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An Examination of Science Fiction with a View Towards Improving Scientific Literacy.

Lucie Lalonde

A Thesis

In

The Department

Of

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ABSTRACT

An Examination of Science Fiction with a View Towards Improving Scientific Literacy.

Lucie Lalonde

Scientific and technological literacy is important in order to have a population that can evaluate new scientific and technological developments. For this, new educational strategies need to be found that promote scientific literacy in science education.

This study examined one aspect of popular culture, science fiction books for children, in an attempt to determine if science fiction would make an effective tool in elementary science education. A content analysis of science fiction books for children was conducted using an evaluation chart created for this purpose. The chart contained five main categories of information. They were: the physical aspects of the book, the science issues the story illustrates, the types and veracity of the science portrayed, the aspects that relate to teacher use of science fiction in the classroom, and the societal issues that surround each story.

This study concluded that science fiction stories aimed at elementary school students contain useful information with regard to their ability to increase scientific literacy. There are several implications of these results. For example, the science curriculum could be developed to include the use of science fiction stories. In addition, pre-service and in-service teacher education could be used to increase teacher awareness of the value of science fiction stories for science education.

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CHAPTER 1 - BACKGROUND

PURPOSE

The purpose of this study is to determine if science fiction can be used as a tool in science education. With the increasing importance of science and technology in society, it is crucial to find ways to draw greater numbers of students in and to foster higher general levels of scientific literacy. As currently taught, science education alienates many students. In particular, various studies have shown that schooling still operates to exclude all but a few (mainly boys) from the top streams in science, math and technology (Jovanovic & King, 1998).

Despite the emphasis on hands-on experimental learning that scientific education preports to include, many students never get the opportunity to engage in this kind of experiential learning because of a lack of resources, teacher time or knowledge of how to construct experimental activities. This means that experiential learning occurs as an isolated incident on field trips outside the school, or in a rare classroom activity. Since it is not always practical or economical to expose large numbers of students to hands-on activities or field trips, students are left without the wonder of discovery most of the year. It is in this regard that science fiction may offer an imaginative route to scientific literacy, which could be effective in the intervals between field trips or hands on activities.

BENEFITS

There are many reasons to look for new ways to improve scientific literacy. Amongst the most important of these are the benefits that would accrue to students, teachers and society in general. For students who feel alienated from science, reading science fiction could provide them with an opportunity to reengage with the curriculum, resulting in an increase in their interest and participation. A related benefit is improved facility with the English language through the development of vocabulary and grammatical skills. Teachers could benefit in situations of limited resources such as, money, time or physical space. As well, the ability to interest their classes creates a more dynamic and rewarding teaching environment. From the perspective of society, any means of improving and expanding science education helps redress the growing need for scientifically literate people in a technological age.

Scientific illiteracy is a problem because a scientifically uninformed population does not have the tools to understand or oppose new scientific discoveries or research that may prove harmful or ill thought out. On the other hand, scientific illiteracy can engender fear of some perfectly safe and desirable outcomes of research. By reducing scientific illiteracy, the population would be in a better position to decide what technology and scientific outcomes would best serve them and the population in general.

QUESTIONS

This thesis will examine two main questions. Does popular culture, in the form of science fiction, contain elements that could improve scientific literacy? Due to the fact that scientific literacy is complex, requiring knowledge of science concepts, science issues, the scientific method and corporate science, this question above is sub-divided into three others:

1. Could science fiction be used to teach science concepts?
2. Could science fiction be used to teach social and moral science issues stemming from science or technological developments?
3. Could science fiction be used to teach about scientific method?

The second question is: does science fiction contain elements that could alienate some students?

NARRATIVE

The working hypothesis of this study was that science fiction is a good medium for promoting scientific literacy. This was my experience beginning at the age of thirteen when I became acquainted with science fiction through television. At that time, I began watching *Star Trek: The Next Generation* even though I had no interest in science fiction or science. I continued watching the show because I was intrigued by the ideas contained in the scientific plot. Soon after, I began reading science fiction and, as an avid reader, began absorbing detailed information on what science and technology could do.

The stories that most captivated my interest were those involving human genetics and evolution. This interest led me to read about certain biological concepts and to take biology as electives in high school, CEGEP and university. Although I did not pursue a career in biology or genetics, I do understand the social issues surrounding these topics.

Another interest which grew from science fiction was exobiology, the study of other species. Only in the worlds of science fiction can a species be created which is similar to the human species in many ways, but which differs from it due to changes in planetary characteristics. It poses the question: What would happen if a species evolved on a planet with different gravity or atmospheric composition? In order to formulate an answer, a person must first have an understanding of how their own world works. This, then, is what led to my enduring interest in science and the formal pursuit of science courses.

Although this personal experience may be anecdotal, it suggests that science fiction can have practical implications for the teaching of science and technology. The premise of this study is that science fiction can open the mind to science and to social issues surrounding science and technological development.

ORGANISATION

Chapter 2 consists of the literature review, which discusses the issues of science fiction, popular culture and science education. Chapter 3 discusses the methodology of this study. The main research method used was a content analysis of science fiction novels for young readers. Chapter 4 includes the analysis of the data as well as the discussion of the results. Chapter 5 contains the conclusions as well as the areas for future research.

CHAPTER 2 - LITERATURE REVIEW

INTRODUCTION

Science fiction may be seen as one part of the larger popular culture of the western world. Thus the review of literature first locates science fiction as a genre within that domain. Then the review of the literature turns specifically to science, science literature, science education, science fiction and science curricula.

The reviewed articles and books were identified through ERIC, psychlit, sociofile, newspaper and library searches. To gather further information, a question was placed on two categories of newsgroups. One type was for teachers while the other was for science fiction enthusiasts. The replies were used to identify the population from which the sample of books for this study was chosen.

POPULAR CULTURE

"Popular culture is made by ... disempowered people out of the resources, both discursive and material, that are provided by the social system that disempowers them" (Fiske, 1989, p.1-2). These "discursive resources" are understood to be "expressive forms widely disseminated in society" such as television (BGSU, 1999). Popular culture also includes such things as literature or stories, media (film, news, television, music, books, magazines and advertisements, which fall into all categories), humour and dress. All cultures

share some of these popular cultural features and some contain them all. It is through these expressive forms that group cohesion is reinforced and a culture's existence re-confirmed.

Popular culture is distinguished from culture as a subset of culture. Culture has many definitions, but one that is relevant here states that "culture refers to the shared ways of thinking, believing, perceiving, behaving and speaking that characterise the members of a social group" (Goodenough, 1996). It also includes particular modes of dress, style of housing, eating customs, and the artefacts of everyday life.

As a subset of culture, popular culture often relates to the pleasurable or enjoyable aspects of everyday life (Giroux & Simon, 1989). Examples of this can be seen in fads, holidays, amusement parks, sports, and clothing styles (BGSU, 1999), and in the idiosyncratic behaviours most people within that culture can identify with. In other words, many aspects of popular culture fall into the category of norms or standards that the society takes for granted and shares.

In one way or another, popular culture reflects the story or stories of a group's way of life. As a particular genre of popular culture, science fiction storytelling has the potential to communicate certain kinds of ideas in familiar and pleasing ways which may otherwise seem too abstract, cold and disconnected from everyday life.

It is important to understand where science fiction fits within the society, which is why popular culture is examined in this section. However, as the

purpose and focus of this study is science fiction and not popular culture, popular culture will not be examined further.

Science Fiction

Science fiction is a genre of storytelling that is distinctive in the western world. It is part of popular culture. Because of this, it can be considered easily available to everyone, with a majority of people having experienced it in one form or another. Science fiction material is most readily available on television, movies, books, and comics.

There are many possible definitions of science fiction. Isaac Asimov (1972) stated that "Modern science fiction is the only form of literature that consistently considers the nature of the changes that face us, the possible consequences, and the possible solutions" (p.10). John Boyd (1974) stated that "Science fiction is story-telling, usually imaginative as distinct from realistic fiction, which poses the effects of current or extrapolated scientific discoveries, or a single discovery, on the behaviour of individuals of society" (p.14). Hal Clement (1975) states that "...if we travel to mars in a story, the vehicle must operate either along physical laws we currently think we know, or at least on more or less convincing extrapolations of those laws" (p.260). Groff Conklin (1958) defines science fiction as "...stories in which one or more definitely scientific notion or theory or actual discovery is extrapolated, played with, embroidered on, in a non-logical, or fictional sense..." (p.16). Bruce Franklin (1978) states that "In fact, one good working definition of science fiction may be

the literature which, growing with science and technology, evaluates it and releases it meaningfully to the rest of human existence" (p.vii) (in Schlobin, 1981). Science fiction stories mirror many of the issues in society at the time they were written (Tulloch, 1995). In its essence, science fiction can be defined as a method of exploring new and established scientific and technological ideas in changing worlds and societies, in the comfortable and common medium of storytelling.

