</b>
<b>A</b>	2	7	8	26
<b>R</b>	8	3	32	11
<b>P</b>	5	14	20	52
<b>O</b>	6	9	24	33
<b>E</b>	0	3	0	11
<b>U</b>	2	2	8	7
<b>TW</b>	4	1	16	4

It is interesting that about a quarter of the humanities class and a third of the science class (24% humanities, 33% science) explicitly write how much they enjoyed looking at the opposite opinion to their own. However, there is little consistency between the responses of the two classes. This is interesting because in all the questionnaires there was remarkable consistency between the responses of the two classes, even on matters relating to scientific literacy and interest in SSIs. It seems that these two tracks (science and humanities) view project work in rather different ways. Certainly, humanities students are required to engage in much more written project work in the rest of their courses. Science subjects are taught, with some laboratory work. This could account for humanities students' greater enthusiasm for research (R, 32% humanities and only 11% science). The fact that the subjects chosen were SSIs might explain the larger percentage of science students (P, 52% science students as opposed to 20% humanities students) who expressed a positive view of the project.

Overall there were general positive comments (P) from the science students and this might reflect that they had been encouraged to select SSIs which are perhaps generally of more interest to science students.

Analysis of question C. Negative reactions.

The same sort of analysis was done for the negative reactions recorded by both classes. The results for U hum and U sci are given in table 7.16 and table 7.17 respectively. The numbers of students within each category is given in table 7.18

Table 7.16 Codes, categories and examples of negative reactions from U hum for Q.C

<b>CODE</b>	<b>CATEGORY</b>	<b>EXAMPLES</b>
<b>TL</b>	Too long because it was too difficult to find suitable articles.	“It was very hard to find academic sources that covered what I needed”.
<b>NCE</b>	Not clear enough instructions on how to find articles etc.	“It was not clear how to find articles”.
<b>OT</b>	Other things	“Working in lottery pairs doesn’t contribute to quality of work.” “I hate typing it.” “I didn’t enjoy presenting the opposite opinion while I think the opposite way.”
<b>NC</b>	No comments	

Table 7.17 Codes, categories and examples of negative reactions from U sci for Q.C.

<b>CODE</b>	<b>CATEGORY</b>	<b>EXAMPLES</b>
<b>TL</b>	Too long	“It took too long” “It took a lot of time to find good articles”.
<b>OT</b>	Other things (problems working with database and working in pairs)	“Don’t like using the database.” “Database annoying.” “Didn’t like working in pair.” “We weren’t able to work with someone we would like to work with.”
<b>NC</b>	No comments	

Table 7.18. Numbers (N) of students giving negative reactions, and percentages

<b>CODE</b>	<b>U hum (N)</b>	<b>U sci (N)</b>	<b>Hum %</b>	<b>Sci %</b>
<b>TL</b>	9	7	36	26
<b>NCE</b>	3	0	12	0
<b>OT</b>	5	9	20	33
<b>NC</b>	5	11	20	41

Overall about 40% of the science students and 20% of the humanities students did not make any negative comments.

In the humanities class 40% complained explicitly that the project was too time-consuming and this I discovered in conversations with them related directly to the time spent searching the database, which most of them did not enjoy. In the positive

responses we see about 25% expressing enjoyment in doing the research, but these students might not have encountered the frustrations that the other 40% express.

The category OT (other things) many of the science students complained about using the database, and didn't enjoy doing the literature search. The way I set up the pairs was not successful (using a lottery) and as mentioned earlier, I will not attempt this again.

As will be seen in section 7.8 accessing relevant academic articles using the databases is time-consuming. Using google scholar has made this process much easier. I also think it more useful for students to be able to evaluate and use a wide range of internet sources.

Analysis of question D. Views on presentations.

It had been my intention to have each pair present the argument and counterargument (with evidence) for their chosen issue.

Question D was added to the questionnaire because many students had come to me while working on the project complaining that they didn't have time to prepare for presentations; it was an extra stress when they had so much work to complete in many subjects before the end of the semester. Overall, 32 out of the total of 49 students were strongly against doing presentations, with most of them citing lack of preparation time. Many of them came to me after class to reiterate their concern that they couldn't cope with giving a presentation; the level of stress towards the end of the semester is serious and needs to be addressed by teachers. A few students also expressed the view that it was a "waste of time" compared to what they would be doing in the lessons i.e. preparing for the final exam (details about this exam is given in Chapter 2).

Of the 17 who showed support for doing a presentation many reflected how useful it would be to speak in front of the class, especially as they hadn't done presentations before and would need to do them during their university courses.

Some of the students who didn't want to give a presentation explained that they would be "embarrassed" or "were shy". A few came to me and explained that they would not speak in front of the class even if I asked them to. Invariably the most reticent are females; sometimes they are obviously religious Jewish girls (identifiable by the long

skirts they wear, and high necked blouses); their shyness is part of the religious strictures concerning modesty that they have grown up with. I don't force anyone to speak in front of the class but I sometimes suggest that those few girls should instead do their presentations to me in front of each other, perhaps in a group of three or four. Almost always that is deemed acceptable, even by the most reserved.

In consideration of all the feedback relating to presentations I decided to go with the majority, and so there were no presentations. If I wanted to have presentations in future the whole project would have to be done earlier in the semester, with presentations completed before the end-of-semester exams loomed.

### 7.3.3 Other research methods

In this section I discuss the following research methods I employed to gather feedback from my students: semi-structured interviews, focus groups and conversations. I describe the successes and failures I experienced and identify the most useful research methods for my project.

At the beginning of the semester I had explained to my students that I was doing a doctorate that basically looked at my methods of teaching and I would appreciate feedback from students on all aspects of the course. They could email me, arrange a meeting with me, or speak to me at the end of any lesson.

I also intended setting up semi-structured interviews and focus groups with the students to get insights into their views on the intervention. I was especially interested in setting up a focus group. I then explained what a focus group was and how it was used to gain insight into peoples' opinions on an advertisement, a particular product (which could be a food, a style of shoes, a political party, or, in this case, something we did in a lesson). In each class I asked five students to volunteer and explained we would meet once a week throughout the semester for about 10 minutes to discuss anything that related to the classes held that week. I thought that by establishing this as a regular feedback mechanism I would get a greater understanding of my students' reactions to my course overall, and, in particular, I would also be in touch with them during the two weeks over which they did the project.

The focus groups failed early on in the semester. The students were inhibited to say anything negative and I think that the whole experience felt contrived. In this situation I was very much in the role of 'the teacher' and moreover, they saw me as the teacher

who would be marking their exams and giving them a final grade. This grade would be an important part of their final grade from the year's study programme and would determine if the student could access their desired course of study. There was too much power invested in me for there to be open exchange in such a formalised setting. The focus group is really a type of 'group interview' and interviewing in all its forms poses considerable challenges. Hitchcock and Hughes point out (2001, p.160) that "interviews are 'situated activities' and the materials produced are 'situated accounts'." They expand on the problem with interviews (2001, p.164):

In an important sense, whatever kind of interview is used the fact that an individual, the researcher or interviewer, is directly involved with another individual means, inevitably, that the presence of the researcher will have some kind of influence on the finds or the data. Many have argued that the more involved the interviewer becomes with the situation the greater will be the potential for researcher effect. The major problem here surrounds the extent to which the interviewer 'leads on' or influences the respondents' responses.

Hitchcock and Hughes (2001, p.164) also mention the likelihood of the respondents giving the responses they think are expected of them. The interview structured or semi-structured can present many challenges. The same challenges as I met in the focus group.

It soon became clear that the feedback I wanted came more naturally in all the chance encounters I had throughout the day This is really no more than using conversation, or what I would like to call 'targeted conversation' as a research tool. Hitchcock and Hughes (2001 p.163) legitimise the use of conversation for collecting data by a researcher:

Conversations are, of course, a major element in any kind of ethnographic field research. Conversations not only constitute an important source of data but might also be regarded as method of research in their own right.

I have considered the value of conversation as opposed to interviews as a means of data collection. I had done a few semi-structured interviews and was struck how stilted the responses were, and it was so clear even from the way the students sat that this was an unfamiliar experience, and one that placed them in a semi-formal setting that shifted them outside their comfort zone – especially here in Israel where every interpersonal encounter is designed to erode formality and to create the perception of a socially equal society. It is a tremendous contrast to my previous life in England with all its overt and

subtle hierarchies. However, there are also assumptions that these closer, almost familial relationships, will somehow provide benefits and support if you are in a tight spot. This 'tight spot' might be a failing grade. It takes time for students to recognise the standards imposed by the university. As a 'representative' of the university I am perceived as an authority figure with tremendous power. A semi-formal interview seems to underline the position of authority that I hold. The formality of the interview is not a comfortable place to access meaningful responses. A conversation in a noisy informal setting helps obliterate the boundaries.

One of the ways of analysing interviews is to record them, transcribe and then perform a content analysis. This is a worryingly sterile way to get meaning from speech. All the non-verbal cues disappear; emphasis and silences are eradicated. Analysing a group conversation might be more impressionistic, but the contributions to the conversation have a spontaneity that provides greater authenticity. It is a multi-dimensional experience where physical and emotional experiences, as well as words, are processed and interpreted by all the participants. There is a speaker but there are also all the others on the periphery of the group who 'chip in'. There are no inhibitions to offer negative views; the voice of dissent can be thrown in, or, as often happens, shouted, from the throng of the group. And there are regular opportunities for such group conversations, especially at the end of lessons when there are always groups of students who want to speak to me and other who hang back to hear what we are talking about. (Privacy is a rare commodity in this society).

It has also been fascinating to realise how much the physical environment where I work facilitates informal exchange and conversation with students. The layout of the building I work in, which is dedicated to the teaching of the pre-academic programme, necessitates that we are constantly in the same physical space. In fact, the building's design is rather reminiscent of Bentham's panopticon for a prison, without the central tower. There is a large open space in the centre of the building and a walkway that goes round the perimeter at each level. The classrooms are all around the outside of the building and open on to this walkway. As students and teachers come out of classrooms they can be seen from anywhere on the perimeter walkway at that level, and by looking down from the upper levels. As soon as I come out of a class room I can be spotted, and any of my students, emerging from another class, can immediately find me.

Even the coffee bar, which is in the open space on the lowest floor, can be viewed from any of the walkways (I will try and get a photo). And we all stand in the same coffee queue as there are no facilities for staff to make coffee. Furthermore, we don't have set office hours for students to come and see us. The staff room has an open-door policy so that students can come and see us anytime (we do not have separate offices in this department). If I am not teaching I am available. Three days a week I am at the University for ten hours a day, teaching three courses each day, and available to students the rest of the time. (The other three days I work in other places). With over a hundred of my own students on the pre-academic programme this places enormous demands on me, but also provides tremendous opportunities to hear the voices of my students on a regular basis.

In conclusion: with so much informal contact with the students providing opportunities for 'targeted conversation', I decided not to continue to construct the constrained and artificial environment of a focus group or a semi-structured interview. I not only see and talk to students every day that I am in the department, but I also see them around the university after they have moved on in their studies, and continue to get spontaneous comments about the course I taught them.

The opportunities to get feedback from my students surround me, I just need to make sure I 'hear' what they are saying.

During this project there were constant complaints about finding suitable articles, and I ended up spending a lot of time working with pairs of students to show them how to use the database to find specific articles that related to their topic of interest. Going back over the negative responses to the end of semester questionnaire (Table 7.9), there are 19 out of the 42 which can be understood as relating to the difficulty of using the Web of Science database. It was clear from the conversations with students that the complaints about the time taken to do the project really related to the time spent finding a suitable article. While it is an important and useful skill to learn, the ability to do research using the database was not the objective of my project. Using the database does require selecting appropriate key words and key ideas, and could be part of a HOCS (higher order cognitive skills) focused programme. However, I had a different aim and this wasn't being met completely in this particular intervention. Furthermore, the focus on an academic database for information gathering is far-removed from the

real world situation. It would be better in the next intervention to give them free run of the internet, with some warning of the pitfalls they are likely to encounter.

#### **7.4. Evaluation and Areas for Improvement**

It was interesting to find consistency in some of the parameters I measured in my classes of 2009 and 2010. Although the percentage of students with one science bagrut was slightly higher among the 2010 cohort, the measure of the Index of Issue Interest was almost identical across the two years with reference to new scientific discoveries and inventions, and medical discoveries. Furthermore, the percentage who declared themselves very interested in science and technology was almost the same in the two years, and attentiveness (A) although slightly lower was not markedly different. This consistency of results across two year groups helps give some confidence in the justification of extending my research into a wider community.

Giving my students the widely used international test for scientific literacy, in the derived sense, i.e. a knowledge-based test, produced high scores, higher than a US cohort with professional degrees (the highest scoring group in the US). Most of the questions are physics related, a subject almost never studied in the last four years of school. This raises the interesting question of how scientific knowledge is acquired. A rapid means of assessing the impact of studying science was possible with my class on the science track who were given intensive courses in the sciences during the first semester. The question of how this affected the Index of Issue Interest was investigated. From Table 7.11 it is clear that there were slight shifts upward in one or two subjects, but overall studying the sciences made no difference to the Index values.

However, for me, as a teacher-researcher, the most important aspect of this semester's action research was a change in my method of teaching, with a shift toward pair work. Pair work with large classes is rarely used because of the perceived problem of noise level and the anticipated lack of work done because the students will chatter together and not work. It was a method I adopted in all my EFL teaching and it was successful. When students were working on a task I could go around and help them as they needed it. There are many advantages to having pairs working together including the fact that with 12 pairs rather than 24 individuals I could give more focussed time to any

problems that turned up. Furthermore, when students presented a difficulty, they had already discussed it and had progressed further than they would have done as individuals. I also learnt that it was better to allow students to choose with whom they worked than to try and socially engineer an ethnically mixed class. The *petek* became established as the principal method of student feedback. Always anonymous, the *petek* was used to give a mid-lesson view of what students thought of a certain activity in class. It could also be used to get students to reflect more deeply about class activities that happened weeks earlier.

The intervention introduced during this cycle of my research allowed the students to choose their own subject of study. They seemed highly motivated and worked hard on every task associated with the project. However, the databases available via the University library website proved difficult and time consuming to work with. Google scholar is easier to use because it is such a powerful search engine and now offers many full length academic articles. There is now less need to use the university databases. There is also much to recommend a ‘real-life’ situation where there is only access to internet sources. In 2011, and subsequently, I made the search for supporting evidence internet-based and therefore simpler. Evaluating the reliability of web information is an important skill that is taught as part of all my EFL classes.

The prevalence of positive comments when I gathered feedback from the students was encouraging. I hoped that the project would be even more successful once I made it easier for them to search for supporting counter arguments to their opinions. This would be the second intervention.

