CANADIAN PRE-SERVICE ELEMENTARY TEACHERS' CONCEPTIONS OF BIOLOGICAL EVOLUTION AND EVOLUTION EDUCATION

ANILA ASGHAR *Johns Hopkins University*
JASON R. WILES & BRIAN ALTERS *McGill University*

ABSTRACT. This study explores pre-service elementary school teachers' understandings of evolutionary science and their feelings and concerns about teaching evolution in Canadian elementary schools. Data were collected through a questionnaire and semi-structured interviews. Most participants reported acceptance of evolution as a scientifically factual phenomenon, and almost three quarters of those who accepted evolution reported that they intend to include biological evolution in their elementary science teaching. A landscape of sensitivities related to participants' decisions about teaching evolution emerged, including concerns regarding the religious beliefs of students and their parents, the pre-service teachers' inadequate understanding of evolutionary science, and their lack of knowledge of related pedagogical techniques. This study calls for more effective training of future teachers in evolutionary science and for teachers to be professionally prepared to deal with potential social challenges and pressures regarding the teaching of evolution in elementary schools.

CONCEPTIONS DES FUTURS ENSEIGNANTS CANADIENS À L'ÉLÉMENTAIRE SUR L'ÉVOLUTION BIOLOGIQUE ET L'ENSEIGNEMENT DE L'ÉVOLUTION

RÉSUMÉ. Cette étude explore la compréhension des futurs enseignants à l'élémentaire de la science de l'évolution ainsi que leurs sentiments et préoccupations quant à l'enseignement de l'évolution dans les écoles primaires du Canada. Les données ont été recueillies au moyen d'un questionnaire et d'entrevues semi-structurées. La majorité des participants ont avalisé la conception de l'évolution comme phénomène factuel sur le plan scientifique, et presque trois quarts de ceux qui ont accepté cette conception ont affirmé qu'ils avaient l'intention d'inclure l'évolution biologique dans leur programme d'enseignement des sciences au niveau primaire. De ces données s'est dégagé un panorama de sensibilités liées à la décision des participants d'enseigner l'évolution, y compris des préoccupations concernant les croyances religieuses des élèves et de leurs parents, la compréhension imparfaite des futurs enseignants de la science de l'évolution et leur manque de connaissance quant aux techniques pédagogiques connexes. Cette étude réclame une formation plus efficace des futurs enseignants de la science de l'évolution et une préparation professionnelle des enseignants pour qu'ils puissent affronter les pressions et les défis sociaux liés à l'enseignement de l'évolution dans les écoles élémentaires.

INTRODUCTION

This study examines the ideas of future elementary teachers about evolution, the underlying principle of biology and one of the most important science concepts. According to the U.S. National Academy of Sciences (1999), "The theory of evolution has become the central unifying concept of biology and is a critical component of many related scientific disciplines. . . . The teaching of evolution should be an integral part of science instruction" (p. 1-2).

As fundamental as evolution may be to basic science literacy, it is all too often neglected in science curricula at all levels, and perhaps most often at the elementary school level (Lerner, 2000; Alters & Alters, 2001; Gross, Goodenough, Haack, Lerner, Schwartz & Schwartz, 2005). In order to gain insight into some possible reasons for this omission, we explored future elementary teachers' attitudes and ideas about teaching evolution in elementary school science classes in a Canadian province. The geographical context of the study is of particular importance because treatment of evolution is prescribed by a new province-wide elementary science curriculum where this study was conducted. Within this curriculum, "evolution of life forms" is categorized as "essential knowledge" under the category of living things. Charles Darwin is mentioned as one of the important scientists whose work has contributed to "fundamental progress in science and technology" (Quebec Education Program, 2001, p. 171). Therefore, the study population is of distinct interest because, according to the provincial curriculum document, these prospective teachers may soon be expected to teach evolution. We were interested in exploring participants' conceptions about evolution and their intentions regarding evolution education. These students had recently completed a basic science course as part of their preparation program in which evolutionary science was addressed.

While there is a growing body of literature about teacher attitudes and understanding of biological evolution in various international settings, relatively little is known about the ways in which Canadian pre-service elementary teachers understand the science of evolution and how they plan to approach any issues related to the teaching of evolution. This study was conducted within the Faculty of Education at a leading Canadian university to explore pre-service elementary school teachers' perspectives about evolution and evolution education.

LITERATURE REVIEW

In Alters and Nelson (2002), it is reported that "not only does the general public lack an understanding of evolution but so does a considerable proportion of college graduates" (p. 1891). In a study with pre-service elementary teachers in the United States, Blank and Anderson (1997) found that less

than 43% accepted Darwin's theory of evolution. Moreover, 88% agreed that "the divine origin of life through special creation" should be taught alongside evolution**.** Students' own "beliefs and dispositions" influence their understanding and acceptance, especially when students' initial understanding about biological evolution is limited (Sinatra, Southerland, McConaughy & Demastes, 2003). Many students who reject evolution appear to do so because they have various cognitive and affective "rationales" supporting their "objections." Furthermore, a "combination of religious and nonreligious rationales" appears to be related to their decision to reject evolution (Alters, 2005, p. 29).

Rutledge & Warden (1999) found that biology teachers' "acceptance or rejection of evolutionary theory as a scientifically valid explanation is potentially important to the role that evolution takes in the high school biology curriculum" (p. 2). Additionally, several studies found that teacher attitudes and views about subject matter can also influence their "curricular and instructional decisions"; teachers spent more time teaching evolution as their own acceptance and knowledge of evolution increased (Tatina, 1989; Carlesen, 1991; Rutledge & Warden, 1999). Helgeson, Hoover & Sheehan (2002) found that among pre-service elementary school teachers introduced to evolutionary issues via a mock-trial activity, there was a slight increase in understanding of evolutionary principles, decreased acceptance of a literal interpretation of the Biblical creation story, and increased acceptance of the accuracy of evolutionary theory. Importantly, the pre-service teachers reported an increased recognition of the "difficulties involved in balancing evolution and creationism in science pedagogy" (p. 11).