POPULAR SCIENCE

Current research states that the science and technology that is common in daily life is more complex than the majority of the population is capable of understanding (Mariano Gago, 1991). It also states that for many people science and technology are uncontrollable forces. Science fiction may function to simplify the overly complex and hence impart a measure of control on the forces, explaining why science fiction has gained popularity along with rapid developments in science and technology in the last century. This feeling that science is an uncontrollable force is what Fiske (1989) means when he discusses disempowered people who create popular culture. Mariano Gago's (1991) view that the popularity of science fiction is increasing due to a feeling of lack of control fits into Fiske's (1989) argument. Because science fiction's popularity is growing, it can be assumed that more people feel that science is growing too quickly and without check, that it is uncontrollable.

Mariano Gago (1991) also points out that science fiction fills the gap between students' curiosity about science and the inability of schools to satisfy all aspects of that curiosity. It is in this that students may feel disempowered and look to popular science as a mediator in the realm of science, its theories and truths.

Lamb and Bartholomew (1975) state that science fiction is popular with young people because it has an image that is socially acceptable, while Berger (1992) states that a person's choice of genre is dependant on their age, and that young teenagers like adventures while teenagers prefer science fiction. Most science fiction for young readers is in the form of adventure stories, while for older readers it is in the form of adventure stories with a more technical plot.

STORIES

All cultures contain stories about their origins -- religious, historical, fantastic and incredible. In Western culture, these stories are told orally, in churches, as well as through books, comics, magazines, movies, and television. All cultures share stories as a medium of popular culture transmission. This being so, stories are an effective popular culture medium to use in classrooms, not only for literature, but for content subjects such as science. As all students should be familiar with storytelling, stories could be used without alienating any children for cultural reasons, because, as mentioned, the medium of stories is universal, if not the content.

More specifically, science fiction is seen as one aspect of western popular culture that may reveal much that is, or is not, scientifically valid, in entertaining ways, to students who are encountering formal science for the first time. These students often need help distinguishing between what is popularly believed to be true and what is considered to be known. Similarly, science fiction may offer a way for communicating complex or abstract science and technological truths, concepts or facts, to students in a way that they readily understand. Students may not have encountered science and technology in school and may find themselves on very unfamiliar ground, but most children in this society have encountered the science fiction genre on TV, in movies or through books and comics. The genre is familiar to them.

Stories And Learning

In his research on fairy tales, Bettelheim (1976) has demonstrated the overwhelming importance of story-telling for the psychosocial development of young children. Although his research focused primarily on pre-school aged children, Bettelheim found that scientific explanations of the world often confuse young children:

> While giving a scientifically correct answer makes adults think they have clarified things for the child, such explanations leave the young child confused, overpowered, and intellectually defeated. ... Scientific explanations require objective thinking. Both theoretical research and experimental exploration have shown that no child below school age is truly able to grasp these two concepts, without which abstract understanding is impossible. In his early years, until age *eight or ten*, the child can develop only highly personalised concepts about what he experiences (Bettelheim, 1976, p.48-49; emphasis mine).

Children today begin learning science well before the age of eight. At this age, then, Bettelheim's research, which indicates that children learn more effectively through stories, has implications for the teaching of science.

Children have always been interested in stories. When children read, they become caught up in the story (Sloan in Carson, 1997). The narrative structure of the story itself is what causes children to engage with it.

> For a story truly to hold the child's attention, it must entertain him and arouse his curiosity. But to enrich his life, it must stimulate his imagination; help him to develop his intellect and to clarify his emotions; be attuned to his anxieties and aspirations; give full recognition to his difficulties, while at the same time suggesting solutions to the problems which perturb him (Bettelheim 1975, p.5).

This implies that required reading, such as textbooks, do not affect students on the same level, so there is less interest and co-operation from this form of reading (Carson, 1997). Science fiction books contain interesting stories with plots that frame many elements of science in ways that can create both meaning and understanding for children and teenagers.

Stories, unlike texts, also have the advantage of being effective for heterogeneous groups of students. Stories affect different people in different ways, and on many different levels (Malcolm, 1997), giving rise to a variety of interpretations. These interpretations allow individual students to grasp the essential meaning, albeit through a variety of intellectual and personal paths. This is an important aspect to keep in mind, as most classes not only have students who struggle and students who learn early, but in multicultural classrooms students bring their own histories and stories to the telling of science

fiction. Stories allow all students to be engaged in an activity while being flexible enough to stimulate them all.

While there may be resistance to the use of stories to teach science, it has already been demonstrated that stories which include material that is appropriate to the curriculum do not negatively affect cognitive learning (Kindler in Lamb & Bartholomew, 1975). In fact, in a study by Zbonikowska (1981), students who read popular science did better in science than those students who read other popular material. For these reasons, it seems appropriate and potentially beneficial to use science fiction stories with upper elementary school children.

Popular Culture as an Educational Tool

Popular culture is a useful tool for teaching because most people continue to assimilate many of the changes in popular culture as they grow. Learning in this sense is not a result of formal training. As changes in popular culture occur, most people adapt quickly and without difficulty. This can be seen by the fact that not many people are considered to be outside the norm with regards to dress, hairstyles, or behaviour patterns. As these change, most people conform to the changes. Clearly there is an immediacy in the acquisition of learning as is relates to popular culture. In other words, learning is both current and enduring, allowing most people to successfully fit into society. Popular culture, then, provides a context that allows individuals to "fit" and "function" in their social world. Since most non-scientists hear about science breakthroughs in popular

media (news, radio, magazines, advertisers...) their science knowledge would benefit from being linked to those popular cultural contexts.

Scientific Literacy

It is necessary to understand what it means to be scientifically literate. As Aikenhead (1990), Fleming (1990) and others point out, a scientifically literate person is one who understands the place of science and technology within the society as a whole, who understands the pros and cons of developments and who can 'see through' the power struggles behind the debates. A scientifically literate person asks why, how and for what purpose, who will benefit, who will suffer? A scientificallyliterate person also requires a general understanding of scientific concepts and knowledge. However, this knowedge alone is not enough to be considered scientifically literate.

Science and technological education and curricula seek to introduce students to facts, concepts, procedures and attitudes that will give them the basis for becoming scientifically and technologically literate.

The Need for Scientific Literacy

Now that scientific literacy has been examined, it is necessary to understand why it is important. With new scientific developments occurring more frequently[1] scientific literacy becomes more important as the knowledge base of science expands due to the increase in research. Also, this new scientific

[1] Due to an increase in corporate funded science, and improvements in scientific methods.

knowledge can give rise to situations that may have associated dangers and risks which the population should understand. Many issues relating to human rights, medicine (drug testing) and the military (weapons development) for example, are affected by scientific discovery and could, conceivably, result in serious impacts on the population. As such, the general population needs to acquire enough scientific literacy to understand how and why some scientific practices and discoveries need to be carefully evaluated or regulated.

Some universities, including Concordia, have recognised and responded to this need for scientific literacy by creating and implementing science classes for non-science students. These classes are attempting to improve scientific literacy by having "user friendly" (Comeau, 1999, p.12) science classes. For example, the classes that Concordia has implemented will increase scientific literacy in the fields of physics, psychology, biology and chemistry through their courses entitled *from particles to galaxies*, and *from neurons to consciousness*.

One example of scientific risk is the human genome project, an international research project which is mapping all human genes. Rarely does one see an article questioning the purpose of this expensive project, nor is there open discussion about the potential dangers that can arise from the knowledge it discovers. One outcome of this research could be human genetic engineering. The dangers of this have been well examined in science fiction. In this particular case, science fiction brings to light the potentially dangerous outcomes of genetic engineering. And generally, science fiction takes on many current controversial scientific issues that need to be examined or seen from a new angle.

Aikenhead (1990) states that views about science have changed from a positive force that could do no wrong to a negative one that could cause many problems. When science was mostly seen as a positive force, a small portion of people opposed the fact that science was not carefully evaluated. Today, more people are demanding the evaluation of science developments. However, there are still few people outside of scientific fields who are skilled or knowledgeable enough to make this evaluation. By incorporating science knowledge within the context of popular culture it may become more accessible to more people and thus more generally useful.

Science is a field that is becoming more important to understand as technology and science advance rapidly. Today's science curriculum does not require that students be prepared to think critically about new science information. Science classes tend to teach students about the science that has already been discovered while glossing over the sometimes fierce debate over which idea or theory is most likely to be valid. Evidence of this can be found in the debate over genetically engineered foods.

In contrast to this pro-scientific bias is the argument between the evolutionists and the creationists, an issue that has been raging for years. Recently, the Kansas school board removed evolution from the school curriculum (Belluck, August 12, 1999), although evolution is the theory accepted by the majority of scientists. This is a prime example of the conflict between entrenched religious explanations of phenomena and scientific explanations of the same phenomena. The challenge for educators is to find ways to bring people's own

stories (in this case creationism) into the classroom to be used as a basis for generating an appreciation for the scientific. This process is clearly much more difficult when debates become politicised.

Science Education

Despite numerous cognitive studies of science learning, science education remains problematic. Researchers have thus begun to look at how science is taught. Three findings, in particular, stand out.

