Developing Scientific Literacy in Grade Five Learners:
A Teacher-Researcher Collaborative Effort
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Abstract

In line with the international goal to develop scientific literacy, the overall aim of this research study was to observe the nature of development of scientific literacy of Grade 5 students as they studied a curricular unit on Weather. This was a qualitative, classroom-based project, where the researcher actively participated in the planning, teaching and assessment of the unit on Weather, in a grade five classroom of an inner city school.

The results of this study point to the development of the three notions of scientific literacy (the what, how, and why of science). These three notions of scientific literacy were achieved because of the collaborative efforts of a researcher and a second-year public school teacher. Thus, we put forward the idea that science educators and/or researchers ought to collaborate with novice teachers to help them translate the ideas learned in the science methods courses into their classroom practice. We also recommend that teacher education programs should adequately prepare prospective teachers in the content and the history and philosophy of science.

Introduction

Over the past century, an adequate understanding of the nature of science has been recognized as an important educational objective worldwide in the development of a
scientifically literate individual (American Association for the Advancement of Science, 1989, 1990, 1993; Council of Ministers of Education, Canada, 1997; National Science Teachers’ Association, 1991). These organizations not only write about the importance of scientific literacy but they also advocate scientific literacy for all students. For example, in Canada, the Council of Ministers of Education, in the Pan-Canadian Protocol for Collaboration on School Curriculum, states that “All Canadian students, regardless of gender or cultural background will have an opportunity to develop scientific literacy” (1997, p. 4).

Who is scientifically literate? Abd-El-Khalick and BouJaoude (1997) define that a scientifically literate person should develop an understanding of the concepts, principles, theories, and processes of science, and an awareness of the complex relationship among science, technology, society, and environment [STSE]. Hence, this definition points to three notions: 1) what of science (concepts, principles and theories), 2) how of science (processes of science), and 3) applications of science (science, technology, society, and environment connections), which summarize the true nature of science.

The first notion of scientific literacy emphasizes that a scientifically literate person understands scientific concepts, principles, and theories. This understanding, however, does not mean that the person should be able to memorize traditional key concepts and principles in physics, chemistry, biology, and so forth. It means, on the other hand, that understanding of these concepts, principles, and theories should help the person to ‘use’ science, rather than to ‘do’ science (Hazen & Trefil, 1991).
The second notion of scientific literacy refers to the ability to recognize that science is the product of human mind, and that scientific knowledge is created by a community of researchers, who are open-minded, intuitive, imaginative, and creative (Arons, 1983). Ramsay (1993) states that the scientifically literate person would also understand that science is tentative, has limitations, and interacts with society on moral, ethical, and social planes. Abell and Smith (1994), Lederman (1992). Furthermore, a scientifically literate person should be aware that science has a past, present, and future, which are helpful in understanding its nature (Abell and Smith, 1994; Lederman, 1992; Stinner, 1995).

Aikenhead (1992) and Fleming (1987) look at the above third notion of scientific literacy, which is the practical application of science. According to these authors, scientifically literate people should understand how decisions are made at the local, provincial, and national government levels, and within the private and individual sectors. These science educators believe that scientifically literate individuals posses critical thinking skills which allow them to: a) evaluate the pros and cons of any scientific or technological development, b) examine potential benefits and costs, and c) recognize the underlying political and societal forces, which drive the development and distribution of scientific and technological knowledge and artifacts. In other words, this notion reflects the relationship among science, technology, and society [STS].

Despite of the constant efforts of many researchers and organizations to develop scientific literacy among teachers and their students, literature in science teacher education abounds with criticisms of pre-service and in-service teachers (Driver, Leach,
Millar, and Scott, 1997; Duschl, 1988, 1990, 1994; Gallagher, 1991; Hodson, 1988; and Lederman & O’Malley, 1990; Monk and Osborne, 1996). They are accused of possessing insufficient understanding of the true nature of science, which leads to lack of scientific literacy among their students. Gallagher (1991), for example, states that teachers have no formal education in the history, philosophy, or sociology of science, nor has their scientific training provided them with much understanding of the processes by which scientific knowledge is formulated. He explains that teachers do not see the practical applications of their science training and as a consequence they frequently fail to point out obvious connections between class work and the world outside of school.