In a study with 989 Indiana public school teachers, Rutledge and Mitchell (2002) found a significant association between teachers' acceptance of evolution and their exposure to biology, evolution, and nature of science issues. Research suggests that biology teacher preparation programs should, therefore, place a high priority on developing a comprehensive understanding of evolution and the nature of science in their students (Rutledge & Warden, 2000, Rutledge & Mitchell, 2002). Additionally, a study that gauged primary and secondary pre-service science teachers' attitudes towards evolution education in Papua New Guinea discovered that while primary trainee teachers exhibited a "poor understanding" and "negative attitudes" towards teaching evolution, secondary science trainees seemed to have a better understanding of the "merits of evolution education" (Vlaardingerbroek & Roederer, 1997). These authors argue that exposure to evolution at the upper secondary level, "in spite of adding little to students' knowledge about evolution, was associated with their increasingly positive attitudes towards evolution education" (p. 363). Teachers' religious beliefs are also found to be associated with pedagogical plans about teaching evolution. Trani (2004) discovered

an inverse relationship between teachers' strong "religious convictions" and their decisions about teaching evolution in classroom.

Alles (2002) concludes that (a) evolution must be a consistent part of biological education to improve students' "working knowledge," (b) evolution should be the foundational and organizing principle of biology courses, and (c) teachers' need to improve their knowledge of evolutionary theory and the nature of science. Pennock (2002) argues that public schools should only teach the scientific idea of evolution to students. He contends that the introduction of creationist ideas as "alternative theories" in the classroom could lead to a "direct confrontation" between students' religious and scientific ideas. "Given that we expect government to neither help nor hinder religion, it would not be a wise policy to open the door to having children's religious beliefs explicitly analyzed and rebutted in public schools in this way," he asserts (p. 125). Nevertheless, studies report that a number of teachers are still not focusing solely on biological evolution in their classes (Moore, 2001, 2002; Trani, 2004; Wiles, 2005).

Research suggests that teachers may face several "obstacles" in trying to develop an in-depth understanding of "evolution by natural selection" in students in accordance with the science content standards (Beardsley, 2004; Bishop & Anderson, 1990; Jensen & Finley, 1995). There does not appear to be one dominant cause for these difficulties; instead, complex interactions within a students' personal conceptual ecology have been identified (Demastes, Good & Peebles, 1995). A study with pre-service science teachers reported "problematic aspects" of teacher understanding of natural selection; even those who had advanced degrees in biology faced difficulties in applying their knowledge in a problem-based context (Saul, Munford, Crawford, Friedrichsen & Land, 2002).

Research indicates that participating in "historically rich" and "inquiry oriented" curricula as well as engaging in historical arguments related to biological evolution helps improve students' understanding (Beardsley, 2004; Jensen & Finley, 1995). Other science educators have added that although an historically rich and inquiry-based curriculum could significantly enhance students' knowledge of evolution, these "one-shot" endeavors may be "insufficient" in developing their "working knowledge" of evolution by natural selection (Alters & Alters, 2001). It is also critical that science teachers are aware of their students' reasons for rejecting evolution, and their broader culture which supports such rejection; this might help instructors to better address their students' concerns and thus facilitate understanding (Alters, 2005).

There appears to be a growing de-emphasis of the teaching of evolution in schools. Various factors have been identified that seem to contribute to the de-emphasis of evolution in high school biology, such as historically restric-

tive board of education policies, opposition from religious groups, pressure from school administrators and parents, and inadequate textbook coverage (Rutledge & Warden, 1999; Kibbler, 2001; Moore & Kraemer, 2005, Wiles, 2005; Wiles, 2006). For example, Moore and Kraemer (2005) report from their study that "parents, administrators, and others have become increasingly active in pressuring biology teachers to avoid evolution" (p. 463).

While reviewing the relevant literature, we found very few studies focusing on evolution education in the context of Canadian elementary education. There appears to be a dearth of literature on Canadian elementary school teachers' or pre-service elementary teachers' knowledge and acceptance of evolution, or of their intentions for teaching evolution to elementary students.

Guiding questions

In this study, we attempted to unravel prospective elementary teachers' attitudes, feelings, and concerns about teaching evolution in Canadian schools, as well as their scientific and religious understandings of evolution. Our guiding research questions were: What do pre-service elementary science teachers in a large Canadian teacher education program think about teaching evolution? What are their attitudes and views about teaching evolution to elementary school students? What issues, if any, do they expect to encounter when teaching evolution? What are their religious and scientific understandings of evolution?

METHODS

Data collection and analyses

The participants were pre-service elementary teachers at a leading Canadian university enrolled in a basic science course that included content related to evolution. This course is part of the teacher education program that is intended to help prepare them to teach grades K-6 in the public and private schools, primarily of Quebec. These students represented a rich diversity with regard to race and culture (students representing various American, European, Middle Eastern/Mediterranean, African, and Asian heritages), religion (Muslims, Jews, Protestants, Catholics, students recognizing Native American religious traditions, Atheists, Agnostics, and others) and socio-economic background. Most of the participants were in their second year of university studies, and the majority of these students were females, with males comprising less than 10% of the population.

Participants were informed that their participation was completely voluntary and would not have any impact on their course evaluation. Data were collected through an anonymous questionnaire administered after the course had ended and grades were reported, and via semi-structured interviews

lasting about 30-45 minutes with eight volunteer participants. Interview participants were assigned aliases. The surveys and interviews were administered only by members of the research team who were not involved in the instruction of these students. Approximately 65% of the students (n = 138) responded to the questionnaire. While the survey questions mainly focused on exploring participant acceptance of evolution and their ideas, feelings, and any concerns about teaching evolution, the semi-structured qualitative interviews were conducted to probe participant understanding of evolution, how their religious beliefs may influence their thoughts about evolution, and any sensitivities about evolution education in elementary science.

