Nadelson, L. S. and Sinatra, G. M. (2010). Shifting Acceptance of the Understanding Evolution Website. *The Researcher, 23*(1), 13 - 29.

Shifting Acceptance of Evolution: Promising Evidence of the Influence of the *Understanding Evolution* Website

Louis S. Nadelson
Boise State University

Gale M. Sinatra
University of Nevada, Las Vegas

This study examined preservice teachers' understanding and acceptance of biological evolution, the nature of science, and situations of chance. Our goal was to examine whether increases in understanding of situations of chance (randomness), the nature of science, and acceptance of evolution, would result in greater understanding of biological evolution in prospective teachers. The participating preservice teachers were tested before and after interacting with the Understanding Evolution website and a similarly designed tutorial to assess their acceptance and understanding of these three domains. Web based tutorials designed to address common misconceptions of the three domains were administered to the experimental group. The control group received evolution and nature of science misconception instruction, and to equate time on task, a filler tutorial which replaced the situations of chance instruction. Pretest analysis revealed evolution understanding was significantly correlated with knowledge of the nature of science and situations of uncertainly. Post test analysis indicated that the tutorials induced a modest but detectable shift in acceptance of evolution, but had no effect on understanding of situations of chance or knowledge of evolution. This suggests that it may be able to achieve modest changes in acceptance of evolution with a relatively modest instructional intervention.

Keywords: *evolution, nature of science, chance*

Biological evolution is a misunderstood and strongly debated scientific phenomenon among much of the lay-public (Alters & Alters, 2001; Gallup Poll, 2008; Miller, 1999). Widely held misconceptions of the theory indicate that the scientific definitions and comprehension of evolution remains elusive to many (Gallup, 2008). The diversity of biological evolution misconceptions range from small misunderstandings to a complete lack of appreciation of the essence and implications of the theory (Dagher & Boujaoude, 2005; McComas, 2006; Miller, 1999; Sadler, 2005). These misconceptions reflect the complex nature of the theory and the range of knowledge that is required to accurately comprehend the process of biological change (Dennett, 1995; Gould, 2002). Research suggests that holding misconceptions of biological evolution can lead to fragmented conceptions and impede understanding the theory as a whole (Alters & Alters, 2001; Miller, 1999). Limited understanding of biological evolution can have a profound influence on the ability to make rational decisions regarding related biological issues such as global warming, genetically modified foods, cloning, and selective breeding (NAS, 1998, 2008). An informed citizenry capable of rational decisions based on a basic and accurate understanding of biological evolution is imperative for the development of

Contact information: Louis S. Nadelson, Boise State University, 1910 University Drive, Boise, Idaho 83725-1700 P-208-426-2856; F-208-426-4006; Email: LouisNadelson@boisestate.edu

appropriate and effective public policy. Most of the lay publics' exposure to the scientific perspective of evolution is most likely be limited to their k-12 education. Preparing K-12 teachers should attend to the multiple domains and constructions associated with the development of understanding biological evolution (Gould, 2002; National Science Teacher Association [NSTA], 1997). This situation necessitates k-12 teachers to be prepared to teach evolution concepts, and provides justification for our exploration of the relationships between evolution related knowledge and methods that can be used to effectively increase potential teachers' knowledge and acceptance of evolution.

Our investigation offers a unique perspective into the exploration of the relationships between knowledge of evolution, perception of the nature of science, acceptance of evolution, and understanding of situations of chance. Further, it is the first empirical study that we are aware of that has investigated the influence of the *Understanding Evolution* website (UCMP, 2006) on knowledge of evolution, perceptions of the nature of science, and acceptance of evolution.

Evolution and Situations of Chance

The depth and breadth of scientific research influencing evolutionary theory has resulted in the development of lengthy and complex definitions of the process. However, Miller (1999) summarizes this complex and voluminous area of scientific study offering this concise definition, "Evolutionary theory weighs the relative contributions of mutation, variation, and natural selection, and tries to understand how the interlocking actions of heredity, sex, chance, environment, cooperation and competition drive the fine details of descent with modification" (p. 54). It is apparent from Miller's (1999) definition of biological evolution that chance or situations of uncertainty play a significant role in defining the theory.

Similar to evolution, chance or situations of uncertainty, is fraught with misconceptions (Nickerson, 2004; Shaughnessy, 2003; Tversky & Kahneman, 1982). Research by Tversky and Kahneman (1982) indicates that people tend to use heuristics to predict chance outcomes and commonly hold deterministic beliefs about situations of uncertainty. For example, it is not uncommon for individuals to regard the outcome of situations of uncertainty as being determined by luck or the result of self-correcting processes. This may be due to what Wolpert (2006) posits to be an inherent tendency of humans to understand phenomena in terms of cause and effect. Individuals will also commonly infer a cause and effect purpose or an intentional agent driving the processes of biological evolution rather than chance processes (Dennett, 1995; Kelemen, 1999). Since chance plays a significant role in the process of evolution, holding misconceptions of both evolution and chance escalates the effort required to develop accurate understanding of evolutionary theory (Garvin-Doxas & Klymkowsky, 2008; Sadler, 2005). The link between evolution and situations of chance suggests there is a need to resolve misconceptions related to situations of chance in order to accurately understand biological evolution.

Evolution and the Nature of Science

The philosophy and motivation for the processes of science are referred to as the nature of science (NOS) (American Association for the Advancement of Science [AAAS], 1993; National Resource Council [NRC], 1996). McComas (1998) describes the nature of science as a, ". . . rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors" (p. 4). Much of the lay public does not understand the norms, methods, or philosophy of science and hold predictable and readily identifiable misconceptions about the NOS (Abd-El-Khalick & Akerson, 2004; Chinn & Malhotra, 2002; McComas, 1998).

According to McComas and colleagues (1998) a common NOS misconception related to biological evolution results from linguistic confusion over the concept of "theory." In science, the term "theory" is used to represent well developed, extensively researched, evidence-based explanations (National Academy of Sciences [NAS], 1998; Scott, 2005). Used on a daily basis, the term "theory" is applied to speculative or tentative situations. Therefore, it is not uncommon for people to confuse the everyday use of "theory" with the scientific one which leads them to misconceive evolution as being a tentative prediction.