## Chapter Eight

### The Intervention

#### 8.1 Introduction

This chapter reports on the intervention that I implemented with the two classes I taught in the Department of Pre-Academic Studies, the *mechina*, at the university. The intervention was introduced in the first semester of academic year 2011-2012. The students were at the same standard of English as the classes of 2009, and 2010, namely p100. As before, one class was on a science track and the other was humanities. The two tracks are designated here U hum (11) and U sci (11).

I describe the intervention in detail in section 8.6, and explain how it was modified in response to the feedback I got from my students when I piloted it in the preceding year. I also look at the way the project was more closely integrated with my regular teaching during the semester.

The earlier sections in this chapter include other investigations carried out with these students. As well as the questionnaire I gave in the previous two years to get basic information on age and sex, I added an additional question to discover ethnicity. Although I did not regard ethnicity as an important consideration in the way I carried out my research, I am aware that ethnicity can impact on learning styles. I had already identified (see page 6-7, p.14) on its importance in the structure of debate and discussion.

I included within my questionnaires other questions that sought to identify student opinions relating to scientific literacy and methods to improve it.

There was an important shift during my research to hear the voice of my students more clearly and this is reflected by the range of issues on which I tried to get direct student feedback.

Below is an overview of the contents of this chapter. The sections of this chapter are:

#### 8.2 Student profiles

Prior to carrying out the intervention I gathered basic information on the average age, male to female ratio, and level of science education of students. In order to avoid sensitive issues around ethnicity I decided on profiling language capacities.

### **8.3. Social scientific issues: student listings.**

In 2009 and 2010 students had been given a list of social-scientific issues and asked to show their level of interest. In 2011 I gave students the opportunity to list any SSI that they could think of and identify the one that interested them the most.

### **8.4. Is scientific literacy important? Student opinions.**

As a result of my research I have become increasingly aware of the importance of hearing the voice of my students. In this section I report on the way I explored student attitudes to scientific literacy.

### **8.5. Science education and scientific literacy: student opinions.**

This section reports on student opinions on how scientific literacy can be improved and the role of an education in science. Data and analysis are presented.

### **8.6 The new intervention**

There is a stage by stage description of the intervention and the way it had been modified following the intervention of the preceding year. A subsection gives a detailed presentation of data and analysis relating to the intervention.

### **8.7 Conclusion**

The overall student response to the intervention is evaluated and directions for further research are indicated.

## **8.2 Student profiles.**

I gave them a basic questionnaire at the beginning of the semester to determine average age; male to female ratio; the number of science *bagruyot*. An additional question see Table 8.2 was added which asked them to list the languages they know, and they were instructed to write their languages in the order of how well they know each one. They were asked to give their mother tongue as the first language in the list; the term ‘mother tongue’ was defined as the one spoken at home. The answer to this question helped me identify ethnicity of my students. The mother tongue probably providing information

about the dominant culture within the home. They were also asked to identify their level of proficiency in the three modalities (reading, writing and speaking). This information is especially helpful in distinguishing those students for whom a second or third language might reflect ethnic origins or be a language studied. Take Arabic, for example, for Arab students it will appear as their mother tongue. Students who list Arabic as a second or third language could be Jewish students with families who came from Iraq or Syria, or they could have learnt it in school. The proficiency scales enable me to distinguish these two groups. The former register higher levels of proficiency in speaking than reading and writing. Those learning Arabic in school have studied the subject primarily to read classic Arab texts and their proficiency in speaking will be at a lower level than the ranking they give to reading and writing.

This method of asking for the hierarchy of languages known by students, together with self-reported levels of proficiency in the three modalities can give insight into ethnicity, and prevailing cultural influences. Although I have not used the information I collected in this way I think it can potentially be a useful method, especially when asking directly about ethnicity is prohibited (as at the University) or is seen by respondees as prying. However, this oblique way of collecting data on ethnicity could have ethical problems. Here it is used to give no more than a sense of the diversity of languages within a class, although the ethnic mix of my class is revealed by this data.

Table 8.1 gives the data on age and sex of my two classes in 2011. This table also includes the data for 2009, and 2010, so a direct comparison across the years can easily be made. Similarly, Table 8.2 includes data for 2009 and 2010.

Table 8.1 Data and analysis: age and sex

<b>Class</b>	<b>Class size</b>	<b>M</b>	<b>F</b>	<b>Average of students' ages</b>
U sci (09)	27	15	12	Average ages: Mean: 22 years    Range: 18-25    Median: 23
U hum (09)	34	18	16	Average ages: Mean: 23 years    Range: 21-25    Median: 23
U sci (10)	25	15	10	Average ages: Mean: 23 years    Range: 19-25    Median: 23
U hum (10)	27	20	7	Average ages: Mean: 23 years    Range: 21-24    Median: 23
U sci (11)	24	11	14	Average ages: Mean: 22 years    Range: 18-25    Median: 22
U hum (11)	27	21	6	Average ages: Mean: 23 years    Range: 19-28    Median: 23

It is interesting that in 2011 the number of females in the U sci class outnumbered the males, and the males outnumbered the females in the U hum class. At the undergraduate level women are found in all science and engineering disciplines, even in the non-biological sciences (where women have traditionally chosen to study).

It should be noted that there were four 18-year-olds in the U sci class. It is unusual to have students straight from school; most students either serve in the army or spend one to three years in national service (this is explained in more detail in Chapter Two). These young students are either Arab students or they are students from underprivileged communities and are sponsored by the army to study at university. The students sponsored by the army are often ethnically Ethiopian, or Druze Arabs, or are students coming from kibbutzim or rural communities in the north of the country where there is a serious shortage of qualified teachers and educational standards are extremely low. About 15% of the University *Mechina* students are on army scholarships. Their university fees are paid (often for first and second degrees) and they also receive a minimal stipend to live on. Many of these students continue to work in paid

employment (even though it is illegal according to the terms of their scholarship) because their impoverished families still need the financial support any member of the family can provide. The students on army scholarships are predominantly found in the science track (though some Ethiopian students have been sponsored to study law so that they can act on behalf of their communities and protect their rights within the legal system). These students are usually bright, poorly educated, and often have complex and stressful family lives. The army pays for a full-time school counsellor to be employed by the *Mechina* to support these students throughout this pre-academic year of study. By contrast, the University employs one other school counsellor to deal with the needs of the other 85% of the students.

The students sponsored by the army also receive extra free tuition in English. It is unusual for them to be in my high level (ptor) class for English, though occasionally I have a small number, as I did in 2011.

Table 8.2 shows the question given to ascertain ethnicity through languages spoken. Table 8.3 gives the data collected relating to language order. An analysis of the data follows this table.

Table 8.2. The Question relating to language fluency, from the profile questionnaire given to the students.

## Languages you know.

Please put them in order of how well you know them.

Language 1 is your mother tongue = what you speak at home.

For each language please put a check in the box which show how proficient you are in each skill. **(1=fluent, 2=quite good, 3=poor, 4=not at all)**

[illegible]

Table 8.3. No. of students in U sci (11) speaking each language, according to the order they listed them.

Order	Heb	Eng	Rus	Fr	Span	Ar	Amh	Dan	Ger	Ukr
1.	18	3	2	1	1					
2.	6	16	1		1			1		
3.	1	6	2	1	1	2	1		1	
4.				1	1					1

Key: Heb = Hebrew; Eng=English; Rus=Russian; Fr=French; Sp=Spanish; Ar=Arabic; Amh=Amharic; Dan=Danish; Ger=German; Ukr=Ukrainian

Students who have third and fourth languages are often revealing where their grandparents came from. Ethnicity is preserved through language, food and customs. The two students with Arabic as a third language probably learnt it at school, though it could reflect third generation Jews whose grandparents came from Arab countries (ethnicity of grandparents from Iraq, Syria and Lebanon, has been preserved through language and food primarily, and sometimes also through traditional customs). However, the fact that they ranked their speaking skills at 4 and their reading and writing skills higher at 3, probably means that they had studied Arabic at school as this is consistent with the way that Arabic is taught in most Israeli schools, i.e. as a literary and not as a spoken language!

Students with Russian as a first language might have been born in Russia and arrived in Israel more recently. The student with Amharic as a third language probably had grandparents from Ethiopia.

The start of term questionnaire contained a question relating to science *bagrut*. It took the same form as in 2009 and 2010. Table 8.4 shows the number of students with a science *bagrut* of 4 or 5 points. I have added the 2011 data to Table 7.2 so that a comparison can be made across the years.

Table 8.4. Assessment of school science education showing numbers taking 4- or 5-point *bagrut* in science subjects.

<b>Class</b>	<b>Class size</b>	<b>Biology no. of students</b>	<b>Physics no. of students</b>	<b>Chemistry no. of students</b>	Total no. of students with at least one science <i>bagrut</i> .	% of class with at least one science <i>bagrut</i>
<b>U sci (09)</b>	27	<b>11</b>	<b>2</b>	<b>3</b>	<b>11</b>	<b>40</b>
<b>U hum (09)</b>	34	<b>5</b>	<b>1</b>	<b>2</b>	<b>7</b>	<b>21</b>
<b>U sci (10)</b>	25	<b>9</b>	<b>3</b>	<b>3</b>	<b>14</b>	<b>56</b>
<b>U hum (10)</b>	27	<b>3</b>	<b>3</b>	<b>3</b>	<b>8</b>	<b>30</b>
<b>U sci (11)</b>	25	<b>11</b>	<b>4</b>	<b>4</b>	<b>15</b>	<b>60</b>
<b>U hum (11)</b>	27	<b>5</b>	<b>2</b>	<b>2</b>	<b>7</b>	<b>26</b>

Table 8.4 shows that in the classes choosing the science track had about the same percentage of students with a single science *bagrut* in 2010 (56%) and in 2011 (60%), with a few having two in each year. No one had three science *bagrut*. In the class on the humanities track those having a single science *bagrut* remained at below a third of the class (30% in 2010, and 26% in 2011)

### 8.3. Social scientific issues: student listings

In 2009 and 2010 I assessed student interest in ten issues which I had listed. In 2011, I decided to approach this in a different way and ask students to list the controversial subjects that they could think of and identify the one that interested them most.

I had in 2009 and 2010 given, them a standard list of issues and asked them to mark whether they were ‘very interested’, ‘moderately interested’, or ‘not at all interested’ in each topic. There were also several blank lines under the list where the student could add any other topic of special interest, but hardly anyone added anything. Providing a comprehensive list makes it difficult to have any original thoughts. So I thought I would try leaving it open and see what they came up with. I did require written answers rather than just throwing the question out orally in class. I find that requesting students to write down their ideas seems to make them more reflective and I always receive better answers.

In the question I gave them, I used a trigger statement to get them thinking about issues in general, and then asked them to identify which they found most interesting. The question is given in Table 8.5.

Table 8.5 Question to find issues that interest students.

There are many **controversial** subjects that regularly appear in the media that relate to medical, scientific or technological issues. Please list as many as you can think of.

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**Now look at the list you have written and put a \* next to the one you are most interested in.**

This question was given to U hum (11). In Table 8.6 is listed the issue each student marked as the one in their list that they were most interested in. A few students failed to identify a single issue in this way.

Table 8.6. The issue of greatest interest as listed by the students themselves

The list of issues students were interested in were (in their own words):

- a) radiation from cell phones
- b) the doctors' strike (*in the news at that time, my note*)
- c) green technology versus oil companies
- d) TV versus books (people will no longer be able to read)
- e) euthanasia
- f) the smart-phone revolution
- g) genetic engineering
- h) is it a good thing to develop technology that can be used in the weapons industry?
- i) medicine – are new inventions good or bad?
- j) global warming
- k) marijuana for patients with cancer
- l) the influence of the internet on our lives
- m) the internet
- n) euthanasia (the medical ethics)
- o) cell phone damage to the brain
- p) abortion
- q) cloning people
- r) dependence of mankind on technology
- s) euthanasia
- t) science and religion
- u) abortion
- v) euthanasia

There are two dominant themes that emerge from this list, one revolves around ethical issues, and the other relates to concern about the impact of technology on our lives. This former category appeared in many of the general lists, even if not asterisked as of special interest, with many students mentioning euthanasia, and four marking it with an asterisk. This questionnaire was given to the students a week after a high profile case in the media relating to prolonging the life of a woman who had been declared brain-dead. And perhaps demonstrates that topicality triggers interest.

Overall I find it especially interesting to note how many in this list in Table 7.8 relate directly to ethical considerations. Although it is not always clear what aspect of an issue the student is referring to, b), e), g), h), k), n), p), q), s), u), v) do require ethical considerations when the issue is being discussed. Indeed, many SSIs do, and yet the teaching of basic ethics does not seem to be part of science literacy programmes or part of general science teaching.

It is important to provide opportunities for discussions centring on ethics because public opinion in this area does affect decisions made by ethics committees. Heyd, Professor of Philosophy at the Hebrew University, who has served as a member of government committees in Israel on surrogacy, euthanasia, organ donation, and genetic technologies, identified unequivocally that public opinion is the prime influence on decisions made by ethics committees (private conversation).

#### **8.4. Is scientific literacy important? Student opinions.**

During the reconnaissance I made a preliminary investigation into whether students felt it was important for public participation in a decision relating to an SSI (see section 6.5.7). I presented the students in the reconnaissance in 2009 with a VOSTS that was incorporated in the questionnaire as Q.14. Table 5.12 showed that 58% of the students wanted public participation in a decision relating to the building of a nuclear reactor.

But I felt this didn't sufficiently explore student attitudes to scientific literacy. I wanted to ask them quite simply if they thought being scientifically literate was important for the public in general, and specifically for themselves. I prefaced the question (Q.9) with a short statement to help ensure that the students were responding to a shared concept of scientific literacy. Upon reflection this statement is too strong and unbalanced so that it is not surprising to see such a large number accept scientific literacy as important. It is

even misleading in attributing governments with an interest in promoting its citizenry to participate in decisions relating to SSI. Governments' prime concern in the field of scientific literacy is in securing the upper places in league tables that are based on the results of knowledge-based scientific literacy test.

The data collected relating to this question is of doubtful value and although shown here is not used in my research.

(See Table 8.7 for these questions and Table 8.8 for the numbers and percentages of students in each class in response to these questions).

Table 8.7. Question 9. Student opinions on status of scientific literacy.