First, in general, science education does not provide an integrated knowledge base because it is often taught in ways that isolate it from other subjects in the curriculum (Carson, 1997). This has both academic and sociological implications because if students can not make the connection between science and its place and meaning in the academic spectrum, they will fail to make the connection between science and its role in society.

Second, researchers have found a gap between the science information that is taught and the reality of scientific discovery today (Nunan & Homer, 1981). This leads students to form inaccurate pictures about how science works, and how it is done.

Third, students most readily learn through media that show the material to be relevant and useful to their lives (Johnstone, 1981 in Martin-Diaz et al., 1992).

In brief, what all of this research seems to indicate is a disconnection between science education and the social world in which it takes place. It is in the gap between the two that science fiction can mediate the divergent worlds of

meaning in ways that brings the two into alignment. Because science fiction stories do not view science in isolation from the world, and because of its narrative format, it provides a more integrated approach, creating a context for understanding. In this way, students are able to see how science affects the world around them.

The Goal of Science Education

The passing on of scientific knowledge is often biased in that most students are presented with one point of view, the merits of which they have no way of evaluating (i.e. evolution or creationism). As non-specialists, they lack the skills to evaluate the validity or usefulness of the results being presented. In the early stages of scientific education, students are called upon to memorise isolated scientific facts or formulas. This creates two problems. First the memorised information can not be used in relation to other information in order to make educated decisions about an issue. Second, it precludes the development of critical thinking skills that will permit these students to evaluate not only the science that they are taught, but also the science that will be discovered and publicised as they mature. This is not the goal of science education.

An alternative which provides a better foundation on which to build scientific literacy can be found in Fleming (1990) who states that:

> "... "sociotechnology", a social process in which the knowledge created by science and the knowledge created by technology are "put at the disposal of people who in general are not themselves competent in these knowledge bases, and who would wield them on behalf of ends reflecting the parochial interpretation of prevailing

> personal, institutional, and social values"" (Goldman, 1984, p.121 In Fleming, p.56).

What Fleming is positing in sociotechnology is a new basis of scientific literacy. He locates this in a social process "... that reflects the "parochial interpretation of prevailing personal, institutional, and social values"" (p.56). This is precisely what popular culture does in general, and what science fiction does in particular. By laying open the biases of science and the prejudices of scientific learning, science fiction creates opportunities that enhance the possibilities of learning and critical thinking about science and technology. This should be the goal of science education.

Science Fiction And Science Learning

There are several ways that science fiction has been used in science education in the past. In some cases, students have been required to find the scientific errors in the stories (Martin-Diaz, Pizzaro, Bacas, Garcia & Perera, 1992). In a study by Dubeck, Bruce and Schmuckler (1990), students were shown science fiction films to teach many different branches of science. In his study, 80% of students in the test group increased in at least one of three criteria when science fiction films were shown in science class. The criteria that were tested were: attitude towards science, knowledge of science as a discovery process, and cognitive development.

There are many themes in science fiction that reflect those in science and in society. This is clearly seen in Marks' (1978) examination of teaching biology with science fiction, in which he listed 17 science fiction themes, their biological

basis, and their potential impact on society. These 17 themes encompass 31 different topics in biology ranging from cells to exobiology.

All fields of science are represented in science fiction. Science fiction can be used to increase students' motivation and interest towards science, as well as to develop positive attitudes towards science (Mariano-Gago, 1991). Czerneda (1999), in particular, advocates the use of science fiction as a teaching tool in order to improve critical reading skills as well as to examine stereotypes of scientists and science.

Science Curriculum

The science curriculum[2] for elementary schools in Quebec is based on natural science which includes the study of biology, the physical world and technology (Government of Quebec, 1984). The science curriculum is currently under review, with a new curriculum to be implemented in 2001 or 2002.

Natural science is examined in relation to the environment on the assumption that early influence about environmental issues will result in a population that is more environmentally responsible as adults. This examination of natural science is to be done using the experimental approach so that the students will be able to build their knowledge base themselves. Students in the upper elementary level spend at least 90 minutes a week on natural science (Government of Quebec, 1984).

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[2] The curriculum is set by Quebec's Ministry of Education.

Many schools in Quebec do not have the equipment or facilities to use hands-on science regularly, or within a framework that promotes the scientific method. In addition, the science program does not attempt to address the reasons for current scientific problems despite the fact that many can now be prevented. The corporate ideology (profit first) is not examined. For example, it is no surprise that engineers are still being taught that the solution to pollution is dilution. This is an inherently dangerous environmental policy, from which we shelter young students.

SCIENCE

In its origins, science was primarily an individual pursuit, often played out in an academic environment. More recently it has evolved into an institutionalised pursuit (Nunan & Homer, 1981). Over time, as the rigours of scientific development demanded more resources, and because scientific development implied power and met nationalistic goals, government funding became an integral part of scientific development. Most recently, as government funding has fallen, scientific development has come to be dominated by the corporate agenda. This implies large, multinational corporations and large budgets. Bluntly stated, these large companies have a vested interest in the results of the studies they fund. Therefore, many studies funded by specific corporations could be suspect because companies do not usually spend millions of dollars on research to determine that their product has negative consequences. In addition, many companies that fund research maintain control

over the publication of results. If the company does not like the results, one rarely ever hears about them because the researchers are required to sign non-disclosure agreements. Despite this, science continues to be seen as an elite activity that is beneficial to society (Nunan & Homer, 1981). And, because of this positive view, most people do not question what occurs in scientific development, despite the obvious biases in some cases.

Science And Ethics

Scientific and technological development often create ethical dilemmas because of their high costs to society, or as a result of their use. According to Nunan and Homer (1981), schools do not discuss ethical issues relating to science. However, many gains could be made by discussing scientific ethics with students. Science education needs to be aware of stages in moral development.

Kohlberg has identified six stages of moral development, through which people progress naturally and in order. These stages progress from a basic understanding of morality (i.e. being good to avoid punishment) to complex understandings (i.e. self chosen ethical principles that are consistently applied). Progression through the stages is dependent on development and level of maturity. However, people can accelerate through these stages when instructed in "direct discussion and dilemma discussion" (Biehler & Snowman, 1997, p.71). Direct discussion and dilemma discussion are useful educational tools which encourage students to challenge each other's thinking, their own assumptions,

developing skills of effective argument and replying to counterarguments (Biehler & Snowman, 1997). These are important skills to develop for critical thinking and issue analysis, particularly in the teaching of science. Students who develop these skills will be in a better position to evaluate the safety, merit, benefits and costs of scientific issues.

Direct discussion and dilemma discussion are not the only methods that encourage the development of these skills. Vitz (1990) advocates the use of stories because they represent ethical issues in contexts that are more grounded in the daily lives of students. Although Vitz did not specifically discuss science fiction, his article discussed narratives in general, which include science fiction. Therefore science fiction could be an important educational tool in the area of science and ethics because it highlights many ethical issues, as well as illustrating how technology can change society. Later in this study, an analysis of whether science fiction stories provide an opportunity for students to learn to evaluate scientific ethical issues will be examined.

Summary

Scientific literacy is becoming more important as science and technological development increase. New methods of increasing scientific literacy are needed for young children. Stories are common in all cultures as well as being excellent learning tools for children. Science fiction is a genre of story which contains scientific ideas. It is also useful because it is a part of popular culture, which makes it available to all students through many different media.

Thus popular culture in the form of science fiction stories is a good tool to improve scientific literacy in elementary school children.

CHAPTER 3 - METHOD

INTRODUCTION

The concern of this thesis is the potential of science fiction for teaching science at the elementary level. In that books for younger readers might provide an alternative to field trips and certain hands on activities, it was decided to focus the research on these, rather than on television or comic books, for example. This also seemed a logical choice in light of the fact that schools are concerned with the development of reading skills and reading interests.

This study is a content analysis of science fiction books. It provides insight into a new method of promoting scientific literacy among elementary school children. The analysis began with an examination of five categories of information, namely:

- the physical aspects of the book
- the science issues the story illustrates
- the types and veracity of the science portrayed
- the aspects that relate to teacher use of science fiction in the classroom
- the societal issues that surround each story.

By analysing the items in each of the categories, it was expected that a clearer picture would develop of how science in science fiction can be used in the elementary school classroom. This, in turn, was used as the basis for determining whether science fiction stories contain any value at all for promoting scientific literacy.

HYPOTHESIS

The hypothesis for this study is that science fiction contains elements that can be used to increase the scientific literacy of elementary school children due in part to the availability of the genre, and the structure of stories.

SUBJECTS

The subjects for this study were twenty science fiction books, which fell into two categories. There were ten books in each category. The first category contained books appropriate for children in grades two to six, while the second category contained books appropriate for children in grade six and above.

The books were chosen from the Golden Duck reading list of recommended science fiction books for children. This source was located in response to requests placed on science fiction and teacher based newsgroups. This list contained no fantasy fiction, which is sometimes included on science fiction lists. Titles were randomly selected from the list of recommended books. This list was used as a filter for books, because it provided an accessible population from which to choose a sample. The books in the sample are listed in Appendix A.

