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Distinguishing Science from Non-Science: Preservice Elementary Teachers' Perspectives on Evolution, Creationism, and Intelligent Design

Ian C. Binns *
UNC Charlotte, USA

Mark A. Bloom
Dallas Baptist University, USA

Abstract: Biological evolution stands out as critically important content for K-12 education as it is considered a cornerstone of the biological sciences. Yet, it remains one of the most socially controversial topics related to science education. In this exploratory study, we are seeking to understand the ways elementary preservice teachers (PSTs) use their views of science to justify including or excluding alternative explanations to evolution in the science curriculum. This investigation included 76 PSTs who were enrolled in an elementary science methods course. Data came from an activity designed by the authors entitled "Science in the Public Schools – School Board Scenario." The scenario proposed that the local school board was considering a motion to alter the science curriculum by introducing creationism and intelligent design (ID) to the unit on biological evolution and the PSTs had to offer their informed recommendations. The two researchers independently read and coded the data using an inductive, constant comparative approach. Findings revealed that 32 would not add creationism or ID, 26 would add both, 9 would add creationism, 6 would add ID, and 3 would only mention them. PSTs came up with diverse explanations for their decision on if to include alternative explanations when teaching evolution. Common rationales emerged within each group and are further explored.

Keywords: *Evolution, creationism, intelligent design, preservice elementary teachers.*

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Introduction

Biological evolution stands out as critically important content for K-12 education as it is considered a cornerstone of the biological sciences (National Academy of Sciences [NAS] & Institute of Medicine [IOM], 2008). Russian orthodox Christian and evolutionary biologist Theodore Dobzhansky asserted that "Nothing in biology makes sense except in the light of evolution" (Dobzhansky, 1973). Broadly defined, evolution is "a core concept in biology that is based both in the study of past life forms and in the study of the relatedness and diversity of present-day organisms" (NAS & IOM, 2008). For decades, evolution has served as the central unifying theme in biological science K-12 curriculum such as the *Benchmarks for Science Literacy* (American Association for the Advancement of Science [AAAS], 1993), the *National Science Education Standards* (National Research Council [NRC], 1996), and the recent *Next Generation Science Standards* (NGSS) (NGSS Lead States, 2013).

Despite the overwhelming amount of evidence from multiple scientific fields, such as biology, geology, anthropology, etc. that supports evolutionary theory, along with the prominence of evolution in the current US science standards (i.e. NGSS), it remains one of the most socially controversial topics related to science education (Hermann, 2008). Ever since the Scopes trial of 1925, different societal groups have clashed over evolution and how (or if) it should be taught in the classroom (Matzke, 2010).

Teaching evolution has proved highly problematic in the K-12 settings due to deeply-held, contradictory beliefs held by the various stakeholders in curriculum development (e.g. school board members, curriculum writers, textbook publishers) as well as the teaching/learning environment (e.g. teachers, students, parents) (Scott, 2009). This is especially troubling considering that a recent study found that "student science achievement is related to the views the public holds toward evolution" (Belin & Kisida, 2015, p. 1067). In other words, student science achievement is higher in states where the majority of the residents want evolution to be taught exclusively. Biological evolution has historically been a particularly sensitive subject for science teachers, as it is sometimes perceived as contradicting religious beliefs

* **Corresponding author:**
Ian C. Binns, UNC Charlotte, Reading and Elementary Education, USA
✉ ibinns@uncc.edu

and, as a result, can be upsetting for teachers (Bloom & Weinburgh, 2007), students, and parents (Scott, 2009). Teachers often find themselves lost as to what is appropriate, safe, and even legal to include in their lessons (Bloom & Weinburgh, 2007; Hermann, 2013).

Most often, tensions regarding teaching evolution emerge in middle and secondary levels of K-12 education, where evolution is much more apparent than in lower grades. However, the elementary years (K-5) are critically important to providing the foundation for understanding evolution in the upper grades (Donnelly & Akerson, 2008; NGSS Lead States, 2013; University of California Museum of Paleontology [UCMP], 2015). Elementary (and middle school) teachers often demonstrate greater misgivings and less support of evolution than high school teachers (Glaze & Goldston, 2015). A recent literature review showed that very few studies have focused on elementary school teachers (Glaze & Goldston, 2015), and those that did, primarily focused on inservice teachers (Nadelson & Nadelson, 2010) and only upon their understandings of evolution; disregarding their acceptance or willingness to teach the theory (Bloom, 1989; Rice & Kaya, 2012). Many teachers simply choose not to teach evolution due to a variety of reasons, including pressure from colleagues and parents as well as negative attitudes from the surrounding community (Berkman & Plutzer, 2011; Pobiner, 2016). This decision to not teach evolution leads to many US students receiving little or no exposure to biological evolution, resulting in a population with highly varied understandings and/or acceptance of evolution. Teachers who do actually teach biological evolution often confuse the issue by integrating alternative explanations into their instruction (e.g. creationism, intelligent design [ID]) (NAS & IOM, 2008) and/or downplay the importance of evolution by asserting that it is "just a theory" and "not fact" (NAS, 1998). Such omissions and/or de-emphasizing of evolution is a direct result of efforts by those who possess strong anti-evolution feelings (NAS & IOM, 2008; Pobiner, 2016). Science educators have emphasized the importance of understanding the nature of science (NOS) in order to distinguish between scientific, non-scientific, and pseudo-scientific explanations (Bloom, 2008; Bloom, Binns, and Koehler, 2015; Losh & Nzekwe, 2011; Scharmann, Smith, James, & Jensen, 2005). Since elementary teachers are responsible for providing the foundational knowledge for students to learn evolution, it is important to determine their views on including alternative explanations when teaching evolution.