The questionnaire included multiple-choice items and open-ended questions. Students needed about 25-30 minutes to complete the questionnaire. There are extant measures of acceptance of evolution, such as the Measure of Acceptance of the Theory of Evolution (MATE) instrument (Rutledge & Warden, 1999); a process for measuring acceptance of evolution described by Sinatra, et al. (2003); and the Evolution Attitudes Survey, developed by Brian Alters and employed with modification by Ingram and Nelson (2006). However, these generally comprise a large number of questions. We decided against employing such instruments because the survey items on which we report in this article were part of a larger questionnaire which also inquired about student knowledge of particular aspects of the provincial curriculum for science in elementary schools as well as their understanding of governmental and local policy regarding evolution education. We were concerned that some students would be less likely to participate if they perceived the questionnaire to be unduly lengthy or that participant fatigue and subsequent error might become a risk if such an extensive measure of acceptance of evolution were employed along with our other survey items. While it is clear that the data obtained via our survey items are not as detailed as results from the MATE or other such instruments would have been, our questions were intended to measure students' reported acceptance of evolution and of deep time in a more succinct fashion with a significant response rate.

A set of survey questions focused on basic demographic information about participant exposure to science and biological evolution. Participants were asked to provide information about the number of science courses taken in high school, college, and university. Additionally, they were asked to indicate when they were first exposed to the scientific concept of evolution and to explain how well they thought evolution was covered in their science courses. They were also asked to identify other sources of information through which they may have learned about evolution.

Some items gauged participant acceptance of evolution and supporting scientific concepts or their intentions regarding teaching evolution. Participant extent of agreement to the statements was reported via a five-point Likert

scale ranging from "strongly agree" to "strongly disagree." For example, participants were asked to indicate their level of agreement to the following two statements related to evolution:

(a)   I accept evolution as a scientifically factual phenomenon.

(b)   Scientists are able to accurately date the age of the universe, the earth, rocks, and fossils in terms of millions and billions of years.

The first statement focuses on the extent to which participants accept evolution, and the second statement refers to deep time, a supporting concept of evolution.

Three questions focused on intentions regarding evolution education. Participants were asked to indicate their level of agreement with statements about teaching evolution in elementary science classes.

(c)   When teaching science to elementary school students, I would include evolutionary concepts.

(d)   While in a science class, if an elementary school student asked where people came from, I would answer with a grade-level appropriate explanation based on the scientific evolutionary model of humans descending from previous, non-human ancestors.

These two statements were followed up by an open-ended question asking them about any concerns they may have about teaching evolutionary concepts:

(e)   Do you have any specific concerns about teaching evolutionary concepts? If so, please explain.

Additionally, confidential interviews were conducted with eight voluntary participants (six females and two males; ages 22-30 years) before the questionnaire was administered to aid in refining the questionnaire. Data was analyzed using qualitative and quantitative techniques. Statistical analyses of the data were performed using the SPSS statistical program. We will be reporting descriptive statistics and correlation analyses in the findings section. Qualitative data (open-ended responses to survey questions and interview transcripts) were analyzed through coding, constructing profiles, and thematic and cross-case analyses to examine the patterns of similarities and differences (Maxwell, 2005; Miles & Huberman, 1994). The constant comparative method was employed to analyze the interview data (Glaser and Strauss, 1967).

The four survey items focusing on acceptance of evolution and teacher intentions about teaching evolution were examined by two science education experts for content validity. These questions were also asked in the interviews that preceded the survey. Participant responses were helpful in refining these statements for the survey. Because the frequency distribution

of the responses was highly non-normal (since respondents tended to answer at extremes), non-parametric Kendall's tau-b correlations were computed to address the reliability of the survey (Gibbons, 1993).

FINDINGS

The findings will be presented in two main sections: (1) survey results and (2) interviews with pre-service elementary teachers.

1. Survey results

(a) EXPOSURE TO SCIENCE: The findings suggest that participants mostly had a greater exposure to science in high school than college (CEGEP)[1] or university levels. All of the participants took at least one science course in high school, and 57% of these pre-service teachers had taken four or more science courses in high school. However, a substantial majority (61%) did not take any science courses in college/CEGEP, and most (69%) had taken two or fewer science courses in university. At the time of this study, all of the participants had just completed the same elementary science course which included instruction in evolution.

(b) COVERAGE OF EVOLUTION: A substantial proportion of the prospective teachers (61%) said that evolution was either not covered or poorly covered in their basic school and university science courses (other than the elementary science course that they had just completed). Few participants (7%) said that evolution was extensively covered in their science programs, while 40% said that they were first exposed to evolution in elementary school. (However, it is not clear whether this exposure was within their formal education or via another source such as television, museum exhibits, religious instruction, or family discussions.) Approximately 32% of the participants were first exposed to evolution in high school. The interview findings discussed later suggest that different participants learned about evolution in various courses (science, history, anthropology, religion, and language) in high school and college/CEGEP.

Participants were also asked to elaborate on their particular response regarding the quality and quantity of coverage of the concept of evolution in their prior formal education (83% responded). The majority (57%) said that it was "barely" or "poorly" covered. They reported that they only learned the "basics" of the concept of evolution in either elementary school or biology courses in high school and university and that it was covered in a "short amount of time." Some (~8%) encountered it in college/CEGEP where it was covered for a "short amount of time." Most recognized that they did not possess an in-depth understanding of evolution. Several participants could not remember what they had learned about evolution in school. About 7% reported having been exposed to evolution instruction either mostly or solely

in anthropology rather than in biology courses. A few had learned about evolution in history or geography courses.

