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Elementary education majors' views on evolution: A comparison of undergraduate majors understanding of natural selection and acceptance of evolution.

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Abstract

Elementary teachers play a crucial role in breaking the cycle of continued evolution controversy. They have the capacity to introduce concepts at the same time students may first encounter anti-evolution messages. This study compares elementary education majors' religiosity, acceptance and understanding of evolution to other majors. Results indicate that elementary education majors maintain a high level of religiosity and a significantly lower acceptance as compared to other majors not tasked with teaching evolution in America's public schools. Elementary education majors maintained levels of understanding of evolution that were not significantly higher than those not planning on teaching elementary students. Rasch analysis indicates that some elementary education majors do maintain high levels of acceptance and understanding of evolution and this particular subset of elementary teachers may be a promising way to increase evolution understanding among K-5 students.

Key Words: evolution, elementary, Rasch

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Background

Evolution is a unifying concept in biology to the extent that "nothing in biology makes sense except in the light of evolution" (Dobzhansky 1973, p. 125). Because of the importance of evolution in the field of biology and beyond, it holds a prominent place in state and national science standards (NGSS Lead States, 2013). The theory of evolution is nearly universally agreed upon by scientists to be the best explanation for the diversity of life, as evidenced by the numerous science, science education, and religious organizations that developed and published position statements supporting the teaching of evolution (Sager, 2008). Despite such widespread support, evolution remains a socioscientific controversy (Hermann, 2008). Given the socioscientific nature of the controversy surrounding evolution, a third of American adults indicate that evolution is absolutely false, a significantly higher proportion than found in any western European country (Miller, Scott, & Okamoto, 2006). Moreover, the percentage of Americans rejecting evolution remained fairly steady over the past few decades. With such a high percentage of Americans rejecting evolution, it is unreasonable to think that more Americans will accept evolution without a significant change in the manner in which evolution is taught to public school students. Students' religious views are often related to acceptance of evolution (Woods & Scharmann, 2001). Students commonly cite their religious views as a reason for believing that evolution should not be taught in high school (Donnelly, Kazempour, & Amirshokoohi, 2009). Some students are exposed to anti-evolution messages that may run counter to the concepts and ideas they are asked to learn during school science.

A cycle of continued evolution education controversy exists wherein children are exposed to anti-evolution messages prior to, or concurrent with, formal science instruction at the elementary level (Hermann, 2011). Students are exposed to ideas about evolution during their elementary school years in the context of school, home, religious, and media exposure (Donnelly & Akerson, 2008). Thus, young children are exposed to anti-evolution messages and in turn, may become adults who continue to challenge the teaching of evolution as parents, teachers, school board members and political leaders. In order to break the cycle of continued evolution controversy, it is imperative that elementary students develop an understanding of science in order to evaluate anti-evolution messages when first encountered (Lombrozo, Thanukos, & Weisberb, 2008). Including evolution education at the elementary level may lead to greater acceptance of evolution by adults (Beardsley, Bloom, & Wise, 2012; Lehrer & Schauble, 2004).

Elementary teachers play a crucial role in breaking the cycle of continued evolution controversy as they have the capacity to introduce science concepts and ideas at the same time students may first be presented with anti-evolution messages. Moreover, evolution is among the content standards for which elementary science teachers are expected to provide instruction. If for no other reason, elementary teachers must teach evolutionary science to completely and accurately address state and/or national standards.

Elementary Evolution Standards

Evolution is a dominant theme throughout the life sciences and is expected to be taught in grades K-12 (NRC, 2012). While standards related to evolution are contained to a greater extent at the middle and high school level, they are also present for grades K-5. Standards at the elementary level provide a foundation upon which further understanding can be built as students progress through middle and high school. For example, LS3.A Inheritance of traits is introduced in the Next Generation Science Standards at the K-2 level and the progression of this core idea extends through all grade bands with increasing sophistication and depth of coverage (NGSS Lead States, 2013, Appendix E). Moreover, if the standards are effectively addressed at the elementary level, they provide students with an understanding of ideas related to evolution that are age appropriate (Horowitz, McIntyre, Lord, O’Dwyer, & Staudt, 2013). While the term evolution refers to a broad spectrum of ideas and processes, the elementary standards are largely written around the principles of natural selection and align well with the five facts and three inferences about natural selection as described by Mayr (1982). As such, the teaching and learning of evolution is often highly focused on natural selection as is the focus of this study.
Examples from the *Framework* include:

- Grade 2: “Some kinds of plants and animals that once lived on Earth (e.g., dinosaurs) are no longer found anywhere, although others now living (e.g., lizards) resemble them in some ways” (NRC 2012).
- Grade 5: “Sometimes the differences in characteristics between individuals of the same species provide advantages in surviving, finding mates, and reproducing” (NRC, 2012).

Although the framework has been criticized for not directly referencing biological evolution or mechanisms of biological evolution in grades K-5, they do contain foundational concepts that can be built upon to understand biological evolution concepts (Wagler, 2012). Many of the foundational ideas present in the Framework were incorporated into the Next Generation Science Standards (NGSS Lead States, 2013). Grade 3-5 examples include:

3-LS3-1. Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exist in a group of similar organisms.

3-LS4-2. Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing.

3-LS4-3. Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.

Despite the emphasis placed on evolution in science education standards, individual state standards have been shown to vary considerably (Cavanagh, 2005; Skoog, 2005). Lerner, Goodenough, Lynch, Schwartz and Schwartz (2012) highlighted an undermining of evolution as a major issue leading to poor state science standards in the United States with many states receiving a lower grade because of weak evolution standards. To further compound the issue, ambiguous or inconsistent evolution standards may leave the decision to teach or avoid evolution up to individual teachers (Goldston & Kyzer, 2009). At the secondary level, where the theory of evolution is expected to be taught in most states, science teachers continue to report that they avoid instruction on evolution or teach alternatives to evolution (Berkman & Plutzer, 2011). Similarly, McCrory and Murphy (2009) reported that 21% of preservice science teachers rejected evolution. The fact that high school science teachers, presumably with college degrees and teaching certification in biology, or at least the completion of several biology courses, choose not to teach evolution may be an indication that elementary teachers with far less exposure to biology may also choose not to teach evolution.