Many authors suggest that to improve teachers’ and consequently their students’ scientific literacy, teachers’ training, such as science methods courses, need to portray the true nature of science (Driver et al., 1997; Duschl, 1990; Hodson, 1988; Monk & Osborne, 1996). The context of such courses should provide the pre-service teachers with opportunities to model not only what is known by science, but also how science has come to arrive at such knowledge. In other words, as proposed by Monk and Osborne (1996), science education of the future teachers should unconditionally consider the question of “how we know”.

We agree with these recommendations. In fact, we made similar suggestions in our earlier paper entitled, Elementary Teacher Candidates’ Conceptualizations of the Nature of Scientific Inquiry: A Phenomenography for Curricular and Pedagogical Decision-making, which was presented at the Congress of Social Sciences and Humanities in Edmonton, Alberta in 2000. In the present paper, however, we would like to take our
recommendations a step further. We postulate that in addition to presenting contemporary philosophy of science in the science methods courses, the science teacher educators and/or researchers need to collaborate with novice teachers to assist them with the implementation of these contemporary ideas into their classroom practice. We would like to emphasize that the teacher-researcher partnership we propose should not follow the traditional, exploitative nature of classroom-based research, where the researcher observes and evaluates the teacher’s knowledge and methods and then leaves the scene (Janesick, 2004). To the contrary, this partnership needs to develop into a strong collaborative relationship with the power to merge theory and practice.

Research questions

The aim of this paper is to answer the following two research questions:

1) What aspects of scientific literacy development were evident in a Grade 5 classroom when the Common Knowledge Construction Model was implemented in the context of a unit on Weather?

2) What is the nature of the teacher-researcher collaborative effort to develop scientific literacy in a Grade 5 classroom?

Methodology and Results

This section of the paper describes experiences of the researcher (Ph.D. student), thus, is written in declarative voice.
This study is situated in a long-term project, which I started in the first year of my Ph.D. program. During that year I was curious to learn what constituted elementary preservice teachers’ curriculum and how they were prepared to teach science after they graduate with the Bachelor of Education degree. Thus, I audited the Science Curriculum and Instruction course (EDU 81.402), which is a mandatory course that leads to elementary teacher certification. I attended the C & I course throughout the year, which consisted of 9 weeks in the Fall Term and 9 weeks in the Winter Term. Each class was 1 hour and 20 minutes long. The science teacher educator –Dr. Smith, who is also my Ph.D. advisor, encouraged me to document the events of the science C & I course as they unfolded. Thus, I took field notes, carried out document analysis, and I also audio taped the conversations between the science teacher educator and her students as well as the conversations among peers.

The professor also asked me to critically evaluate her approach to teaching. Consequently, in each class I wrote my observations, comments, and suggestions and after each class, we met to discuss the events. I benefited from this experience during the second year of my Ph.D. program. At that time, I got an opportunity to teach two sections of the Elementary Science Curriculum and Instruction course at the University of Manitoba and my advisor was assigned to teach the other two sections. Therefore, it was an excellent opportunity for us to collaborate and co-construct the C & I course.

We met every Friday to plan the agenda for the next week’s class. We decided that we both would implement our shared ideas into the phases of the Common Knowledge Construction Model (Ebenezer and Connor, 1998). This model consists of
four interactive phases: 1) Exploring and Categorizing, 2) Constructing and Negotiating, 3) Translating and Extending, and 4) Reflecting and Assessing. Through this model, the pre-service teachers learn how to teach science from a rational perspective: exploring and categorizing (learning to explore and categorize children’s ideas using different methods), constructing and negotiating (learning to negotiate accepted views with children using different teaching strategies), translating and extending (learning to make connections to everyday life situations as well as technological and societal issues), and reflecting and assessing (learning to assess children’s ideas before, during, and after the unit).

I liked the idea of using the model because it reflects the nature of scientific inquiry. I also saw a correlation between the model and Manitoba science curriculum. In other words, I noticed how by introducing this teaching model, I can help my students--the future teachers--to teach Manitoba curriculum in a simple yet innovative way. Also, because I was going to teach this course for the first time, I knew that if I use the model, my classes would be organized, meaningful and well structured. We made certain changes to the previous year’s course outline.

**Pilot study**

While attending the C & I course I saw an opportunity to conduct a pilot study to examine how the pre-service teachers transform their thinking about the nature of scientific inquiry throughout the duration of the course. Twenty one (70%) out of 35 pre-service teachers responded to my invitation and gave me a written consent to participate
In my pilot study, however, I present the data that I collected for Natalia—one of these pre-service teachers.