(c) SOURCES OF INFORMATION: Participants mentioned various sources of information about evolution, including television, internet, movies, documentaries, IMAX films, books, magazines, and encyclopedias. Museums were also mentioned frequently. Several students referred to specific television outlets (e.g., Discovery Channel) and print resources (e.g., *National Geographic* magazines) well as movies (e.g., *Jurassic Park*). A few also mentioned religion and church. Several participants wrote that most of their learning about evolution took place in formal education at K-12, CEGEP, and university levels. Family and parents were also frequently mentioned.

(d) ACCEPTANCE OF EVOLUTION AS A SCIENTIFICALLY FACTUAL PHENOMENON: Drawing on the relevant literature reporting that teacher acceptance of biological evolution has important implications for their pedagogical decisions about teaching evolution, we inquired about participants' extent of agreement to a statement about the scientific factuality of evolution. Most accepted evolution as a scientifically factual phenomenon (71% either strongly agreed or agreed). This rate of acceptance among the prospective teachers is higher than acceptance rates reported by Blank & Anderson (1997). This could be related to the fact that they had just finished a basic science course in which this topic was addressed. Still, 29% did not agree that evolution is scientifically factual. A similar trend was reflected in their responses to the statement about scientists' ability to accurately date the age of the universe, the earth, rocks, and fossils in terms of millions and billions of years; 83% either agreed or strongly agreed with the statement, whereas 17% did not agree that these scientific dating methods were accurate. (Table 1).

TABLE 1: Participants' ideas about evolution and teaching evolution (N=138)

	AGREEMENT	DISAGREEMENT OR UNSURE
• Evolution is a scientifically factual phenomenon	71%	29%
• Scientists are able to accurately date the age of the universe, the earth, the rocks, and fossils	83%	17%
• Including evolutionary concepts in elementary science	71%	29%
• Including grade-appropriate explanations of human evolution in elementary science	61%	39%

The acceptance of the accuracy of scientific methods of calculating the age of the earth and universe was positively associated with the acceptance of the scientific factuality of evolution; 79% of those who accepted the accuracy of the methods of dating the age of the universe and earth agreed that evolution is a scientifically factual phenomenon. Non-parametric correlation – Kendall's tau-b – suggested that there was a positive and statistically

significant relationship between these variables (tau-b= .42, p< .01). In other words, those who do not accept the accuracy of scientific methods of dating the earth, rocks, and fossils are not likely to consider evolution to be scientifically factual.

(e) TEACHING ABOUT EVOLUTION AT THE ELEMENTARY LEVEL: As mentioned earlier, evolution is included as a fundamental concept in the current province-wide elementary science curriculum in Quebec (Quebec Education Program, 2001). Almost all of the participants were training to teach in Quebec. They were specifically asked to share their plans about teaching evolution in elementary science. While 71% agreed that they would include evolutionary concepts in elementary science, 29% did not respond in agreement. About 61% responded positively to the statement about explaining human evolution based on the scientific evolutionary model of humans descending from previous, non-human ancestors in a grade-appropriate manner to elementary students, whereas 39% either were not sure or did not agree with this statement (Table 1).

It is important to note that 73% of those who accepted evolution as a scientific fact agreed to include biological evolution in elementary science teaching. The relationship is statistically significant (tau-b = .24; p < .01). This suggests that those who accept evolution to be scientifically factual are more likely to include it in their elementary science teaching. It also suggests that rejection of evolution is associated with intention to exclude it from elementary science teaching. Likewise, about 69% of those who considered evolution to be scientifically factual wrote that they would explain the origin of human beings from an evolutionary perspective. The correlation analysis showed that acceptance of evolution and intention to include human evolution in science teaching are positively related to each other (tau-b = .32, p< .01). Furthermore, among those who had taken four or more university science courses, 83% wrote that they would teach evolution concepts in elementary school. Conversely, among those with no science courses at the university level, other than the one they had just completed, only 40% indicated that they would include evolution in elementary science.

(f) CONCERNS ABOUT TEACHING EVOLUTION IN ELEMENTARY SCHOOL: Participants indicated several concerns about teaching evolutionary concepts in science (~ 79% responded).

PARENTS' RELIGION AND OPPOSITION TO EVOLUTION: Approximately 22% of these pre-service teachers were concerned that the religious beliefs of the parents of students might cause the parents to be opposed to evolution education. They viewed it as a "delicate," "sensitive," and "touchy" matter. Some were concerned about "confusing students" or "going against parents' and students' strong religious views" about creationism.

CONFLICT WITH RELIGION: Approximately 26% indicated the "conflict" and "incompatibility" between the "religious view of creation" and scientific evolution as a matter of concern. Some were concerned about "offending" people's religious beliefs by teaching evolution. Some thought that it was important to present "both" religious and scientific explanations. Some were concerned that exposure to evolution might "interfere" with students' beliefs. Only 3% explained in unambiguous terms that they would teach evolution even if it were at odds with people's religious beliefs about creation.

About 11% were concerned about various types of challenges in regard to teaching evolution. Some shared their concerns about how to deal with "opposition" to evolution in religious schools. Some participants wrote, it would be challenging to teach evolution to students with strong religious beliefs about creation. Some felt that it was challenging to deal with the "debate" around evolution as a "theory" or "fact." One felt that "finding age appropriate materials [about evolution] might be a challenge." Another participant wrote that it was "challenging" to present "different views" and "let children" decide what they wanted to accept.

Because the teaching of evolution is mandated in the current elementary science curriculum in Quebec, and this is where each student performs over 700 hours of in-school student teaching, it is important to recognize various pedagogic concerns pointed out by the participants about teaching evolution. A few participants thought that "evolution should not be a priority in elementary school." Some emphasized the need to be "better prepared" for teaching evolution to children. Some expressed the need for professional training in pedagogy. As one of them wrote, "Where do I begin to explain and at what grade level is it appropriate to teach?" Another participant asked, "Why are we not taught how to teach evolution? . . . It is a sensitive subject to many and could cost us our jobs if not approached appropriately."