It is apparent that an accurate comprehension of biological evolution requires an accurate conceptualization of situations of uncertainty and the nature of science (Alters, 2004; McComas, 2006; Miller 1999; Sadler, 2005). Yet, since misconceptions are common to all three of these interrelated constructs, this presents a significant barrier for learning and teaching the scientific view of evolution. Therefore, in studies of learners' knowledge of evolution there is justification for assessing their levels of understanding of situation of uncertainly and their understanding of the nature of science. Given the established link in the literature between these three constructs, it is likely that they interact to influence the understanding of evolution.

Evolution, Acceptance, and Religiosity

Evidence shows that the majority of individuals in the United States do not *believe* in evolution (Miller, Scott, & Okamoto, 2006), which is argued to be different than understanding evolution (Rutledge & Warden, 1999; Smith & Siegel, 2004). Because belief and knowledge are distinctly different ways of classifying ideas the warrants necessary for supporting these approaches differ (Shtulman, 2006; Smith, 1994). Those that make the distinction between these two perspectives posit that belief is based on faith and does not require empirical evidence, whereas knowledge is acquired through observations, logical proof, or empirical evidence from the nature world (Scharmann et al., 2005; Smith, 1994, Southerland, Sinatra, & Matthews, 2001). The distinctions between belief and knowledge are important because it suggests that is it possible to believe in evolution and not understand it, and also possible to understand but not accept evolution. Since there is a possibility that acceptance and knowledge are independent there is warrant for assessing acceptance of evolution as a distinct construct that may occur separately of knowledge.

Acceptance can be rather stable, with links to belief systems that are not readily influenced (Lawson & Worsnop, 1992). Typically, one would expect no significant change in acceptance over brief periods of time. Perhaps, one of the strongest belief systems indicators of evolution acceptance is level of religious commitment, or *religiosity* (Alters & Alters, 2001; Miller, 1999; Nadelson, 2007; Scott, 2005). Key to this point is the notion that levels of acceptance tend to remain fairly stable and are not likely to experience the same levels of change that knowledge may experience with instruction (Lawson & Worsnop, 1992; Scharmann, et al., 2005). The interplay and independence of the acceptance of evolution, knowledge of evolution, and religiosity provides a rationale for examining all three constructs when investigating individuals' perspectives of evolution.

Evolution and Shifting Conceptions

Perhaps one of the most intriguing aspects of misconceptions is their robust nature. It has been well documented that once individuals develop conceptions (correct or incorrect) they tend to resist adopting alternatives perspectives even when presented with conflicting evidence (Mason & Limon, 1999; Sinatra & Pintrich, 2003). Changing conceptions is fundamental to teaching and learning (Murphy & Mason, 2006; Sinatra & Mason, 2008; Vosniadou, 1994), yet less dramatic conceptual shifts, may be required to achieve conceptual change.

The basic process of teaching for conceptual shifts involves assessing students to determine their levels of held misconceptions, then implementing an instructional intervention intended to resolve the misconceptions, and then post assessing to determine if shifts have taken place (Dole & Sinatra, 1998; Murphy & Mason, 2006). Vosniadou (2003) recognizes the challenges associated with teaching for conceptual shifts as she writes that it is a, "…gradual affair often accompanied by misconceptions, inert knowledge, internal inconsistencies, and lack of critical thinking" (p. 377). Nussbaum, Sinatra, and Poliquin, (2008) define conceptual shifts as, "nascent revisions of knowledge that can serve as precursors to more substantial knowledge restructuring or conceptual change" (p. 6). Although the process of conceptual change associated with radical restructuring is typically long term, shifts in conceptual understanding and acceptance of evolution have been demonstrated with relatively short, but well crafted interventions (Matthews, 2001; Scharmann et al., 2005). This provides the justification for our investigation of the influence of a relative brief encounter with instructional materials that were specifically designed to address misconceptions of evolutionary biology.

Evolution, Teachers, and Misconceptions

Research has revealed that students completing study in K-12 and higher education programs frequently retain the misconceptions of biological evolution they brought with them to instruction (Blechmann, 2006; Matthews, 2001; Rutledge & Warden, 1999). Since teachers are products of the educational system, it is anticipated that they would also hold misconceptions of evolution. Further, misconceptions have been documented to be held even by experts (Palmquist & Finley 1997; Tversky & Kahneman, 1982) which provides support for our prediction that teachers would hold misconceptions of biological evolution. This is a concern because as Jarvis and colleagues (2003) report, teachers that hold misconceptions are destined to teach their naïve conceptions to their students, which indicates that educators influence on student conceptual development is not always for the better (Driver, Squires, Rushworth, & Wood-Robinson, 1994; Fisher, 2004; McComas, 1996; NRC 1996; Yip 2001). To address this situation, there is a need for evidence based approaches that are effective at teaching complex concepts such as evolution to prepare teachers to effectively teach these concepts to their students.

Because teachers tend to teach what they were taught (Deemer, 2004; Kikas, 2004; Llinares & Krainer, 2006) it may be most effective to address teachers' fundamental knowledge of biological evolution before they enter service, while that are still students. Preservice teachers have not yet entered the profession at a level of service, and therefore, may be more open to considering alternative explanations

(Darling-Hammond & Bransford, 2005; Hoy, Davis, & Pape, 2006; Pajares, 1992). This suggests there may be a greater chance to confront preservice teachers' misconceptions of biological evolution, promote conceptual shifts in their acceptance of the theory, increase their content knowledge, and prepare them to be more effective at teaching the related concepts than in-service teachers.

Purpose

This research tests the notion that it may be necessary to teach the nature of science and situations of uncertainty in context to shift learners' understanding and acceptance of the related concepts within biological evolution. Thus, our study assessed preservice teachers conceptions of biological evolution, the nature of science, and situations of uncertainty, before and after they engaged in a computer based instructional interventions linking these three areas in context.