Elementary Evolution Instruction

There is value in introducing elementary level students to age-appropriate concepts of evolution and concepts that are foundational to understanding evolution (McVaugh, Birchfield, Lucero, & Petrosino, 2011). Studies indicate that foundational concepts of evolution can successfully be taught to elementary students. In France, elementary level students are successfully taught concepts such as, animal classification, interrelationship trees, and a comparison of natural selection to intelligent design (Chanet & Lusignan, 2009). In the United States, Nadelson et al. (2009) developed and taught lessons on speciation and adaptation to kindergarten and second grade students using inquiry and modeling. The students were able to communicate an understanding of similarities and differences of forearm structures. 'Evolution readiness' was successfully taught to fourth grade students in Texas, Missouri and Massachusetts (Horowitz et al., 2013). These students learned about adaptations, variation within species and inheritance of traits. Similarly, K-4 students were able to understand complex topics like natural selection and genetic drift (Campos & Sa-Pinito, 2013). Children aged 5 to 8 years demonstrated a capacity to apply basic principles of natural selection three months after receiving instruction utilizing a 10-page picture book about fictional mammals with different trunk thicknesses resulting from a climatic change (Keleman, Emmons, Schillaci, & Ganea, 2014).

Despite the promising evidence that elementary students are capable of learning evolution, there is little evidence suggesting elementary school teachers possess the knowledge to do so. This may not be surprising given that the outcome of many K-8 science education programs, even graduate school programs, may be teachers' uncomfortable teaching evolution despite the fact that they may be perceived as being adequately prepared (Nadelson & Nadelson, 2010). Ashgar, Wiles and Alters (2007) reported that among the Canadian pre-service elementary teachers in their study, most lacked an understanding of even the most basic concepts of evolution, and almost a third planned to avoid or had reservations about teaching evolution.

Compared to secondary teachers, fewer elementary teachers were comfortable with teaching evolution (Fowler & Meisels, 2010) and elementary teachers have a lower level of acceptance of evolution (Fowler & Meisels, 2010; Levesque & Guillaume, 2010; Losh & Nzekwe, 2011). Elementary teachers are often unaware that evolution is even part of the required curriculum (Nadelson & Nadelson, 2010; Vlaardingerbroek & Roederer, 1997). This phenomenon is not specific to one country as Prinou, Halkia and Skordoulis (2011) suggested in their study of Greek primary school instruction on evolution that the "primary education in our country is inadequate to introduce the theory of evolution of organisms to children" (p. 284). Thus, they call for a drastic change in the structure of primary school curricula and the training of educators.

So, with respect to elementary evolution instruction, a problem exists. On the one hand, K-5 science standards demand students and teachers have a commanding understanding of science content and some studies indicate elementary students can effectively learn concepts foundational to evolution. On the other hand, there is evidence that elementary teachers are unprepared to effectively teach evolution. Moreover, it may be that the issue extends beyond evolution specifically, and relates to the teaching of science in general. In 2012 only 39% of elementary teachers reported feeling very well prepared to teach science (National Science Board, 2014). As such, the structure of elementary schools and the structure of elementary teacher preparation programs may provide a barrier to elementary education majors receiving adequate science and pedagogy instruction to effectively teach evolution. Put another way, due to the generalist nature of many elementary teacher education programs, elementary teachers often complete the same number or, or less, science courses than any other non-science major on a college campus. Nadelson and Southerland (2010) found a significant correlation between amount of coursework in biology with acceptance and understanding of evolution among undergraduate students. They went on to hypothesize that there may be a critical threshold of coursework that must be achieved to significantly impact levels of understanding or acceptance of evolution (Nadelson & Southerland, 2010). Likewise, biology majors have been shown to have a greater knowledge of natural selection and a greater acceptance of evolutionary theory compared to nonmajors (Partin, Underwood, & Worch, 2013). Completion of an evolution course has also been found to be a predictor of classroom time devoted to teaching evolution (Berkman, Pacheco, & Plutzer, 2008; Donnelly & Boone, 2007). Knowledge of evolution tends to increase with greater exposure to evolution (Kim & Nehm, 2011; Moore, Brooks, & Cotner, 2011).

Most students know very little about evolution and tend to retain only what is necessary to pass examinations before reverting back to their original beliefs (Nehm & Schonfeld, 2007). There are markedly different views on evolution between biology majors and non-majors with non-majors being less supportive of the teaching of evolution (Paz-y-Mino-C & Espinosa, 2009). Science majors have also been shown to have a greater knowledge of natural selection and acceptance of evolution compared to non-science majors. (Paz-y-Mino-C & Espinosa, 2009).

Clearly non-science majors, those not enrolled in a major in a science department, complete less science coursework than their science major counterparts, but many non-science majors are required to take some science courses to fulfill their graduation requirements. Like non-science majors, elementary education majors also complete less science coursework than science majors. A recent survey indicated that 6% of elementary science teacher had not had any college science, 20% had courses in one of three areas (life science, physical science or Earth science), and only 38% had courses in two of the three areas and 36% had courses in all three areas (Banilower et al., 2013). Moreover, only 39% of elementary teachers feel very well prepared to teach science compared to 77% for mathematics and 81% for reading/language arts (Banilower et al., 2013).

With respect to their scientific coursework, elementary education majors are more similar to non-science majors in the number and type of science coursework completed than they are to science majors and science education majors. This study explores the extent to which elementary education majors differ in their understanding of natural selection and acceptance of evolution as compared to majors whose careers do not place them in a position to educate the nation's children.