In the first step of my pilot study, I evaluated Natalia's prior-teaching understanding of the nature of science (field notes #1), which were her answers to prior-instructional questions mentioned. Then, I collected other data throughout her C and I course and teaching practica, in the following chronological order: audio-taped participation in a group discussion on November 1, 1999 (field notes #2); audio-taped interview #1 on November 11, 1999 (field notes #3); written midterm exam on November 12, 1999 (field notes #4); audio- and video-taped P-STAR conference presentation on January 27, 2000 (field notes #5); audio-taped interview #2 on February 2, 2000 (field notes #6); written final assignment (field notes #7) due on March 6, 2000; audio- and video-taped interview #3 on April 20, 2000 (field notes #8).

To analyze the data, I first carefully read each set of the field notes and at the same time I color coded the information to generate themes. There were several themes that emerged from this stage of the study, for example: teacher guided inquiry, student led discovery, mechanics of teaching, making connections to everyday life, teaching and learning through senses, scientists as children, importance of verbal instruction, curriculum assessment, tentative character of scientific knowledge, importance of history and philosophy of science, the scientific method, and many methods of conducting scientific inquiry.

The results of the first step of my pilot study indicated that Natalia’s understanding of the nature of science unfolded with the progression of the Elementary
Science Curriculum and Instruction course. For example, at the beginning of the course, this pre-service teacher believed that both scientists and science teachers conduct scientific inquiries by means of the step-by-step scientific method. At the end of the academic year, however, she was able to acknowledge that there are many methods of science. Furthermore, she realized that scientific theories are tentative and that science is socially and culturally embedded. Additionally, she identified the importance of the history and philosophy in teaching and learning of science.

In the second step of my pilot study, I continued my research with Natalia once she obtained her first job as a grade seven teacher in the Sunny Valley School. At that time she was teaching a science unit on Materials and Structures, French, and Social Studies. The main purpose of this part of the study was to observe how she portrays the nature of science to her students. I initially planned to conduct classroom observations for a period of one month. But, after two weeks, Natalia decided that she would like to use the time assigned to science to finish the French curriculum and consequently I had to terminate my classroom observations.

While in Natalia’s classroom, I assumed a role of a critical observer who tape-records all of the classroom conversations. Bogdan and Biklin (1992) would classify this routine of mine as non-participant observation. When observing the science classes in the Sunny Valley School, I often had a feeling that the teacher did not have a long-term plan as to how to teach this curricular unit and that every class was treated as an isolated case. Sometimes I was under the impression that her students were wasting time. I also observed that she struggled with the content of this curricular unit. She admitted that she
was not adequately prepared and that she felt that she was “just one hour ahead of her students”. Additionally, contrary to what was advocated in her science methods class by Dr. Smith, she did not employ the Common Knowledge Construction Model to teach the curriculum. The following statement, given by Natalia herself, best summarizes her experiences during her first year of teaching.

“I felt unprepared, I felt that I did not have any knowledge in science, I did not know what to teach. I was even afraid of their questions. I was totally lost…I was looking forward to the professional days when I could meet other teachers and share ideas…”

Present study

After teaching the Elementary Science Curriculum and Instruction course and after concluding the pilot study I was determined to find out how the Common Knowledge Construction Model plays out in the school classroom with respect to the nature of science hence scientific literacy of the students. This time, however, I wanted to get first hand experience by, not only observing a teacher and his/her students, but, by being involved in the planning of the lessons and by witnessing how the lessons are being taught. In other words, I was interested in a teacher-researcher collaborative effort in planning, teaching, and assessment. I was eager, then, to work with a teacher who would actually incorporate the Common Knowledge Construction Model into his/ her teaching. Additionally, I wanted to collaborate with a teacher who understands and includes aspects of the nature of science into his/her science teaching. I also preferred working with a teacher-researcher who understands and is committed to research. I was particularly interested in finding a teacher who is a former student of mine and who is
familiar with the Common Knowledge Construction Model since working with such a teacher would allow me to observe how she/he translates the nature of science I addressed in class into his/her classroom practice.