Research Question and Hypotheses

The research questions guiding this investigation were:

1) Does acceptance of evolution shift when common misconceptions of the theory are explicitly addressed and refuted?
2) Is instruction targeted at promoting understanding of the nature of science, situations of uncertainty, and biological evolution effective in reducing misconceptions and promoting positive shifts in conceptions about all three phenomena?
3) Does pre-service teachers' understanding of biological evolution shift when instruction is combined with situations of uncertainty?

We hypothesized that the preservice teachers' acceptance of evolution would increase if common misconceptions about the theory are explicitly addressed. We also hypothesized that understandings of the nature of science, situations of uncertainty, and biological evolution would be fostered through the use of web-based instruction, explicitly designed to address misconceptions of these phenomena. Finally, we hypothesized that instructional content that integrated biological evolution, situations of uncertainty, and the nature of science in the context of evolution instruction would lead to greater reduction in misconceptions and increased understanding of these topics than instructional content that only combined biological evolution and the nature of science.

Method

Participants

The participants in our study were preservice teachers recruited from undergraduate teacher education programs at two different universities. Efforts were taken to assure participants from the two institutions were evenly distributed across condition and therefore we randomly assigned them to our two groups. We eliminated the seven participants that were present for only one of the two research sessions from our data analysis. Our final samples consisted of 32 experimental group participants recruited from the first data collection site and 32 for the control group. Twelve additional experimental group participants were added from the second data collection site and 13 more participants to the control group for a total of 44 in the experimental group and 45 in the control group. The participants' demographic characteristics are presented in Table 1.

Table 1
The Demographic Measures for the Control and Experimental Groups

Measure	Experimental	Control
Yrs of College	2.00	1.77
Female	36	37
Male	8	8
18-20 yrs old	13	15
21-25 yrs old	24	24
26-35 yrs old	5	5
36-45 yrs old	2	1
Caucasian	31	37
Asian	4	3
Latino	5	3
African American	4	2

Measures

Demographics. We developed a demographics instrument to gather participants' age, gender, race, years of education, number of college level science courses, number of college level mathematics courses, intended grade level of instruction, intended subject of instruction, college major and college minor, and level of religiosity. In our measure of religiosity we asked participants to rank their level of religious commitment on a scale of one to ten, with one representing no religious commitment and ten representing a high level of commitment.

Concept inventory of natural selection. The *Concept Inventory of Natural Selection* (CINS) instrument (Anderson, Fisher, & Norman, 2002) was used for assessing understanding of natural selection. Natural selection is a fundamental concept in the theory of evolution and therefore, we inferred the participants' CINS scores to represent their knowledge of evolution. This selected response instrument evaluates students' understanding of natural selection using scenarios as a basis for the 20 multiple choice items. A sample of undergraduate students that were used in the development of their instrument achieved a level of 46.4% correct, which is close the targeted a level of difficulty of 50% by Anderson and colleagues. This indicates that our participants, who have a similar science background to the undergraduates in the instrument validation study would be expected to answer about 50% of the questions of the CINS correctly. Anderson and colleagues report, "The KR_{20} for the test was 0.58 for Section A and 0.64 for Section B. A good classroom test should have a reliability coefficient of 0.60 or higher…so the CINS values are acceptable." (p. 963). The development of the CINS using undergraduate students, had acceptable levels of reliability, and tested for understanding of natural selection, all which indicate this was an appropriate instrument for assessing knowledge of evolution in our study.

Measure of acceptance of the theory of evolution. The *Measure of Acceptance of the Theory of Evolution* (MATE) instrument (Rutledge & Warden, 1999) was used to measure participants' acceptance of the theory of evolutionary. This 20-item questionnaire uses a five point Likert scale ranging from "Strongly Disagree" to "Strongly Agree" for participants to rate their response to items such as, "The theory of evolution is incapable of being scientifically tested." The MATE is scored using composite values from the 20 items with the lowest level of acceptance being 20 to the highest level of acceptance being 100. To determine comparative levels of acceptance Rutledge (1996) provides the following scores and categories; 89-100, Very High Acceptance; 77-88, High

Acceptance; 65-76, Moderate Acceptance; 53-64, Low Acceptance; and 20-52, Very Low Acceptance. In the instrument validation study an internal reliability of .98 was achieved. The MATE items, the reliability values, and application with post-secondary participants, suggest that the MATE was appropriate for assessing our participants' acceptance of the theory of evolution.

Statistical reasoning assessment. We used the *Statistical Reasoning Assessment* (SRA) instrument (Garfield, 2003) to evaluate conceptual understanding of situations of uncertainty. Most of the items on the SRA test for the application of a common misconception or documented heuristic related to situations of chance. The SRA requires minimal knowledge of statistics; therefore, we determined it was appropriate for our assessment of understanding of situations of uncertainty. The instrument was developed and validated with college students, and uses 20 items to assess general knowledge of stochastic processes. The instrument reliability was reported to be .70 based on test-retest analysis. Acceptable prior reliability results, the assessment of general knowledge of stochastic processes, and the validation using college students suggest that this was a suitable instrument for determining knowledge of situations of uncertainty.

Scientific attitude inventory II. The *Scientific Attitude Inventory II* (SAI II) instrument (Moore & Foy, 1997) was used to measure perceptions of the nature of science. This 40 item instrument uses a five point Likert scale to measure emotional and intellectual perspectives of the nature of science. The instrument uses a combination of positive and reverse statement items, which are combined to form six conceptual domains in the nature of science. Developed using undergraduate college students, the instrument was reported to have a Cronbach's Alpha reliability coefficient of .78 with the lowest 27% scoring 3.05 and the top 27% scoring 3.98. The established reliability, the validation with college students and the assessment of the nature of science made the SAI II an appropriate choice for our research project.