INSTRUMENT

The instrument used to select and organise the data from the books is a chart which I developed (Appendix B) that is made up of five categories, which contain 31 specific criteria. The five categories are:

- physical aspects of the books
- science content
- scientific behaviour
- societal issues
- teacher and classroom issues relating to the books.

Physical aspects of the books include seven categories. Length, title/author and publication year are exactly what they say. Visual elements provides a general description of the cover and, whether the text contains pictures. The quality of the story includes a subjective view of the overall quality and entertainment value of the story. The characters category provides information about the characters: their gender, are they believable, likeable... The areas of science category identifies which fields of science are found in the books, such as biology or physics.

The criteria in the category for "science content" follows. Scientific difficulty was evaluated by indicating the earliest grade level for which there is appropriate material. Clarity is the degree to which the science in the story can be easily found or isolated. The validity of the scientific approach includes the methods and reasons that the science in the book was used. The number of scientific concepts, both fictitious and true indicates how many scientific ideas or technological instruments a book contains and whether or not they are real or imaginary. From these criteria, a picture of the science context becomes apparent. This was used to gage whether the science is appropriate for the

grade level targeted as well as whether there is sufficient science to warrant a teacher's time and use of the book.

"Scientific behaviour" looks at scientific method, including experimental learning, hypothesising, scientists doing research or other related activities, ethical or unethical science and scientific debate on specific issues are the behaviours in question. This category illustrated how much actual scientific activity is contained in the books.

"Societal issues" includes positive and negative outcomes of science, current issues in society that are reflected in the books, the scientific impact on society, gender, race and social class issues. This evaluated whether the books showed a range of scientific outcomes, as well as the issues related power.

"Teacher and classroom issues" evaluates how straightforward the science is and the amount of science included. Vocabulary indicates the amount and variety of scientific words in the text and the number of words in each science field. The extent to which the book matches the curriculum was evaluated by examining the number of science concepts that are included both in the curriculum and the books. Critical evaluation was determined by examining the number of scientific issues that lend themselves to debate. Demonstrable science and hands-on learning include any activity ideas motivated by the sample. This illustrated how easily a particular book may be adapted or included in the classroom.

The chart was formatted in this way because it provided a method of managing a large range of information in a logical and clear manner. Some of

the items in the chart were suggested from Pottle (1996) but the science categories were based on issues that are important in science, as identified from the literature reviewed. Therefore, this chart contains the categories required to provide an answer to the questions in this study.

The strengths of this instrument are that it is clear and easy to follow, and its information is categorised logically and usefully in relation to the questions asked. Its open style allows space for comments, reflections or examples. The weaknesses of this method are that the categories are broad and if more than one person were collecting the data ways would have to be found to ensure inter-rater reliability. For example, category headings may be defined differently by different researchers. The scope of this study did not allow for this.

PROCEDURE

Each book in the sample was read by the researcher. As the reading progressed, notes were taken on all material that was required to complete the data chart. Once each book was finished, the evaluation chart was completed with the notes taken during the reading.

Once the charts were completed, the data were examined in an effort to answer the questions posed. A breakdown of the analysis for each question will now be discussed.

Could science fiction be used to teach science?

To answer this question, the sample was analysed to see which scientific concepts matched those found in the science curriculum. The percentage of the sample which contained curriculum materials was calculated, as well as the percentage of concepts that fit each curriculum topic. This provided an indication of whether the science fiction books are useful from a curriculum point of view.

In addition, the density of scientific concepts was calculated for the whole sample and both categories (grades 2-6, and grades 6+). The density was calculated by dividing the number of concepts by the length of the book. It was also be calculated by page, which means that the number of pages between concepts were calculated. This indicated whether a book contained enough science per page to make it worth reading for a whole class.

Vocabulary was also examined by density, as above, but it was also evaluated by subject. Each vocabulary word was placed with other words from the same field of science. This determined which field is most dominant in any given book. This allowed a ratio of the popularity of different fields in science to be determined.

The last two criteria that were examined for this question were demonstrable science and hands-on learning. They were examined for feasibility, including cost, equipment availability, space requirements, time requirements and safety of the project. This indicated whether science fiction books contained useful ideas that teachers can implement.

Could science fiction be used to teach science issues?

To answer this question, the books were analysed to find out the ratio between positive and negative outcomes of science. A positive outcome of science is one that impacted society in a beneficial manner, for example the discovery of penicillin. A negative outcome of science is one that does not benefit society, for example pollution. A ratio of 1:1 will indicate that the books were well rounded in their portrayal. However, since views of science are primarily positive, a ratio with greater negative outcomes could also be a useful tool in science education.

The next analysis involved real world science issues. The books were analysed to see what real world issues are portrayed and the science categories to which they belong. And finally, each issue was evaluated on whether it was mentioned in passing, as a major plot element, or if the whole plot is based on the issue. This determined whether the books contain useful or meaningful issues that teachers could explore. As issues are involved concepts, a book does not necessarily need to contain many issues. One or more which are mentioned are sufficient.

Ethics shown in the book was determined by calculating the proportion of books which showed ethical, unethical or did not mention ethical activities. The ethics calculated were scientific ethics, and not societal ethics.

The final criteria that was examined for this question if that of impact or changes in society caused by scientific development. This was calculated by finding out what percentage of impacts were caused by issues that our society is

currently or has previously dealt with, of impacts based on fictitious science issues and which books do not show an outcome from scientific development. This identifyed the percentage of books that contained information relevant to our society.

Could science fiction be used to teach about the scientific method?

This was evaluated by examining the categories of hypothesising, scientists doing science and scientific debate. If a book contained examples of at least two of these three categories they were said to exhibit the scientific method. The percentage of books that exhibited the scientific method were then calculated.

Does science fiction contain elements that could alienate some students?

This determined whether science fiction books have content that is acceptable as it relates to power issues. The issues explored were the issues of race, gender and social class.

This question was analysed by determining the number of times that aliens were portrayed as either 'bad guys' or 'good guys'. This identifyed whether "the other" is stereotyped. The gender of the protagonists was also evaluated. This identifyed if the books contained any gender biases. The final criteria that was examined is that of social class. The percentage of books that indicated social class was calculated, and then those that do were analysed for how social

class is broken down. This identifyed whether science is limited to one social class in science fiction.

CHAPTER 4 -RESULTS / DISCUSSION

INTRODUCTION

This section analyses the data collected from the twenty books identified in Appendix A in light of question 1 (including the three sub-sections of this question) and question 2 from the Procedure of the Method Section. It was found that there is merit in using science fiction in science education. It will be examined in detail in the following sections.

COULD SCIENCE FICTION BE USED TO TEACH SCIENCE?

The indicators used to answer this question were science concepts and curriculum, vocabulary density, and demonstrable and hands on science. These indicators were chosen because they relate directly to the content of science education, and as such are important in evaluating whether science fiction can be used to teach science.

Science Concepts And Curriculum

When science concepts and curriculum were examined, it was found that 91.67% of the sample contained concepts that were included in the Quebec science curriculum. There were 19 different scientific concepts in the sample that were included in the curriculum. Of the 12 general objectives in the curriculum, nine were represented by the sample, which means that 75% of the curriculum was represented by the sample. The percentage of the sample that fell into each represented category is found in table 1.

Table 1: Percentage of scientific concepts per curriculum category.

Curriculum category	All	2-6	6+	Both
Personal potential	0.95	5	0	0
Nature	20	5	0	31.25
Experimental approach	1.9	10	0	0
Plants	5.71	5	14.29	3.13
Animals	15.24	0	23.81	17.19
Water	16.19	25	19.05	12.5
Air	10.48	30	4.76	6.25
Soil	19.05	20	23.81	17.19
Manufactured products	10.48	0	14.29	12.5

As seen, the categories that are most frequently represented are those dealing with the earth sciences, animals, water, soil and nature.

Since the sample contained a high proportion of concepts that fit the curriculum, and because a high proportion of the curriculum was represented, it can be concluded that science fiction books are a good source of material for complementing the curriculum, especially in the fields of earth science.

Scientific Concepts

The density of scientific concepts for the sample is found in table 2.

Table 2: Density of scientific concepts by veracity and category.

Density	Total	True	False
All	.11	.06	.04
2-6	.13	.07	.06
6+	.09	.05	.03

As seen in both groups, the proportion of scientific concepts that are true is greater than that of the false concepts.

These proportions can also be examined by calculating the number of pages between instances of new scientific concepts as well. When examining both categories and all concepts, a new scientific concept will be encountered every nine pages, on average. This provides a more readily available number by which to evaluate whether a book contains enough science to merit reading the book. The number of pages between a new scientific concept for each category is shown in table 3.

Table 3: Number of pages between new science concepts.

Pages	Total	True	False
All	9	16.7	25
2-6	7.7	14.3	16.7
6+	11	20	33.3

It is possible for books to have a higher frequency of scientific concepts, as only new concepts were used in the calculation. Multiple instances of the same concept were treated as one. Therefore, these frequencies are the minimum number of concepts that can be found in the stated number of pages.

As seen in the literature review, both real and fictitious scientific concepts have merit in teaching science. Because of this, evaluation of whether there is enough science per book will be based on the calculations for both true and false concepts.