Scott, was able to participate in this study and he met all of the specified criteria. At that time he has been teaching, on full time basis, for one and half years in the Red River School Division. His school, Prairie View Elementary, was located in inner city. He started working as a teacher in May of 2001, immediately after graduating from the University of Manitoba with a Bachelor of Education degree.

This was a qualitative research project, which Strauss and Cobrin (1992, p.17) define as “any kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification”. It is a process that results in conclusions derived from data gathered by a variety of means, such as observations, interviews, documents, videotapes, researcher’s personal reflections. Sandra Mathison (1988) in the article entitled “Why triangulate?” explains that “good qualitative practice obligates the researcher to triangulate to enhance the validity of research findings” (p.13). As suggested by Mathison and many other qualitative researchers (Bogdan & Biklin, 1992; Janesick, 2004; Strauss and Corbin, 1990; Taylor and Bogdan Wolcott, 1988; among others), I collected multiple sources of data, which is referred to as triangulation. My data collection followed the three primary fieldwork strategies, such as experiencing, enquiring and examining, known as the three E’s (Wolcott, 1992, p.19). Consider Table 1 for the summary of the data collection techniques.

**Table 1. Data collection techniques (the three Es)**
The majority of data were collected through participant observation. My active participation began by collaborating with the teacher to plan the unit based on the phases of the Common Knowledge Construction Model and to develop specific lessons characterizing the nature of scientific inquiry. Then, once he started teaching the unit, I was a participant observer in all of the 36 science classes. According to Spradley (1980) participant observations are undertaken with two purposes in mind: 1) to observe the activities, people, and physical aspects of situation, and 2) to engage in activities that are appropriate to a given situation that provide useful information. In line with Spradley’s recommendations, as a participant observer, I purposefully looked for opportunities to actively participate in various tasks and I made sure that students saw me as an active participant. During class time then I tried to participate in every activity. For example, when students were discussing their ideas or manually designing the weather instruments, I circulated among groups, asked them questions, and listened to their conversations.

All classroom interactions, (both large group and small group) were video- and/or audio-taped. Subsequently, I transcribed all electronic recordings verbatim. These transcripts also include comments about the students, teacher(s), school, as well as my interpretations, hunches, preconceptions, and comments for future inquiry. Hence, my
transcripts consist of descriptive information and personal comments, which are designated as O.C. for observer’s comments (Taylor & Bogdan, 1998). In addition to video-taping and tape-recording I kept a journal and encouraged Scott to do the same. Furthermore, students’ written work, such as: science journal, science notebook, homework, assignments, and tests were collected, photocopied, and then returned to the students. Field notes were coded and themes were generated. I generated patterns and meanings from the collected data by color coding (Taylor & Bogdan, 1998). The three themes are: 1) science understanding, 2) understanding how scientists work, 3) application of science.

Science understanding

Hazen and Trefil (1991) clarify the difference between the ability to use science and the ability to do science. According to these authors, doing science involves the ability to do what scientists do, for example, sequence a section of DNA. Using science, on the other hand, involves having enough background knowledge in molecular biology to be able to understand how new advances in this field occur, and what the consequences of these advances are likely to be for the person’s family.

If we apply Hazen’s and Trefil’s (1991) reasoning to our study on Weather, using science would mean acquiring enough background knowledge on weather to be able to make informed decisions in everyday life. The unit on Weather provided many opportunities to put theory into practice. Firstly, the students utilized their knowledge to design different weather instruments, such as: weather vain, anemometer, barometer, and rain gauge. Then, they used their own instruments to measure current weather conditions.
In addition to making their own measurements, students visited Environment Canada Website and recorded scientists’ current and future measurements of temperature, wind speed, wind direction, and precipitation. They also used this Website to check the satellite image maps and interpret what kind of weather was heading their way. After that the students used their measurements as well as the measurement done by scientists to write a weather report. Finally, the students interpreted the data and made weather related recommendations, such as to what to wear to school, what to do after school, how to plan the weekend, etc. Both the report and the recommendations were announced to the whole school via the intercom. Consider one of these announcements:

Good morning!

This is Prairie View School Weather report for April 29, 2003. The sky is sunny and the temperature is currently seven degrees Celsius. The winds are blowing from the west at seven kilometers per hour. We can expect a high of 12 degrees Celsius and a low of minus four degrees Celsius. We do not expect to see rain today. Tomorrow we can expect to see sunny skies with a high of fifteen degrees Celsius and the low of minus four degrees Celsius. Our advice for the weather conditions is that it will be a good day for kite flying and wear shorts.