Retention of understanding evolution tutorials. We developed the *Retention of the Understanding Evolution Tutorials (RUET*) instrument to assess the fidelity of the interventions as measured by the participants' content retention. The assessment focused on the contents of the two common *Understanding Evolution* (UCMP, 2006) tutorials (misconceptions of evolution and the nature of science), and did not include contents from the third instructional tutorials (situations of uncertainty and life and travels of Charles Darwin) because these were not common across groups. We developed this instrument using the sentence verification technique of measuring reading comprehension (Royer, 2001). In this technique sentences are selected from targeted content and then are slightly modified, radically modified, paraphrased, or maintained in their original form. Participants are then asked to read the sentences and respond to whether or not the sentence or sentence contents appeared in the tutorials. Correct responses indicate retention and comprehension of the content. For the RUET we selected twelve sentences and formed groups of three sentences for each of the four conditions.

We developed digital forms of all of the instruments which were delivered using Zoomerang, an internet based survey provider. This allowed us to regulate access, maintain administration fidelity, and ease data recording and retrieval.

Instructional Interventions

All instructional interventions were web-based tutorials allowing participants to guide their own levels of engagement with the content. The evolution and the nature of science instruction was created by the University of California's Museum of Paleontology (UCMP) (2006) and appeared on the *Understanding Evolution* website (http://evolution.berkeley.edu). The NSF funded *Understanding Evolution* website explores multiple facets of the theory of evolution and was designed to be used by teachers and students to learn more about evolutionary biology (Scotchmoor & Thanukos, 2007), therefore we decided this was an appropriate sources of content for our tutorials.

To monitor participant engagement with the instructional interventions, the web-based tutorials were delivered from a local file server.[1] The *Understanding Evolution* (UCMP, 2006) tutorials are extensive; therefore, we limited our instructional content to the components that specifically addressed misconceptions of evolution and the nature of science. The evolution misconception information was contained within 23 linked web pages and the nature of science information utilized 11 linked web pages. Each page addressed a specific concept using a combination of about 150 to 200 words supported by graphics or photos.

We developed our web-based situation of uncertainty tutorial to conform to the style of the *Understanding Evolution* (UCMP, 2006) website in terms of design, layout, proportion of text and graphics. Our web-based tutorial focused on various aspects of situations of chance in the context of biological evolution. For example, we presented the normal distribution of many species characteristics and how extreme variations within the distribution could develop into new species over time. We also discussed the random nature and influence of mutations in the context of Gould's (1986) notion that if the *tape of evolution* was to be "played" again the outcome most certainly would be different. This tutorial used five linked pages and was also delivered from a local server to regulate participant access.

Because our control and experimental groups were receiving different set of tutorials, we took steps to balance time on task. Therefore, we developed a filler tutorial for our control conditions that was comparable to the situations of uncertainty tutorial. This tutorial also conformed to the style of the *Understanding Evolution* (UCMP, 2006) design in terms of layout, text, and graphics. This tutorial used five linked pages to discuss the life and travels of Charles Darwin. Although somewhat related to the theme, we took steps to assure that we did not include any content related to that assessed by our measures. As with the other tutorials this was stored and delivered from a local server to regulate access.

Procedure

Participants were randomly assigned to either the experimental or control group. The participants were not made aware of the group to which they had been assigned. The pretest and instruction session and the post-test session took place one week apart. A total of 1.5 hours of engagement was required, 60 minutes for the pretest and instruction session and 30 minutes for post-test session.

Data collection and instruction took place in campus computer labs with each student assigned to an individual workstation. The digitally based instructional interventions

[1] Permission was granted by the University of California, Museum of Paleontology, to store the information on a local retrieval system.

were delivered from a campus web server allowing us to regulate student access. We used two different sets of web pages to control navigation through the directions, instruments, and tutorials.

We began our investigation by assessing our participants' demographics and pre-testing them on their understanding and acceptance of biological evolution, understanding of the nature of science, and understanding of situations of uncertainty. Immediately following pre-testing we directed the participants toward web-based instructional interventions. Our instructional interventions were different for the two groups. Both experimental and control group participants browsed a web-based tutorial debunking the common misconceptions of evolutionary theory and another web-based tutorial presenting nature of science concepts in the context of evolution. The experimental group alone also browsed a web based tutorial on situations of uncertainty in the context of evolution. To assure equal time on task, the control group received a filler web-based tutorial on the life and travels of Charles Darwin. Immediately following the completion of the tutorials we administered the RUET, our retention and comprehension assessment tool. One week later we post-tested all participants using the *MATE, CINS, SAI II, and SRA*. We delayed the post-test one week to determine the influence of the tutorials on the participants' acquisition of knowledge and change in acceptance.

Results

We began our analysis with a comparison of the demographics and pre-test scores to determine if there were significant differences between the students recruited from the two universities. Our analysis revealed that the participants from the two universities differed significantly in their number of mathematics courses $t(87) = 4.68$, $p < .01$. However, participants from both institutions were nearly evenly distributed between the experimental and control groups and our analysis did not reveal any significant differences between these two groups at pretest. Therefore, we conducted all further analysis using all participants with a complete data set regardless of their institutional affiliation.

Retention of understanding evolution tutorials. The analysis of the outcomes of our comprehension and retention assessment revealed that the experimental group averaged 64% correct while the control's average performance was 68% correct. The results revealed there was no significant difference between the groups in their comprehension and retention of the two shared tutorials.

Preliminary Analyses

We began our analysis of the pre-test measures by determining if there were significant differences of MATE, CINS, SRA and SAI II on these measures at pretest between our two groups of participants' from different institutions. We conducted an independent samples t-test for each of our measures and as would be anticipated we found no significant differences between the groups. This provided justification for continuing our reliability analysis of the pre-test measures using all participant scores. Further, the equivalent scores provided justification for conducting the correlational analysis of the pre-test measures of knowledge and acceptance producing values that were representative of the pre-service teacher population from which our samples were drawn.

Our analysis of the pre-test measures continued with the determination of the reliability of our study instruments and a comparison of measures to those reported in the validation studies. We calculated the internal reliability using Cronbach's alpha for the *CINS, MATE, SAI,* and *SRA using pre-test data*.