Students in grades 2-6 can easily read 7or 8 pages in a week, which would be the minimum required to introduce them to a new science concept. Students in grade 6 would need to read 11 pages to achieve the same goal. In both cases, the volume of reading required by the students would be

manageable for the majority of the class, especially if the teacher was using an integrated approach to teaching where this reading could also be used for other subjects.

There is one drawback in using this calculation. Some books may have scientifically unrelated concepts following each other, or they may cluster many of the science concepts in the same chapter. These instances would require a teacher to make decisions regarding specific implementation of the books to optimise their potential. However, since these limitations could be overcome through teacher activities and planning, it will be concluded that there are sufficient scientific concepts to justify reading science fiction in the classroom.

Vocabulary Density

The vocabulary density of the sample and number of pages between new vocabulary words are found in table 4.

Table 4: Vocabulary density and pages by category

Vocabulary	Average/book	Density	Pages
All	8.52	.06	16.7
2-6	8.91	.07	14.3
6+	8.17	.04	25

As shown, new vocabulary occurs every 14 pages for grades 2-6 and every 25 pages for grades 6 and up. On its own, the vocabulary density is not high enough to warrant introducing science fiction into the classroom. Vocabulary is usually learnt by topic, and usually all the words are taught at the same time in order to create an overview of the topic involved. There is no advantage in learning one isolated vocabulary word through science fiction.

When the sample is examined for vocabulary by subject, Figure 1, it is apparent that the majority of the vocabulary belongs to the subjects of biology and physics. Therefore, when these subjects are studied, science fiction provides a large source of vocabulary that could complement other biology or physics vocabulary learning.

On its own, vocabulary density in science fiction does not indicate the use of science fiction to teach science, with minor exceptions. However, if it were implemented for other reasons it could be used in addition to other vocabulary instruction.

Hands-On And Demonstrable Science

Hands-on and demonstrable science will now be evaluated by feasibility and presence in the sample. Hands-on activities are defined as being carried out by students, while demonstrable activities are carried out by the teacher. Hands-on science obtained a feasibility score of 1.23, while demonstrable science obtained a score of 1.57. The feasibility scores were obtained by averaging the scores for cost, equipment availability, space requirements, time requirements and safety of the project. A score closest to one indicates projects which are most feasible, while scores furthest from one indicate projects that are least feasible. The possible range of scores was 1 to 2.83 but every score fell below the mid-point, which was 1.92. Because of this, all ideas for demonstrable and hands-on science could be implemented by teachers. The percentage of hands-on and demonstrable science in the sample is found in table 5.

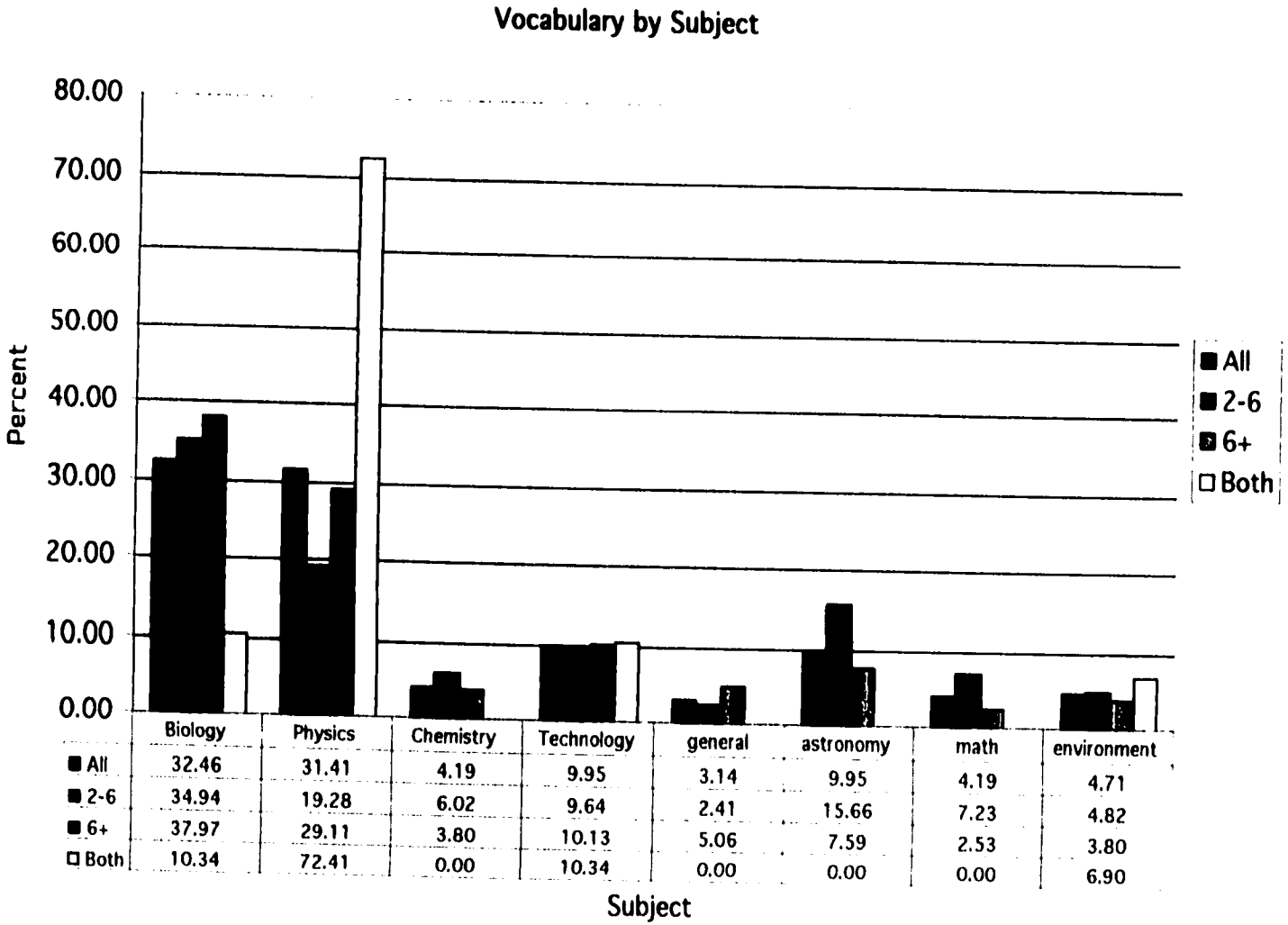

Figure 1: Vocabulary by subject

Table 5: Percentage of sample that contains hands-on and demonstrable science.

Percent	Hands on	Demonstrable
All	60.87	47.83
2-6	54.55	45.45
6+	66.67	50.00

As shown, 60.87% of the sample contained hands-on science while 47.83% contained demonstrable science. When hands-on and demonstrable science are calculated together, 70% of the sample contains at least one of either type of activity.

Because every science activity found was feasible, and because 70% of the sample contained suggestions for hands-on and demonstrable science activities, it is concluded that science fiction books are good sources of ideas for demonstrable and hands on science activities.

Conclusion To Question 1

The preceding analysis has shown that science fiction books are a good source of complementary science curriculum materials as well as ideas for classroom science activities. It has also been shown that the density of scientific concepts is sufficient to warrant using science fiction in the classroom, and vocabulary can also be a good source of science material for biology and physics. Therefore, it is possible to conclude that science fiction could be used to teach science.

COULD SCIENCE FICTION BE USED TO TEACH SCIENCE ISSUES?

The indicators used to answer this question were positive (i.e. penicillin) and negative (i.e. pollution) outcomes of science, scientific and societal issues, ethics, and impacts on society. These indicators were chosen because they involve issues that relate to, and result from science and as such are important in evaluating whether science fiction can be used to teach science. It is relevant to know how science impacts on society, and this can be examined through outcomes, issues and ethics.

Positive And Negative Outcomes

The ratios between positive and negative outcomes resulting from scientific development are found in table 6.

Table 6: Ratio of positive and negative outcomes

	Ratios
All	3:5
2-6	1:2
6+	2:3

The ratio for the sample is 3:5. This means that for every three positive outcomes of science shown that there are five negative ones. This indicates that science fiction tends to show the dangers of scientific development with greater frequency than its benefits. In a society where science is seen as a "good" thing, it is beneficial to question all beliefs that are taken for granted by introducing ideas that bring them into question. Therefore, by using science fiction, which presents more negative than positive outcomes, in science education, a balance can be created between views of positive and negative scientific outcomes.

Scientific And Societal Issues

There are 25 individual scientific/societal issues found in 65.23% of the sample. They belonged to four categories, biology, physics, chemistry and the environment. A breakdown of the issues by subject and category is found in figure 2. The category of 'both' refers to specific issues that are discussed in both the grade 2-6 and the 6+ categories. As seen, biological and physical issues are the most prevalent subjects in the sample. Biological issues are most common in the 6+ group, while physical issues are most common in the 2-6 group. The issues were also analysed for their importance in the stories. As seen in figure 3, 57.89% of the issues are presented in passing.