**Q9.** Please read this:

**Governments all over the world are interested in making sure that the public leave school and university with a good level of scientific literacy. They feel that, in a democracy, there are many important issues relating to science and technology that the general public should understand and have an opinion about.**

**a)** Do you think it is important for the general public to be scientifically literate?

Yes No Perhaps Don't care

**b)** Do you think it is important for you to be scientifically literate?

Yes No Perhaps Don't care

**c)** Do you think you are scientifically literate?

Yes No Perhaps Don't care

I added the 'don't care' category to allow students to express absolutely no interest in this subject. Interestingly it was never chosen as a response to any of these questions,

Table 8.8 Data relating to **Q.9** giving student opinions on importance of scientific literacy.

Numbers of students are in brackets. Percentages are next to them.

	Yes		No		Perhaps	
	U sci	U hum	U sci	U hum	U sci	U hum
<b>9a)</b>	(23) 82%	(18) 78%	(1) 4%	(1) 4%	(4) 14%	(4) 17%
<b>9b)</b>	(28) 100%	(21) 91%				(2) 9%
<b>9c)</b>	(7) 25%	(3) 13%	(3) 11%	(5) 22%	(18) 64%	(15) 65%

It is perhaps interesting to note that there seems to be a discrepancy between their aspiration to be literate and the state that they perceive themselves to be in. Even the science students are expressing some sort of deficit here. Further research is required to identify exactly what the students understand by the term scientific literacy, and in what way they feel that they are not competent.

### **8.5. Science education and scientific literacy: student opinions.**

This research has made me realise how many assumptions underpin the whole field of scientific literacy. And perhaps the most pervasive is the notion that science as taught in school is in some measure of paramount importance. Although some scientific knowledge and understanding is required to discuss certain SSIs in a meaningful way, it is important to consider whether the standard school science curriculum as it is constructed at the moment provide what is needed for scientific literacy. I had understood from discussion with students in previous years that they felt the science *bagruyot* were not worth taking. Students saw them as specifically targeting students who were going on to university to study a science subject. But even students going on to study science at university felt they would cover everything they needed in the first year courses at university. And most students studying science at university have not taken any *bagruyot* in science subjects. It made me wonder what view students had of the relevance science *bagruyot* to scientific literacy. The question I asked is below in Table 8.9 and the results are in Table 8.10.

All the data I had previously collected showed that all the students had tremendous interest in science, even those students going on to study humanities subjects. Maybe students on the humanities track should study some sort of science literacy course at university. Students are never consulted on what they feel they need to learn. As university teachers we always assume we are in a position of knowing, while students are in the position of learning. I began to investigate what my students felt was important for them to learn. This arose because my research had shifted me, as a teacher, from a position of authority into a position of partnership. The views of students in their mid-20s who are making a major personal commitment to studying have important contributions to make in defining the syllabus they are taught. It could be formulated in a more collaborative way. If lecturers feel certain subjects must be taught, the reasoning for incorporating those particular subjects should be explained. Question 11 (Table 8.11) explored ways that students might regard as important in increasing scientific literacy, Table 8.12 gives the data for both classes.

Table 8.9. Question on science *bagrut*. (The reference to the issues in questions 1-8 are the standard list of issues which I first included in the reconnaissance questionnaire see Section 6.5.6 Q. 12)

<b>Q. 10.</b> Which of the following statements do you agree with (please put a check in the box)			
	Agree	Disagree	Don't know
You need a 5-point <i>bagrut</i> in a science subject to understand the issues given in the beginning of this questionnaire.			

Table 8.10. Data for **Q.10** on science *bagrut*

	Agree		Disagree		Don't know	
	(No.)	% of class	(No.)	% of class	(No.)	% of class
U sci (11)	(2)	7	(28)	93	none	
U hum (11)	(1)	4	(22)	92	(1)	4

The data in Table 8.10 makes it clear that the science *bagruiyot* are not regarded by students as helpful in achieving science literacy. On the other hand, as can be seen in Table 8.12 there is tremendous support for science education both at school and at university. A more detailed analysis of the data in Table 8.12 is given beneath that table.

Table 8.11. **Q.11** on increasing scientific literacy.

**Q.11** Here are some ways that have been suggested to make people more scientifically literate. Please show how important you think each one is.

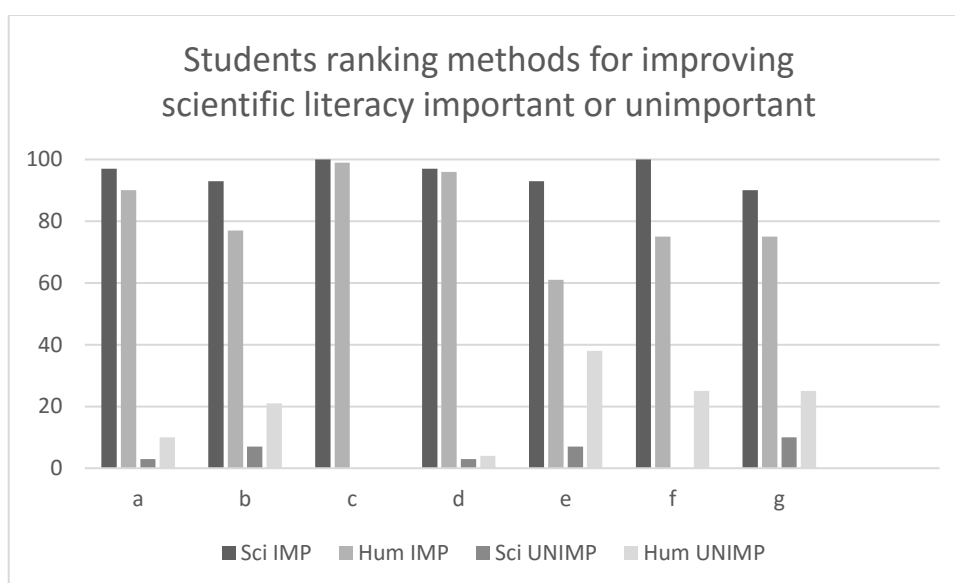
	<b>Very important</b>	<b>Important</b>	<b>Unimportant</b>
a) Science education at school.			
b) Some science education at university (even for humanities students)			
c) At school: learning to read critically.			
d) At university: having courses for everyone on critical reading.			
e) Visiting science museums.			
f) Having local lectures in community centers on important issues.			
g) Having special government websites on the internet which provide information on specific issues.			

The data for Q.11 is shown in Table 8.12 and the chart below it.

In order to clarify the items in Q.11 which were regarded as important, I combined the values for very important and important for the science class, and also that data for the humanities class. In the chart below the two dark colour bands to the right of each bar show the percentage in each class that thought the item unimportant. (The much longer length of bars occupied by the two lightest shades shows the percentage that thought the item important or very important).

Table 8.12. Data for **Q.11** on increasing scientific literacy, comparing U sci (11) and U hum (11). Numbers of students, N, given in brackets. Percentage of class next to it. This information is put into chart form (below)

	Very important		Important		Unimportant	
	U (sci) (N). %	U (hum) (N) %	U (sci) (N.) %	U (hum) (N) %	U (sci) (N) %	U (hum) (N) %
a)	<b>(20) 67</b>	(19) 79	<b>(9) 30</b>	(5) 21	<b>(1) 3</b>	(3) 10
b)	<b>(13) 43</b>	(3) 10	<b>(15) 50</b>	(16) 67	<b>(2) 7</b>	(5) 21
c)	<b>(24) 80</b>	(17) 71	<b>(6) 20</b>	(7) 29		
d)	<b>(18) 60</b>	(11) 46	<b>(11) 37</b>	(12) 50	<b>(1) 3</b>	(1) 4
e)	<b>(10) 33</b>	(2) 7	<b>(18) 60</b>	(13) 54	<b>(2) 7</b>	(9) 38
f)	<b>(14) 47</b>	(5) 21	<b>(16) 53</b>	(13) 54		(6) 25
g)	<b>(11) 37</b>	(10) 42	<b>(16) 53</b>	(8) 33	<b>(3) 10</b>	(6) 25



This chart uses data from Table 8.12

Sci IMP = U sci Very important + U sci Important

Hum IMP = U hum Very important + U hum Important

Sci UNIMP = U sci Unimportant

Hum UNIMP = U hum Unimportant

This chart shows that for items e) f) g) there is a group of humanities students ranking the items unimportant. In the other items hardly anyone in either class ranks them as unimportant.

There were some results here in **Q 11** that surprised me, notably the answers given to **11b)**, and **11 d)**. Responses to Q 11b) showed that about 80% of the Humanities class thought it important, or very important to have some science education at university, only a fifth rejected the idea as unimportant. It would be interesting to offer an appropriate course for discussing SSIs to humanities students and see what sort of uptake there would be.

Equally exciting are the responses to question **11 d)** with 97% and 96% in the science and humanities classes respectively supporting the idea of having critical reading courses for everyone at university. These courses could offer the opportunity to discuss ethical and socio-political matters in texts relating to SSIs.

The responses to the other questions also warrant comment.

Q 11e). About 60% of humanities students regarded visits to science museums as important or very important. (93% in the case of science students). I think the figure for the non-science students is surprisingly high and perhaps reflects the large number of popular outreach programmes that science museums initiate throughout the country.

Q 11f). The idea of using community centres as places to provide information on SSIs through lectures (and perhaps discussions) received enormous support. With 100% of science students and 75% of humanities students citing that community centers are very important or important in helping make people more scientifically literate. These responses reflect the importance of community centres in every neighbourhood throughout the country. These centres are closely integrated with the needs of the community and are usually well-run, lively institutions. Perhaps it would be interesting to engage these centres in setting up discussions around SSIs, not something they see as part of their communal role at present.

Q11g). The responses to this question indicate how useful government portals might be in providing resources and information on SSIs, particularly of local relevance.

Unfortunately, at present government websites are often highly skewed in providing biased information in favour of their prevailing opinion. However, websites could be constructed as a source of useful and more objective data.

Below Q11 students were able to write their own comments. The responses were really interesting but only came from the humanities students - none of the science students wrote anything (perhaps because they felt confident about declaring the importance of science education for all without any further justification).

Many of the humanities students added comments and I am including four here that represent the views overall. These examples are also typical of several conversations I had subsequently with individual humanities students about whether they would actually take science courses while studying at university. The views expressed below are thoughtful, and clearly expressed. The science/humanities dichotomy is perhaps becoming an increasingly irrelevant view of education.

Comments written by students in the humanities class:

**Student 1:** *I am not interested in science, but I believe it is necessary and important for it to be part of every person's basic education and knowledge.*

**Student 2:** *Every person should have a basic general knowledge in order to understand the world better. It will also give the individual better tools to criticize when necessary.*

**Student 3:** *A basic education in science should be part of the core curriculum in school. One science course, at the very least, should be mandatory in university.*

**Student 4:** *Science isn't isolated. Being able to be critical about scientific subjects directly relates to a person's striving for knowledge – and this is the main thing. Shoving science down people's throats will not produce real scientific literacy – the system needs to make sure that people will have the will and ability to really be scientifically literate. (Underlining is that of the student).*

Looking at these comments I am impressed by the clarity of the writing and the forcefulness with which the students expressed some of their ideas.

## **8.6 The new intervention**

### **8.6.1 General context**

In response to student feedback to the intervention I introduced in 2010, I changed the intervention for my 2011 classes in two fundamental ways. Although it remained a separate, identifiable project, it became better integrated into my course as a whole rather than an adjunct that seemed primarily to relate to the use of the library database. Furthermore, the library databases would no longer be the sole source of supporting materials; instead, the internet as a whole would also be available as a rich source of information. Of course, taking information from the internet requires extra care to ensure reliability but I included within my course a lesson on ‘Information on the internet’ to explore the problems that might be encountered. However, the project in these classes has always been designed to give students an opportunity to work with academic articles found through the database, and so I still asked for sources from the database but also permitted the use of sources from the internet in general.

The integration of the project meant a slight, but important, shift in many of my lessons. The underlying principles of my teaching basically remained the same. However, in 2011 I initiated the idea playing devil’s advocate when discussing controversial texts. The background to the integration of this activity into classroom discussion is given below in section 8.6.2

I would generally describe my course as one in critical reading; it is a course which leads students away from being passive readers towards being interactive, interrogative, readers, who are in constant dialogue with a text – asking questions and exploring meaning. All classes involve exploratory talk. This subject and the ideas behind it are discussed in Chapter 3, Literature Review, in section 3.9. This constructivist approach to teaching acknowledges the importance of facilitating students to integrate new ideas within a pre-existing framework of the knowledge that they have already formulated. At a most basic level it means the first steps in approaching a new text is to ask a series of questions: “What do I already know about this subject?” “How do I know those things? Have I read other texts on this subject, or seen a TV programme about it?” “What questions do I expect this text will answer?”

This stage of situating new information within a personal field of pre-existing knowledge is something that high-level readers do automatically. Reading a headline and perhaps a few opening sentences builds an expectation about the content of the

article. A glance at the pictures, or subheadings, will result in us rapidly constructing a model of the article – with expectations of the sort of information it is most likely to provide and the sort of questions it will probably answer. There is an interrogative relationship with a text that means we are challenging what we are reading and integrating it with other relevant information and ideas which we have constructed through earlier experience. Readers also need to be able to identify how the author is influencing the reader through the use of rhetorical devices. The reader needs to be aware that an author has purpose in writing a text, and that agenda/personal bias needs to be identified. Making this process a conscious, voiced, part of a lesson leads to important exploratory discussion interweaving with the reading of a text at an early stage of being presented with a text.

#### 8.6.2 Introducing ‘devil’s advocate’.

In my lessons I have always encouraged discussion on issues associated with the texts that were being read. I have always tried not to impose my own views on a class discussion so that there is room for students to develop their own ideas. So to counteract any perceived bias of my position I routinely offered perspectives from both sides of a discussion about an issue. One of my students was deeply frustrated with me and asked outright “But what do **you** think?” What an interesting question? Did it matter what I thought? Or was it more important to understand the arguments underlying my position, and to acknowledge that I could convincingly take both sides of an argument? There were indeed two sides to an argument, though not always evidentially based. Topics relating to politics and religion were totally polarised and were faith based (even political opinions) so they were not engaged in within the classroom.

The project, which required students to find evidence for the counter argument to their own opinion, can be seen as consolidating the position of the devil’s advocate. I didn’t express it in those terms but conceptually the project was consistent with the overall approach adopted throughout the course.

#### 8.6.3. The intervention: stage by stage

The project followed the introduction to the databases (Web of Science and EBSCO). Introduction to these databases was a university requirement for the course I was

teaching. Students also had a lesson on how to find sources of information on the internet and check for reliability.

Students were told that they would be doing a research project and could work in pairs or in groups with a maximum of three. The students were required to drop a note in my box in the department with the names of the people they wanted to work with. There was an option to work alone but nobody elected to do that. Almost everyone chose work with a partner.