Methods

Participants

Surveys were completed to varying degrees by 311 students across majors who were currently enrolled in introductory biology classes, elementary science methods classes, secondary science methods classes, and upper level astronomy classes which focus on origins. Students were asked to participate in the study by the course instructor and were informed that the study was approved by the IRB, voluntary, and had no impact on their standing in the course. These courses were selected to include participants in a range of majors. In order to compare participants across majors, it was necessary to group participants by a range of majors. The five groups were developed for the original survey and were carried over to this survey. They include: arts, humanities and social science; business and nursing; elementary education; secondary science education; and science and engineering. All students at the university are required to complete two laboratory science courses. Science and engineering majors complete the largest number of science courses. This group contains five times the number of life science majors compared to physical science and engineering. The largest group of students to which access was easily attained was the elementary education majors. Other majors were grouped considering both the amount of science courses required and, to the extent possible, by the college in which majors reside. Nursing students and business students were grouped together since access was limited to these majors. Nursing majors do complete biology for health professions, allied health chemistry, anatomy and physiology and microbiology; however, the major is not offered through the college of science and mathematics. Secondary science education majors and science and engineering majors are offered through the college of science and mathematics. No social science majors are required to complete more than two science courses. One of the courses that students take to complete the laboratory-based science requirement is an introductory biology class in which the survey was distributed to non-majors.

The introductory biology class contained students from the freshman through senior rank and fulfills the university general education requirement for a lab-based science course. The course can be taken by students in any university major. The secondary science methods class is taken only by students majoring in a science content area with a secondary teaching concentration. It is typically taken the semester prior to student teaching so students in the class are typically seniors. The upper level astronomy class is mostly taken by juniors and seniors and is open to all majors. Elementary education majors at the university complete a science and mathematics semester in which they take, among other courses, an earth science course and a biology course that are a mixture of content and pedagogy and an internship experience teaching science and mathematics in local elementary schools. These students were surveyed in either the earth science or biology course. Elementary education majors do not take any additional science coursework after this semester which occurs late in their third year or early in their fourth year of study.

It was hypothesized that elementary education majors understand and accept evolution at (a) the same level as majors who are not expected to teach science to children, but (b) below the level of secondary science education and science/engineering majors. The hypothesis was that there is no significant difference between majors' religiosity.

Of the 311 students who completed the survey, 26% were male and 74% were female. Survey respondents ranged in age from18 to 50 years of age with 86% ranging between 18 and 23 years of age. The majority of participants (84.3%) attended a public high school. Over 85% of the participants were Caucasian followed by 6.7% who were African American and 5.7% were Asian. English was the native language for 96.5% of the participants.

Forty-five percent of the participants were juniors followed by 27.6% who were seniors. Over 41% reported they had a college grade point average over 3.5 with 39.4% reporting a GPA between 3.0 and 3.49. Of the participants who responded, 56.4% reported they had liberal political views and 29.5% reported having conservative political views.

Instruments

Students at a state university in the Mid-Atlantic region of the United States participated in both pre- and post-test surveys which included demographic information, a measure of religiosity, eight questions from the Conceptual Inventory of Natural Selection (Anderson, Fisher, & Norman, 2002), and the twenty item Measure of Acceptance of the Theory of Evolution (Rutledge & Warden, 1999). The Conceptual Inventory of Natural Selection (CINS) instrument was used in this study since the elementary NGSS standards are aligned to concepts directly related to natural selection. Students in each of the classes were asked to complete an anonymous survey containing four sections. The first section contained demographic questions. The second section contained five questions that measure religiosity (Neff, 2006). For this sample the reliability of the religiosity measurement using Cronbach's alpha was .67. The low value may be due to the low number of questions. The third section contained eight questions from the 20-item CINS and was developed to measure ten evolutionary concepts. The eight question "finches" section of the CINS was selected to reduce the length of the survey and increase the likelihood that participants would complete the entire survey. The finches section covers eight of ten evolutionary concepts and is robustly correlated (.932) with the entire CINS instrument (Ha, Baldwin & Nehm, 2015). For our sample, the reliability was measured using Cronbach's alpha and was .62 which is very close to the reliability found by Ha et al. (2015) of .61 for the same 8 questions. The last section of the survey contained all twenty items from the MATE. The MATE covers six concepts and utilizes a five-point Likert scale. The reliability of the MATE was .92 which is in agreement with other studies (Ha et al., 2015 and references therein). For this study, survey results were analyzed after submitting the raw data to Rasch analysis. It should be noted that Cronbach alpha has several issues such as assuming the responses are expressed on an equal-interval metric and pertain only to persons, not items (Boone, Townsend, & Staver, 2011). Rasch analysis was used to investigate both the reliability of items and the reliability of persons (Boone et al., 2011).

Rasch Modeling

The Rasch model is probabilistic based upon logits (Rasch, 1960) which allows for an adequate measure of those items that are less likely to be endorsed by participants (Lamb, Annetta, Meldrum, & Vallett, 2012). Rasch techniques provide measures that are expressed on an equal interval scale permitting the use of parametric tests for statistical analysis, as well as, the ability to compare differences in respondents just as one would when collecting data with instruments like a meter stick (Juttner, Boone, Park, & Heuhaus, 2013). Rasch analysis was utilized in this study to convert non-parametric data into parametric data and to better understand the relationship between the persons responding to the survey and the survey items. Raw scores were converted to a common metric of logits in which ordinal data was transformed to a linear measure (Linacre, 2002). Thus, those familiar with the CINS and MATE instruments will note the reported mean scores are in logits rather than the typically reported raw scores. The logit scale is an interval scale providing consistent value or meaning for locations on a person-item map thereby making it possible to compare how much difference exists between any two locations (Bond & Fox, 2007).