Literature Review

Throughout the world and especially in the United States, there is widespread public uncertainty regarding evolutionary theory, specifically human evolution (Miller, Scott, and Okamota, 2006; Newport, 2014; Pew Research Center, 2013; Swift, 2017). In 2013, Pew reported that 33% of American adults polled agreed with the statement "humans and other living things have existed in their present form since the beginning of time." In the longest running survey of Americans' acceptance of evolution to date, Gallup reports that in 13 polls conducted between 1982 and 2017, 38-47% agreed with the statement "God created human beings pretty much in their present form at one time within the last 10,000 years or so." Indeed, Miller et al. (2006) report that America falls second to last among 34 countries surveyed in agreeing with the statement "human beings, as we know them, developed from earlier species of animals"; only Turkey scored lower.

The 2017 Gallup poll indicated that acceptance and understanding of evolution are linked to level of education and religious preference (Swift, 2017). These factors can contribute to general misconceptions about evolutionary theory, which prove difficult to resolve, as well as strong opposition, due to religious beliefs, which contradict the scientific theory (Liu, 2012). The University of California, Berkeley's "Understanding Evolution" website (University of California Museum of Paleontology, 2015) lists nine common misconceptions regarding evolutionary theory. They are:

1. Evolution is a theory about the origin of life
2. Evolutionary theory implies that life evolved (and continues to evolve) randomly, or by chance.
3. Evolution results in progress; organisms are always getting better through evolution.
4. Individual organisms can evolve during a single lifespan.
5. Evolution only occurs slowly and gradually.
6. Because evolution is slow, humans cannot influence it.
7. Genetic drift only occurs in small populations.
8. Humans are not currently evolving.
9. Species are distinct natural entities, with a clear definition, that can be easily recognized by anyone.

Such misconceptions about the basic elements of evolutionary theory, along with the religious contradictions, certainly contribute to a lack of confidence and reticence to accept the theory as a plausible scientific explanation. Indeed, misconceptions and religious affiliation are the most influential agents to diminish the teaching and learning of evolution (AAAS, 1993; Miller, 2008; NAS & IOM, 2008).

Problem for Teachers

Sadly, while evolution is of critical importance to science literacy, oftentimes, even teachers fail to understand evolution sufficiently to teach it. Zuzovsky (1994) found that 19 of 27 teachers studied explained antibiotic resistance in insects using Lamarckian rather than Darwinian perspective. In a much larger study, Rutledge and Warden (2000) found that over 40% of teachers were unable to correctly answer questions regarding environmental changes and natural selection. Asghar, Wiles, and Alters (2007) reported that most Canadian pre-service elementary teachers lacked an understanding of the most fundamental elements of evolutionary theory. Glaze, Goldston, & Dantzler (2015) found that teachers of all grade levels demonstrated incomplete or incorrect understandings of basic scientific terms such as theory and law.

In addition to navigating the science content of evolution, Hermann (2013) describes how teachers must also be sensitive to myriad social, religious, and political factors when they approach teaching evolutionary theory. Many times, teachers fail to know what content regarding evolution is appropriate, or even legal, to teach in a public school classroom (Bloom & Weinburgh, 2007).

Teach at Elementary Level

These problems are confounded at the elementary level where some contend that young children lack the abstract reasoning skills to learn complicated content such as evolution (Marini & Case, 1994). Other researchers, however, contend that it is important to teach evolution in elementary schools (Fail, 2008; Hermann, 2011). This includes proposed curriculums/standards (Duschl, Schweingruber, & Shouse, 2007; Fail, 2008; UCMP, 2015) as well as interventions with elementary students (Emmons & Kelemen, 2015; Fail, 2008; Kelemen, Emmons, Schillaci, & Ganea, 2014; Nadelson et al., 2009). Kelemen et al. (2014) and Nadelson et al. (2009) both showed that elementary students are capable of learning evolution. Additionally, some suggest that 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' Willingness to Teach Evolution

Very little research has looked at what elementary school teachers think about teaching evolution. Several studies found that at least some of their participants advocated for teaching evolution exclusively (Asghar et al., 2007; Levesque & Guillaume, 2010; Losh & Nzekwe, 2011; Nadelson & Nadelson, 2010; Nehm & Schonfeld, 2007). In their study of preservice elementary teachers, Asghar et al. (2007) found that while 71% agreed evolution should be taught, only 11% stated they had no concerns about teaching evolution. However, several studies reported that participants felt that when evolution is taught, they should also include creationism (Asghar et al., 2007; Bloom, 1989) or both creationism and ID (Berkman & Plutzer, 2011, 2015; Levesque & Guillaume, 2010; Nadelson & Nadelson, 2010; Nehm, Kim, & Sheppard, 2009).