Our analysis of our participants' knowledge of natural selection (*CINS*) scores and our reliability calculation (Cronbach's alpha = .63) resulted on values are nearly identical to those reported in the instrument validation study (Anderson, Fisher, & Norman, 2002). Our participants score approximately 46% correct which was nearly identical to the 46.4% that the authors reported with their sample of undergraduate students. This indicates that the CINS measure of natural selection performed as expected and provided us with a reliable measure for inferring our participants' knowledge of evolution (see Table 2).

The analysis of our measure of participants' acceptance of evolution (*MATE*) revealed an internal reliability coefficient (Cronbach alpha = .93) commensurate with the value reported in the instrument validation study (Rutledge & Warden, 1999). The average of the participants' scores was in the low 70s which indicated a moderate level of acceptance of the theory of evolution (see Table 2) according to the instrument designers.

The internal reliability assessment of the measure of perceptions of the nature of science (*SAI II*) was also found to have a Cronbach's alpha of .79 which is nearly identical to the value reported in the instrument validation study (Moore & Foy, 1997). In comparison to the outcomes reported in the instrument validation study our participants fell in the middle of the range of values, which indicated that our participating preservice teachers had about average perceptions of nature of science (see Table 2).

Our assessment of situations of chance knowledge (SRA) did not perform as reported in the instrument validation study (Garfield, 2003) which could be reflective of our sample size. Our internal reliability calculation was found to have a Cronbach's alpha of .55, which is one the lower end of acceptable reliability. The similar experimental and control group mean scores and standard deviations suggest that the pre-test levels of understanding of situations of chance were consistent between the two groups (see Table 2).

Table 2

The Means, Standard Deviations and Reliability Calculations Pre-Test Measures

Pre-test Measure	Experimental	Control
	M (*SD*)	*M* (*SD*)
Evolution Knowledge (CINS)	9.20 (3.08)	9.36 (2.42)
Evolution Acceptance (MATE)	72.30 (12.51)	70.02 (17.55)
Nature of Science (SAI II)	3.37 (.41)	3.47 (.44)
Situations of Chance (SRA)	7.35 (2.59)	7.82 (2.47)

Our preliminary analyses concluded with the calculation of the correlations between our pre-test scores for CINS, MATE, SAI II, SRA, and our demographics measures. Our correlational analysis revealed three significant relationships between our demographics measures and our assessments of knowledge and acceptance (see Table 3). Age was found to be positively correlated with the nature of science beliefs ($p < .05$), which indicates that as age increased there was an increase in more scientific perceptions of the nature of science. Gender was found to be correlated with understanding of situations of uncertainty, ($p < .01$) with males outperforming females. Our third significant correlations was an inverse relationship between religiosity and acceptance of evolution ($p < .01$), which indicated that as religious commitment increased acceptance of evolution decreased. Our correlational analysis also revealed two significant relationships between our measures of knowledge and acceptance. Participants' knowledge of evolution was significantly correlated with situations of uncertainty ($p < .01$), which is consistent with the findings of Sadler (2005). Our second significant correlation was between knowledge of evolution and knowledge of the nature of science ($p < .01$), which is consistent the conjecture of McComas (2006).

Instructional Interventions Effects

The effects of the instructional interventions were determined by comparing pre-test and post-test scores on the MATE, CINS, SRA and SAI II. We conducted a repeated measures ANOVA to compared the pre-test and post-test scores using our experimental and control groups as the between-subjects grouping variable.

Our first research question asked: *Does acceptance of evolution shift when common misconceptions of the theory are explicitly addressed and discredited?* To determine the answer to this question we conducted a repeated measures ANOVA comparison of pre-test and post-test MATE scores, using group as the factor. Our results revealed a main effect of time $F(1,87) = 4.70$, $p < .05$, with an effect size of .05 and a power of .57. This indicates that there was small but significant shift in all participants' levels of acceptance of the theory of evolution from pre-test to delayed post-test one week later as measured by the MATE. The means and standard errors for the pre-test were 71.13, ($SE = 1.67$) and for the post-test scores were 73.38 ($SE = 1.57$). The results did not reveal a significant interaction indicating that the groups did not have a differential change in their levels of evolution acceptance as measured by the MATE. We attribute this outcome to the instructional interventions targeted at demystifying misconceptions of evolution and on the nature of science in the context of evolution that were common across groups and therefore, influential on all participants' acceptance of the theory.

Our second research questions asked: *Is instruction targeted at promoting understanding of biological evolution, the nature of science, and situations of uncertainty, effective in reduced misconceptions and promoting positive shifts in conceptions about all three phenomena?* Closely related was our third research question which asked: *Does pre-service teachers' understanding of biological evolution shift when instruction is combined with situations of uncertainty?* To answer these questions we conducted repeated measures analysis of pre-test and post-test scores using the group as the factor variable.

Knowledge of biological evolution. Our repeated measures ANOVA did not reveal a significant change in CINS scores over time indicating that there was not a significant change in understanding of evolution as measured by this instrument due to instruction. Further, there was no significant interaction indicating that there was no differential change in understanding between the experimental and control participants.

Understanding of nature of science. Our repeated measures ANOVA of the SAI II assessment of perceptions of the nature of science revealed no significant changes from pretest to posttest for either study group. This indicates that the nature of science instruction did not influence participants' understanding or emotions toward the nature of science. This was surprising since both groups received tutorials focused specifically on the nature of science.

However, since the nature of science is complex and multifaceted; the initiation of shifts in perceptions of this concept may require a more extensive intervention than we provided in our study.

Situations of uncertainty. As mentioned previously the internal reliability of this instrument was found to be lower than expected from prior research. Therefore, results using this instrument need to be considered cautiously. Our repeated measures ANOVA failed to reveal any significant differences for time or group. We attribute this lack of change in understanding of situations of uncertainty by the experimental group to the relatively brief tutorial, and the complexity of the content. As with other misconceptions of knowledge, we posit a more robust and comprehensive tutorial would be required to induce conceptual shifts in situations of uncertainty.