Rasch Analysis

The Rasch software Winsteps was used for analysis. Model fit indices were reviewed to assure the instruments fit the Rasch model. Model fit was assessed by analyzing item infit and outfit MNSQ data not within the 0.5 to 1.5 range (Boone, Staver, & Yale, 2014). While several items were outside the accepted range, the items were not removed as the purpose of this study was not to develop or refine the instrument. Rather, person fit for the items outside the 0.5 to 1.5 MNSQ range were analyzed. Individuals with a z-residual of 2 or higher or -2 or lower were documented and investigated and individuals who did not fit the Rasch model were removed from the data for the instrument in question. Individual item responses outside this range indicate idiosyncratic answers and were removed to bring the MNSQ values within the acceptable range (Boone et al., 2014, p. 165-174). For the religiosity measure, eight students were removed; however, only 231 of the 311 participants chose to complete this section of the survey. Ten individuals were removed from the MATE data due to responding unexpectedly and 24 individuals were removed from the CINS data for the same reason. As a result, the outfit MNSQ for Religiosity ranged from 0.71 to 1.44, the CINS ranged from 0.54 to 1.39 and the MATE ranged from 0.70 to 1.43.

Analysis of Variance

Following the Rasch scaling, an analysis of variance was conducted for religiosity, understanding of natural selection and acceptance of evolution. ANOVAs were utilized to test for statistical significance comparing the means of all groups. Post hoc analysis was then run to determine which majors showed differences with the elementary education majors. To further understand the interaction between the elementary education majors and the CINS and MATE instruments, Wright maps were created.

Results

ANOVA

A review of the mean scores indicated that the elementary education majors' religiosity was numerically higher than all other groups with the exception of the business and nursing majors (Table 1). After conducting Levene's test for homogeneity I found that the assumption of homogeneity of variance was violated; therefore, the Brown-Forsythe *F*-ratio is reported. There was a significant effect of university major on religiosity, $F(4, 138.56) = 5.44$, $p < .001$. In general homogeneity could not be assumed between pairs of groups. Where homogeneity could not be assumed robust Games-Howell post hoc tests were used (Field, 2013). These tests revealed significant differences between the elementary education majors and the science and engineering majors, $p = .00$, $d = 0.43$. There were no significant differences between the elementary education majors and arts, humanities or social science, $p = .68$, $d = 0.11$, business and nursing $p = .41$, $d = 0.16$, and science education, p = .52, $d = 0.18$.

Table 1

Religiosity Games-Howell post hoc comparison of majors to elementary education majors

Group	M	SD	Group	M	SD	Effect size**	Cohen category*
Arts, humanities, social science (48***)	1.72	1.10	Elementary ed (116)	1.98	1.21	.11	Small
Business, nursing (30)	2.31	.82	Elementary ed	1.98	1.21	.16	Small
Science sec. ed (16)	1.59	.87	Elementary ed	1.98	1.21	.18	Small
Science, engineering (13)	1.08	.54	Elementary ed	1.98	1.21	.43	Medium

*** Number of participants in this group of majors out of a total 223 participants
** Effect size = Difference of Means/Pooled Standard Deviation
* Cohen Category Small < .20 Med = 0.50 Large > .80

Table 2 shows the mean CINS score for each group. Note that the elementary education majors had the lowest mean score (-.32) of all groups. With respect to understanding of natural selection I found that the assumption of homogeneity of variance has been met. I found that there was not a significant effect of university major on understanding of natural selection, F (4,282) = 2.04, p = .09, among different groups of majors' understanding of natural selection. Tukey's post hoc analysis test revealed no significant difference between the elementary education majors and any other group of majors. The results indicate that elementary education majors do not have a better understanding of natural selection as compared to other majors not tasked with teaching children.

Table 2

Conceptual Inventory of Natural Selection LSD post hoc comparison of majors to elementary education majors

Group	**M**	**SD**	**Group**	**M**	**SD**	**Effect size****	**Cohen category***
Arts, humanities, social science (64***)	.14	2.17	Elementary ed (142)	-.32	1.70	.12	Small
Business, nursing (32)	.27	1.75	Elementary ed	-.32	1.70	.17	Small
Science sec. ed (28)	.17	1.73	Elementary ed	-.32	1.70	.14	Small
Science, engineering (21)	.65	1.86	Elementary ed	-.32	1.70	.26	Small

*** Number of participants in this group of majors out of a total 287 participants
** Effect size = Difference of Means/Pooled Standard Deviation
* Cohen Category Small < .20 Med = 0.50 Large > .80

A review of the mean scores indicated that the elementary education majors' acceptance of evolution was numerically lower than all other groups (Table 3). Table 4 shows the Rutledge and Sadler (2007) categorical levels of acceptance converted to logits. Elementary education majors' relative acceptance of evolution is categorized as moderate acceptance. Business, nursing and arts, humanities, and social science majors are categorized as having high acceptance. Science and engineering majors and science secondary education majors are categorized as having very high acceptance. After conducting Levene's test for homogeneity it was found that the assumption of homogeneity of variance was violated; therefore, the Brown-Forsythe F-ratio is reported. There was a significant effect of university major on acceptance of evolution, $F(4, 131.70) = 9.54$, $p < .001$. In general homogeneity could not be assumed between pairs of groups. Where homogeneity could not be assumed Games-Howell post hoc tests were used. These tests revealed significant differences between the elementary education majors and the science and engineering majors, $p = .01$, $d = 0.43$, science education majors, $p < .01$, $d = 0.40$, and arts, humanities or social studies majors, $p = .01$, $d = 0.25$. There were no significant difference between the elementary education majors and business and nursing $p = .98$, $d = 0.05$.