In contrast to secondary teachers, fewer elementary teachers were comfortable with teaching evolution (Fowler & Meisels, 2010). Further, elementary teachers have a lower level of acceptance of evolution when compared to secondary teachers (Fowler & Meisels, 2010; Levesque & Guillaume, 2010; Losh & Nzekwe, 2011). Even more critical, some reported that elementary teachers in their investigation were unaware that evolution is even part of the required curriculum (Nadelson & Nadelson, 2010).

Result of Controversy = Softening Evolution or Including Creationism/ID

Due to the confounding problems that elementary teachers face when approaching evolution instruction, if elementary teachers even teach evolution, they present it is such a way that students are left to doubt the accuracy of the content that was taught. Teachers often compromise their evolution instruction in two noteworthy ways. First, teachers will present evolution as "just a theory" (Asghar et al., 2007; Berkman & Plutzer, 2015; Miller, 2008), implying that theories are less robust than other scientific knowledge. Second, even more troubling is the willingness some teachers have to include non-scientific explanations alongside evolutionary theory (Berkman & Plutzer, 2011; Blank & Anderson, 1997; Sickel & Friedrichsen, 2013).

Teacher Education Programs

An important goal of a teacher education program should be to develop their preservice teachers' understanding and acceptance of evolution so that they may teach it in their future classroom. It is known that as teachers' acceptance and knowledge of evolution increased, they spent more time teaching evolution (Carlesen, 1991; Rutledge & Warden, 1999; Tatina, 1989). Science educators recommend NOS instruction as a vehicle to developing deeper understanding of

evolution (Bloom & Weinburgh, 2007; Glaze & Goldston, 2015; Sickel & Friedrichsen, 2013). Sinatra, Southerland, McConaughy, and Demastes (2003) suggest that incorporating NOS instruction with evolution instruction could alleviate some of the aforementioned concerns that teachers face when teaching evolution. More importantly for the present investigation, Lombrozo, Thanukos, and Weisberg (2008) argue for the inclusion of instruction on the nature of science at the elementary level in order for children to "begin to develop an understanding of science to properly evaluate antievolution messages when they are first encountered" (p. 295). Therefore, it becomes more important to determine how preservice elementary teachers may approach instruction on evolution.

Statement of Purpose

The present investigation sought to determine how preservice elementary teachers would approach instruction on evolution. Specifically, the research questions for the present investigation are:

1. What views do preservice elementary teachers hold on the possible inclusion of creationism and intelligent design in the K-12 science curriculum?
2. How do elementary preservice teachers justify including or excluding alternative explanations to evolution in the science curriculum?

Method

Participants

Participants in this exploratory study included 76 elementary preservice teachers (PSTs): 73 females and 3 males. Ages ranged from 21 to 30. The PSTs were in the second semester of their junior year, which is the integrated methods block semester of the elementary education program in a large, public Mid-Atlantic University. The semester includes the following five methods courses: science methods, English/language arts, social studies, reading for grades 3-5, and math for grades 3-5. These courses are completed prior to the start of their year-long experience in a local elementary school. Each course met once a week for a total of three hours per week. The 76 PSTs were enrolled in three separate sections of the elementary science methods course. Each section was taught by the same professor (first author) and was alike in every way. Additionally, the enrollment demographics were similar and typical for students in previous sections of the course.

Procedure

We were interested in how elementary preservice teachers justify including or excluding alternative explanations to evolution in the science curriculum. This study took place in the three sections of the elementary science methods course. The purpose of this course was to prepare preservice elementary teachers to teach science to elementary school learners. The course emphasized a hands-on, inquiry-based approach to teaching science. Several topics comprised the course: lesson planning using the 5E approach (Bybee, 1997); integration with English/language arts using science trade books; state and national standards; use of technology; the 4-Q research strategy (Cothron, Giese, & Rezba, 2006); engineering design; and NOS (Lederman & Lederman, 2014; NGSS Lead States, 2013). It is important to note that this course did not include any explicit instruction on evolution, creationism, or intelligent design. Table 1 shows the course activities that addressed the targeted NOS aspects and when in the course each activity was taught. Note the course occurred over 16 weeks.

Data collection.

Data collected for this research came from an activity entitled "Science in the Public Schools - School Board Scenario" (see Appendix A). The activity was designed by the authors and was intended to assess the PSTs conceptions of science and then to challenge them to use their definition of science to justify the inclusion or exclusion of creationism and intelligent design (ID) into the public schools' science curriculum. The scenario proposed that the local school board is considering a motion to alter the science curriculum by introducing creationism and ID to the unit on biological evolution and the PSTs will be offering their informed recommendations. Before soliciting the PST's opinion regarding this issue, a general explanation of evolution, creationism, and ID was provided. The PSTs were then asked to write down their opinions of each (using their own definition of science to justify their position) and to draft a mock letter to the school board to provide their final recommendations. PSTs' responses ranged from a few sentences to multiple paragraphs.