TYPE OF SCHOOL: It is quite likely that some of these pre-service teachers will be employed by schools associated with a particular religion. Religious schools are common in Quebec, and many public schools have unofficial religious affiliations. In Canada, even private religious schools may receive substantial government funding. A few participants (~3%) were concerned about addressing evolution in a religious school. One participant wrote, evolution is a "highly controversial topic in religious schools." Another wrote that his decision to teach evolution would "depend on the type of school, I would teach in."

CONCERNS ABOUT LACK OF UNDERSTANDING OF EVOLUTION: Some participants (~7%) recognized their inadequate understanding of evolution and expressed concerns about teaching it.[2] They stressed their own content knowledge and pedagogic deficiencies about evolution. They clearly expressed that they "don't know much about it," and therefore, had concerns about "teaching it properly."

BELIEFS ABOUT RELIGION AND EVOLUTION: Some participants (5%) also recognized the ways in which their own conflicting beliefs about creation would influence their decision about teaching evolution. One participant wrote, "I wouldn't teach [evolution]. It is anti-biblical and I care more about God than science." Another participant also wrote that she would not teach evolution because her religious notions contradict evolution: "I would never teach evolution because I'm a Christian and it goes against my beliefs." Some believed in giving children the opportunity to decide by "presenting a few different theories and letting them decide what they want to believe." One of them stressed her epistemological distinction between "theory" versus "truth" in relation to evolution and wrote that she would teach evolution as a "theory" and not as "the truth." One of these participants thought that "scientific and theological explanations are compatible." However, she also wrote that she would be sensitive to students' family beliefs.

NO CONCERNS: Approximately 11% of the participants stated that they have no concerns about teaching evolution. Nevertheless, some did mention that they have "no prior experience with it."

Important trends related to pre-service teachers' acceptance of evolution and their intentions, concerns, and sensitivities about teaching evolution to elementary students emerged from the survey findings. Most participants (61%) reported that evolution was either not covered or "barely" included in their formal education. A majority accepted evolution as a scientifically factual phenomenon (71%) as well as scientists' ability to accurately date the age of the universe and earth (83%). Also, the acceptance of the scientific factuality of evolution was positively associated with the acceptance of the accuracy of dating the universe. Similarly, a majority (71%) intended to include evolution in elementary science and 61% wrote that they would explain human evolution according to the scientific model. The intention to teach evolution was positively associated with the acceptance of evolution. Participants shared diverse concerns that would potentially influence their curricular and pedagogic decisions about teaching evolution, including: (a) parents' religion and reaction to evolution, (b) conflict between religious and scientific perspectives on evolution, (c) type of school, (d) participants' lack of understanding of evolution, and (e) participants' own conflicting religious and scientific beliefs.

In the following section we will present our interview findings focusing on participants' knowledge and understanding of evolution. Additionally, we will discuss these participants' specific concerns about teaching evolution.

2. Interviews with Pre-Service Elementary Teachers

Data from the qualitative interviews with eight voluntary participants yields interesting findings about pre-service teachers' understanding of evolution

and their ideas about including evolution based explanations in elementary science.

EXPOSURE TO SCIENCE AND BIOLOGICAL EVOLUTION: All of the interview participants had taken at least one science course at some level in their formal education, and most of their exposure to science was in high school. Only three participants had taken a university level science course in addition to the basic elementary science course they had all just completed.

UNDERSTANDING OF EVOLUTION: Although half had a basic knowledge of the science of evolution, they did not demonstrate a clear understanding of the concept and the mechanisms through which evolution takes place. Four participants had a vague notion of evolution and thought of it mostly in relation to human beings. Most of these participants (five) seemed to accept evolution as scientifically factual. One of them was "not sure" about it; she was not able to form an explicit position on evolution because of her lack of understanding of this concept. Two participants discussed evolution primarily in light of their religious beliefs about origins of life and the universe and the creation of human beings. In the following discussion we will analyze pre-service teachers' understanding of evolution using illustrative excerpts and examples from the interview data.

Alan, Jane, and Cordelia thought that the idea of evolution is "logical," "cool," and "makes sense" because scientists have gathered ample evidence supporting this idea. They understood evolution as development of all living beings, including "complex" organisms and "humans," from "simple" life forms, "progression of living beings through time," "complex relationships among all organisms," "adaptation of organisms in different environments through the evolutionary process," and "survival of the fittest." They accepted scientific evolution. As Jane explained,

> The scientific model of evolution is cool. It's interesting to learn. It's definitely interesting to see what things were and what they became [through evolution]. . . . The idea that everything that's alive on this earth started with a single-celled organism and eventually evolved and progressed to the different things; the whole concept together is cool.

Other participants' views reflected their religious and scientific perspectives and the ways in which both frameworks interacted and informed each other. Peter acknowledged that his "religious" perspective influences his scientific understanding of these ideas. Although he accepted the process of evolution, he had issues with the scientific explanations about the origin of life, the earth, and the universe because of his Catholic religious beliefs (whether or not his beliefs accurately represent mainline Catholicism).

> I do believe in scientific evolution, but whether it was because of the big bang or what not . . . . There's a lot of evidence that backs up the evolution. So, of course, it puts into question certain issues as to how the beginning

of earth began. I'm not sure if I completely agree with all of that…for me, the earth was created by God.

Peter seems to maintain a dichotomous position in relation to two fundamental ideas in the biological and historical sciences, evolution and big bang theory. He finds the process of evolution of life on earth "very logical," and although the scientific idea about the origin of life "makes sense" to him, he finds it "difficult" to accept it because it conflicts with his religious beliefs about the creation of human beings. He is not sure how life originated.