Table 3

Measure of Acceptance of the Theory of Evolution LSD post hoc comparison of majors to elementary education majors

Group	**M**	**SD**	**Group**	**M**	**SD**	**Effect size****	**Cohen category***
Arts, humanities, social science (66***)	2.43	1.70	Elementary ed (162)	1.65	1.31	.25	Small
Business, nursing (31)	1.77	1.07	Elementary ed	1.65	1.31	.05	Small
Science sec. ed (31)	3.13	1.90	Elementary ed	1.65	1.31	.41	Medium
Science, engineering (21)	2.99	1.49	Elementary ed	1.65	1.31	.43	Medium

*** Number of participants in this group of majors out of a total 301 participants
** Effect size = Difference of Means/Pooled Standard Deviation
* Cohen Category Small < .20 Med = 0.50 Large > .80

Table 4
Categorical levels of the acceptance of the theory of evolution, associated raw MATE scores, and MATE scores transformed into logits

Category	**MATE Scores**	**MATE Scores in Logits**	**Majors**
Very High Acceptance	89-100	2.88-6.84	Science, engineering; Science sec. education
High Acceptance	77-88	1.77-2.87	Business, nursing; Arts, humanities, social science
Moderate Acceptance	65-76	1.04-1.76	Elementary education
Low Acceptance	53-64	.44-1.03	
Very Low Acceptance	20-52	-2.02-.43	

The results indicate that elementary education majors have a relatively high degree of religiosity, low understanding of natural selection, and moderate acceptance of evolution. However, as noted by Boone et al. (2011) rarely in science education is the meaning of such differences considered. To bring meaning to this difference, I conducted Rasch analysis to produce Person-Item or Wright maps which provide an opportunity to reflect on the qualitative aspects of participants’ interactions with the CINS and MATE instruments. I was particularly interested in the level of understanding of natural selection and acceptance of evolution for individual elementary education majors as opposed to the group as a whole.

Wright Maps

Figure 1 presents the Wright map of the 158 elementary education majors who completed the CINS instrument. The left side of the Wright map provides a summary of the person measures. Students at the bottom are those with the lowest understanding of natural selection and those near the top exhibited the highest understanding of natural selection. The right side of the map presents the Rasch measures for each of the eight CINS items used in this study. Items at the bottom are those that were easier for students and those near the top are those that were more difficult. Given the large and numerous gaps between items it is clear that the results would have been richer had all twenty CINS items been included. The elementary education majors showed a slightly lower level of understanding, shown as M in Figure 1, than the scale item shown at 0 and denoted by +M. The mean of the person ability (M) is slightly lower than the mean of the item difficulty (+M) suggesting that some of the items were too difficult for the typical elementary education major surveyed.

Figure 2 shows the Wright map of the 158 elementary education majors who completed the twenty item MATE instrument. The left side of the Wright map provides a summary of the person measures. Students at the bottom are those with the lowest acceptance of evolution and those near the top exhibited the highest acceptance of evolution. The right side of the map presents the Rasch measures for each of the twenty MATE items. Items at the bottom are those that were easier for students to agree with and those near the top are those that were more difficult for students to agree with. The Wright map indicates that the MATE instrument is not particularly effective in differentiating acceptance of evolution as many of the items are too easily agreed with by all participants as seen by the condensed clustering of MATE items between -0.5 and 0.5 logits. Moreover, many of the items could be eliminated or revised as indicated by the high number of items at the same location along the vertical axis in Figure 2 (Wagler & Wagler, 2013). The elementary education majors showed a higher level of acceptance, shown as M in Figure 2, than the scale item shown at 0 and denoted by +M. Since the mean of the person ability is higher than the mean of the item difficulty, the MATE instrument was too easy for the typical elementary education major surveyed suggesting overall some of the elementary education majors maintain a high level of acceptance.

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Figure 1. Wright map of the Conceptual Inventory of Natural Selection (Anderson et al., 2002) completed by elementary education majors (n = 158, 8 items). Person measures are plotted with a "#" representing 3 participants and each "." represents 1 to 2 participants. CINS items are labeled CINS. Items at the top of the map represent items that are more difficult. Items at the base of the map are easier

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 0                +M MATE#9  MATE#12
               #  |  MATE#3  MATE#7  MATE#8  MATE#18     MATE#20
                  |S MATE#5  MATE#11
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-1             .  +  MATE#1
              low | easy
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Figure 2. Wright map of the Measure of Acceptance of the Theory of Evolution (Rutledge and Warden, 1999) completed by elementary education majors (n = 158, 20 items). Person measures are plotted with a "#" representing 2 participants and each "." represents 1 participant. MATE items are labeled MATE. Items at the top of the map represent items that are more difficult. Items at the base of the map are easier

Correlation

Among the entire sample of all majors, religiosity was negatively correlated with acceptance of evolution (r = -.30, $p \leq .01$). A significant relationship was not found between religiosity and understanding of natural selection (r = -.09, p = .23). Likewise, among elementary education majors' religiosity was not correlated with understanding of natural selection (r = -.05, p = .65), but was significantly negatively correlated with acceptance of evolution (r = -.23, p = .02). Among the entire sample there was a statistically significant (r = .43, $p \leq .01$) correlation between understanding of natural selection and acceptance of evolution. Similarly, there was a statistically significant (r = .36, $p \leq .01$) correlation between the elementary education majors' understanding of natural selection and acceptance of evolution.