They also had to choose a controversial socioscientific issue that interested them and write a brief statement of the issue. I recommended that they chose an issue where they shared the same point of view. They also wrote a brief statement of that point of view. I was keen that they chose something where they shared an opinion so that they could work co-operatively in the search for information and evidence of the opposing opinion. This would reduce the workload that students had complained was so onerous when I ran the project in 2010.

The range of issues they chose were quite limited, with many issues being chosen by several pairs of students. The opinions they chose to support were from both sides of the debate. A few students suggested subjects that interested them but did not fulfil the requirement of being a controversial issue. They were asked to resubmit. The table below shows the recurring themes.

Table 8.13

**Samples of topics chosen and statement of point of view (in students' own words)**

<b>Topic</b>	<b>Point of view</b>
Genetic engineering in agriculture.	We believe that it is the best solution against pests in agriculture.
The use of nuclear reactors for producing energy.	We support power generation using nuclear reactors. Nuclear reactors produce energy with fewer pollutants compared to traditional fossil fuel based power plants. In addition, building, maintaining and generating energy in nuclear reactors cost much less.
The use of nuclear reactors for producing electricity.	Nuclear reactors produce a lot of environmental damage.
Artificial Intelligence	There is the potential misuse of AI system. There is a very likely possibility that this technology will be used by future armies and bring harm to humans on an inconceivable scale.
Investing resources on space research.	Humanity should not invest resources on space research because people are suffering here on earth. We are just unable to say to a hungry child that he should go to sleep hungry tonight because a spaceship needs the money more than he does.
Sending robots or men to Mars.	It is better to send robots than men to Mars
Stem cell research.	Stem cell research should be allowed.
Euthanasia	I oppose this because it is against my religious belief.
Investing resources on space research.	In today's global economy, when poverty rates are increasing, the substantial budget that is directed towards space research is unjustified.
IVF for older women	We believe that women should not be able to have babies post menopause.
IVF for older women	Women should be able to have babies when they are older.
Cloning of humans	Our opinion is that the medical advantages of human cloning are so significant that it minimizes the whole ethical issue and therefore should be legal.
Cloning of humans	Genetic cloning of people is unethical.
Vegetarianism	Meat is unhealthy to eat.
Animals in medical testing	Animals should not be used in medical testing.

I checked these notes and returned them next lesson with comments. Issues based on religious belief would be difficult to substantiate with an evidentially-based argument. There was a need to recognise the difference between an evidentially-based opinion and a 'belief'. Students with 'belief' based arguments chose other controversial subjects.

The next stage was about to begin. I asked them, in class, and in cooperation with their working partner to write the opposite opinion beneath their own. I walked round and checked that something clear and meaningful was written. And then, to their astonishment, explained that I wanted them to find evidence to support the opposing view. This was not what they expected.

They were asked to find, if possible two sources from the Web of Science database, and two sources from the internet. The internet sources had to be evaluated for reliability. This was something we had looked at in some detail in class.

If they found it difficult to find relevant articles through the database they could just use internet sources. They had to write the full bibliographic reference for each of the journal articles and copy paste the abstracts. For the internet sources I required the URL and the relevant information copied into their project document. They were also asked to write a few sentences explaining how each of these sources supported the opposing opinion. The project was their homework assignment for the week and I expected no more than 2-3 hours to be spent on it.

The top of the document had the student names. The main statement of the issue. Their opinion. The opposite opinion. Followed by the evidence (both academic and internet resources). A few sentences explaining the relevance of the evidence to the opinion it was supporting.

The final projects were presented with pride and a sense of accomplishment. Many of the projects were longer than the two or three pages I was expecting, and included an extensive discussion on the opposing opinion. I read them all and arranged to speak individually to the students about their project work – mainly to give them encouraging feedback, and occasionally to point out possible bias in some of the sources they had chosen. But for me this project was more about process than the final product. I did ask the students if they would return their projects to me so that I could keep them and refer to them (anonymously) in the research I was doing. If they wanted to keep them I asked if they could provide me with a photocopy. Over half of the projects were returned for me to retain for reference.

#### 8.6.4 Student responses: data and analysis.

At the end of the semester, a couple of weeks after the projects had been handed in by the students, I asked them to think about the project and give me their feedback on the half sheets of A4 that I handed out (blue for humanities and yellow for science). The questions written on the board are shown in Table 8.13.

Table 8.14 Questions written on the board for student feedback.

- A. What do you think the project was trying to teach you? Give up to three things.
- B. What do you think was most useful?
- C. Any other comments. Positive or negative.

The responses were anonymous, folded in half and put in a carrier bag on my desk at the end of the lesson.

I had intentionally left a couple of weeks between the completion of the project and collecting student comments so that they would perhaps reflect more generally on the project.

I did a content analysis of the peteks for each class separately. The process was the same as I had done before, but I have not yet described it in detail and will do so here. Each petek is numbered consecutively. I make a large table with the headings shown below in Table 8.14. For each petek I fill in the comment columns A1, A2, A3 (for each of three things that students gave in response to question A). B was usually just a reference to A1, A2, or A3. General comments (Q. C) were listed on a separate page.

When the whole table is filled in for a single class, it is two or three pages long. I look over it and pull out those phrases (or words) that are recurring and then build a new table where those phrases are listed in the first column, in the second column I write the number of the petek in which those phrases appear. I then check through each of the original peteks to make sure that the categorisation of each comment is appropriate. I then give a tally for each response, as shown in Table 8. 15 for question A, and Table 8.16 for question B.

Table 8.15 The headings for content analysis

No.	A1	A2	A3	B
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Table 8.16A. Comments on intervention. Responses to Q.A (see Table 8.13)

<b>Key phrase referring positively to...</b>	Hum (11)	Sci (11)
a) value of looking at opposite opinion/ open-mindedness	15	14
b) learning how to use database	13	14
c) learning how to do research on the internet/finding reliable sources on the internet.	4	10
d) learning how to do research	8	9
e) value of working in pairs/teams/groups	2	3
f) improvement in English skills (reading/writing/analysing text)	4	7
g) learning about a subject of interest/understand scientific ideas		5

I have shown different responses b) c) d) separately but they all relate to developing research skills. Students sometimes more than one of these. I should note that all students in both classes made some reference to the fact that one of the purposes of the project was to develop research skills.

Table 8.16B Analysis of peteks relating to purpose in terms of coding used in first intervention, in terms of % of class. Includes data from 2010 (Table 7.12B)

<b>CODE</b>	<b>CATEGORY</b>	Hum (11) %	Sci (11) %	Hum (10)	Sci (10)
<b>R</b>	Improve research skills	100	100	44	85
<b>T</b>	Improve thinking skills	68	56	22	40
<b>E</b>	Improve English skills	18	28	30	52

Many students (almost half of each class) cited "learning how to use the database" as one of the things they thought the project was designed to teach them, others referred to using the internet specifically and almost a third of each class saw the project as generally teaching them how to do research.

Although all students found supporting evidence from the internet, the majority also found articles through the database. It is not clear why the students in these classes didn't complain about the difficulty of finding articles on the database when this had been found to be such an onerous task the year before. The students had chosen a similar range of topics and worked in the same ways (either co-operatively, side-by-side, as a pair or searching separately and comparing what they discovered). I would like to suggest that because they were not restricted to finding only database sources they did not feel that if they didn't find anything on the Web of Science they had no other option. In 2010 the students faced the possibility of not finding any articles on the database and therefore failing to fulfil the requirements of the project. The students with whom I worked in 2010 were all very worried, and I noted in my diary that two students came to me "in despair". I suspect that if you know that you can find information on the internet the database feels supplementary and is approached in a more relaxed way. In 2011, without pressure, students were able to approach the database as more of an adventure of discovery.

It should be noted that doing a Google search in 2011 was more difficult than using that search engine now. It was then in many ways similar to using the Web of Science database – requiring careful selection of keywords. Today, even Google Scholar responds to questions, and has similar coverage to the Web of Science, except that the latter only covers peer-reviewed journals while Google Scholar also includes non-peer reviewed journals. A Google search also provides access to Google Books where a search of key terms can provide the relevant pages in scholarly books, even when the whole book is not available online. Google now provides everyone with internet with a wealth of readily accessible information, although the searcher still needs to be wary of bias in all articles, both in peer-reviewed and non-peer reviewed journals.

It was clear that many of the students were totally engaged and fascinated by this project. Many came to show me what they found as they discovered it, not because they needed help, but because they were so amazed to find so much information relating

to the contrary opinion. Some students in their comments referred to “seeing how much knowledge is out there just waiting to be explored” and “the huge amount of knowledge in the database”. This was a first encounter with accessing information, and made students realise the immense possibilities.

The percentage of students in each class who identified the project as helping to see the opposite side of an argument was 68% for U Hum (11) and 56% for U Sci (11). This is an increase on the percentages in 2010 who identified that the project was trying to “teach them new thinking skills” (this was the term most of them used in 2010, rather than specifically referencing looking at the opposite opinion). In 2010 22% of U Hum (10) and 40% of U Sci (10) stated this as a reason for giving the project. The increase in the percentage of science students identifying the project as being aimed at developing the ability to understand the opposite point of view or critical thinking went from 40% to 56%, and it was a much more substantial change among humanities students going from 22% to 68%.

In Table 8.18 I have selected twelve illustrative comments in response to Q.B, the comments are taken from both classes. Only one comment referenced the project as being an extension of the concept of playing devil’s advocate, a term I had used one earlier in the semester. I had been careful not to reuse the term again during the semester because I didn’t want students merely to echo the term back to me when I asked for student feedback after the project. A few of their responses commonly used the expression “open-minded”, which was a term I never used. It is important that student feedback is clearly written in their own words and does not parrot teacher phrases; in this way, one can have greater confidence that what the students write is an authentic, reflection of their own thinking.

Table 8.17A. Comments on intervention. Responses to Q.B (see Table 8.13)(showing numbers and % of class )

Key phrase referring positively to...	Hum (11)	Sci (11)	Hum (11)%	Sci (11)%
a) value of looking at opposite opinion/ open-mindedness	9	9	41	32
b) learning how to use database	9	10		
c) learning how to do research on the internet or finding reliable sources on the internet.	1	3		
d) learning how to do research	2	4		
b) + c) + d)	12	17	55	61
e) value of working in pairs/teams/groups		2		
f) improvement in English skills	1			
g) learning about a subject of interest/understand scientific ideas		3		

8.17B Comparing results from 7.16A (2011) and Table 7.15 (2010)

CODE	Category	U hum (11) %	U hum (10) %	U sci (11) %	U sci (10) %
R	Research skills	55	32	61	11
O	Open-mindedness	41	24	32	33
E	English skills	0	0	0	11

Table 8.16B shows how much students in 2011 valued the research skills they got (over half of both classes regarded this as the most important thing they learnt from the project). In 2011 there was an increase in the number of humanities students identifying critical thinking/open-mindedness as the most important thing that they had got from the project.

Among science students the percentage remained unchanged. However, it is important that a project focused on research could be regarded by at least a third of all students as affecting the way they think.

I include in Table 8.18 a selection of their comments and have scanned a selection of their original peteks (see Appendix E)

Table 8.18. A selection of comments in response to Q.B., referring to the most useful part of the project. Quotes from answers relating to taking the opposite point of view.

Hum 2.	To be open minded in reading opinions.
Hum 3.	To look at other views and be more open-minded to them.
Hum 4.	To try and get into the mind of your intellectual rival.
Hum 5.	Searching for opposite opinions.
Hum 13.	The most useful thing for me was to look at the other side of my opinion.
Hum 24.	I found the critical thinking the most useful.
Sci 2.	Looking for the contrary to our opinion.
Sci 3.	To look at pros and cons of the issue I chose.
Sci 7.	The devil's advocate was good. It made me see the opposite side.
Sci 9.	One could see a different opinion than his own.
Sci. 14.	How to open our minds to hear and understand the opposite of what we think.
Sci 25.	It opened our minds.

For many the skills they acquired through searching the database was cited as the most useful element of the project, others referred specifically to doing research on the internet.

Particularly interesting and gratifying was the fact that in 2011 there were only two negative comments out of the two classes. One commented that “the project is in low level” and the other complained that “the project was kind of a surprise and should be mentioned in the beginning of the semester.” No student ever came directly to me to complain about any aspect of the project. They did come and make positive comments about how much they enjoyed doing it. Giving them freedom to access information on the internet seemed to solve the complaints I had received from the year before.

In 2011 there were lengthier comments were made to Q.A. For example: “The demands of the project in itself presented the idea that no opinion is right on its own – it should be based on research and a good argument. Having to research for answers to base my own opinion on has helped me learn that. In addition, I learned I am able to hold an open mind to a sensitive subject and opinions I essentially disagree with. More than anything, it seems important to learn an attitude of open mindedness to other points of view.”

And another: “To every controversial issue there are two sides and in order to understand the issue we need to know both sides.”

A few other students included some general comments – all very positive – for example:

“A fun, new way to teach me about depending on myself, trusting my abilities, broadening and raising my knowledge”.

“The project wasn’t boring because I wasn’t forced to work on a topic I wasn’t interested in”.

I saw all the students after the end of the semester on the days of the exams and then later after they had received final grades, and there continued to be positive feedback. In the following year, when walking through the university campus, I would occasionally bump into my former students individually (only humanities students because science subjects are taught on another campus on the other side of the city). On three occasions the students said how useful the project had been. It was possible they were referring to the research skills they used but when I asked in what way the project had been useful, they all said something along the lines that it made them look at opinions in texts more critically.

It would be interesting and important if a proper longitudinal study could be done to see whether an intervention like this has any impact in subsequent years on how students view and formulate opinions and whether they retain an increased openness to other people’s opinions.

## **8.7 Conclusion**

This stage of the intervention sees a major shift in my perception of my role as teacher. I think I have always naturally assumed a position of authority; in a university setting lecturers are assumed to know what their students should be learning and how they should acquire a certain corpus of knowledge. Asking my students for their opinions on course content and giving them greater autonomy in the project was a really positive experience. I continued to encourage pair work whenever possible, something the students regularly acknowledged as something they really enjoyed and valued.

The intervention itself achieved a great deal of what I hoped it would – students, without prompting, described the project as encouraging them to be more open-minded. I also did not get, as in the previous year, any complaints about difficulties of using the library databases. I ascribe this to the fact that I allowed them to use the internet freely. They continued to use the Web of Science/Knowledge but were not confined to it. Many also acknowledged how much they appreciated being able to choose their own

subject for study. Speaking to them out of class it was clear that they devoted more time than I expected. This was a project about process rather than content and by allowing students to select their own subjects of study I saw high levels of commitment.