Table 1. Activities to develop PSTs' understandings of science

Targeted Aspect	Week 1	Week 2	Week 6	Week 11	Week 12
Science relies on evidence	- What is science discussion - Candle demonstration - Comics - Fossil Tracks	- Professor Xargle (Ansberry & Morgan, 2010)	- Science-o-nator - Mystery Tube		- Polar Bear Activity
Science is subjective					- Polar Bear Activity
Science is tentative	- Candle demonstration - Comics - Fossil Tracks		- Mystery Tube		
Observations/Inferences	- Candle demonstration - Comics - Fossil Tracks	- Professor Xargle (Ansberry & Morgan, 2010)	- Science-o-nator - Mystery Tube		- Polar Bear Activity
Scientific Process	- Fossil Tracks			- Building Bridges (EiE)	- 4Q strategy
Engineering Design Process				- Building Bridges (EiE)	
Places of Work	- DAST with discussion				
Science is falsifiable	- What is science discussion				
Science uses testable explanations and predictions	- What is science discussion		- Mystery Tube		- Polar Bear Activity
Science studies natural phenomena	- What is science discussion		- Mystery Tube		

Design and Data Analysis

A non-experimental descriptive qualitative design was used for this investigation. Initial analysis sought to determine if the PSTs would include or exclude alternative explanations to evolution in the curriculum. Follow-up analysis focused on the reasons for their decisions. The qualitative analysis software ATLAS.ti was used to analyze the school board scenario. The two researchers independently read and coded the data using an inductive, constant comparative approach (Glaser & Strauss, 1967). After initial coding, the researchers met to compare their results. Some codes were split into two or more codes while others were collapsed into a single code. After coming to consensus on the codes represented in the data, the researchers re-coded the data and compared their results to ensure inter-rater reliability. These codes were used to characterize the PSTs rationales for including or excluding alternative explanations to evolution in the curriculum. To increase validity and trustworthiness, the data analysis included peer debriefing as well as an external audit (Creswell, 2013).

Results

This study explored how elementary preservice teachers justify including or excluding alternative explanations to evolution in the science curriculum. Figure 1 shows a breakdown of the 76 PSTs (in percent) by their opinions with respect to including creationism and/or ID in the science curriculum. Twenty-six (34.2%) stated they would add both creationism and ID, 9 (11.8%) stated they would add creationism, 6 (7.9%) stated they would add ID, 3 (3.9%) stated they would at least mention creationism and/or ID, and 32 (42.1%) stated they would not add creationism or ID. Each of these three PSTs indicated that they would not make creationism and/or ID an emphasis of their teaching, but would at least mention one or both. One of these PSTs, PST54, was not as firmly entrenched in the "yes they should be mentioned" category. She stated that she would vote against creationism and ID as well as argued that they "are not appropriate for the classroom." While she showed some signs of conflict in her responses, she still argued that creationism is "definitely something that should be mentioned in the science classroom."

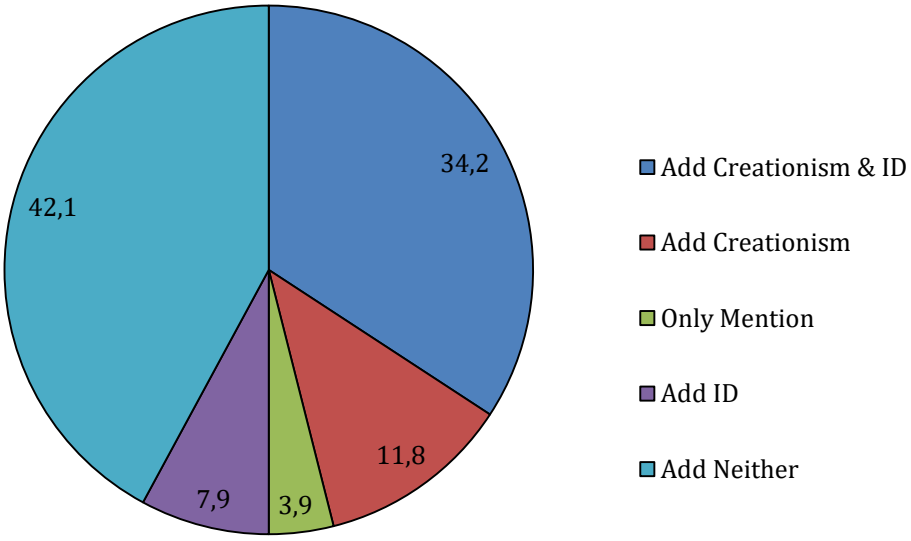

Figure 1. PSTs' opinions on including creationism and/or ID in science curriculum (n=76).

Characterizations of each group

Table 2 shows the common rationales behind the decisions of PSTs in each group. While each individual PST came up with diverse explanations for their decision on if to include alternative explanations when teaching evolution, the rationales included in Table 2 are those that are most common amongst the PSTs in that group. These were used to develop a characterization of the PSTs in each group.

Table 2. Common Rationales for PSTs' Perspectives on Including Alternative Explanations when Teaching Evolution

Group	Characterization
Add creationism & ID	Naïve view of scientific evidence
(*n* = 26; 34.2%)	
Add creationism	Science requires evidence
(*n* = 9; 11.8%)	Naïve view of scientific evidence*
	Science is based on experimenting and testing*
Add ID	Science requires evidence
(*n* = 6; 7.9%)	Naïve view of scientific evidence
	Creationism based on faith
	In science, proof equals certainty
Add neither	Science requires evidence
(*n* = 32; 42.1%)	Science is based on experimenting and testing
	Creationism based on faith
	ID based on faith*
	Evolution has evidence*
	Purpose of science is to ask and answer questions and provide explanations*
Just mention	Purpose of science is to ask and answer questions and provide explanations
(*n* = 3; 3.9%)	Purpose of science is to explain how and why things work
	Purpose of science is to study the world/universe

Note: The descriptors above with an * indicate at least 40% of the PSTs in that group demonstrated that characteristic. All other characteristics were demonstrated by at least 50% of the PSTs in that group.