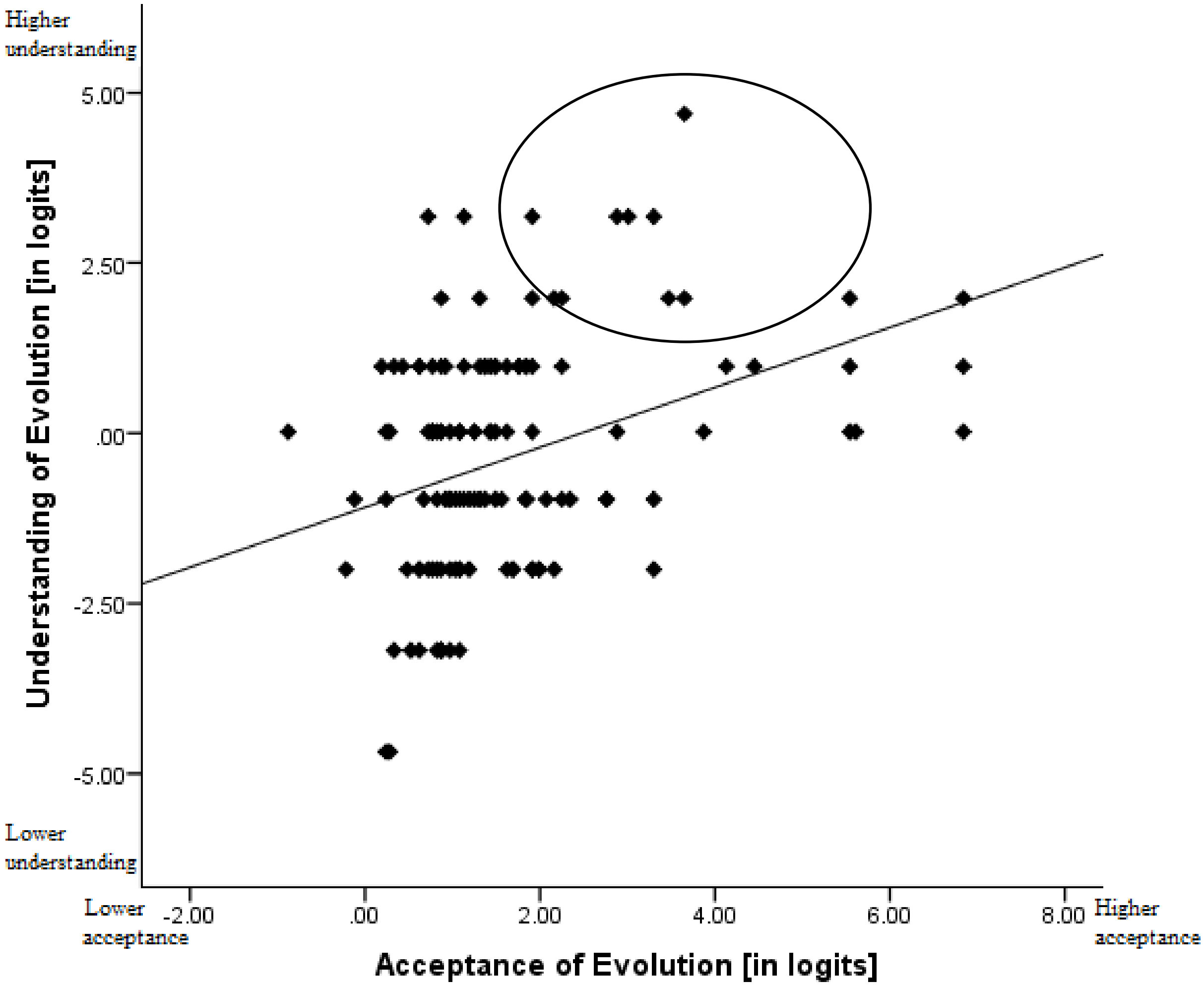

Fig. 3 Scatterplot of elementary education majors' CINS and MATE measures (r = .36, p ≤ 0.01, N = 136). A higher logit measure for Understanding of Evolution denotes a higher understanding of evolution. A higher logit measure for Acceptance of Evolution denotes a higher acceptance of evolution.

Juttner et al. (2013) demonstrated how information from correlations and scatterplots can be tied to Wright maps and that model is utilized here. The scatterplot in Figure 3 indicates that there are several elementary education majors with a relatively high understanding of natural selection (those individuals towards the top of the Y-axis). There are other elementary education majors with a relatively high acceptance of evolution. Finally, there are a few elementary education majors that maintain both a high acceptance of evolution and understanding of natural selection (see the circled data points in Figure 3). Conversely, there are numerous individuals near the bottom left of the scatterplot that maintain both low acceptance of evolution and low understanding of natural selection.

Discussion

The purpose of this study was to determine the extent to which elementary education majors' understanding of natural selection and acceptance of evolution differs from other majors not tasked with teaching evolution in America's public schools. Since religious explanations for the origin of species that contradict evolution can interfere with teacher motivation to teach evolution (Nadelson, 2009), religiosity was also measured. The hypothesis was that religiosity would not be different across majors since there was no reason to believe one group would be more or less religious than another. However, the elementary education majors' religiosity measure was second only to the business and nursing majors. While the purpose of this study was not to identify religious denominations, Losh and Nzekwe (2011) found that Fundamentalist Christians were over represented among future elementary school and math teachers, though a third of secondary science education majors had no formal religious affiliation.

When looking at this particular group of elementary education majors a significant negative correlation was found between religion and acceptance of evolution which is in agreement with literature in this area (Donnelly, 2009; Trani, 2004; Woods & Scharmann, 2001). Individuals who find science and religion to be in conflict may be resistant to learning evolution (Meadows, Doster, & Jackson, 2000) and religious affiliation and church attendance are predictors of evolutionary acceptance among a museum-going population (Barone, Petto, & Campbell, 2014). There is a significant difference in acceptance of evolution for religious versus not religious individuals and higher levels of religiosity and identifying as a Christian negatively impacted students' understanding of evolution (Rissler, Duncan, & Caruso, 2014). Given the interaction between religiosity and understanding and acceptance of evolution, the fact that elementary education majors maintain a high religiosity may influence their willingness to teach evolution (Nehm, Kim, & Sheppard, 2009; Nehm & Schonfeld, 2007; Trani, 2004). Religious beliefs can also impact teacher acceptance and curriculum and instruction choices (BouJaoude et al., 2011; Goldston & Kyzer, 2009; Rutledge & Mitchell, 2002).