This means that the issue was probably used as a description of the society or setting in which the story takes place. 21.05% of the issues are presented as a major plot element which means that it is actively discussed by the characters on more than one occasion. 21.05% of the issues are incorporated into the plot of the story which means that most actions, plans or discussions involve the issue in question.

While the most useful books for discussion purposes contain major elements of an issue, issues mentioned in passing can also be an effective starting point for discussion purposes. Books that are entirely based on an issue are less useful for discussion because the author has fully argued their own interpretation of an issue. Therefore, 78.9% of the issues found could be used as starting points for discussions. However, since only 65.23% of the sample contained issues, there is only a 51.47% chance that any one book will contain useful issues for starting discussions. Therefore, due to this probability of finding

books which contain useful issues, it can be concluded that science fiction books are a somewhat effective means of integrating scientific/societal issues into the classroom. Teachers would find 1 out of every 2 books useful which explains why it can only be considered somewhat useful.

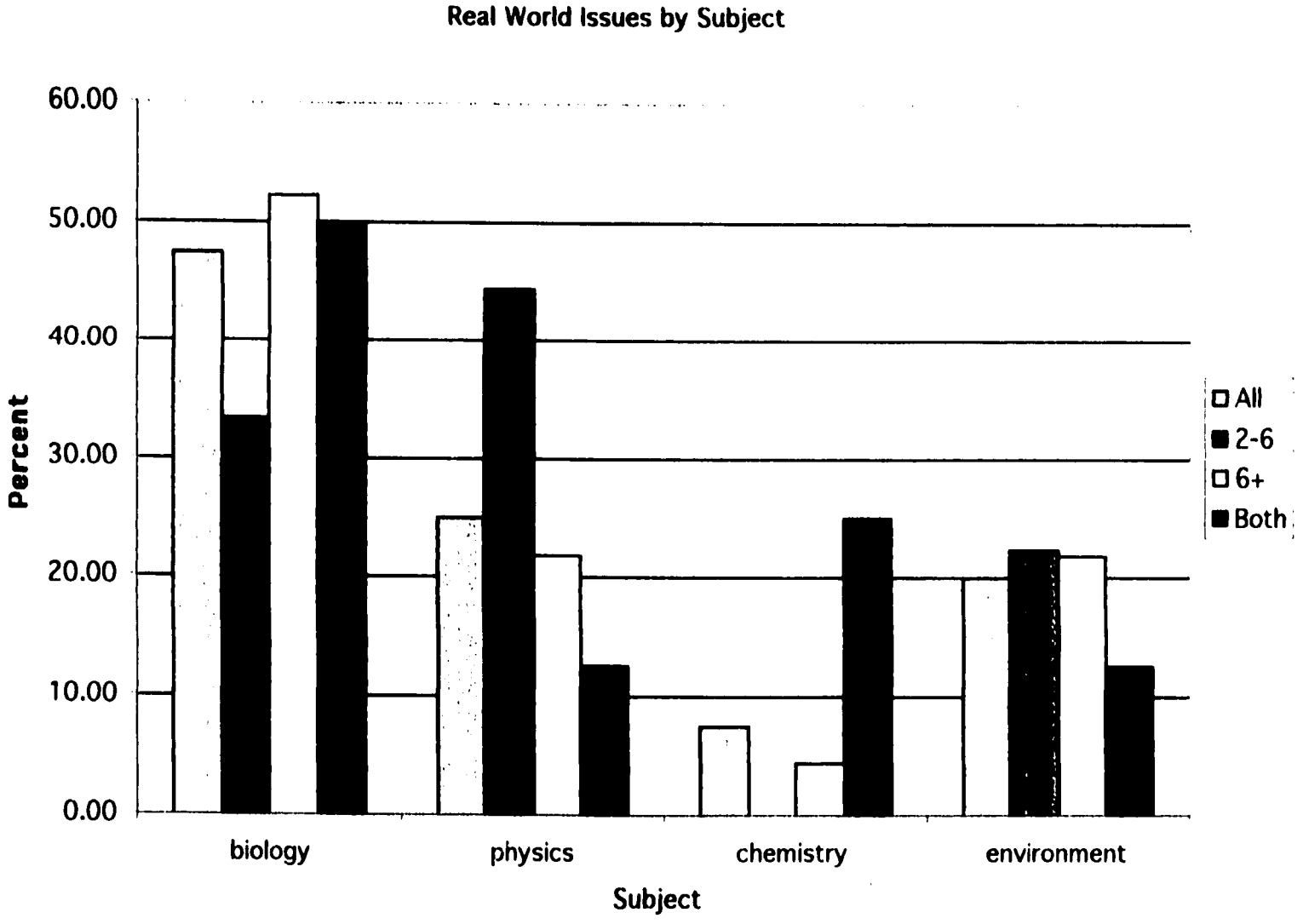

Figure 1: Real world issues by subject.

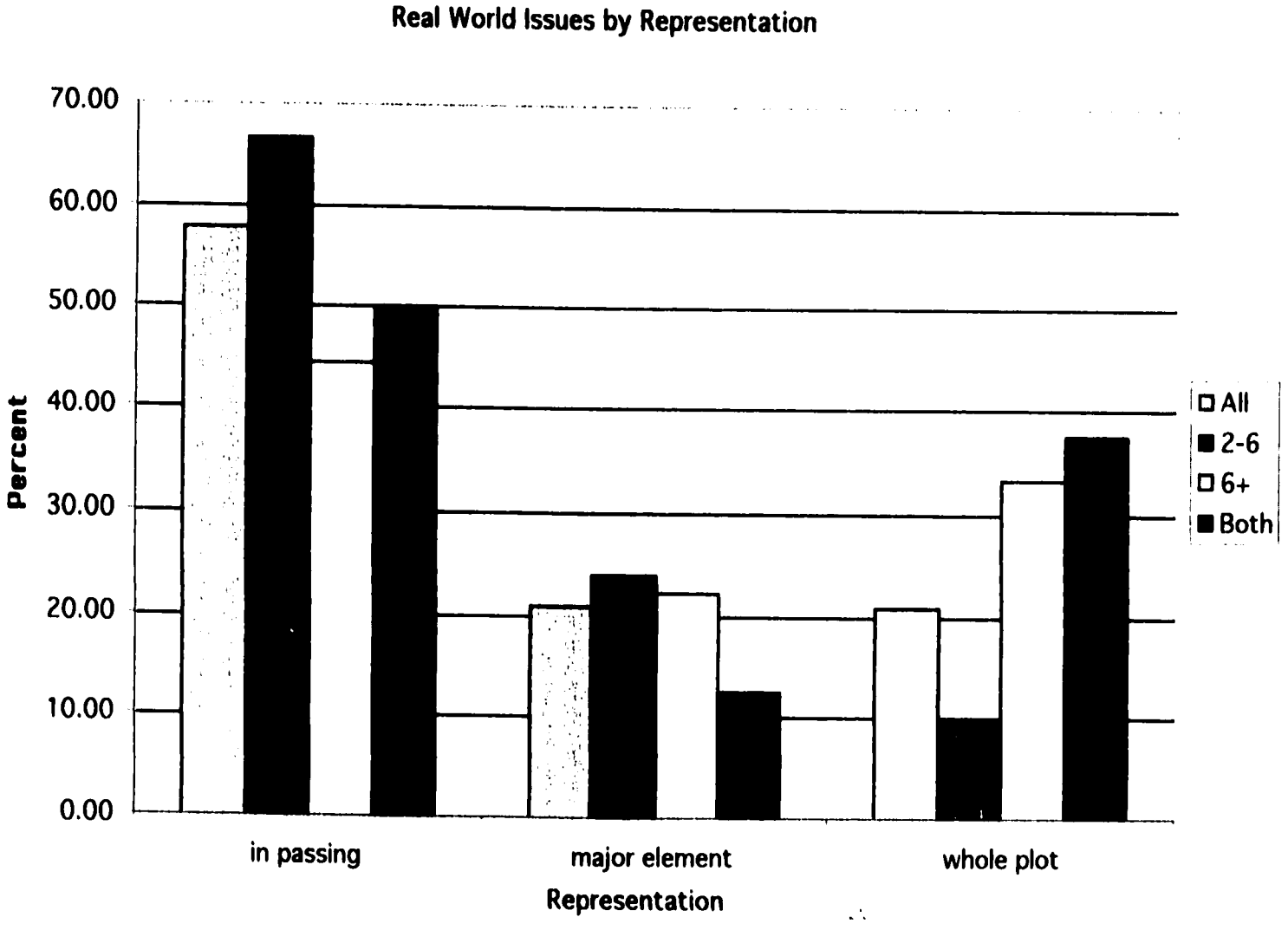

Figure 2: **Real world issues by representation.**

Ethics

Figure 4 contains the proportion of ethical actions, unethical actions, and books that have no ethical content. As seen, there is an even split between books that do not show ethics and those that show unethical actions. Only four percent of the sample shows ethical behaviour. This is useful in science education because it is easier to understand ethical decisions when faced with concrete examples of unethical activities. In addition, having examples that are unethical offers a greater opportunity for debate and discussion, which are good methods of learning as seen in chapter 2. Therefore, only 48% of the sample is useful for this purpose. However, 55% of the sample is useful in the grade 2-6 group. If ethical and unethical are considered together, 64% of the 2-6 group could be used. This means that science fiction could be used to discuss ethics more often with younger students.