> I'm Catholic. It's from Adam and Eve and how God placed Adam and then Eve and that's how we evolved … How the first life form began…I don't know. Again, that's difficult. Only because, it questions my religion. That's the only reason. But, the scientific explanation, it's logical and it makes a lot of sense…of how it began by molecules forming and later developing into little particles and things slowly built from there.

Emma, Kate, Allie, and Meena seemed to have a vague understanding of evolution and mostly articulated it in terms of human evolution. Emma went to a Jewish school and learned about human creation from a predominantly religious perspective. Emma thought that evolution meant "the beginning of humanity and mankind." She repeatedly emphasized that she did not have a clear understanding of evolution. "I don't really know a real definition of what it is," she said. Kate and Allie accepted scientific evolution, even though their notions regarding evolution were relatively vague. As Kate explained it, "Evolution to me means… how humans evolved through other forms progressively. Well, we did come from animals, right," she added. Meena mostly discussed her ideas about human evolution in relation to her Islamic religious perspective.

> I am somewhat of a religious person. I do believe that there's a God and we were all created. But, I also believe that we went through the evolution process . . . as humans, we have evolved as a species also. . . I think that it was possibly part of God's plan. Because I think that God and science are very inter-connected. So, I generally believe that there is a God and that we were put here on this earth.

Meena seems to "believe" that human beings were created by "God and placed on the earth." She understands "human evolution" in terms of the changes that have "occurred" in "human body and mind" over thousands of years. Meena's ideas about the origin of human beings are informed by her religious beliefs; however, she has integrated some aspects of evolution to make sense of the "progress" of human beings on earth in terms of their physical and mental development over long periods of time.

During the interviews, we also explored participants' notions about the evolutionary significance of geological stratigraphy, with the layers of rocks in the Grand Canyon as an illustration. They mostly understood the Grand Canyon in terms of "different layers of sedimentary rocks," "changing over

the years," and showing "evidence of past times," without citing any specific examples to illuminate their understanding. Some reported that they were either not "familiar with" or were "uncertain about" what the different layers of rocks "show." Upon further probing, five participants alluded to the presence of "different organisms," "bones," and "changes in organisms" in different layers of rocks. None of the students articulated in their primary descriptions anything about the relative ages of the rock layers, but upon deeper probing in the interviews, all of them were able to reason that the "deepest layers are the oldest." Interestingly, although most of the participants seemed to have a basic, intuitive knowledge about layers of rocks such as those at the Grand Canyon, none of them invoked the term evolution while explaining the relative ages of the strata and the fossils of the different organisms preserved in those layers.

TEACHING EVOLUTION IN ELEMENTARY SCIENCE: The interview participants were asked to explain how they would approach some important concepts in elementary science, such as explaining the similarities and differences among living organisms. Most hoped to teach this topic through a hands-on "constructivist" pedagogy by "bringing in animals and plants" to the classroom, "visiting the zoo," and "showing fossils" to enable children to compare and discuss the similarities and differences among different living organisms. None of them included an evolutionary explanation while discussing their pedagogic ideas to facilitate children's understanding of the relationships among living organisms. Most said that their first step would be to improve their own understanding of evolution. Several participants mentioned that they would consult internet resources related to evolution.

Since children are generally curious about the origin of human beings, they want to know where we came from, we asked these participants how they would address these kinds of questions from children in their classrooms. Five students said that their explanation would be grounded in evolution. While acknowledging their own lack of clarity of the concept, Emma and Allie said that they would teach the scientific idea because it is "accurate" and "logical" and they could share the evidence supporting evolution with children. Cordelia and Kate said that they would rely on "visual" materials, such as charts and posters showing fossils and "skulls," especially in grades 5 and 6, to help children understand human evolution. Most participants wanted to use the scientific explanation of evolution. They expected to have diverse classrooms with children coming from various cultural and religious backgrounds, and did not want to focus on any particular religious views in their classrooms. Three students, Peter, Jenni, and Meena, however, said that they would acknowledge and even discuss other cultural and religious perspectives about human evolution alongside the scientific concept. Peter's pedagogic decision is influenced by his religious beliefs and he intends to include creationist beliefs in his teaching. "I feel that it's important for me,

as a teacher, to let them know . . . that it's not the only way that people believe life began."

Similarly, Jenni also said that she would teach the scientific idea, but she would at least acknowledge that there are "other beliefs that people hold about the origin of human beings." Meena said that she didn't intend to "impose" her "own views" about human evolution on her students. She would "try to go towards the scientific route, as opposed to the religious route." However, on further probing she revealed that she would present alternative [religious] "views" to her students. "No, I wouldn't go into details about each one. Just to teach them that this is what the scientific method is; however, there are other views out there and they are equally as valid and they should be respected," she explained.

DISCUSSION

The findings from the surveys and interviews suggest that most of the prospective elementary teachers seemed to lack an understanding of the most basic concepts in the science of evolution. Almost two-thirds said that evolution was either not covered or poorly covered in their high school, college, and university science courses. This trend echoes what we found in the relevant literature in relation to science teachers' limited understanding of evolution and conceptual difficulties they face in learning and applying this concept. Similarly, half of the interview participants had a very basic idea of the science of evolution, but they did not understand the mechanisms of evolution. Most thought about evolution primarily in terms of "human evolution," and their religious beliefs strongly influenced their scientific understandings. Several participants acknowledged their own lack of understanding of evolution and the ways in which their religious view of creation interfered with their scientific understanding. As discussed earlier, various studies have pointed out that students' religious beliefs and dispositions influence their scientific understanding of evolution.

Although these prospective teachers had just finished a university course on elementary science in which they were exposed to concepts relating to biological evolution through lectures, laboratory exercises, videos, discussions, visits to a natural history museum, and assignments focusing on various fossil specimens and the evolutionary history of earth, almost a third did not report acceptance of evolution as a scientifically factual phenomenon. Similarly, many had doubts about the accuracy of the scientific methods of measuring the age of the universe, the earth, and fossils.