Among these elementary education majors there was no significant correlation between religion and understanding of natural selection. However, there may be factors other than religiosity that influence elementary education majors' ability to understand evolution. Elementary education majors in this population complete up to four science courses, two of which are designed to provide content knowledge and pedagogical content knowledge. Elementary education majors complete a class on the principles of biology which includes the topic of evolution. They also complete a physical science class and a life science and an earth space science course which is roughly two-thirds content and one-third pedagogy. Of these four science classes, only one contains direct instruction on evolution and a second provides minimal additional instruction on evolutionary ideas. Perhaps lack of exposure to a higher number of science content courses at the university level combined with the complex nature of the mechanisms by which evolution occurs also influences ability to deeply understand evolution (Nadelson & Southerland 2010). Knowledge of evolution has been shown to increase the more a student is exposed to evolution (Kim & Nehm, 2011; Moore, Brooks, & Cotner, 2011).

The hypothesis that elementary education majors' acceptance of evolution would be lower than science majors, but not lower than other majors was not supported. Elementary education majors maintained the lowest level of acceptance of evolution as compared to the other majors surveyed, statistically lower than all majors except business and nursing. The finding that elementary education majors' acceptance is the lowest of all surveyed majors does not provide a context of the level of acceptance of each group of majors. To better understand which items on the MATE instrument elementary education majors most readily endorse, I conducted a preliminary Rasch analysis of the data. A Person-Item map (Wright Map) revealed that, although they maintained the lowest acceptance of evolution as compared to other majors, the elementary education majors displayed a pattern indicative of an overall moderate acceptance of evolution as classified by Rutledge and Sadler (2007). For example, the elementary education majors were least likely to agree with statements like “With few exceptions, organisms on earth came into existence at about the same time” and “The theory of evolution is incapable of being scientifically tested.” Further, they were most likely to agree with statements, such as “Organisms existing today are the result of evolutionary processes that have occurred over millions of years” and “The age of the earth is at least 4 billion years”. Thus, while the elementary education majors’ scores on the MATE as a group are lower than all other majors, some individual majors’ views are consistent with individuals who generally accept evolutionary theory. Moreover, the Person-Item map (Figure 2) revealed within the entire sample of elementary majors at the university, there is a smaller subset of elementary education majors who maintain a higher level of acceptance of evolution than their peers. By only analyzing the variance among different majors, the fact that some elementary education majors in this population maintain a high level of acceptance is less readily identified. This finding is consistent with that of Arthur (2013) in demonstrating that evolution acceptance is not a binary choice; rather acceptance of evolution falls along a continuum. Rasch analysis may be underutilized in research studies to make more sense of data. Without conducting Rasch analysis, a conclusion of this study would paint a more negative view of elementary education majors’ acceptance of evolution when comparing scores across majors. In viewing the Wright maps, the picture is clearer and suggests that while elementary education majors’ acceptance as a group is moderately high, a subset of elementary education majors’ acceptance of evolution can be categorized as high to very high according to the categorical levels of Rutledge and Sadler (2007) as seen in Figure 2.

The hypothesis that elementary education majors’ understanding of natural selection would be lower than science majors, but not lower than other majors was supported. Elementary education majors’ understanding of natural selection was not significantly different than any other major. Elementary education majors did not score significantly different than other majors whose future careers do not require teaching science topics to young children, though they did maintain the lowest mean understanding of natural selection. Perhaps this finding is to be expected since most elementary teacher preparation programs require the completion of approximately two college level science courses (Fulp, 2002). Nadelson and Nadelson (2010) reported that the outcome of K-8 science education programs, even graduate school programs, may be teachers’ uncomfortable teaching evolution but who may be perceived as being adequately prepared. Despite surveying K-8 teachers with graduate degrees they found some teachers (a) felt evolution was not a part of the curriculum they were expected to teach, (b) had a low familiarity with evolution, (c) did not feel qualified to teach evolution, and (d) may not view evolution as an important topic in life science. Their study is particularly important as it demonstrates that many elementary teacher education programs may not be effective in preparing students to understand evolutionary content as well as the importance of evolution as a unifying topic in life science and other sciences. Moreover, many elementary education majors may graduate still feeling as if they are not capable of teaching evolution.

It is worth noting that among this population of elementary education majors, acceptance of evolution was moderately high despite a generally low understanding of evolution. Rather than basing acceptance of evolution on an evaluation of the strength of the science supporting the theory of evolution, this group seems to have come to a conclusion that the theory of evolution is sound science despite their lack of a strong understanding of that science. This interaction is one which deserves further investigation beyond the scope of this exploratory study.

As with the acceptance of evolution, Rasch analysis provided a clearer picture of the elementary majors' understanding of natural selection. The Person-Item map (Figure 1) again helped identify a subset of elementary education majors that do maintain a high level of understanding of natural selection. While this subset is small (approximately 9-10 percent) compared to the number of elementary education majors surveyed, the existence of such a subset indicates that some elementary education majors possess more content knowledge than others. Perhaps there is a tendency to focus on the elementary education majors as a group, and in doing so the overall mean score is indeed low. However, by looking at individuals within the Wright map, it is clear that not all elementary education majors in this population have a low understanding of natural selection.

Given the often hypothesized statement that understanding of evolution is related to acceptance of evolution, this analysis was also conducted. Some of the previous studies suggest there is not a relationship between acceptance of evolution and understanding of evolution (Bishop & Anderson, 1990; Demastes, Settlage, & Good, 1995; Lord & Marino, 1993; Sinatra, Southerland, McConaughy, & Demastes, 2003), while others suggest such a relationship may exist (Deniz, Donnelly, & Yilmaz, 2008; Johnson & Peeples, 1987; Rutledge & Warden, 2000; Trani, 2004). The results of this study indicate a positive relationship between understanding of natural selection and acceptance of evolution among the entire sample of all majors combined and among elementary education majors as a group. A similar finding of a relationship between acceptance and understanding of evolution was reported by Rice and Kaya (2012) in a sample of 240 preservice elementary teachers.