Due to the low probability of finding books with ethical issues, it can be concluded that science fiction stories are not useful for introducing ethical concepts into classrooms.

Impacts On Society

Scientific impacts on society were also examined. 79.49% of the sample identified scientific impacts on society. Table 7 identifies the percentage of real impacts that are being or have been dealt with by our society and the percentage of those that are fictitious.

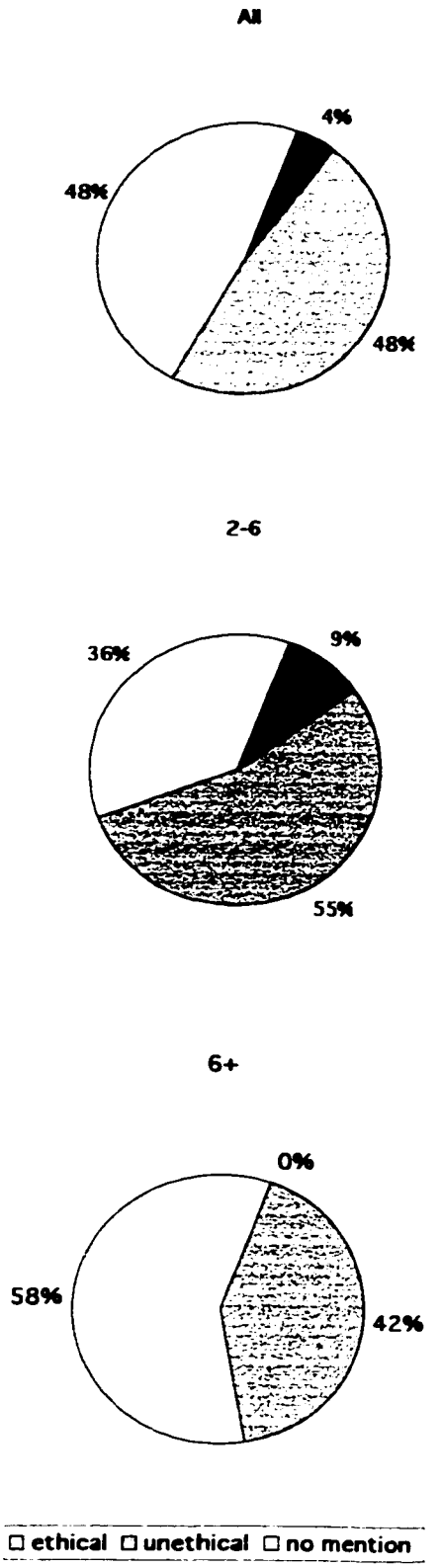

Figure 4: Ethics by group.

Table 7: Societal impacts by type and category

Impact	% Real	% Fictitious
All	57.14	42.86
2-6	100	0
6+	36.84	63.16
Both	100.00	0

57.14% of the impacts identified are current or past issues in our society. Many of the fictitious impacts are close to becoming real issues. If developments in fields such as genetics continue to occur as they are now, science will have advanced to the point where at least two of the fictitious impacts will become real issues. This means that as time progresses, new issues will develop and imagined ones will be realised. Therefore, it is useful to use science fiction to evaluate current and potential scientific impacts on society.

Conclusion To Question 2

As seen, the ratio of positive to negative outcomes is useful to balance the perception of science as a "good" thing. While scientific/societal issues do not occur frequently enough on their own, if they were discussed along with scientific impacts on society, which is increasing as science progresses, it could be useful to implement science fiction in the classroom. Ethical examples in science fiction are more likely in grades 2-6. Therefore, science fiction could be used to teach science issues in elementary schools. However, more teacher preparation would be necessary due to the 50% probability of finding useful scientific/societal issues in science fiction books. Nevertheless, as any discussion or debate requires extra teacher preparation, it does not preclude the use of science fiction to teach about science issues.

Could Science Fiction Be Used To Teach About The Scientific Method?

The indicators used to answer this question were hypothesising, scientists doing science, and scientific debate. These indicators were chosen because they are contained in the scientific method, and as such are effective in evaluating whether science fiction can be used to teach about the scientific method.

Scientific Method

The sample was examined to calculate the percentage of books that displayed at least 2 of 3 indicators included in scientific method. These books exhibit the scientific method. Table 8 shows the breakdown for each of the categories.

Table 8: Percentage of sample that exhibits scientific method

	% Yes
All	30.43
2-6	9.1
6+	50

As shown, only 30% of the sample exhibited the scientific method. As scientific method is a research technique, it is not surprising that it is rarely found in narratives. It is however found in textbooks and experienced through hands on science activities.

Conclusion For Question 3

Hypothesising, scientific debate and scientists doing science are not effectively learned through textual media. They are learned through expository

texts and through experience using the method. From this, it can be concluded that science fiction books are not useful resources in teaching about the scientific method.

Does Science Fiction Contain Elements That Could Alienate Some Students?

The indicators used to answer this question were stereotyped views of aliens, gender, and social class. These indicators were chosen because they relate directly to issues of power and views of the "other", and as such are important in evaluating whether science fiction is acceptable for classroom use.

Alien Stereotypes

When positive and negative views of aliens were examined, it was found that there were an equal number of positive and negative portrayals. This could not lead students to develop the idea that those who are different are bad or suspect. This has societal implications in a multicultural environment where students encounter people with different customs and values from their own. If students draw any inferences about aliens from the science fiction stories, it will be that differences do not always mean evil.

Gender

Gender was examined by determining whether the protagonists in the story were male, female, or mixed groups, referred to as 'both'. As the target audience for the sample was grades 2 to 6+, the protagonists of the stories were young. Because of this, any career scientists portrayed are background characters. This means that the gender of those conducting science is usually

unavailable. Therefore, gender focused on the protagonists, who were often participating in science activities despite their amateur status. Figure 5 shows the gender breakdown by category.

If the category for female and both are taken together, it is seen that 56% of the overall sample contained female characters. However, when examining the grades 2-6 group, only 45% of the books have female characters. In the grade 6+ group, 67% of the sample contains females. This is an advantage, because this is the age where students begin to make decisions about which high school program to follow. A large number of books with female characters will encourage girls to re-evaluate their perceptions of scientific careers. This trend would also be useful in the younger group. However, female presence in the 2-6 group could be increased with careful teacher selection of books. Therefore, gender is not widely skewed in the sample and science fiction books could be appropriate in the elementary classroom.

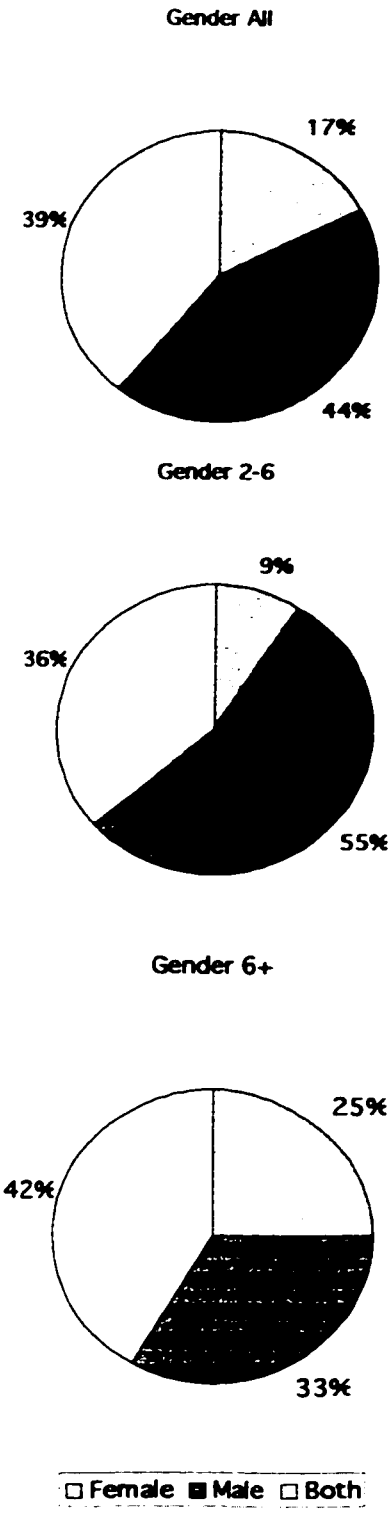

Figure 5: Gender by group.

Social Class

Social class was examined to determine whether there was a large imbalance in the representation of the protagonists' social class. Figure 6 represents the results for social class by category. In each case, the percentage for lower class and upper class are equal. This indicates that anyone can be involved in science regardless of social class. While the proportions of social classes are not all equal, they are all represented, which is not often the case in other media. For this reason, it can be concluded that the portrayal of social class does not provide a reason to exclude science fiction from the classroom.

Conclusion To Question 4

The findings indicate that there is no stereotyped view of the other as evil, and as gender and social class are not skewed in the sample, it can be concluded that science fiction stories do not contain elements that could alienate students.