Understanding how scientists work

Arons (1983) explains that the scientifically literate person would be able to recognize that science is a product of a human mind, and that scientific knowledge is created by a community of researchers who are open-minded, intuitive, imaginative, and
creative. This notion of scientific literacy was most evident in Scott’s own understanding, which was translated into his teaching. Contrary to Duschl’s (1988) report that the predominating account of the nature of scientific inquiry in classrooms reflects an “authoritarian view in which scientific knowledge is presented as absolute truth and as a final form”, Scott’s teaching illustrated that scientists are open-minded and that scientific knowledge is tentative. Consider Scott’s conversation (transcribed verbatim) with a student:

Scott: Okay, so right, we looked at the scientist’s predictions for the week and they weren’t always exactly right, okay. You guys, scientists are not always right, and that is something that you have to understand. A lot of people look at scientists and say, wow, they are very smart people, and they must have all the answers. They don’t. What scientist do is they figure out what questions they don’t have the answers to and then they go and try and find them, okay. It’s all part of research, inquiry and exploring. So, scientists don’t know for sure what’s going to happen over the week but their prediction is their best guess.

Scott: Why do you think that there is such a difference between what they predicted for the week and what was actually recorded?

Jane: They do not know for sure what is going to happen and they are not always correct because they do not know everything.

Scott: Okay, so Jane, your answer is right along the lines that I was looking for there, why did you think that there is such a difference between what they predicted for the week and what was actually recorded? You guys, because we are not fortune tellers, as Sammy said, we are not fortune tellers and we are not god, we don’t know for sure what is going to happen, so when the scientists predict what they think will happen, okay, they can’t be 100% correct the whole time, that’s why there is that difference.

Application of science

According to Pedretti (1997), understanding of the relationship among science, technology, society, and environment (STSE) allows the students to see the world in a different, more holistic, rather than mechanistic, way. Such understanding, Pedretti
claims, helps the students to reconsider human needs in relation to natural resources in an effort to maintain a life-giving and life-sustaining environment. Likewise Lederman and O’Malley (1990) suggest that understanding of science-technology-society interactions enables the students to make more rational decisions with respect to societal and personal issues.

The connection among science, technology, society and environment is a significant component of the Common Knowledge Construction Model. Ebenezer and Connor (1998) advocate that while studying any science unit, students need to be able to apply their knowledge into society and environment. Hence, they need to choose a relevant societal issue, make informed decisions, and take the necessary actions. Because of the location of our city in the Red River Valley, our students decided to concentrate on flood. They initially studied how floods happen and then they were determined to share their knowledge with their schoolmates. Specifically, they created posters and wrote letters to the students from another class or to staff to inform them how to be prepared in case of potential flood situation Consider excerpts from a letter by Robin:

Dear Grade One,

I am writing to you about floods. We have to look out for floods in our city, because it is located between the Red River Valley and if it rains too much, the river will get overflowed, and it can create a flood... One of the dangers of floods is homes can be wrecked by floods, and people can loose their homes, belongings, and even pets. We can prepare for a possible flood at home by having a flood survival kit. Some of the items that should be in a flood survival pack are: non-perishable food, first aid kit, a big bottle of clean water, clothes, inflammable mattress, and other items.

Conclusions and Recommendations
Driver et al., (1997) report that there is a significant difference between learning about science and learning of science. Learning about science (the "how" of science) relates to how scientific knowledge is established and added to, what the grounds for its credibility are, and how the knowledge in science is maintained. Learning of science (the "what" of science), on the other hand, relates to the scientific knowledge about the natural world. Learning about science has been strongly supported by philosophers of science education (Duschl, 1990; Hodson, 1988; Jenkins, 1996; Matthews, 1992, 1994; Monk and Osborne, 1996) and those who have studied children's conceptions of the nature of science (Carey, Evans, Honda, Jay, & Unger, 1989; Solomon, Duveen, & Scott, 1994). These authors have suggested that teachers' understanding of the contemporary perspectives of the nature of scientific inquiry is crucial to cultivate appropriate scientific attitudes in the children they teach.

Natalia admitted that she did not feel prepared to teach the content of science in grade seven. She did not feel confident to teach the "what" of science. She also did not portray the "how" of science, in spite of the fact that the contemporary philosophy of science was emphasized in her science methods course.