Study Limitations and Future Research

The students that participated in this study are all from the same university in the Mid-Atlantic region. The views of evolution they maintain may differ from those of students in other regions for a variety of reasons. The intent of this article is not to transfer the findings to other populations, but to inform the science education community of the potential that current coursework for elementary education majors may not produce the desired results. At this institution, this work suggests that there is a great deal of variance among elementary education majors' understanding of natural selection and acceptance of evolution. However, there is a small subset of our elementary education majors that would be prime candidates for serving as science specialists working directly with K-5 students or K-5 teachers to enhance their science instruction. As such, other researchers may want to explore the extent to which various majors and teacher education programs result in an understanding and acceptance of various scientific ideas, concepts, theories and laws, especially evolutionary theory.

The purpose of this study was primarily to determine university students' understanding of natural selection and acceptance of evolution. Because the literature on these topics often indicates interactions with religiosity, a measure of religiosity was included in the survey. The reliability of the instrument was low and therefore the results and conclusions of this study should be read cautiously with that in mind despite the fact that Rasch analysis provides another additional assurance that the persons and items fit the model. Likewise, although the MATE is widely used, it is not without criticism (Wagler & Wagler, 2013) and the reliability of this instrument was low as well which is consistent with other studies (Ha et al., 2015). As such, the results of this exploratory study provide insight into elementary education majors at this institution, but further research with a larger and broader sample, and perhaps with different survey instruments, are required for the conclusions to be generalizable and to yield even more confident results.

This study would provide more robust results if the actual major of participants were captured rather than collapsing the majors into five categories. Likewise, additional demographic information may have been valuable but was omitted due to the length of the total survey.

Acceptance of evolution as measured by the MATE may not equate to willingness to teach evolution. Future work might explore the relationship between understanding of evolution, acceptance of evolution and willingness to actually teach evolution in a public school classroom. Further, additional research is needed to develop a clearer picture of the relationship between understanding of evolution and ability to effectively teach evolution. Future research exploring the knowledge and evolution acceptance of in-service elementary teachers would provide greater insight into the extent to which teachers are willing and able to teach evolution to K-5 students.

Conclusions

Prior research suggests that elementary teachers need further education and professional development to effectively teach evolution (Ashgar et al., 2007; Nadelson & Nadelson, 2010). Recommendations include that preservice teachers should receive more instruction on evolution (Berkman & Plutzer, 2012; Moore, 2004) and that curriculum and textbooks should be changed (Prinou et al., 2011). Losh and Nzekwe (2011) are concerned that "elementary school science resides in a curriculum crammed with many other subjects" though their suggestions are limited to adding additional topics and activities into elementary education science methods classes. Fowler and Meisels (2010) suggested incorporating evolutionary content into required science content for elementary majors. Berkman and Plutzer (2015) go even further suggesting that teachers would be better prepared to teach evolution if they took stand-alone classes in evolution, worked in active research laboratories, and took a course that afforded students the opportunity to explore the relationship of their faith to evolutionary science. While these are all fantastic ideas, they may not be attainable within university teacher preparation programs that prepare teachers for an elementary classroom generalist model. Programs that prepare elementary teachers to teach multiple subjects rarely have space in their program for extensive science instruction or multiple science methods courses. If elementary education majors do not receive this coursework within their teacher preparation programs, they may not seek it out on their own through professional development opportunities (Nadelson & Nadelson, 2010). It may not be possible to provide high quality evolution-related learning experiences for all elementary education majors. Evolution education is not the only area of science education for which science educators have called for increased teacher preparation (Hermann, 2013). Devoting additional time within an existing methods class, or adding additional classes, is often not possible when programs are near the maximum number of credit hours students need to graduate and the addition of another class or classes may extend graduation beyond the much anticipated four year timeline. Additionally, although content interventions have been shown to improve preservice biology teachers understanding of evolution, preferences to teach anti-evolutionary ideas are not as easily changed.

Rather than attempting to increase the science content knowledge and pedagogical content knowledge of all elementary education majors, another option is to identify subsets of elementary education majors that already possess that knowledge and are accepting of evolutionary ideas. In this study I was able to identify a subset of elementary education majors who are already accepting and/or understanding of evolutionary ideas. Utilizing these teachers may be a more effective and efficient way to increase elementary students understanding of evolution than attempting to prepare all elementary education majors to do so. The results of the present study indicate that several of the elementary education majors surveyed maintain high levels of acceptance of evolution and understanding of natural selection. Perhaps, another way forward is to cultivate the elementary education majors within a larger program with knowledge and acceptance of evolution into elementary science education specialists. Elementary science specialists are believed to have more science content knowledge and pedagogical knowledge which may result in higher quality science learning experiences for elementary students (Schwartz & Gess-Newsome, 2008 and references therein). Within existing programs, there may be a subset of elementary education majors who could be ideal candidates for science specialist positions in elementary schools and work directly with elementary students during science lessons or work with generalist elementary teachers to enhance their science instruction. Indeed, there is evidence that with sufficient professional development, classroom implementation guides and/or kits containing activities elementary teachers can effectively teach evolution (Berti et al., 2010; Horowitz et al., 2013). Elementary teachers possessing a deep understanding of evolution can be utilized to provide instruction to K-5 students, help design curricular materials for teachers in their school and/or district, provide instructional support for other teachers implementing evolution lessons, and provide evolution related professional development for K-5 teachers. Identified elementary teachers could assume a position other than a classroom generalist and support science instruction broadly and evolution instruction specifically. While this may be viewed as a radical departure from many current models of elementary teaching, the frequency of reports indicating low acceptance and understanding of evolution across numerous sample populations, including biology teachers, demands a radical departure from the current model of instruction.

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