Add Creationism and ID. Twenty-six PSTs stated they would add both creationism and ID to the science curriculum (see Figure 1). Half of these PSTs held naïve views of scientific evidence, meaning they included inaccurate examples of evidence to support their argument to add creationism and ID. For example, several PSTs included responses such as "there is evidence for creationism, therefore it should be discussed along with evolution and intelligent design in the classroom" (PST58). This is representative of comments from PSTs who argued that evidence exists for creationism or ID, but failed to provide any specific examples of evidence. Some PSTs' responses were more specific. For example, in her response, PST6 argued "Creationism should be put into the curriculum due to how effective the Bible is and the real life examples that are given. We can revert to the bible (sic) for creation, weather, birth, death, genetics, etc." Several other PSTs also referred to the Bible as evidence to support their decision to add both creationism and ID.

Other than naïve view of scientific evidence, there was very little consensus amongst these 26 PSTs when it comes to their definitions of science or the purpose of science. Yet, some common statements emerged. For example, five of the PSTs in this category used the argument that evolution is "just a theory" to support their decision to add creationism and ID in the classroom. PST71 stated that "Teaching all three of the theories as theories is what's important. None of these theories should be taught as true because they aren't scientific law." Five PSTs seemed to not understand the difference between a scientific theory and an everyday theory. For example, PST47 asked "all three of these are theories, so why should only one be taught?" She used this argument to put evolution, creationism, and ID on the same level, failing to recognize the difference between a scientific theory and an everyday theory. Finally, some PSTs devalued evolution in other ways, stating, "we were not there to see 'evolution' happen" (PST68) or by alluding to "problems with the theory of evolution" (PST58).

Even though all of these PSTs wanted to add creationism and ID to the curriculum, some included accurate statements about science. For example, eight recognized that science is based on experimenting and testing, seven noted that science requires evidence, four characterized science as subjective and three as tentative, and three emphasized that science deals with nature.

Surprisingly, one PST recognized that science is NOT based on faith and three PSTs argued that creationism is based on beliefs. When asked to define science in her own words, PST26 stated "science is a type of learning that includes specific, detailed, and proven data or facts to explain certain topics. Science is not based on opinions, faith, or unproven data." This PST recognized the importance of evidence in science and that science is not based on faith, yet she still wanted to add creationism and ID to the curriculum. There is a disconnection between her definition of science and her arguments for adding both creationism and ID. In her response to the question on creationism, PST26 argues that "there is data (the Bible) that explains certain events & landscapes," thus revealing a naïve view of what is considered to be scientific evidence.

Three PSTs recognized that creationism is based on beliefs, yet maintained a variety of reasons for added both creationism and ID to the curriculum. For example, when asked to define science, PST3 states "Creationism is based from religious beliefs…ID is just a belief that hasn't really been tested." Additionally, she says that evolution "has strong evidence supporting it." Based on these responses, it would seem that PST3 has some understanding of science. However, her later responses indicate much confusion. She indicates that since creationism is based on religious beliefs, it could possibly "influence how the scientist tests the theory." Later PST3 argues that even though creationism is based on religious beliefs, it "does not make it wrong. It just changes how the scientist would go about testing to prove the theory." Her responses indicate that she seems to understand the role of perceptual frameworks and that science is subjective, yet she uses this knowledge to support the notion that creationism is science.

Add Creationism. Nine PSTs stated they would add creationism to the science curriculum (see Figure 1). Five recognized that science requires evidence. Some explicitly defined science as something requiring evidence. PST24 said "science is about having research and evidence." Others implicitly acknowledged the importance of evidence when arguing against ID. For example, PST2 argued that ID should not be added to the curriculum because it should "at least have some type of evidence to support that it's true."

Four of these nine PSTs included statements that showed they did not have an accurate understanding of scientific evidence. Each of these PSTs used this to argue for the inclusion of creationism. For example, when asked if creationism should be added to the curriculum, PST69 said "there is evidence to support [creationism] such as the Grand Canyon being formed by the Great Genesis flood." Although this argument is similar to PSTs who wanted to add both creationism and ID, unlike those PSTs, PST69 argued that ID does not have enough evidence, simply saying she would not add ID "because they didn't have evidence."

Finally, four PSTs recognized the importance of experimenting and testing in science. For example, PST22 described science as "the act of asking questions and forming experiments to answer these questions." This is representative of what the others said about experimentation and testing.

Other than the three identified characteristics (Table 2), there was very little consensus amongst these nine PSTs when it comes to their definitions of science or the purpose of science. In addition to the accurate view that science requires evidence, some PSTs who wanted to add creationism held other accurate views. For example, one stated that science is tentative, one characterized science as subjective, three emphasized that science tries to disprove things, and two that scientists like to ask and answer questions and provide explanations.