## Chapter Nine

### Discussion and conclusion

#### Introduction

In this chapter I will discuss the findings of the research described in Chapter 6 (Preliminary Reconnaissance), Chapter 7 (Further reconnaissance and piloting the intervention), and Chapter 8 (The Intervention). I will show how my findings addressed my main research question and my five sub-questions. The sub-questions are listed here:

1. How can the term ‘scientific literacy’ be usefully defined in the context of my action research?
2. How can I endeavour to improve my students’ scientific literacy (within the meaning I ascribe to scientific literacy)?
3. How do levels of interest towards science and technology among my students compare with those of similar groups in other countries?
4. Is the degree of interest in scientific issues associated with the field of studies students are pursuing at university: specifically, do science students show more interest than those on a humanities track?
5. Can I collect any data that will contribute to the discussion of the relevance, or otherwise, of science education in school and its impact on scientific literacy?

The chapter sections are:

**Section 9.1 Defining scientific literacy** – addresses the issues raised by the first two of my four sub-questions I presented at the beginning of this thesis.

**Section 9.2 Assessing Scientific Interest** – reflects on the findings of my research relating to sub-questions 3, 4 and 5.

**Section 9.3 The teacher-student dynamic** – considers how my role as a practitioner-researcher changed my classroom dynamic, the relationship with my students, and my teaching methods.

**Section 9.4 Outcomes of the Intervention** – discusses the development and outcomes of my intervention and contextualises it within the framework of my main research question:

How can the scientific literacy of Israeli university students be improved as part of an advanced academic English programme?

### **9.1 Defining scientific literacy**

In the literature review, Chapter Three, I discuss the diversity of meaning that accompanies the term “scientific literacy”. My conceptualization of the term owes much to sociological researchers in the field who acknowledge the value of personal knowledge, acquired through life experience, rather than through instruction. There is a shift away from understanding scientific literacy as being related to the acquisition of knowledge. The definition that I have adopted sees scientific literacy as a series of skills, and in this I am following the ideas and extensive research of Norris and Philips (2003). These skills include not only a high-level of reading comprehension (which I already teach as part of my course) but also those skills associated with critical thinking. Improvement in critical thinking skills is of direct value in improving scientific literacy. I chose to focus on that skill associated with acknowledging the value of counter arguments.

### **9.2 Assessing scientific interest.**

I selected as the prime focus of my research two of my classes of students at a university *mechina* (pre-academic programme). These classes were students with limited high-school science education. Forty per cent of students on the science track had a single science *bagrut* (almost exclusively in biology), and in the class on the humanities track only twenty per cent had a single *bagrut* in a science subject (again almost exclusively in biology). These figures corresponded closely to those of my two top classes (level 1) studying at a college of engineering, with the class of academically more proficient students having 50% with a single science *bagrut*, and the slightly lower academically proficient students having only 20% of students with a single science *bagrut*. All these science *bagrut* were mainly in biology, with very few taking chemistry, and hardly any taking physics.

It could be argued that my *mechina* students at the university are an atypical group of students. Highly motivated and aspiring to gain places at university, where entry to any field of study is highly competitive, especially in all science subjects. It is, however, important to note that studying at *mechina* is a well-established educational path in Israel. Most institutions of tertiary learning offer a pre-academic programme to bridge the knowledge gaps which many students have post high-school. Attending a *mechina* does show motivation but since most young people today intend to get a post high school qualification, studying in *mechina* is not an exceptional path to choose within Israel.

However, my class on the science track in the university *mechina* had about 20% of students who wished to study medicine. These are highly motivated students who needed to get a 99% average across all the subjects they study at *mechina* in order to gain a place at medical school – no more than about three or four a year will achieve this. The others will go and study other subjects, and many will pursue medical studies in Bologna, Italy, or in Hungary. It is important to consider whether this highly motivated, high-achieving group could skew my results. Throughout my research I have always worked with two classes, one on a science track and the other committed to studying humanities. Any major discrepancy between these two groups could be ascribed to the skewing of results by that faction of highly motivated and academically successful students in the science class (about 20% of the class, according to their declared intent to study medicine at university).

The fact that the humanities class produced data that was consistent with that of my classes at CE (where admission criteria are low or, in some years, non-existent) indicates that it might be reasonable to regard them as a more representative sample of students in tertiary education than those at U on the science track. The similarity in scores was clear when comparing U Hum and CE T (the academically weaker of the two CE classes (see Table 6.10).

My questionnaires collected data on levels of interest in a range of topics, and gave students an opportunity to declare how well-informed they considered themselves. From this data two indices were computed: the index of interest and attentiveness. These provided me with a direct quantitative comparison with international data computed in the same way. There was the possibility that my cohorts were so far removed, socially and culturally, from international assessments that any comparison

was invalid. However, it was interesting to note that on the topics relating to sports and politics my groups showed values for the index of interest and attentiveness at the same level as both the European Union and Canada (the only global regions for which there exists comparable data). This helped give me more confidence in comparing the data for index of interest in the two categories 'inventions and discoveries' and 'medical discoveries'. My students (both science and humanities) were amongst the highest recorded internationally (see Tables 6.6, p.107, and Table 6.10, p.112). The value in comparing data internationally is that it raises the possibility that high scores for the index of interest are not necessarily the result of science education in school.

Enquiring about their interest in some contemporary issues with scientific/technological content showed that many issues received a high Index of Interest. It should be noted that an index value of 50 shows that all members of the class declared that they were moderately interested in a subject. An index of 60 from a class of 30 students could mean that around 7 students were very interested while the rest showed moderate interest (see Table 6.10).

Furthermore, when presented with a VOSTS question, the answers from about two-thirds of all my students showed that they felt public opinion should be included when government was making decisions with scientific, technological, and environmental relevance (see Table 6.11). From my classroom experience it became clear that issues with medical content (e.g. relating to euthanasia, vaccination of children) were seen as subjects in which government policy should be strongly influenced by public opinion.

Although the vast majority of these students had received little or no science education in high school, my data seems to support the idea that a majority of the cohort were interested in scientific issues and wanted their voice to be heard within public debate in decisions with scientific/technological content.

The data sets I collected across 2009, 2010 and 2011 showed internal consistency across the years, with levels of interest and attentiveness having similar values in the study populations in each year.

Data collected in 2011 (Chapter Eight) showed that 100% thought scientific literacy important, and over 90% did not regard a science *bagrut* being important to gaining that literacy, although they all thought science education at school was important. This is an important and interesting distinction. However, as explained in that chapter, the question was perhaps flawed and misrepresented the term scientific literacy, but I don't

think it totally invalidates the results given here. It would have been preferable to have first explored what the students understood by the term scientific literacy.

But it is worth noting that over three-quarters of the humanities students thought it important, or very important, to receive some science education while at university (see Table 8.12, p.176), though the nature of the content was not explored in my research.

I had also given a scientific literacy test early on in my research. Here my students scored higher than every group that had been assessed internationally, including the group that claimed the highest scores in the US (i.e. those with a professional degree). The scores of my humanities students were also higher than those gained in the US by high school graduates, or those with professional degrees. And while international comparisons ignore those parameters that make my Israeli cohort different from counterparts in other nations, my data does lend support to the argument that perhaps school science education is not a marker for levels of scientific literacy, even when the term is focussed on knowledge acquisition.

I did not investigate within this research how my students acquired their scientific knowledge. But it should be noted that they fared particularly well on those science questions unrelated to biology, and did rather dismally on the one question that was biologically related. This perhaps offers additional support for the idea that study for state exams (*bagruyot*) does not promote increased scientific knowledge in those areas that have been designated by international testers as being particularly relevant in assessing scientific literacy.

### **9.3 The teacher-student dynamic**

Engaging in an action research project made me reflect not only on the methods of teaching I adopted but the whole teacher-student construct that framed my role as teacher. This project had started out with me assuming that my students' scientific literacy would be improved if I ensured that they were able to read text and gather information in a more critical way. I thought I would include rhetorical analysis of text, and show them how authors, even scientific authors, are highly manipulative of readers. I always wanted to show how texts, even scientific texts, are situated within their own cultural-political framework. And these activities were an integral part of the content of my teaching within the academic reading programme.

However, it was the chaos which accompanied the open discussion forum that I offered in class (initially relating to the topic ‘violence in society’) which highlighted the problem of getting students to discuss contentious issues. They had an inability to listen to another opinion, let alone show any respect for someone with a contrary point of view. It was out of this experience that the termly project based on playing devil’s advocate was developed.

My classroom changed during this research from individuals working alone to pair working whenever possible, and this was appreciated by most students. It was student feedback that alerted me to the fact that this might be a more useful way of organising work in class. When working in pairs the students seemed engaged in whatever had been set and produced good work.

At every stage, my observations and reflections were directed towards improving the student learning experience. Their detailed feedback was of great importance.

My prime method of accessing student feedback became the *petek*, and this enabled me to capture student opinion on matters relating to my teaching during the lessons themselves, or some days or weeks later. As a practitioner-researcher I found myself shifting my perspective from being teacher-centred to being student-centred. Questions that became important included: what do my students think I am trying to teach them? Do my students want me to change my teaching methods? Do they share my view of what is important/relevant in this class?

I also tried to change the physical environment by rearranging the chairs (with attached mini desk flaps) to form a semi-circle around me, rather than the formal ranking of rows (with back row students always a little disengaged from the class). In the packed classrooms at the university this was rarely possible. I also started doing more teaching sitting, instead of always prowling around and performing standing up. This made me more part of the class, but was not always possible when there were many rows of students and those at the back did not have direct line of sight with me. I also welcomed opportunities for engaging in chance encounters in the *mechina* building wherever possible, not approaching the students but making myself available to talk to.

I have discussed (section 7.3.3, p.157) the problems of using focus groups and semi-structured interviews in gathering student opinion. The teacher-student power relationship is particularly strong in a university setting. I am responsible for their class

grade, and marking their exams. They see their future as within my hands. The formalised structure of a focus group, or an interview, only produced non-controversial comments. The anonymity of the *petek* allowed for more meaningful responses.

## 9.4 Outcomes of the intervention

### 9.4.1 Challenges of working with my students.

My action research with the intervention focused on two classes on a year's pre-academic programme at the University. Both classes already had a *ptor* (an exemption) in English. This is awarded to students who achieve a score of 133 and above on the nationally accredited psychometric exam in English. This test focuses on knowledge of vocabulary and high level analytical reading skills. I had taught *ptor* students for four years at the university prior to commencing my research in 2009 and found they had high levels of reading and speaking, but their writing skills were weak. However, giving short written responses as required on the *petek* was comfortably achieved by all the students in all the years of this research project. Where I have quoted from their *petek* responses I have always done so word-for-word. At no point during the interventions I introduced did students complain about the challenge of working in English. It might be suggested that these students could have been primarily mother-tongue English speakers, but of the two classes questioned about their spoken language proficiency only six students listed English as their mother language, and that does not necessarily indicate proficiency in reading or writing.

It did not seem that working in English affected the progress and outcome of the project. However, the dynamics of the classroom, which reflect student-student and student-teacher relationships, were embedded within a complexity of socio-cultural contexts that I am still trying to fathom after working in Israel for 11 years. The classroom dynamics affect both teaching and learning styles. It is outside the scope of this action research project to analyse this in detail; however, reflecting on the nature of the teaching experience within an **Israeli** institution is an important element in my research.

During the course of this research I changed the working pattern within my classroom and moved to using pair work wherever possible. My fear that it would degenerate into chaos was misplaced. Doing things together is a strong pattern of behaviour in Israel;

individual study is rare outside the classroom. Within university and college libraries, large areas are set aside for working with a partner or in a group. University libraries often provide many small, bookable rooms for groups of students to work together, and there are large areas where tables and computers are provided and talking is allowed. Few students engage in solitary, silent study. My students thrived when working in pairs. They seemed more focussed on the work. Their *petek* feedback showed how much they enjoyed the opportunity to work in this way.

Ultimately, it was my classroom experience which determined the content and structure of my intervention. I had been intending to make this research focus on critical reading strategies that would help my students become more aware of the socio-political context of all texts, even those that purport to be exclusively factually based (for example, science writing at all levels from newspaper reporting to journal articles). And this was an important element of my teaching when we were analysing texts. However, the inability of my students to hold a reasonable classroom discussion became the main influence on the interventions that I developed.

Introducing discussion in the classroom revealed several problems that needed addressing. Firstly, everyone spoke at the same time. This was easily dealt with by introducing a rule that only one person can speak at the time. But still the discussion was primarily a forum for expression of deep passion. Argument and counter argument were presented but there was no construction of argument based on what others said. There is a great deal of literature on the role of exploratory talk, i.e. constructive engagement through discussion, in student learning within the school environment (Simpson et al.2010). But my focus did not concern developing exploratory talk. I felt there was something of fundamental importance lacking in my students that needed to be addressed: an inability to acknowledge the value in any counter argument.

Adapting a devil's advocate approach to discussion seemed to offer a way forward and became the basis of the interventions I implemented.

#### 9.4.2 The intervention

All students in the *ptor* classes were required to do a project as part of their first term's study in the English classes within the *mechina*. Each teacher has complete freedom in their choice of project. Students in these classes were taken to the computer lab for an introduction that to the library databases (Web of Science, EBSCO). In preparation for their university studies, I also included a general lesson on evaluating information

obtained on the internet, providing my students with an overview of useful sites on the internet and how to use the search engines of Google-scholar and Google-books. In recent years the Google search engines have become so powerful that they are more useful than the library databases. However, articles not available through open source can often be accessed online through the university library.

The project offered me the ideal opportunity to introduce and monitor an intervention. Traditionally, all the teachers of students in level 1 and *ptor* classes gave them a project based on using the library databases. Most teachers asked the students to find an article on a particular subject and write a summary. Students from all the classes regularly meet informally during break time and talk about what they are doing in class. At the outset of work on the project, my students would recognise that the project they had looked a little different from the other class projects. However, there was nothing to alert them to the fact that it would unfold in a totally different way to the other projects. Indeed, they would probably have seen it as a variation on the theme which other teachers made explicit i.e. giving practice in researching using the library database. It was important to me that I did not give them any indication that I was using the project as a vehicle to make them more critical thinkers, and change their perception and understanding of people who hold counter views to their own. (Detailed descriptions of the intervention are given in chapters six and seven).

By veiling my project objective, it allowed me to get feedback on what students thought the project was actually trying to achieve. The responses I got on the *peteks* and orally were interesting. The student responses showed that my small intervention could be identified by most students as changing their attitude to counter arguments.