With regard to pedagogical intentions, most indicated that they would include evolution and expressed their willingness to teach human evolution in elementary science. However, almost a third of the future teachers either were planning to avoid evolution or had reservations about teaching this

concept in elementary science classes. Similarly, more than a third reported that they might avoid the topic of human evolution. Acceptance of evolution was positively related to participants' decision to include evolution in their teaching as suggested by many studies. Additionally, acceptance of evolution was positively and moderately associated with their ideas about scientific calculations for the ages of the earth and the universe.

Our analysis has revealed insights about what evolution means to these prospective elementary teachers; their religious and scientific epistemologies; and their sensitivities, apprehensions, and intentions about teaching this concept in elementary science. The survey and interview data unveiled a landscape of sensitivities that these prospective elementary teachers consider when contemplating teaching evolution to children. This landscape of sensitivities includes concerns about (a) parent religion and opposition to evolution, (b) conflict between creationism and evolution, (c) type of school where they would be employed – public vs. private and secular vs. religious schools, (d) lack of understanding of evolution, (e) prospective teachers' own beliefs about religion and evolution, (f) inadequate knowledge of pedagogical techniques to teach evolution at the elementary level, and (g) imposing their scientific ideas on students holding contradictory beliefs about evolution. While the relevant literature discusses some important factors that influence evolution education in schools, such as opposition from religious groups and pressure from parents and school administrators, the participants in this study articulated a wide array of issues concerning the teaching of evolution in elementary science. In-depth interviews with participants further clarified their specific sensitivities, apprehensions, and intentions about teaching evolution to elementary school students.

Almost three quarters of the participants reported that they intend to teach the concept of evolution in a "grade appropriate manner" in order to help children gain a better understanding of the concept. However, most stressed in the interviews and the survey the need for improving their own understanding of evolutionary science. In regard to teaching about the origin of life and human beings, most of the interview participants said that they would approach these topics from the framework of science because, given the likelihood of significant religious diversity in their classrooms, they did not want to focus on any particular religious belief. It is important that most participants repeatedly underscored their own lack of understanding of evolutionary concepts. Some participants, however, said that they would discuss other cultural and religious perspectives about human evolution alongside science to acknowledge that there are alternative ideas about evolution which are "equally valid" and should be respected.

Generally, none of the interviewees exhibited a clear understanding of the scientific concept of evolution. The majority seemed to accept the scientific model of evolution because they found it "logical" and that it "makes sense."

Some were uncertain due to their lack of knowledge of the concept; some did not accept it completely because of their conflicting epistemological beliefs about science and their religion in relation to the origin of universe, life, and human beings. Additionally, most did not seem to have a clear idea about the significance of geological stratigraphy in relation to evolutionary evidence. Although most seemed to have a fundamental idea about different layers of rocks, none articulated an understanding of the relative ages of the strata without significant probing and did not independently connect the fossils preserved in these strata with evidence of evolution. In our future studies we hope to ascertain the prevalence of these sensitivities among Canadian pre-service elementary teachers.

Some of the limitations of this study are related to external validity and generalizability of the findings. Since there were relatively few items in the section of the survey on which we are reporting, only the face validity of these items was determined by science education experts. The generalizability of the findings is limited since it was mainly a qualitative exploration concentrated on investigating the ideas of a particular cohort of prospective elementary teachers who were a part of a particular teacher education program at one Canadian university. Nevertheless, the quantitative data provided a useful appraisal of the prevalent trends across the cohort.

CONCLUSION AND IMPLICATIONS

The findings of this study corroborate the relevant literature's call for developing a better understanding of the basic concepts of evolution and fostering a positive attitude towards evolutionary science in pre-service elementary teachers through experience and evidence. Biological evolution was reportedly not covered well in participants' previous formal education. Moreover, participants identified a variety of concerns, sensitivities, and apprehensions about teaching this concept in elementary science and their own deficient understanding of the science of evolution. This study further supports the need for appropriate pedagogic training of future elementary teachers to be professionally prepared to critically reflect on, and deal with, any challenges and pressures regarding the teaching of evolution in elementary schools. In our future studies we hope to explore changes in prospective elementary teachers' understanding of evolution through an experimental design.

NOTES

1. The postsecondary system in the Province of Quebec includes a two-year general program of colleges (CEGEP) which students must complete after the completion of high school (7-11) before proceeding to university education. The bachelors programs at the university level normally span three years (French acronym – CÉGEP – Collège d'enseignement général et professionnel – College of General and Vocational Education).

2. It is important to note that the participants reported this without prompting.

REFERENCES

Alles, D. (2001). Using evolution as the framework for teaching biology. *The American Biology Teacher, 63,* 20-23.

Alters, B. (2005). *Introduction to evolutionary thinking: Problems with teaching, learning, and creationism.* In J. Cracraft and R. Bybee (Eds.), Evolutionary Science and Society: Educating a New Generation. Proceedings of the BSCS, AIBS Symposium, November 2004, NABT Convention Chicago, IL. Washington DC: American Institute of Biological Sciences.

Alters, B. & Alters, S. (2001). *Defending evolution in the classroom : A guide to the creation/evolution controversy.* Boston: Jones and Barlett Publishers.

Alters, B. & Nelson, C. (2002). Perspective: Teaching evolution in higher education. *Evolution: International Journal of Organic Evolution, 56,* 1891-1901.

Beardsley, P. (2004). Middle school student learning in evolution: Are current standards achievable? *The American Biology Teacher, 66*(9), 604-610.

Bishop, B. & Anderson, C. (1990). Student conceptions of natural selection and its role in evolution. *Journal of Research in Science Teaching, 27,* 415-427.

Blank, L. Andersen, H. (1997) Teaching evolution: Coming to a classroom near you? *Reports of the National Center for Science Education, 17*(3), 10-13.