However, a range of inaccurate views of science emerged from this group. For example, three were unable to discern scientific theories from everyday theories, two argued that science is based on believing, and one claimed that "science comes from having faith in the unobservable" (PST22). The three PSTs who were unable to discern scientific theories from everyday theories argued that creationism and evolution were equivalent. In her response to if she would add creationism to the curriculum, PST21 specifically said it should be included "because none of these theories are able to be tested and observed first-hand."

Add ID. Six PSTs stated they would add ID to the science curriculum (see Figure 1). Several common characteristics emerged from this group (see Table 2). For example, four of the six PSTs understood that science requires evidence. PST17 stated "science is based on evidence" in several places. PST62 was more specific, stating "it [science] requires having evidence to prove what we know." Two of these four used the argument that science requires evidence to directly support their decision to NOT include creationism. For example, PST31 said

I wouldn't vote [for] creationism to be added to the science curriculum because there is no evidence. No evidence that suggests there was a flood prior to existence. Have there been fossils or any type of proof other than a hand written Bible…?

PST31 recognized that the Bible does not count as scientific evidence. Yet, PST31's response to the ID question indicates a fundamental lack of understanding regarding ID. She said "There is an abundance of evidence that suggests things were made by an intelligent designer, also known as humans."

However, three of the four PSTs who argued that science requires evidence also held naïve views of scientific evidence. Each of these three PSTs continued to use the argument that science requires evidence as a way to support their decision to include ID in the curriculum. Two of these PSTs seemed to rely on the short explanation of ID included in the school board scenario. For example, when asked if she would include ID, PST17 indicated she would "say yes due to the fact there is evidence to prove the theory (watch) so this may be able to be observed." This PST inaccurately thought that the "watch" argument referenced in the short explanation of ID sufficiently represented scientific evidence. PST62 stated "As students study the different structures that exist, it would be hard to think that these

intricate, detailed structures could have come out of anywhere. The evidence would lie within the intricate structures of nature and the uses these structures complete."

Three PSTs accurately understood that creationism is based on faith and used this to support their argument that creationism should not be added to the curriculum. For example, PST39 stated "I would have to say no I would not allow [creationism] because of the religious aspect." Finally, three PSTs inaccurately argued that the presence of proof is the same as certainty in science, seeming to not understand the tentative nature of science.

These six PSTs who wanted to add only ID to the curriculum also used some additional arguments to support their decisions. Some accurate views emerged: one PST argued that creationism is not science, two pointed out that creationism cannot be tested, two maintained that science is limited to the natural world, two explained that science is tentative, two identified the purpose of science as to ask/answer questions and provide explanations, and two characterized science as involving experimenting and testing.

Just one additional inaccurate view emerged, which described ID as science. To support her decision to add ID to the curriculum, PST39 said she would add ID "because it shows the importance of the science in our world. Since it is not specific in who the creator is it can be accepted by most cultures." While there is some confusion as to the intent of this statement, it appears that she implied that ID is science. She also seems to understand that there are religious connotations with respect to ID.

Add neither. Thirty-two PSTs stated they would not add creationism or ID to the science curriculum (see Figure 1). More of a consensus is observed among this group when compared to the other groups. Twenty-four of these 32 PSTs (75%) recognized that science is based on evidence. For example, regarding including creationism in the curriculum, PST7 argued

No, I wouldn't because I do not believe that the elements contained in the creationism theory entail the attributes of science. There is no measureable data to inform their theory and they reject using science principles to back up their claims about when and how the earth was created.

With respect to ID, PST7 used a similar argument, stating "this theory [ID] really has no information that is reliable or valid that can be measured in a way that proves this theory to meet the basic principles of science." Both of her arguments focused on the importance of using what she calls the "principles of science," which she describes as using evidence, coming to consensus, and relying on information that is measurable and observable.

At least half of the PSTs in this group also indicated that science is based on experimenting and testing (19 out of 32) and creationism is based on faith (16 out of 32). Just under half of these PSTs (14 out of 32) recognized that ID is based on faith, 13 out of 32 recognized that evolution has evidence, and 13 out of 32 recognized a purpose of science is to ask and answer questions and provide explanations.

Most of the 32 PSTs who said no to adding either creationism or ID to the curriculum used at least one of the above characteristics as justification. However, two did not rely on any of the above characteristics. PST30 included that science is "something that is observable, changeable, and can be tested," but failed to use this description to support his decision. Similarly, PST59 addressed that science is not based on belief as well as that science "is the ability to find out explanations," but she failed to use these descriptions to support her decision. Instead, PST30 and PST59 both relied on the notion that religion does not belong in schools to support their decisions.

Each of these PSTs included other accurate statements about science that are worth mentioning. For example, six said that science is tentative, six said that both creationism and ID cannot be tested, six explicitly argued that religion is not science, and eight said that scientists try to determine how and why things work. Additionally, all of the accurate descriptions of science identified in the data were used by at least one person from this group except for proof equals evidence and rational.

Very few inaccurate descriptions of science emerged from this group. In fact, only four of the identified inaccurate descriptions of science were used by this group of PSTs: proof is the same as absolute certainty (9 out of 32), science is a belief system (6 out of 32), evolution is just a theory (1 out of 32), and there are flaws in evolution (1 out of 32).