This intervention also supported my research goal to improve scientific literacy. There can be no useful participation in discussions relating to issues of scientific/technological/environmental importance without investigating, understanding, evaluating, and respecting opposing opinions. Of course, it can be argued that this forms the basis of any meaningful discussion on any subject. Science literacy might require more explanation and information on some of the more technical aspects of a subject but, ultimately, citizens should be hearing both sides of an issue, and challenging strongly held opinions (both their own and those of others). Many of the issues might be of immediate personal relevance, and here I am thinking, for example,

of my student whose wife was about to give birth and he wanted to challenge his own view that she should be in hospital rather than at home for the delivery. And, of course, there are wider societal implications for developing scientific literacy: to help develop informed democratic societies which hopefully will be able to claim their right to mould and influence the world we live in.

## Chapter Ten

### Final reflections

#### Introduction

This chapter provides an opportunity to take a brief look back over the path taken, and to identify future possibilities that might result from my action research. The sections in this chapter are listed below:

**10.1 Path taken.** A brief description of how my interest in this research first began and how it progressed. This section includes information on how the results of my action research are being incorporated by other teachers.

**10.2 Contribution to knowledge**

**10.3 Implications and future research**

**10.4 Limitations of my research design**

**10.5 Application of my research**

**10.6 Closing remarks**

#### 10.1 Path taken

The first seeds of this research were sown many decades ago when I was working as a medical physicist at St Mary's Hospital, Paddington, London, where choices of treatment and investigative procedures went totally unquestioned by patients. Not only did the patient view the doctors' decision as sacrosanct but when I wanted to explain a procedure patients expressed the view that this was something they didn't want to understand, and probably would not be able to understand. I left my job and research, and moved to science journalism as a move towards helping to inform the general public about science and medicine. But the pressures to produce headline copy meant a loss of integrity in reporting, and I moved on to education of high school students. Slowly it became clear that there were gaping inadequacies in education and when I joined a university in Israel eleven years ago I saw an opportunity to investigate and tackle what I was beginning to identify as the failings of current education in developing a citizenry that would envisage itself as true partners in government decisions relating to developments in science, technology and medicine.

The action research project gave me the opportunity to probe ideas on scientific literacy, and then investigate how my students could be engaged in the endeavour to promote their own scientific literacy.

This research began with an extensive review of the literature on scientific literacy. And there were several formative ideas that emerged from this intensive period of reading, which took over year in the first phase of this project. It soon became clear that many authors felt the standardised testing of scientific knowledge did not provide a useful basis for defining 'scientific literacy'. The detailed arguments are presented in the Literature Review, Chapter Three. For example, Kenneth Prewitt's noted that "scientific literacy" begins at "the point of interaction between science and society" and not with science itself (Prewitt, 1983), and Keith Devlin introduces the concept of 'scientific awareness', noting that "it is pointless to define scientific literacy in terms of any particular body of scientific knowledge." (Devlin 1998, p.559). The extensive research of Norris and Phillips (2003) identifies the problems of interpreting meaning and the inferring of authorial intentions in popular scientific articles. For them these interpretive tasks "transcend scientific knowledge and knowledge about science", and highlight the importance of a more fundamental definition of scientific literacy not dependent on scientific knowledge, but requiring the ability to think critically. The literacy program that I taught university students, among other students, was already dedicated to ensuring that my students were able to read critically – for example: understanding the significance of social, political context on meaning; the use of rhetoric in affecting meaning.

Embarking on action research I became more sensitive to my classroom experience and recognised that there was a serious inability among my students to listen to opinions contrary to their own, and even to show any degree of respect to someone holding those opinions. Changing these attitudes became the focus of my interventions. The ability to be open-minded is a core skill within critical-thinking.

The intervention I devised did seem to impact on students, according to their own feedback, and has become integrated in all the programmes I teach. Moreover, several other teachers at the university are now adopting my 'devil's advocate' project within their own courses. Particularly gratifying is the inclusion of this project within a new

English *bagrut*. I have called it 'Know your own mind?' and I have been invited to write the lesson plan for it, and present it as part of the professional training programme that will be offered to teachers who will be introducing this high-level English programme within their schools. Methods for investigating the validity of information gleaned from the internet is part of this package.

Monitoring of student feedback was an important issue in my action research, and I devised a method I called 'the *petek*'. This simple procedure of getting snapshot responses from students written anonymously on coloured half sheets of A4 is being more widely adopted among teachers both within the university and among teachers working in high schools.

## **10.2 Contribution to knowledge and understanding**

My contributions to knowledge are derived from the findings from the research I did to address my initial research questions. The research questions are listed here:

1. How can the term 'scientific literacy' be usefully defined in the context of my action research?
2. How can I endeavour to improve my students' scientific literacy (within the meaning I ascribe to scientific literacy)?
3. How do levels of interest towards science and technology among my students compare with those of similar groups in other countries?
4. Is the degree of interest in scientific issues associated with the field of studies students are pursuing at university: specifically, do science students show more interest than those on a humanities track?
5. Can I collect any data that will contribute to the discussion of the relevance, or otherwise, of science education in school and its impact on scientific literacy?

Paralleling these research questions are the following sections, which help clarify my contribution to knowledge in the context of each question. Section headings:

10.2.1 Scientific literacy as critical thinking

10.2.2 My intervention – a method for developing open-mindedness in the context of improving critical thinking.

10.2.3 Comparing the interest of my students in science with that of other international cohorts.

10.2.4 Interest in science among humanities' students.

10.2.5 Impact of school science on interest in scientific issues.

#### 10.2.1 Scientific literacy as critical thinking

Having explored the discussion surrounding the term scientific literacy in Chapter Three (The Literature Review) I have adopted the view that scientific literacy, in the context of the ability to discuss SSIs, necessarily includes critical thinking skills.

By improving critical thinking, I am directly contributing to an improvement in scientific literacy.

It seems possible that in order to develop scientific literacy core thinking-skills need to be integrated within the education system at all levels. I identified the importance of showing open-mindedness in discussions as being a core-skill. I felt it important to improve this skill, so that students could participate in meaningful discourse. An ability to be self-critical and open-minded are an essential part of any discussion of SSIs, and perhaps should therefore part of any program designed to improve scientific literacy.

#### 10.2.2 Method for developing open-mindedness in the context of improving critical thinking.

While there is much dispute about the definition of scientific literacy, the aims remain the same: to ensure a citizenry can meaningfully engage in decisions relating to SSIs, particularly those issues that are felt to be personally relevant. I have suggested that scientific literacy should be seen as driven by a set of critical thinking skills and not by a knowledge-base. Critical thinking includes the ability to acknowledge contrary opinions to one's own, and developing such an ability can be seen as a valuable contribution to the development of scientific literacy. I used a project based on devil's advocate to help students understand that counter opinions can be evidentially based, and need careful consideration. The students themselves identified the project as providing them with awareness of the value of other opinions, and referred to the ability that they had acquired as 'open mindedness'. Their feedback showed that they were aware of changes in their decision-making process. They wrote statements that showed

an increase in their ability of valuing counter opinions, which is of fundamental importance in any decision making process.

This study was unable to monitor whether there any long-term effects of this intervention. There was some unsolicited feedback from students encountered a year or two years after completing their *mechina* studies which suggests they saw the intervention as helpful in formulating opinions in their degree studies (this feedback was only from humanities students who continue to study on the campus where the *mechina* is situated).

### 10.2.3 Comparing the interest of my students in science with that of other international cohorts.

As an interpretivist action researcher there are caveats when making international comparisons between one's own findings or data sets and those of other countries. The context of my research is within a unique socio-cultural framework, and making any sort of comparison needs to acknowledge the wider influences on all data collection.

However, the comparisons I made of the Index of Interest, Attentiveness, and scientific literacy scores could help to challenge the international coupling of these scores with school science education. The fact that my students ranked highly on all these measures when compared to their international peers perhaps can be seen to challenge the linkage between school science education and each of these different measures of scientific literacy. A decoupling of school science and scientific literacy has far-reaching implications which deserve much wider discussion.

The success of my students compared to their international peers in a scientific literacy test, does suggest that my students gained their science knowledge autonomously. My students, like the majority of Israelis, will read newspapers avariciously, and certainly there is wide reporting of science and technology within the Israeli press. My students also reported watching science programmes on TV (National Geographic being a favourite). Newspapers and television have been identified as essential sources of scientific knowledge in the general population (Nisbet, 2002). And for any student curious to find out more about any topic the internet is an immediate resource – even available on their smartphones. This is an area for future research. It is important to

identify how knowledge is acquired independently of school teaching as this could help understand how to build lifelong learners. It also suggests that the content of school science does not need to focus on the acquisition of knowledge but could offer skills of analysis and evaluation i.e. critical thinking skills.

#### 10.2.4 Interest in science among humanities students

My university students on the humanities' track showed similar interest in science, technology and medical discoveries as the students in the college of engineering. (Table 6.3). These groups showed slightly lower values than those university students on the science track.

However, there was a high level of interest among humanities' students to receive some science education at university. It is important that discussion of SSIs should not be confined to those who are studying science. More research needs to be done here, but the indication is that students committed to studying the humanities would engage with courses on science. The content and demands of such a course would need careful consideration, and perhaps should be embedded within a critical thinking program.

#### 10.2.5 Impact of school science on interest in scientific issues.

My findings showed a high level of interest among *mechina* students in media coverage of topics relating to science, technology and medical discoveries. This result is interesting because they have received a very low level of science education at school. It indicates their interest is independent of school studies.

There is research that suggests that their interest in science is because they have had little high-school teaching in the subject. This view is supported by a body of evidence cited by Vedder-Weiss and Fortus (2010, p.200). Many of these findings note a substantial decline in students' motivation to learn science during the adolescent years. This marked decrease in motivation has also been found in other subject areas and researchers in this field have suggested that this is the result of education policies that do not listen to the students' voice, and does not allow them to make choices about curriculum (Osborne et al., 2003). It is of value to mention that Vedder-Weiss and

Fortus own research (2010) in Israeli schools showed a decline in student motivation to learn science in traditional elementary schools, and, even more worrying, an increasing resentment to extra-curricular science-related activities. They also compared these findings with attitudes and motivation among students studying in democratic schools where the emphasis is on a student-centred educational experience.

My findings seemed to support the idea that the absence of traditional high-school science instruction results in high levels of interest in science persisting through high school.

### **10.3 Implications and future research.**

There are four sections here:

10.3.1 Impact of school science on interest in scientific issues.

10.3.2 Redefining scientific literacy.

10.3.3 Student feedback.

10.3.4 Critical thinking and open-mindedness.

#### **10.3.1 Impact of school science on interest in scientific issues.**

Acknowledging that the absence of school science teaching does not seem to negatively impact on interest in science has several implications and casts doubt on the efficacy of a content-based knowledge driven curriculum. This is an area I would like to do further research into both at the high school and tertiary level.

If the content-base of school science is to be diminished in preference to creating critical thinking and engaged students, then the tertiary level of science education needs redesigning. There is much to be said for an Israeli system that allows and even encourages students to take science degrees without any formal school-level qualifications in the subject. Indeed, this is how most students enter science degree courses in university and colleges. It is possible to teach all the necessary basics within tertiary education. This would enable school science to be considered as something other than a stepping stone to tertiary level science studies.

Courses could also be offered in subjects relating to general scientific issues to non-science students at tertiary level. The content would need to be driven by relevance to student interest.

### 10.3.2 Redefining scientific literacy.

If school science does not impact positively on attitudes towards science, and it not a requirement for studying science at a tertiary institution, then perhaps school science can assume a different role. This is problematic because the vested interests of the high-school science teaching community, and that of the ministry of education, (in all countries), make this a difficult area to introduce radical changes. It even makes it a problematic area to make the subject of research. Redefining scientific literacy suggests that school science should not be knowledge-based but should be seen as an opportunity to maintain curiosity in the field. And perhaps should aim at developing broad critical thinking skills needed for meaningful reciprocal discussion.

### 10.3.3 Student feedback.

There is much to recommend that monitoring student attitudes to content and teaching should be integrated into all courses. The concept of a student-teacher partnership in constructing curricula and defining learning goals is of fundamental importance. The *petek* could become a useful way of garnering student response to their study programmes and class activities.

### 10.3.4 Critical thinking and open-mindedness.

Devil's advocate seems to offer a simple way of helping students develop both critical thinking and respect for an opposing opinion. It would need further research to verify its value in other settings. Within this activity the need to be able to evaluate information on the internet is essential. In our contemporary society this could be integrated within school teaching. The internet moves fast and teachers in all subjects need to be able to keep up with developments online so that they can use them with their students. Ideally there should be a website, perhaps maintained by the Ministry of Education, to facilitate teachers and students doing research on the internet.

I am now preparing a unit for a new *bagrut* in English, entitled 'Debate and International Communication'. My method for developing counter arguments will be

used within this curriculum, and will form a classroom project. There will also be a module (which I am writing) on using the internet for research.

#### **10.4 Limitations of research design**

There are several aspects of my research design that need to be examined because they directly affect the information I collected. I have considered the design under four headings.

- a) Selecting the study population
- b) The research tools I used.
- c) The research tools I didn't use.
- d) How the design of future research could be improved.

##### **a) Selecting the study population**

This has been dealt with in section 9.2, p.194, but I would like to summarise it here. I chose the two top classes I teach at the university *mechina*. I selected *ptor* students, who already had an exemption in English, because I wanted to have students who felt comfortable in working in the three modalities: writing, reading, and speaking. The essays they wrote for me at the beginning of the semester demonstrated their command of English. I chose one class on the science track and one on the humanities so that I could look at differences between them. I saw the same differences between them in the groups I took in 2009, 2010, and 2011. This internal consistency was important in all the measures I made of the two groups. It does add some value to my findings knowing that the levels of interest of the students etc. were so similar across different cohorts in each year. This stability of measurements across different cohorts does indicate that research across several years might allow for useful comparisons.

I did consider that my university *mechina* students might be an exceptional population because of their motivation to study for a year at a *mechina*. This was the reason that in the first year of my action research I included two other classes in much of the reconnaissance I did. These two extra class were in a regular college of engineering, which has minimal entrance requirements. And these college students were already starting a degree course so they represented a more typical Israeli student population. They shared with the *mechina* students the fact that they, like the vast majority of Israeli students, have received little science education at school.

The results from the *mechina* students were comparable to the results from the college students, showing that my *mechina* students could possibly be considered as representative of a wider student population.

b) The research tools I used

I used questionnaires to gather data about sex, level of school science education, interest in specific SSIs, and general level of interest in popular science and technology articles in the media. Levels of interest were indicated on a 3-point Likert scale and were then computed using a standard algorithm to give a single weighted value for each student; this process allowed class averages to be computed for the Index of Interest and Attentiveness.