Discussion

This is the first study we are aware of that empirically measured the effectiveness of instructional content from the *Understanding Evolution* (UCMP, 2006) website in promoting greater acceptance or knowledge of evolution. Producing a shift in acceptance of evolution as measured by the MATE by merely asking individuals to interact with the *Understanding Evolution* website instructional content is a promising and important outcome. Participant interaction with the *Understanding Evolution* content was brief, which could explain the relatively small shift in acceptance. Our detection of a shift in acceptance of evolution suggests that the *Understanding Evolution* website may be an effective means of increasing visitors' acceptance of evolution and is worthy of further exploration. Our results are also consistent with other research (Matthews, 2001; Scharmann et al., 2005) that attribute brief interventions to shifts in conceptions.

Our results revealed a shift in the acceptance of evolution for both the experimental and control groups, indicating that the instructional intervention influenced their acceptance of evolution even with differential interventions. This outcome is most likely explained by the common exposure to the same *Understanding Evolution* tutorial that explicitly addressed common misconceptions of evolution using an engaging combination of text and graphics. We were encouraged to find a change in acceptance of evolution given that this construct tends to be relatively constant and robust (Gallup, 2008; Miller, 1999; Scott, 2005). Our results indicate that short term interventions that explicitly address misconceptions may be effective at increasing acceptance. More in depth and longer term interactions with the *Understanding Evolution* website may lead to increases in knowledge and acceptance or produce conceptual shifts of both these constructs. It is important to note that shifts in acceptance of evolution are not always accompanied by growth in knowledge of the topic (Sinatra, Southerland, McConaughy, & Demastes, 2003).

Our results also confirmed several findings of previous research. We found a significant negative relationship between level of religiosity and acceptance of evolution, which was not surprising since this is a common association (Miller, 1999; Scott, 2005). We also detected a relationship between knowledge of the nature of science and knowledge of evolution. This relationship is posited to be key to understanding evolution and has been the topic of previous research (Scharmann et al., 2005). Perhaps the most noteworthy finding was the relationship between knowledge of evolution and knowledge of situations of uncertainty. Although posited by Sader (2005), empirical evidence supporting this relationship has been sparse. This is an important finding because it provides an empirical link for the importance of knowledge of situations of uncertainty to developing an understanding of biological evolution. This is an excellent topic for additional exploration in future research.

As discussed previously, many concepts and processes in science, mathematics and other domains involve aspects of both belief and understanding (Smith & Siegel, 2004; Southerland, et al., 2001). Although related, we have found a slight shift in acceptance in evolution without a parallel change in knowledge of evolution, which indicates that individuals may increase their levels of acceptance of a concept while retaining misconceptions. This is noteworthy due to the relationships between belief, knowledge, and conceptual shifts. This outcome suggests directions for future investigations to determine what conditions promote change in acceptance versus knowledge and to examine the relationship between these constructs.

By targeting participating preservice teachers' misconceptions of situations of chance and the nature of science we were attempting to reduce conceptual obstacles that are posited to interfere with the development of accurate understanding of the theory of biological evolution. However, our results did not reveal an increase in understanding of biological evolution even when accompanied with instruction in reasoning in situations of uncertainty and the nature of science provided in the context of evolution. The combined complexity of these three concepts may require a more rigorous intervention that includes explicit examples and longitudinal explorations than our limited intervention was able to provide. Our results provide warrant for additional investigations exploring instructional approaches and combinations of content that are effective at increasing understanding of evolution and the related constructs.

The study results provide support for the need for additional evolution curriculum for preservice teachers prior to their entering service which is critical given reports indicating that students enter and exit college level science courses holding the same misconceptions (Sadler, 2005). The preservice teachers in the project were nearing the time in their program when they would begin their practicum and field experience. Therefore, they were unlikely to enroll in additional mathematics and science coursework prior to entering service (NRC, 2007), and yet may be more impressionable at this stage with regards to learning more about evolution. Science and mathematics methods courses may be the last opportunity in these students' teacher preparation curriculum to explore content related to NOS, situations of uncertainty, and biological evolution, and address the commonly associated misconceptions prior to service. Our research indicates the *Understanding Evolution* (UCMP, 2006) web site is effective for increasing awareness of evolution and is a potentially useful resource for preparing preservice teachers for teaching concepts associated with biological evolution. The instructional effects of other combinations of content from the *Understanding Evolution* web site and related evolution education instructional materials are ripe with opportunity for investigation.

Limitations

There are several limitations to our study. First, our study sample was moderately sized, with 89 cases available for final data analysis limiting the power associated with the analysis. Additionally, the sample was nearly evenly divided between the experimental and control groups which further reduced power. A larger sample size may reveal additional pertinent relationships and significant measures.

Another limitation for this study was the format of the instructional interventions. The interventions were web-based tutorials which participants browsed independently in a computer lab environment, with each participant controlling the pace of the instruction. Although instructions were provided and participation was monitored and time on task was consistent, the extent in which the participants engaged with the tutorial content that could not be controlled or fully monitored. A greater effect may result if the intervention is delivered using different methods, such as face-to-face instruction, that would encourage a deeper level of participant engagement through interaction and discussion.

A related limitation is the nature of the instruments used in the study. The self reporting, selected response instruments did not address the concepts in an integrated manner. Therefore, the instruments did not directly measure participant ability to integrate and apply the content from the study domains in a manner in which evolution concepts might be taught.

The final limitation to be discussed addresses concerns regarding the participants selected for involvement in our study. Although the participants in our study were all preservice teachers, they were also all undergraduate students and therefore, limited in their college experience. The narrow range of college level experience represented in our sample may have constrained our ability to detect significant outcomes. A broader sample that represents a range of undergraduate and graduate experience may reveal different outcomes.

Conclusion

This research revealed that a relatively modest instructional intervention can produce slight but significant shifts in acceptance of the theory of evolution as measured by the MATE. We also confirmed the latent and compound aspects of evolution misconceptions held by preservice teachers. The compound nature of these misconceptions reflects the need for learning concepts in context and developing understanding to assure the formation and expression of correct conceptions in seemingly unrelated domains. As found in this study; conceptions and misconceptions of situations of uncertainty and the nature of science appear to coincide with the misconceptions of biological evolution.