For science is a belief system, most of the PSTs were vague, such as "science is based on beliefs" (PST30) or that people "believe in evolution" (PST27). In her response to the "what is science" question, PST51 was more specific, stating that science is "believing in something faithfully until finding it to be true or false. Scientist [*sic*] must stand by what they

believe in." From this statement it seems that this PST is conflating believing and evidence, thinking that perhaps scientists just want to believe something until they find evidence to back it up.

The one PST who referred to flaws in evolution used the argument twice. In her response to if she would add ID to the curriculum, PST67 said she would vote no "based on my definition of science." She further stated that ID "lacks experiments and evidence" to back up the claims. However, she added that the "possible flaws in evolution can be addressed in the unit of evolution without bringing ID into the picture." Her response to the third question included a similar statement. Thus, while this PST is opposed to adding ID to the curriculum, she is open to the idea of including "possible flaws in evolution" without explicitly addressing ID. This argument aligns with the more recent efforts of the likes of the Discovery Institute (Binns, 2013).

Just mention. Three PSTs stated they would at least mention creationism and/or ID (see Figure 1). The only consensus within this group focused on the purpose of science, not on the description of science (Table 2). Additionally, there was no unanimous consensus, even though there were only three candidates. The characteristics that emerged with respect to the purpose of science were ask and answer questions and provide explanations, explain how and why things work, and study the world/universe. Comments related to all three of these characteristics were vague. For example, for ask and answer questions and provide explanations PST50 said science "is the way of finding answers to all of our questions." For explain how and why things work, PST61 said science focuses on "why things are the way they are." Finally, for study the world/universe, PST54 said that "science is the study of the world around us." While consensus emerged with respect to these three characteristics of the purpose of science, all of the responses were vague and PSTs provided no explicit examples.

It is interesting to note that while there was little consensus for these three PSTs, none of them included any inaccurate statements about science. Some of the additional accurate characteristics addressed by these three PSTs included creationism is based on faith, ID is based on faith, science includes discovery and exploration, science is based on experimenting and testing, science is tentative, and science studies life. Only the comments that addressed creationism and ID are based on faith were explicit. PST54 recognized that both creationism and ID are based on faith and used this argument to support her decision to not explicitly add them to the curriculum. For creationism, she said she would vote against it "solely because of the religion aspect" (PST54). For ID, she said she would vote against it "because it includes the existence of a supernatural creator, which can again fall under religion" (PST54).

Discussion

In this exploratory study, we were interested in how elementary preservice teachers justify including or excluding alternative explanations to evolution in the science curriculum. At the conclusion, PSTs demonstrated various perspectives on their willingness to include alternative explanations to evolution in the science curriculum consistent with other studies (Berkman & Plutzer, 2011, 2015; Levesque & Guillaume, 2010; Nadelson & Nadelson, 2010; Nehm et al., 2009). Twenty-six (34.2%) stated they would add both creationism and ID, 9 (11.8%) stated they would add creationism, 6 (7.9%) stated they would add ID, and 32 (42.1%) stated they would not add creationism or ID (see Figure 1). Finally, three (3.9%) stated they would at least mention creationism and/or ID.

Qualitative analyses revealed common rationales used by PSTs in each group. The most common justification offered by the PSTs for including both creationism and ID was due to a naïve view of scientific evidence. For example, these PSTs argued that scientific evidence exists, such as Biblical record, for either creationism or ID. Within the category of adding only creationism, the most common justifications were that science requires evidence, naïve view of scientific evidence, and that science is based on experimenting and testing. PSTs in this group recognized the priority of evidence in science, but like the previous group, several also referred to the Bible as evidence for creationism. Surprisingly, a common justification was that science is based on experimenting and testing, which are not characteristics of creationism.

PSTs who indicated that they would include ID, but not creationism, justified their decisions with science requires evidence, naïve view of scientific evidence, creationism is based on faith, and in science, proof equals certainty. As expected, these PSTs characterized ID as more scientific than creationism and that ID is not based on faith. They recognized the priority of evidence in science, but inaccurately argued that sufficient evidence existed to prove ID. However, they failed to discern scientific from nonscientific evidence.

PSTs who argued that they would include neither creationism nor ID to the curriculum understood that scientific claims are based on evidence derived through experimenting and testing. They assert that both creationism and ID are based on faith and therefore not scientific. They identify evolution as the only option among the three that provides a scientific explanation based on evidence. Finally, among the PSTs who opted to not include creationism and ID, three indicated they would mention them in their classroom. None of these three PSTs provided an articulate definition of

science, but they emphasized the purpose of science as asking questions and providing answers. Therefore, they felt that for the purpose of inquiry, at least mentioning creationism and ID was suitable.