The first year of this action research, 2009, was viewed as an opportunity to pilot the questionnaire and make sure that it didn't take the students more than 10 minutes to complete, and that the questions were easily understood. In the three years I used this questionnaire (with about 200 students) no question was ever left unanswered and no student asked for clarification of meaning.

Single open-ended questions were also given to students to get their views on a wide range of topics including attitudes to astrology and qualities of a good teacher.

A standardised multiple choice question, a VOSTS, was given to ascertain to what extent students feel they should be part of decision-making in an SSI. This was a long question that took a lot of concentrated reading. I used it in one year and got sufficient data from two classes.

I also used the *petek* extensively to get a snapshot of my students' opinions on a wide range of classroom activities. This method is described by McKernan (1996, p.134) as a projective technique, and enables students to record in their own words a response to a single question. For example, I used it to discover if students enjoyed working in pairs, and in recording what they thought they gained from the intervention/project.

The *peteks* were coded and analysed. It became my main source of student feedback on the project. It was important not only for the views expressed by the students but it also made them reflect on the process of the project and what they had gained from it. This

reflection can be seen as a metacognitive process that reinforces the actual experience and helps them integrate the practice within their thinking (this is difficult to demonstrate, but further research could attempt to do it).

It takes a great deal of time to code and analyse, and to ensure that I had done the coding carefully I repeated it a year later. Ideally I would have liked someone else who knew nothing about my project to do the coding and analysis, but there wasn't anyone to call upon.

All the research data collected was anonymous. This was very important because of the influence of the teacher-student power relationship. I deal with this in more detail in the following section on 'the research tools I didn't use'.

#### c) The research tools I didn't use.

At the beginning of the semester and during the semester I repeatedly explained to my students that my policy was to give a class grade of 100%. This was particularly easy to do with the top classes who had a high level of language proficiency and were generally conscientious students. I wanted to try and diminish one aspect of the teacher-student power relationship. I didn't want them to see me as the purveyor of grades. However, the fact that they kept asking about their class grade throughout the semester meant they found this idea difficult to grasp. And their attitude towards me within a focus group, and in the few semi-structured interviews I set up, made me realise that the students felt themselves embedded within a power hierarchy that placed me in a position of authority, and someone to please.

I had assumed at the outset of my action research that I would be using structured and semi-structured interviews, and focus groups. At the start of the preliminary reconnaissance in 2009 I set up two focus groups at the university *mechina*, one from each of the two *ptor* classes that were part of this study. In each class I asked for around five students to volunteer to be part of a focus where we would meet perhaps once in two weeks and discuss, for about 15 minutes, different aspect of the course I was teaching, from course content to homework. I explained that this was being doing in the context of my doctoral studies, and I briefly described what action research was. Five students volunteered in each class.

Asking for volunteers is in itself a process that brings forward the boldest, most vociferous students. The occasions on which we met was completely unrewarding. All questions received only brief positive answers, and they spoke with one voice. There was nothing engaging or authentic about this experience. It was clear that they thought of their future as being in my hands. This might be a different experience if the person interviewing or facilitating a focus group was not the teacher who marked their exams. It would have been interesting if I could have absented myself from these sessions and got someone else to chair them. This was not a possibility.

Other research tools I would have liked to use would have been videoing the class, but I was told that this would not be acceptable to the university, even if videoed from the back of the room so that students remained unidentifiable. When I asked about audio recording classes, I was told by department head “it is not something we do”, and I was also informed that students would regard it as unacceptable because they would feel it was not anonymous when voices could be easily identified. It would cause student discomfort in the classroom and was not something that should be done.

I suspect that with the ubiquity of modern cell phones, students will become less sensitive about being recorded. It is perhaps worth noting that unlike the UK, security cameras in a civilian setting are extremely rare and are never placed on university campuses. This might in part explain the reluctance to allow recording in the classroom. Furthermore, unlike schools, recording of teachers in universities and colleges never take place as part of professional development. I think the reluctance of my department to allow recording is because university teachers regard their classroom as sacrosanct. If I am allowed to record in my classroom would that establish a precedent that would allow university authorities to encourage classroom recording. My fellow teachers were extremely unhappy that I should pursue the possibility of carrying out a recording in my classroom.

It should perhaps also be noted that observation of university teachers, by the head of department, is very rare – only for new teachers in their first semester of teaching will they be observed on one or two occasions. Veteran teachers are never observed. And no teacher ever enters another teacher’s classroom to watch their teaching.

### 10.5 Application of my research

There are three ways in which I have been able to apply my action research.

Firstly, I have initiated a research project, in the faculty of humanities in the university where I teach, that is based on the methods and methodology of action research. All first year students in the faculty get a course in writing essays in Hebrew. Some of the material has been transferred from being taught classes to three online PowerPoint presentations. This move to online courses is a widespread move among universities in Israel, it enables them to save money by reducing the number of teachers. In none of these new online courses has there been any attempt to evaluate the student experience of using them. I have developed questionnaires to get feedback from the staff and students. Focus groups will be set up to discuss the course content, with the facilitator coming from outside the department.

We have already got over hundred and fifty questionnaires from the first cycle. And are now designing another stage of the research for next semester – this will hopefully include focus groups to discuss the content of the presentations.

The second way that my experience of action research is being introduced more widely is by encouraging colleagues to gather feedback from students through the use of the *petek*. I am also hopeful to get the use of the *petek* included within teaching training programs for school teachers, so that they will be able to use it in their classrooms. This is one way to encourage more teachers to participate in the reflective processes associated with action research.

The third application of my research is at the Ministry of Education, where a new English bagrut is being developed, which I have been closely involved in. It has several modules that relate to critical thinking skills and my devil's advocate will be one of them.

I have also begun to initiate my devil's advocate project in other institutions of tertiary learning in Israel.

### 10.6 Closing remarks

My introductory chapter opens with the first stanzas of Yehuda Amichai's poem *From the Place Where We are Right*. His words are haunting:

From the place where we are right  
flowers will never grow  
in the spring.

The place where we are right  
is hard and trampled  
like a yard.

This action research project has made me forever re-evaluate whenever I feel I am right, I hope it will do the same for my students.

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## **APPENDIX A**

### **FORM OF APPROVAL**

Permission is given for Susan Goodman to submit her research, done at the Mechina of the Hebrew University of Jerusalem in 2009-2011, for a doctoral degree at Sussex University, UK. (Title of thesis: An Investigation into Improving Scientific Literacy in Israeli University Students within an Academic English Reading Programme)

Signed\_\_\_\_\_

## FORM OF APPROVAL

Permission is given for Susan Goodman to submit her research, done at the Mechina of the Hebrew University of Jerusalem in 2009-2011, for a doctoral degree at Sussex University, UK. (Title of thesis: An Investigation into Improving Scientific Literacy in Israeli University Students within an Academic English Reading Programme)

Signed \_\_\_\_\_

האוניברסיטה העברית בירושלים  
המחלקה למחקר חינוכי  
ע"ש יוסף שאלתיאל

## APPENDIX B

Essays on sources on influence.

Extracts from essays in response to my suggestion that my students write about a book, a person or an event that influenced them/changed their lives.

### A. Influence of people

A1. *Two weeks ago I started learning at the University. At the beginning everything was new to me...But as the time past by I felt I belong and met great people. During the last weekend I stayed at the dormitory with two new friends I made. It was a great experience, we kept the shabat. The girls were so inspiring, their faith was so strong and genuine...I never thought about prayers. They made me think about my life. It is strange how people that share the same goals have such a different point of view. I know that I am young and I am exposed to new things. But these girls really amazed me. And who knows maybe it is a totally new beginning.*

A2. *Something that influenced on my life is my mom...6 months ago my mom discovered that she has cancer...She was hospitalized for 3 months. I used to sit next to her everyday. I didn't go to school because I wasn't able to function...I used to pray for her every morning. The doctor didn't give her a chance to live. In a conversation I had with her doctor, I remember him looking into my eyes and saying that my mom is about to die. After few weeks, my mom happened a miracle and she started getting better against all the chances. I think it made me stronger...I became more mature and responsible. I can face every obstacle.*

A3. *Being a minority kid didn't affect him at all, unlike myself my cousin didn't let anyone bring him down, he always stayed focused on his target, not letting anyone stand in front of it. So due to his great efforts and his great determination, my cousin became the first military Druze pilot. My cousin helped me in plenty of ways...So I've decided that I should move along with this and start helping those whom need any kind of support, hoping it will help them do the best they can, it's what I call "returning the favor".*

A4. *The person who had the biggest influence on me is my councler for the last three years Limor X. Limor is the councler of a program called "Ofek", this program is about helping ethiopian children to be successful in*

*their high-school...she also helped me in my personal life. She was the one that helped me believe in my self ...*

*A5. I was about 9 years when in the first time in my life I saw a real long run competition in the Olympic games...In that competition Aile Garrei Selase, an Ethiopian runner, won the first place...A lot of people might think that I like Aile G. Selase because he is from Ethiopia, like me, this might be one of the reasons but definitely not the only one...I like he gives fight until the end and don't give up in the middle. Another reason is although he is from a poor country like Ethiopia he still find the time and the power to move on with his dream.*

*A6. ...Ever since I was a child, I looked up at my brother for support, for guidance and as a role model, till this very day. Shmuel as always been decisive and strong minded, he overcame a lot in his life, from the long journey to Israel to the injury he suffered in 2004 in Gaza, while serving in the army, which resulted in the doctors remove his right leg beneath the knee...this is why I want to be a combat doctor and help soldiers in the front line...I come from a family of survivors and I strive for victory.*

*A7. ...My "hero" was Franklin D. Roosevelt...I learned about Roosevelt during my 7th grade studies and since then he made a great influence on me. His confidents and his determination have always overwhelmed me. Just like he said in one of his speeches: "The only thing we have to fear is fear itself" – this goes to show that this was a man who feared nothing and I admire him for that.*

**B. Influenced by an event**

*B1. It may sound weird but the thing that changed my life is not a book or a person, it is a television channel that made me realize what I want to do when I grow up. This channel called "Reality TV" and you can't see it anymore here in Israel. The channel showed most of the time shows about doctors...Now after 8 years from the discovery channel I still believe with all of my heart that I need to be a doctor, not just a doctor, a surgeon!*

*B2. I was influenced the most by a project called Kdam-Atidim. It's a project which gathered all the Ethiopian teenagers who have the potential to succeed according to their grades. The aim of this project was to give us motivation and to prepare us in the best way to the bagrut exams...I was*

*proud to be part of this project and thanks to it I have the motivation to fulfill my dream and succeed in life in all aspects.*

*B3. In generally, I don't think there was a specific thing that influenced my life in a drastic way. But as a dancer, there was one dance, that a god friend choreographed which affected by way of thinking about the form of dancing. I always thought that a good dance should be performed while using all the stage but when I first saw my good friend's dace I realized that my way of thinking was wrong. She danced in a small circle, which means in the dance language – dancing inside yourself...As a result of this change, I am able to choreograph better, and express my feeling better, trough dance.*

*B4. In our school, the journey to Poland wasn't a painfull search after our lost generations but a peacefull search of our jewishness,;...becoming a better jew...Nothing really touched me but Auschwitz was something else, you could feel it...We've been to some other places after Auschwitz, some were more special and some were more painfull but there was nothing llike Auschwitz!! When we got home, sweet sweet home, Israel, we landed and went straight to the capital, to pray. I didn't care, I couldn't concentrate, all I wanted to do is get to Netanya and go to my sister's kinder-garden and give her a big kiss!*

*C. Influenced by something read*

*C1. If I should explore my past, searching for a special article or book that I've read, there is definitely a distinctive one which has changed my life: it's part of a book "Here goes nothing" by Udi Miron. The book, generally speaking, is about a man who spontaneously decided to go on a journey, exploring his mom's life...before she immigrated to Israel when lived in Polin and France during World War 2...he realized he is not just their kid who was born here and grew up in a kibbutz in the north – they are the same. They have the same legacy and purpose. This part has changed my life because it made me realize that I'm part of them too – part of that legacy – to live develop and love this Country. This book has made me patriotic and made me realize, I'm in the right place.*

*C2. "Little women" was one of the first book I read. It was my first expose to the world of reading and I could not stope from there...When I read the story I felt guilty for thinking money got a main part of our life and we won't be able to manage without it. I was wrong. Those four 'little women' tought me that if you surround by love, laughter, happyness, it means you need nothing more.*

C3. ... *"In the Beginning" by Meir Shalev explores the different beginnings and illuminates them...The book changed my perspective about the stories in bible and created questions in my mind...All these questions made me look at the stories from the bible in a criticizing and questioning way. The stories are more than just stories, but full with feelings...*

C4. *Coraline is a fantasy/horror novel...This book influences me because it makes me wonder if there is another world where my parents, brothers, and friends behave differently than they behave in the world we know. Furthermore, it is nice to think about a place where there are no wars, economic problems, or malignant disease...*

C5. *The Bible, in my opinion is the greatest and the most important book of all times...Although I am not a great believer in god it can be seen that all of its storys psalms and laws been written in pursuit for a better society.*

C6. *"A person looks for the meaning of life" by Dr. Victor Frankle, a holocaust survivor. He wrote about his experience in the concentration camp in Poland...Dr. V. Frankle reveals the ways of coping when a person exists in a difficult situation. He claims that 'it doesn't matter where and in what situation you are just be optimistic, think about the best experiences that you had in the past. The book really influenced on me. Since I read this book I started to look to my life in another way.*

C7. *The book that had a major influence on me is "Catch 22"... The book made me realize that we should always criticize the systems we most respect and take for granted ...*

C8. *"The Princess who Believed in Fairy Tales" by Marcia Grad. The book changed my way of thinking and my aspect of life...the book made me realize that we don't need to believe in fairy tales, we must believe in ourselves.*

C9. *One of the most influential poems that I have ever read was "what I've done" written by Rock band Linkin Park. The song talks about long term issues that remain unsolved and encourage people to finally face those problems once and for always. 2 years ago, I gained 30 pounds within 6 months ...Reading the poem lyrics motivated me to look forward and start at the beginning of a new life. I*

*started working out, eat healthy and by doing so I've managed to achieve 40 pound weight loss.*

C10. *The book "A Trumpet in the Wadi" has a big influence on my life. Since I read this book, my point of view had changed. I think that Alex's death which happened because of the Arab and Israeli conflict in our country, comes to teach us how to live life...without thinking of what people say about us. Another lesson that I learned from this book is that the exterior appearance of people or their ethnic group isn't important. The most important thing is the personality of the person.*

(My note: on the top of the page the student had written the Aramaic abbreviation 'beit-samech-dalet', meaning 'with the help of heaven'. Only done by very orthodox Jews.)