References

Abd-El-Khalick, F., & Akerson, V. L. (2004). Learning as conceptual change: Factors mediating the development of preservice elementary teachers' views of nature of science. *Science Education, 88*(5), 785-810.

Alters, B. J. (2004) *Teaching biological evolution in higher education: Methodological, religious, and nonreligious Issues.* Boston: Jones and Bartlett.

Alters, B. J., & Alters, S. M. (2001). *Defending evolution: A guide to the creation/evolution controversy.* Sudbury, MA: Jones & Bartlett.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

Anderson D. L., Fisher K. M., & Norman G. J. (2002). Development and evaluation of the conceptual inventory of natural selection. *Journal of Research in Science Teaching* 39(10), 952–978.

Chinn, C. A., & Malhotra, B. A. (2002). Children's responses to anomalous scientific data: How is conceptual change impeded? *Journal of Educational Psychology, 94*(2), 327-343.

Dagher, Z. R., & Boujaoude, S. (2005). Students' perceptions of the nature of evolutionary theory. *Science Education, 89*(3), 378-391.

Darling-Hammond, L., & Bransford, J. (Eds.). (2005). *Preparing teachers for a changing world: What teachers should* *learn and be able to do*. San Francisco: Jossey-Bass.

Deemer, S. (2004). Classroom goal orientation in high school classrooms: Revealing links between teacher beliefs and classroom environments. *Educational Research, 46* (1), 73-90.

Dennett, D. (1995). *Darwin's dangerous idea: Evolution and the meanings of life*. New York: Simon & Schuster

Dole, J. A., & Sinatra, G. M. (1998). Reconceptualizing change in the cognitive construction of knowledge. *Educational Psychologist, 33*(2/3), 109-28.

Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. (1994). *Making sense ofsecondary science*. New York, NY: Routledge.

Fisher, K. M. (2004). The importance of prior knowledge in college science instruction. In D. W. Dunal, E. L. Wright, & J. B. Day (Eds.). *Reform in Undergraduate Science Teaching for the 21st Century* (pp 69-83). Greenwich, CT: Information Age Publishing.

Gallup, G. (2008). Evolution, creationism and intelligent design. Retrieved October 11, 2008, from http://www.gallup.com/poll/21814/Evolution-Creationism-Intelligent-Design.aspx

Garfield, J. B. (2003). Assessing statistical reasoning. *Statistical Education Research Journal*, *2*(1), 22-32.

Garvin-Doxas, K. & Klymkowsky, M. W. (2008). Understanding randomness and its impact on student learning: Lessons learned from building the biology concept inventory (BCI). *CBE Life Science Education, 7*(2), 227-233.

Gould, S. J. (2002). *The structure of evolutionary theory.* Cambridge, MA: Harvard University Press.

Gould, S. J. (1989), *Wonderful life: The burgess shale and the nature of history*. New York: W. W. Norton & Co.

Hoy, A., Davis, H., & Pape, S. J. (2006). Teacher knowledge and beliefs. In P. A. Alexander & P. H. Winne (Eds.), *Handbook of Educational Psychology, 2nd ed*. (pp.715-737). Mahwah, NJ: Lawrence Erlbaum.

Ingram, E. L., & Nelson, C. E. (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.

Jarvis, T., Pell, A., & McKeon, F. (2003). Changes in primary teachers' science knowledge and understanding during a two year in-service programme. *Research in Science & Technology Education, 21*(1), 17-42.

Kelemen, D. (1999). Functions, goals and intentions: Children's teleological reasoning about objects. *Trends in Cognitive Sciences, 12,* 461– 468.

Kikas, E. (2004). Teachers' conceptions and misconceptions concerning three natural phenomena*. Journal of Research in Science Teaching*, *41*(5), 432–448.

Lawson, A. E. & Worsnop, W. A. (1992). Learning about evolution and rejecting a belief in special creation: Effects of reflective reasoning skill, prior knowledge, prior belief and religious commitment. *Journal of Research in Science Teaching*, *29*(2): 143-166.

Llinares, S., & Krainer, K. (2006). Mathematics (student) teachers and teacher educators as learners. In A. Gutierrez & P. Boero (Eds.), *Handbook of research on the psychology of mathematics education: Past, present and future* (pp. 429-459). Rotterdam: Sense Publishers.

Mason, L. & Limon, M. (1999). *Reconsidering conceptual change: Issues in theory and practice.* Dordrecht: Kluwer.

Matthews, D. (2001). Effect of a curriculum containing creation stories on attitudes about evolution. *American Biology Teacher, 63*(6), 404-409.

McComas, W. F. (2006). *Investigating evolutionary biology in the laboratory*. Dubuque, WI: Kendall/Hunt Publishing Company.

McComas, W. F. (1998). *The nature of science in science education rationales and strategies*. Boston: Kluwer Academic Publishers.

McComas, W. F. (1996). Ten myths of science: reexamining what we think we know about the nature of science. *School Science and Mathematics*, *96*(1), 10-16.

McComas, W. F., Clough, M. P., & Almazroa, H. (1998). The role and character of the nature of science. In W. F. McComas (Ed.), *The nature of science in science education rationales and strategies* (pp. 3-40). Boston: Kluwer Academic Publishers.

Miller, J. D., Scott, E. C., & Okamoto, S. (2006, 11 August). Public acceptance of evolution. *Science*, 313, 765-766.

Miller, K. R. (1999). *Finding Darwin's God: A scientist's search for common ground between God and evolution*. New York: Cliff Street Books, HarperCollins.

Moore, R. W., & Foy, R. L. H. (1997). The scientific attitude inventory: A revision (SAI II). *Journal of Research in Science Teaching, 34*(4), 327-336.

National Academy of Sciences. (1998). *Teaching about evolution and the nature of science*. Washington D.C.: National Academy Press.

National Academy of Sciences. (2008). *Science, evolution and creationism.* Washington, D.C.; National Academy Press.

National Research Council (2007). *Taking science to school: Learning and teaching science in grades K-8*. R. A. Duschl, H. A. Schweingruber, A. W. Shouse (Eds.). Washington, D.C.: The National Academies Press.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

National Science Teachers Association. (1997). An NSTA position statement on the teaching of evolution. *Journal of College Science Teaching*, *27*(1), 7–8.