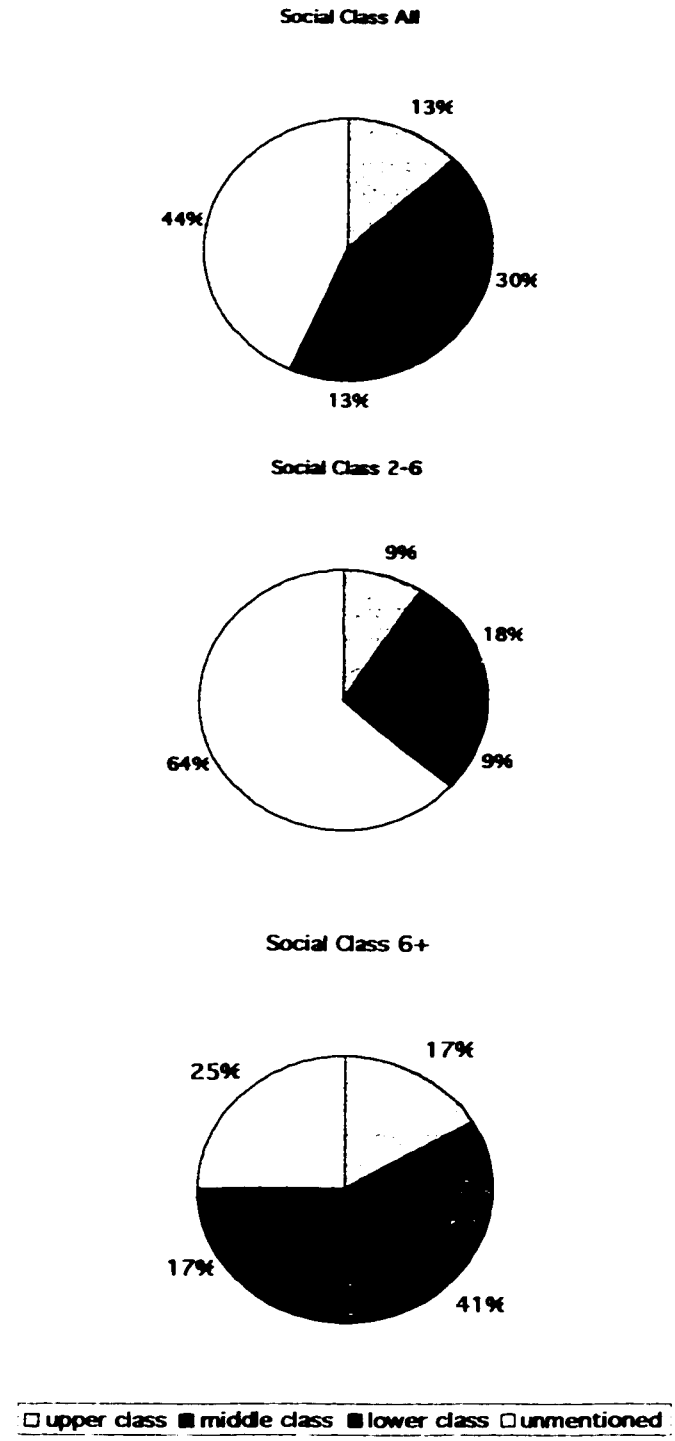

Figure 6: Social class by group.

CAN SCIENCE FICTION BE USED TO IMPROVE SCIENTIFIC LITERACY?

This first question in the study asked: Does popular culture, in the form of science fiction, contain elements that could improve scientific literacy?

Now that the three sub-questions have been answered, it is possible to determine whether science fiction can be used to improve scientific literacy. As stated in the previous section, all areas under consideration but one showed that science fiction is useful in science teaching. The issues examined were either very useful, useful, somewhat useful or not useful with regards to their ability to be incorporated in to the science classroom. Very useful items were ones that rated highly and which could easily be used in science education. Useful items were ones which could be used, but with attention paid to the way in which they were implemented. Somewhat useful items were ones which could be used, but which were not sufficient on their own to make complete examples. Not useful items were ones which had no value in the classroom. The following table illustrates which items belong to each rating.

Table 9: Tested items by usefulness

Very useful	Useful	Somewhat useful	Not useful
Matches curriculum	Density of scientific concepts	Vocabulary density (general)	Scientific method
Sources for hands on and demonstrable ideas	Scientific / societal issues	Ethics	
Ratio of Positive: Negative	Vocabulary density (biology / physics)		
Societal impacts			

Since 90% of the items examined can be used in science education, and because 70% are useful or very useful, it can be concluded that science fiction could be an effective tool in science education. Therefore, it can be concluded that popular culture, in the form of science fiction, could be used as a tool to increase scientific literacy.

Conclusion

In sum, this chapter has examined items in science fiction novels which affect scientific literacy. Each of the questions answered except one, scientific method, were shown to be useful for improving scientific literacy. Therefore, it was concluded that science fiction is a good strategy to improve scientific literacy in elementary school.

CHAPTER 5: CONCLUSIONS

INTRODUCTION

To recapitulate, this study sought to identify whether science fiction novels are a useful strategy for increasing scientific literacy in elementary school. It concluded that there was sufficient scientific material within the novels to use them in elementary school classrooms. Science fiction novels could be used to increase scientific literacy.

LIMITATIONS OF THE STUDY

There are several limits to this study. The population from which the sample was taken consisted of North American, English-language books. The focus of the study was intended to be North American, but this geographical circumstance could limit the conclusions that can be drawn from the data. In addition, the fact that the sample was English limits the usefulness of the data for French schools within Canada. The sample for each of the two grade groups was small enough that there is the possibility that it might not be representative of the actual style of most science fiction books in each category. Also, the fact that one specific field of science, for example biology, was not chosen as a focus means that there may not be enough books in each discipline to draw a clear conclusion for each different field of science.

Because this study is a content analysis, it cannot indicate whether this method of instruction would be well received by teachers or students, nor can it

evaluate the budgetary feasibility on implementing a program with new textual materials. It also does not explore the outcomes of such a program with regards to those students who do become scientists. Would this program adequately prepare them for such a carrier?

Areas For Further Research

Theoretically, popular culture, in the form of science fiction, is a good tool for increasing scientific literacy. It remains to be seen in a school-based study whether science fiction can actually bring about this increase. This study did not examine whether teachers would be able or willing to adapt science fiction stories into their science lessons, or whether they could adapt science fiction into an integrated lesson plan. Also, this study did not examine student's perceptions or interests in using non-standard textual vehicles in their science class. As with any educational tool, it is either enhanced or hindered by a teacher's method of implementation. While science fiction books contain issues that could be useful in science education, they will not be apparent if teachers do not know how to isolate or implement the issues in the books.

Other methods of implementation (summer reading lists, in school choice of reading, integrated use of books...) may also provide the stimulus for creating interest which leads to scientific literacy without actual teacher intervention. In addition, it would be useful to examine other genres of science fiction such as television, movies, and comics. There may be stories other than science fiction

which could increase scientific literacy. Further research should focus on these issues.

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APPENDIX A:

GRADES 2-6

Asimov, Greeberg, Waugh	Young mutants
Cameron, Eleanor	Stowaway to the mushroom planet
Coville, Bruce	Space Brat 2: Blork's evil twin
Coville, Bruce	I left my sneakers in dimention X
Curtis, Philip	Invasion of the brain snatchers
Dadey, Debbie	Aliens don't wear braces
David, Peter	Worf's first adventure
O'Brien, Robert C.	Mrs. Frisby and the rats of NIMH
Service, Pamela	Stinker from space, Stinker's return
Slote, Alfred	My robot buddy

GRADES 6+

Bova, Ben	End of exile
Christopher, John	The White mountains, The city of lead and gold, Pool of fire
Danziger, Paula	This place has no atmosphere
Heinlein, Robert A.	Have space suit will travel
Heinlein, Robert A.	Tunnel in the sky
Hoover, H.M.	The bell tree
Hughes, Monica	Invitation to the game
Karl, Jean E.	But we are not of earth
Norton, Andre	Forerunner: the second venture
Slote, Alfred	Clone catcher

APPENDIX B:

Physical Aspects of the Books

Title of book/Author	Publication year	length of book	Areas of science	Visual elements	Characters (likable, sympathetic, interesting)	Quality of the story

Science Shown in the Books

Scientific difficulty	Is the science clear	Validity of scientific approach	# of science concepts: Total	# of science concepts: True	# of science concepts: Fictitious

Scientific Behavior Shown in the Books

Scientific method	Hypothesizing	Scientists doing science	Ethical science	Scientific Debate

Societal Issues Shown in the Books

Positive outcomes of science	Negative outcomes of science	Can the science be linked to real world science issues	Impact on society	Gender	Racial distribution	Social class

Teacher and Classroom Issues Relating to the Books

Amount of required teacher intervention	Vocabulary	Does the science in the story mesh with the curriculum	Areas where critical evaluation could be fostered	Does the book have demonstrable science	Do ideas in the story lend themselves to hands on learning