This points to two conclusions. Firstly, we believe that pre-service teachers need better preparation in the content of science in order to feel confident to teach the K-8 science curriculum. Natalia and Scott did not have the opportunity to take a science course that would educate them to teach the whole spectrum of the K-8 science curriculum. They were required to take six credit hours in sciences and to fulfill this requirement both of them took Earth Science from the Geology Department. This course, however, is most relevant to two curricular units: Rocks and Minerals in grade four, and
Weather in grade five and seven. Hence, Scott benefited from the science course he has chosen while Natalia did not.

We propose, then, that pre-service teachers are advised and/or required to take a course that explores science from an interdisciplinary perspective, with an aim to foster scientific literacy and develop critical thinking skills. Such course needs to draw topics from biology, chemistry, geography and physics and these topics must be relevant to the Manitoba elementary and middle years science curriculum. The University of Winnipeg, for example, is taking steps to implement a multidisciplinary science course, which is aimed at Education and Liberal Arts students who are looking for a general knowledge of science at a qualitative level.

Secondly, we maintain that science methods courses should depict the contemporary philosophy of science, especially because several authors declare that there are limited courses or suggestions available to the teachers that would help them to promote principles of the nature of science (Abell & Smith, 1994; Loving, 1989; Palmquist & Finley, 1997). Lederman (1999) suggests that to promote the contemporary philosophy of science at schools, professional development activities for teachers should consider ways to translate these contemporary understandings into classrooms. To accomplish this goal, science educators and/or researchers need to reach out beyond the methods course. That is, collaborating with novice teachers to help them translate some of the ideas learned in the science methods courses into their classroom.

There was a great difference in Natalia's and Scott's teaching and consequently their success in developing scientific literacy in their students. However, we never collaborated with Natalia. She was not offered any help with lesson planning, class
preparation, or teaching. Scott, on the other hand, worked very closely with the researcher who, in turn, was advised by the university professor.

Collaboration between university based and school based practitioners has recently received a lot of attention. Several researchers reported that the development of a relationship between university researchers and public school practitioners is problematic at best (Connelly and Clandinin, 1990; Johnston, 1990). These authors claim that university researchers often treat schools simply as data collection sites, rather than contexts for the mutual construction of knowledge with experienced practitioners. Researchers act as if they have "the knowledge to improve the teaching practice if only the teachers would accept it and integrate it into their teaching" (Johnston, 1990, p.174). Furthermore, they devalue teachers' practical knowledge and treat them as objects to be studied. In this study, however, we bridged the world of a researcher with the world of a teacher by engaging in this teacher's practice, not as external imparters of knowledge, but as participants in a shared construction of knowledge.

Lieberman (1986) identified three models of collaboration between school teachers and university researchers: cooperative, symbiotic, and organic. They explained that the cooperative type of collaboration usually involves short-term projects characterized by delivery of information from the university to the school. Symbiotic collaboration engages reciprocity between researchers and school personnel to design and implement curricular changes, instructional designs, school improvement programs, and evaluation systems. Organic model, on the other hand, seeks to identify an issue that can be jointly owned and provides for the development of common interests. We believe that
the teacher researcher collaboration in this study was of organic nature with a shared
interest to develop scientific literacy of the students.

In summary, we theorize that the results of this study will urge faculties of
education to reevaluate their science requirements for the Bachelor of Education degree
and consider implementing an integrated science course as a required course for future
elementary and middle years teachers. We also believe that the results of this project can
inform other science teacher educators as to their pre-service teachers' initial views of the
nature of science and encourage them to emphasize the nature of science in their science
methods courses. Furthermore, we hope that the findings of this project will convince
science educators and/or researchers to recognize the value of collaborating with novice
teachers, when possible, to assist them with the translation of theory into practice which
would lead to the development of scientific literacy of their students.

References

Abd-El-Khalick and BouJaoude (1997). An Exploratory Study of the Knowledge Base

Conceptions of the Nature of Science. International Journal of Science Education. 16,
475-487.

Aikenhead, G.S. (1992). The Integration of STS into Science Education. Theory into
Practice. 31(1): 27-35.

American Association for the Advancement of Science. (1989). Project 2061: Science
for all Americans. Washington, DC: The American Association for the Advancement of
Science Inc.

American Association for the Advancement of Science. (1990). Science for all