Carlesen, W. (1991). Effects of new biology teachers' subject-matter knowledge on curricular planning. *Science Education, 75,* 631-647.

Demastes, S., Good, R., & Peebles, P. (1995). Students' conceptual ecologies and the process of conceptual change in evolution. *Science Education, 79,* 637-66.

Gibbons, J. D. (1993). *Nonparametric measures of association*: *Quantitative applications in the social sciences.* Newbury Park, CA: Sage.

Glaser, B. G., & Strauss, A. L. (1967). The discovery of grounded theory: Strategies for qualitative research. Chicago, IL: Aldie.

Gross, P., Goodenough, U., Haack, S., Lerner, L., Schwartz, M. & Schwartz, R. (2005). *The state of science standards.* Washington, DC: The Thomas B. Fordham Foundation.

Helgeson, L. J., Hoover, J. & Sheehan, J. (2002). Introducing preservice teacher to issues surrounding evolution and creationism via mock trial. *Journal of Elementary Science Education, 14,* 11-24.

Ingram, E. & Nelson, C. (2006). Relationship between achievement and students' acceptance of evolution or creation in an upper-level evolution course. *Journal of Research in Science Teaching, 43*(1), 7-24.

Jensen, M. & Finley, F. (1995). Teaching evolution using historical arguments in a conceptual change strategy. *Science Education, 79,* 147-166.

Kibbler, A. (2001). Teaching critical thinking: Evolution in the classroom. Retrieved December 05, 2005 from http://alumni.indiana.edu/magazine/jan-feb01/evolution.html.

Lerner, L. (2000). *Good science, bad science: Teaching evolution in the States.* Washington, DC: The Thomas B. Fordham Foundation.

Maxwell, J. A. (2005). *Qualitative research design: An interactive approach* (2nd ed.). Thousand Oaks, CA: Sage Publications.

Miles, M. B. & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Thousand Oaks, CA: Sage Publications,

Moore, R. (2001). Educational malpractice: Why do so many biology teachers endorse creationism? *Skeptical Inquirer 25*(6), 38-43.

Moore, R. (2002). Do standards matter? How the quality of state standards relate to evolution instruction. *The Science Teacher 69*(1), 49-51.

Moore, R. & Kraemer, K. (2005). The teaching of evolution and creationism in Minnesota. *The American Biology Teacher, 67*, 457-466.

National Academy of Sciences (1999). *Science and creationism: A view from the National Academy of Sciences* (2nd ed.). Washington, DC: National Academy Press.

Pennock, R. (2002). Should creationism be taught in the public schools? *Science & Education, 11*, 111-133.

Quebec Education Program (2001). *New directions for success together: Preschool education*. Elementary education. Government of Quebec: Ministry of Education.

Rutledge, M. & Mitchell, M. (2002). High school biology teachers' knowledge structure, acceptance and teaching of evolution. *The American Biology Teacher, 64*, 21-28.

Rutledge, M. & Warden, M. (1999). The development and validation of the measure of acceptance of the theory of evolution instrument. *School Science and Mathematics, 99*, 13-18.

Rutledge, M. & Warden, M. (2000). Evolutionary theory, the nature of science and high school biology teachers: Critical relationships. *The American Biology Teacher, 62*, 23-31.

Saul, C., Munford, D., Crawford, B., Friedrichsen, P., & Land, S. (2002). Scaffolding preservice science teachers' evidence-based arguments during an investigation of natural selection. *Research in Science Education, 32*, 437-463.

Sinatra, G., Southerland, S., McConaughy, F., & Demastes, J. (2003). Intentions and beliefs in students' understanding and acceptance of biological evolution. *Journal of Research in Science Teaching, 40*, 510-528.

Tatina, R. (1989). South Dakota high school biology teachers and the teaching of evolution and creationism. *The American Biology Teacher, 51*, 275-280.

Trani, R. (2004). I won't teach evolution; it's against my religion. And now for the rest of the story… *The American Biology Teacher, 66*, 419-427.

Vlaardingerbroek, B. & Roederer, C. (1997). Evolution education in Papua New Guinea: Trainee teachers' views. *Educational Studies, 23*, 363-375.

Wiles, J. (2005). Is evolution Arkansas's "hidden" curriculum? *Reports of the National Center for Science Education 25*(1&2), 32-36.

Wiles, J. (2006). Evolution in schools: Where's Canada? *Education Canada, 46*(4), 37-41.

ANILA ASGHAR is an Assistant Professor at the School of Education, Johns Hopkins University, US. Her research interests involve diversity issues in science education including religion, culture, and science in Islamic societies.

JASON R. WILES is Manager of the Evolution Education Research Centre at McGill University. His research interests are in science education with a focus on the learning and teaching of biological and geological evolution.

BRIAN ALTERS is the Tomlinson Chair in Science Education, is named Sir William Dawson Scholar, and holds appointments internationally at McGill and Harvard. He is the Director of the Tomlinson Project in University-Level Science Education, and Director of the Evolution Education Research Center.

ANILA ASGHAR est professeure adjointe à la School of Education de la Johns Hopkins University, aux États-Unis. Ses intérêts en matière de recherche portent sur les questions de diversité dans l'enseignement des sciences, y compris la religion et la culture, ainsi que les sciences dans les sociétés islamiques.

JASON R. WILES dirige le Centre de recherche sur l'enseignement de l'évolution de McGill. Ses recherches portent sur l'enseignement des sciences avec un accent sur l'apprentissage et l'enseignement de l'évolution biologique et géologique.

BRIAN ALTERS, titulaire de la chaire Tomlinson en enseignement des sciences, est chercheur-boursier Sir William Dawson et assume des charges d'enseignement à McGill et à Harvard. Il est directeur du projet Tomlinson en enseignement des sciences au niveau universitaire et directeur du Centre de recherche sur l'enseignement de l'évolution.