Nadelson, L. S. (2007). Preservice teachers' understanding of evolution, the nature of science, and situations of chance. (Doctoral Dissertation, University of Nevada, Las Vegas, 2007) Dissertations & Theses: Full Text database, AAT 3261083.

Nickerson, R. (2004). *Cognition and chance, the psychology of probabilistic reasoning*. Mahwah, NJ: Lawrence Erlbaum Associates.

Nussbaum, E. M., Sinatra, G. M., & Poliquin, A. (2008). The role of epistemic beliefs and scientific argumentation in promoting conceptual change. *International Journal of Science Education, Online First* (1), 1-23.

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*(3), 307-332.

Palmquist, B. C., & Finley, F. N. (1997). Preservice teachers' views of the nature of science during a postbaccalaureate science teaching program. *Journal of Research in Science Teaching, 34*(6), 595-615.

Royer J.(2001). Developing reading and listening comprehension tests based on the sentence verification technique (svt). *Journal of Adolescent and Adult Literacy 45*, (1), 30–41.

Rutledge M.L. (1996). *Indiana high school biology teachers and evolutionary theory: Acceptance and understanding*. Doctoral dissertation Ball State University.

Rutledge, M. L., & Warden, M. A. (1999). The development and validation of the measure of acceptance of the theory of evolution instrument. *School Science and Mathematics*, *99*(1), 13-18.

Sadler, T. D. (2005). Evolutionary theory as a guide to socioscientific decision-making. *Journal of Biological Education, 39*(2), 68-72.

Scharmann, L. C., Smith, M. U., James, M. C., & Jensen, M. (2005). Explicit reflective nature of science instruction: Evolution, intelligent design, and umbrellaology. *Journal of Science Teacher Education, 16*(1), 27-41.

Scotchmoor J. & Thanukos A. (2007) Building an understanding of evolution: An online resource for teaching and Learning, *McGill Journal of Education, 42*(2), 225-244.

Scott, E. C. (2005). *Evolution vs. Creationism*. Berkeley, CA: University of California Press.

Shaughnessy, J. (2003). Research on students' understanding of probability. In J. Kilpatrick, W. G. Martin, & D. Schifter (Eds.), *A research companion to principles and standards for school mathematics* (pp. 216-226). Reston, VA: NCTM.

Shtulman, A. (2006). Qualitative differences between naïve and scientific theories of evolution. *Cognitive Psychology, 52*(2), 170-194.

Sinatra, G. M. & Mason, L. (2008). Beyond knowledge: Learner characteristics influencing conceptual change. In S. Vosniadou (Ed.). *International Handbook of Research on Conceptual Change* (pp. 560-582). Netherlands: Springer.

Sinatra, G., & Pintrich, P. (2003). The role of intentions in conceptual change learning. In G. M. Sinatra & P. R. Pintrich (Eds.), *Intentional conceptual change* (pp. 1-18). Mahwah, NJ: Lawrence Erlbaum Associates.

Sinatra, G. M., Southerland, S. A., McConaughy, F., & Demastes, J. (2003). Intentions and beliefs in students' understanding and acceptance of biological evolution. *Journal of Research in Science Teaching, 40*(5), 510-528.

Smith, M. U. (1994) Counterpoint: Belief, understanding, and the teaching of evolution. *Journal of research in science teaching*, *31*(5), 591–597.

Smith, M. U., & Siegel, H. (2004). Knowing, believing, and understanding: What goals for science education? *Science & Education*, *13*:553-582.

Southerland, S.A., Sinatra, G.M. & Matthews, M.R. (2001). Belief, knowledge, and science education. *Educational Psychology Review*, *13*, 325–351.

Tversky, A., & Kahneman, D. (1982). Judgment under uncertainty, heuristics and biases. In D. Kahneman, P. Slovic, & A. Tversky (Eds.), *Judgment under uncertainty, heuristics and biases* (pp 3-21). New York: Cambridge University Press.

University of California Museum of Paleontology (2006, October). Understanding evolution. Retrieved October 3, 2006, from The University of California Museum of Paleontology, Berkeley, and the Regents of the University of California. Web site: http://evolution.berkely.edu.

Vosniadou S. (1994). Capturing and modeling the process of conceptual change. *Learning and Instruction*, *4,* 45-69.

Vosniadou, S. (2003). Exploring the relationships between conceptual change and intentional learning. In G. M. Sinatra & P. R. Pintrich (Eds.), *Intentional conceptual change* (pp. 377-406). Mahwah, NJ: Lawrence Erlbaum Associates.

Wolpert, L. (2006). Six *impossible things before breakfast: The evolutionary origins of belief*. London: Faber and Faber.

Yip, D. Y. (2001). Promoting the development of a conceptual change model of science instruction in prospective secondary biology teachers. *International Journal of Science Education, 23*(7), 755-770.

Table 3

Correlations between Pre-test Measures for all Participants (N=89).

Measure	2	3	4	5	6	7	8	9	10	11
1. Age	0.01	.37**	0.14	0.2	-0.04	-0.08	0.07	0.06	0.03	.29*
2. Gender	--	-0.11	-0.02	0.09	.30**	-0.11	-0.01	0.14	.30**	0.17
3. Yrs College		--	0.1	.35**	0.05	-0.11	0.05	0.02	-0.08	0.15
4. Math Courses			--	.30**	0.04	0.04	0	-0.11	0.05	0.08
5. Sci Courses				--	-0.02	-0.11	0.03	0.07	-0.07	0.06
6. Anticipated Grade Level of Instruction					--	0.02	0.02	0.02	0.12	-0.11
7. Religiosity						--	-0.13	-.60**	-0.07	0.04
8. CINS							--	0.15	.35**	.32**
9. MATE								--	0.17	0.1
10. SRA									--	0.17
11. SAI II										--

* $p < 0.05$ level (2-tailed) ** $p < 0.01$ level (2-tailed)