C11. *Arie Arneri, a journalist in the Israeli news-paper 'Yediot-Acharonot' wrote a biography book about David Levi. David Levi is an Israeli politician who was born in Morocco and emigrated to Israel in 1957, age 20...When they got to Israel they located in a small town...where there was nothing but tents...David Levi, a construction worker, ...became a member of the "Knesset" ...and also a member in the Israeli government- as a Deputy prime Minister, Minister of Foreign Affairs...*

*I learned that if you want something in your life its only in your hands, if you really want something you should work hard – but in the end you will succeed...*

C12. *My first Article that really influence me, deep inside, was "I have a dream" from Dr. Martin Luther King...I think this article will be my source of inspiration for ever, because every time I feel weak or disturbed I go back to the article to fill my soul with inspiration.*

C13. *Abshalom Signal is a book about the efforts and the ideology of the first pioneers who came to Israel to settle it...During the last year I had dilemmas about my futures in life and the army. After I read that book my dilemmas disappeared because the hero of the book was actually an agronomist and not a combat soldier...I understand that I can make a change ...as a scientist.*

C14. *...I have chosen White Fang by Jack London...Through Fangs story we learn about human cruelty, compassion and treatment to animals in a way that totally changed my beliefs and perspectives and made me like animals, appreciate and protect them.*

C15. *I want to tell about the book of Dan Brown The devinci code...The story teach us that family is the important thing in the world...I learn to upricciate more the thing that my family do for me.*

C16. *"The Last Lecture" by Randy Pausch...Randy words reached me on a more personal level than nay other book I have ever read. A dying man final view of life, a true clear headed mind. I learn the important lesson of appreciating every gift and opportunity life trow at us. As Randy said "We cannot change the cards we are dealt, just how we play the hand".*

C17. *My love toward books began when I was in the 6th grade. My mom took me to one of the local library. There between the dusty shelves I had found the book that started my passion towards books, Harry Potter and the Grail of fire. It took me two months to finish the book...Harry Potter changed my life and I'm glad it did.*

C18. *I don't read many books, but this book really changed my perspective of life. The book called "The Secret" ...The writer says...if you want something so bad, the universe will do anything to give you what you want...I must say I didn't believe in it so much, but after sometime, I saw I got all the thing that I have asked for.*

## APPENDIX C

### Why the mechina?

Excerpts from some of the short essays written in response to the question “Why did you decide to come to the mechina?”

1. *I needed to improve my learning skills.*
2. *I went to a school that didn't prepare its students for bagrut...I began to suffer with serious depression.*
3. *After the army I started to ask myself what I want to do...*
4. *... not high enough grades for medical school*
5. *...after the army I had no real clue on what I want from myself*
6. *to get study skills to prepare me for academic life.*
7. *I am here to push myself as far as I can.*
8. *it is a new chance*
9. *After the army I wondered long and hard what to do.*
10. *To erase my past as a mischievous high school student*
11. *at school I didn't think about study*
12. *study in the Mechina involves a lot of sacrifice*
13. *my best chance to get into university*
14. *I haven't study for three years*
15. *I need to make up for my grades at high school*
16. *For the last two years I've been thinking what to with my life...I want to help improve the lives of other people ...I hope this year you will help me find the best way to do it.*

Most students also refer to the reputation of the University Mechina as the best in the country with ‘the best teachers’. Also many students mention that they need to improve their grades to get into medical school.

## **APPENDIX D**

### **Sample Projects**

### 1. Topic of choice - background

The development of artificial intelligence (AI) & its usage in fields, which involve human decision-making, is growing ever more prevalent. Whether in medicine, education, finance or even military operations, AI systems are becoming more and more ubiquitous- hidden away in the inner-workings of many of the aspects of modern life and "assisting" professionals to make practical & sometimes even ethical decisions. Some of the current implications of AI systems (such as in medicine) are unarguably positive & helpful. Yet, as with many other technological advances, acquiring the ability to use AI systems in positive ways, has led to the acquired ability to use AI systems in more calamitous ways. Moreover, some would argue that some areas of human decision-making are best left for humans. In other words, since computer soft-wares cannot be held accountable for the loss of human lives, they should not be placed with the responsibility for human lives. The question that arises is, whether the positive development & usage of AI systems should be permitted to continue, or perhaps stopped immediately in-order to avoid the negative consequences.

### 2. Personal opinion

My own opinion is, that concerning the potential misuse of AI systems, being developed today, in the near future, two facts stand above all existing uncertainty:

- ▲ As with all types of technological development, attempting to predict the possible future implications of AI systems, currently under development, is but mere guesswork. Therefore, attempting to prevent such possible occurrences from taking place, is an exercise in futility. Proof to this claim can be found throughout the course of human history (more evidently, though, over the past three hundred years – since the beginning of the industrial age). It seems that morality & ethics have never been able to maintain proper control of humanity's use of technology.
- ▲ There is a very likely possibility of this technology being used in the future by armies, in order to bring harm to human (perhaps even civilian) lives on an inconceivable scale. This, I believe, cannot be compensated by any potential gain in the field of finances or logistics.

I therefore believe that the ongoing research & development of practical AI systems must be put to a halt, for the sake of future lives. The stakes are simply too high.

### 3. counter-arguments

#### A. Computing machinery and morality

By: Whitby, Blay. *AI & Society*, Apr2008, Vol. 22 Issue 4, p551-563.

##### Abstract:

Artificial Intelligence is a technology widely used to support human decision-making. Current areas of application include financial services, engineering, and management. A number of attempts to introduce AI decision support systems into areas which more obviously include moral judgment have been made. These include systems that give advice on patient care, on social benefit entitlement, and even ethical advice for medical professionals. Responding to these developments raises a complex set of moral questions. This paper proposes a clearer replacement question to them. The replacement question asks under what circumstances, if any, people would accept a moral judgement made by some sort of machine. Since, it is argued, the answer to this replacement question is positive, urgent practical moral problems are raised.

##### Point of relevance:

The author argues that it is possible to underline the areas in which AI should not be accepted as a moral judge, thus preventing its unintended misuse.

#### B. Lethality and autonomous robots: an ethical stance

Arkin, R.C.; Mosikina, L.; *Technology and Society*, Las Vegas, NV; June 2007

##### Abstract:

This paper addresses a difficult issue confronting the designers of intelligent robotic systems: their potential use of lethality in warfare. As part of an ARO-funded study, we are currently investigating the points of view of various demographic groups, including researchers, regarding this issue, as well as developing methods to engineer ethical safeguards into their use in the battlefield.

##### Point of relevance:

This article suggests that developing ethical safeguards for the use of AI systems is not only possible, it is an ever-growing field of research among researchers and designers of intelligent robotic systems.

Subject of project: the benefits of nuclear energy.

Our opinion: nuclear energy is "environment friendly" and the process of producing it is cheaper than producing fossil-fuel energy. Furthermore, constructing the plant itself is cheaper.

**Devil's advocate:**

#### **Opinion no. 1**

Although nuclear energy provides a substantial source of power, it bears some great dangers, such as an accident in a nuclear reactor. *"When the whole system or an individual component of a nuclear power plant causes the reactor core to malfunction, it is known as a nuclear meltdown. This occurs most commonly when the sealed nuclear fuel assemblies that house the radioactive materials begin to overheat and melt. If the meltdown becomes too severe, the radioactive elements within the core can be released into the atmosphere and around the area of the power plant. These radioactive materials are highly toxic to all organic life."*

URL address: Dangers of Nuclear Power Plants | eHow.com  
[http://www.ehow.com/about\\_4759852\\_dangers-nuclear-power-plants.html#ixzz1h4WGnBQ4](http://www.ehow.com/about_4759852_dangers-nuclear-power-plants.html#ixzz1h4WGnBQ4). Date of access: 20/12/11

#### **Opinion no. 2**

Another problem associated to nuclear power plants, is dealing with nuclear waste disposal: - *"Nuclear power is not a clean energy source: it produces both low and high-level radioactive waste that remains dangerous for several hundred thousand years. Generated throughout all parts of the fuel cycle, this waste poses a serious danger to human health. Currently, over 2,000 metric tons of high-level radioactive waste and 12 million cubic feet of low level radioactive waste are produced annually by the 103 operating reactors in the United States. No country in the world has found a solution for this waste. Building new nuclear plants would mean the production of much more of this dangerous waste with nowhere for it to go."*

URL address:  
[http://debatepedia.idebate.org/en/index.php/Argument:\\_Nuclear\\_energy\\_produces\\_dangerous\\_radioactive\\_waste](http://debatepedia.idebate.org/en/index.php/Argument:_Nuclear_energy_produces_dangerous_radioactive_waste). Date of access: 20/12/11

### Opinion no. 3 – academic source

In her piece, the author blames the International Atomic Energy Agency (IAEA) along with the World Health Organization, for covering up the true dimensions of the Chernobyl nuclear catastrophe, and for not assisting the surrounding populations that affected, which was much larger than reported. She also expresses her opinion on the use of nuclear reactors for energy generating purposes.

One of the most relevant paragraphs in the text:

*From many points of view, the nuclear establishment was extraordinarily lucky that the inevitable, major accident happened in the USSR. Not only was it able to claim (falsely) that such a catastrophe could never happen in the West, but the collapse of communism provided a convenient explanation for subsequent increases in health problems, with the destruction of health services and deterioration in social welfare. These have indeed produced a health crisis and an unprecedented fall in life expectancy, which puts the nuclear powers in the uncomfortable position of indicting either the savage capitalism imposed on populations after 1989 or radioactive contamination from Chernobyl.*

*Fortunately, they have been able to roll out the usual suspects: the victims themselves, who indulge in radiophobia, irresponsible behavior, apathy, and even parasitism (or state assistance), though it is conceded that social and economic factors have been unfavorable. It is, of course, entirely possible to separate out and control for these factors, as independent researchers have done in studies comparing the health of populations in territories with high, medium, and low contamination. The latest U.N. action plan for Chernobyl cynically qualifies the nuclear disaster as a "low-dose event," thus reproducing two lies: the harmlessness of low-dose radiation and the very small number of victims. Problems are qualified as psychological, as populations have lapsed into apathy, helplessness, and "dependency syndrome" (57).*

*The full text can be found here:*

<http://www.swetswise.com/FullTextProxy/swproxy?url=http%3A%2F%2Fbaywood.metapress.com%2Flink.asp%3Ftarget%3Dcontribution%26id%3DK855H82489M17330&ts=1324377573831&cs=3229511118&userName=4421.ipdirect&emCondId=4421&articleID=154345171&yevoID=3164449&titleID=103867&referer=2&remoteAddr=132.64.209.70&hostType=PRO&swsSessionId=+qXDf0ICl0w0ftOlctPGxg...pas c2>

### Reference:

Author: Katz, Alison Rosamund

Title: Health consequences of Chernobyl: the New York academy Of Sciences publishes an antidote to the nuclear establishment's pseudo-science

Name of the journal: INTERNATIONAL JOURNAL OF HEALTH SERVICES

Volume: 40

Issue: 4, published in 2010

Pages: 679-698

1999

**Our opinion:** We believe that Artificial Intelligence and Artificial Consciousness are plausible .

**Sources that support the opposite opinion:**

1. **Title:** Why not Artificial Consciousness or Thought?

**Author:** Richard H. Schlagel

**Journal:** Minds and Machines

**Volume number:** volume 9, number 1.

**Pages:** 3-28

**Publisher:** Springer Netherlands

**Date:** February 1999

**Abstract:**

The purpose of this article is to show why consciousness and thought are not manifested in digital computers. Analyzing the rationale for claiming that the formal manipulation of physical symbols in Turing machines would emulate human thought, the article attempts to show why this proved false. This is because the reinterpretation of 'designation' and 'meaning' to accommodate physical symbol manipulation eliminated their crucial functions in human discourse. Words have denotations and intensional meanings because the brain transforms the physical stimuli received from the microworld into a qualitative, macroscopic representation for consciousness. Lacking this capacity as programmed machines, computers have no representations for their symbols to designate and mean. Unlike human beings in which consciousness and thought, with their inherent content, have emerged because of their organic natures, serial processing computers or parallel distributed processing systems, as programmed electrical machines, lack these causal capacities.

2. **Title:** Intelligence in Computers

**Author:** Andrea Meibos

**URL:** <http://qirien.icecavern.net/punkus/school/ai2.htm>

3. **Title:** AI is possible... but AI won't happen: The future of Artificial Intelligence

**Author:** Mark Humphrys

**URL:** <http://www.computing.dcu.ie/~humphrys/newsci.html>

**Reference:** talk given at the "Next Generation" symposium, the "Science and the Human Dimension" series, Jesus College, Cambridge. The proceedings were formerly on the New Scientist web site. The talk was republished in Neo magazine, June 1998.

**APPENDIX E**  
**SAMPLE *PETEK*S**

(Two per page, placed horizontally next to each other).

I think that the project (15)  
 teach as to be open  
 minded to the ~~op~~ posit opinion  
 II. It teach as to explore to  
 investigate and not ~~take~~ taking  
 anything as granted  
 III. To learn ~~the tool~~ how  
 to use the tools of the  
 university ~~as~~ such as  
 the database and the library  
 and extra  
 (B) the know tools we got  
 and the difficulty to understand  
 the posit opinion

4. the project taught as how  
 to investigate and search for  
 knowledge, and how to prepare ourselves  
 In order to write an opinion article.  
 B. In my opinion the most useful  
 part of the project was finding  
 articles that show the opposite  
 opinion to the one I have.

(7)

A. Analyzing high level texts. <sup>2-</sup>

- Getting to know Scientific articles better
- Understanding that there are Opinions from both side of the coin. to just about anything and one should at least consider the other side, understand where it comes from.

B. Taught me how to handle high level of article (both reading and Analyzing)

(2)

A) I think the project was firstly to introduce us to the "web of Science", learn how to use it and know more places to look for information.

It was also about researching by using the right words and looking at a range of areas of study that we did not interacted with.

And it was also to confront us with looking and reading the opposite opinion from ours.

B) The searching in the "web of Science" was very useful, but also having to look for the contrary of our opinion.

A, I think the project was trying to teach us to use information more freely, to think about what we are reading for better understanding. Also I believe we were taught to find reliable information.

① I think it was trying to teach us how to read abstract and according to the information in it, understand if the text is relevant. Also, it was trying to teach us how to work with the university's online library in English - unlike we are used to.

② I think it opened our mind because unlike other things we do after school when we are home, this work had to do with our own interest and opinion.

12.

- A. How to find reliable sources of information in the internet how to base your assertion but also how to be open-minded towards other opinions.
- B. It gave me a chance to expand my knowledge in areas I was actually interested in so the process wasn't boring because I wasn't forced to work on a topic I wasn't interested in.