Implications for Future Research and Practice

The arguments PSTs put forth to include creationism and ID deviated from science in several notable ways. For example, some of the PSTs who were in favor of adding creationism and/or ID also described evolution as "just a theory," implying that theories lacked sufficient evidence to be considered as fact, which is consistent with prior research (Asghar et al., 2007; Berkman & Plutzer, 2015; Miller, 2008). This reveals a misunderstanding of the tentative nature of science and a lack of understanding of the basic nature of scientific theories. Theories are explanatory constructs used to make sense of observable phenomena in nature and are tentative in nature (Lederman & Lederman, 2014; McComas, 1998). This tentativeness is manifested when scientists adjust, modify, and even replace theories with better explanations when new data justifies such changes. This tentativeness of science reflects the continuing improvement of scientific claims and should not be interpreted as a weakness of science. PSTs who referred to evolution as "just a theory" are doing just that and are reflecting a view that evolutionary theory is a questionable, possible explanation proposed by scientists. As such, it is not surprising that these PSTs would be willing to offer equal time for alternative explanations such as creationism and ID.

Other PSTs justified their decisions to add creationism or ID by stating that evidence existed to support these explanations. However, the evidence to which they referred was often the written text of the Bible. This demonstrates a basic lack of understanding of what constitutes scientific evidence. Scientific explanations must be supported empirically by physical, observable, measurable evidence (McComas, 1998; NAS & IOM, 2008). The Bible, while offering an origin story counter to evolution, is not supported by such evidence and is, therefore, not scientific.

A critical characteristic of scientific claims is their falsifiability (NAS & IOM, 2008; Popper, 1959). When empirical evidence is found that violates a scientific explanation, it must be revised or replaced. This only applies if one constrains science to natural laws. Creationism and ID both include a supernatural cause as a critical component to their explanations of origins. Such a supernatural cause is not falsifiable because it, by its very nature, supersedes natural laws. As such, both creationism and ID are not falsifiable and thus not scientific.

Conclusion

These PSTs completed a course that successfully incorporated instruction that emphasized NOS as suggested by the literature (Bloom & Weinburgh, 2007; Glaze & Goldston, 2015; Lombrozo et al., 2008; Sickel & Friedrichsen, 2013). Yet, our results seem to suggest that despite being exposed to this type of instruction, their understandings of science may not develop sufficiently to make informed decisions about specific, socioscientific issues. Clearly, results from the present investigation indicate a need for even more instruction on targeted aspects of NOS such as science is tentative, relies on evidence, and science only addresses natural phenomena (Binns & Bloom, 2017). These all seemed to be areas of weakness for many of the PSTs in the present investigation. Thus, it is imperative to determine what, if any, other factors play a role in preservice elementary teachers' decisions on including or excluding alternative explanations to evolution in the science curriculum.

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Appendix A

Science in the Public Schools – School Board Scenario

Scenario:

You have been elected to your local school board. There is currently a motion to alter the science curriculum in the local schools regarding their presentation of evolution. Currently, evolution is the only scientific explanation provided for the diversity of life on Earth. A growing population of concerned parents are advocating for introducing Intelligent Design and/or Creationism into the unit on evolution. A brief description of evolution, Creationism, and Intelligent Design are provided on the back of this page. Your opinion on this matter should be based upon your understanding of what is or is not scientific, so begin by defining the word, "Science". Then, read the description of each position and, based upon your understanding of science, answer the following questions on the answer form provided. Be sure to justify your positions.

1. What is Science?

Evolution: Evolution explains the diversity of life on Earth as having evolved from a common ancestor. According to evolutionary theory, life evolved from non-living matter approximately 3.8 Billion years ago in the form of bacteria and that through genetic drift, natural selection, and speciation, millions of distinct species have evolved and gone extinct over the subsequent billions of years. Evolutionary theory claims that humans evolved approximately 200,000 years ago (about 65 million years after the dinosaurs went extinct).

Creationism: Generally speaking, Young Earth Creationists (YECs) believe Earth to be between 6,000 and 10,000 years old and base this judgment on Biblical genealogies that trace the birth of Jesus back to Adam. YECs hold fast to literal interpretations of Genesis account (as found in the first book of the Christian Bible) of the world being formed in just 6 days and they date the Earth using this interpretation. YECs generally reject modern-day physics and chemistry derived radioisotope dating methods, geo-physical explanations of geological formations, as well as plate tectonics. They attribute such structures as the Grand Canyon and geological strata to Biblical events such as the Genesis flood and a vast water vapor canopy that existed prior to the flood. Further, they reject evolutionary theory and believe that plants and animals found today were created in their current form and that extinct species (e.g. dinosaurs) lived contemporaneously with humans.

Intelligent Design: Intelligent design (ID) is a recently developed idea, which is being promoted as a viable alternative to a pure creationist or evolutionist position. ID developed from William Paley's *Natural Theology* (1802), which put forth the now-famous watchmaker argument, which claims that when one observes the complexity of a watch, one knows, inherently that an intelligent designer was responsible for its creation. ID advocates argue that structures and systems such as the flagellum and the proteins involved in blood clotting are too complex to have evolved and claim that with the removal of any component of them, they would cease to function. Because of the extreme unlikelihood that they could have evolved, they maintain that one must attribute their existence to a supernatural creator.

Creationism – How will you vote?

2. Based upon your definition of science, would you vote to allow Creationism to be added to the science curriculum? Why or why not?

Intelligent Design – How will you vote?

3. Based upon your definition of science, would you vote to allow Intelligent Design (ID) to be added to the science curriculum? Why or why not?

Your message to the School Board

4. In the space below write what you are going to tell the school board. How would you justify your responses using evidence from your definition of science and questions 1 and 2 to support your statements?